Finding Balance

November 6 - 9, 2017
The Westin Westminster • Westminster, Colorado

Hosted by the
Colorado Lake and Reservoir Management Association
An Affiliate of NALMS

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The North American Lake Management Society’s mission is to forge partnerships among citizens, scientists and professionals to foster the management and protection of lakes and reservoirs.

NALMS
PO Box 5443
Madison, WI 53705-0443
p: 608-233-2836
www.nalms.org

Disclaimer
The information and suggestions presented at the International Symposium of the North American Lake Management Society are subject to constant change and, therefore, should serve only as a foundation for further investigation. All information, procedures and materials contained or used as part of the International Symposium should be very carefully reviewed and should serve only as a guide for use in specific situations. Questions regarding such information, procedures and products should be directed to the specific individuals, companies and/or organizations submitting said items and information.

The opinions expressed by presenters, speakers, discussion panelists, committee members and exhibitors are those of said individuals and are not necessarily those of the North American Lake Management Society nor the conference sponsors.

Program subject to change.

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On behalf of the North American Lake Management Society and the Colorado Lake and Reservoir Management Society (CLRMA), our local affiliate host, we would like to welcome you to Denver for our 37th annual International Symposium: “Finding Balance.” This theme is intentionally broad as we consider the entire gestalt of our watery environs, not just the water. Be sure to thank the local host committee for putting together a first class scientific program, and providing opportunities to renew old friendships and make new ones. Perhaps you are eyeing the workshop with prized photographer John Fiedler, or a specific scientific session to sharpen an aspect of your professional knowledge – no one should lack something to do in Denver.

I’m happy to report we are able to fund the largest number (18) of student travel grants in NALMS’ history as we continue to strengthen our future leaders. Please extend a warm welcome to all of our students, check out their exciting research, encourage their endeavors, and most of all, participate in the auction to help fund next year’s cohort.

We would also like to thank all the symposium sponsors and exhibitors, without whom there would be a large void. Please take time to check out their latest offerings or services, some discounted during the symposium.

If you are interested in the business of the society, the board will meet all day Sunday to recap the past year and chart next year’s business; please feel free to attend if you are in Denver early – the meeting is open to all. A summary of activities, next year’s budget and board transitions will be presented at the annual Membership meeting on Tuesday, please plan to attend it. There’ll be a plethora of activities after hours, plan to celebrate with NALMS and friends at traditional events such as the Annual Awards Reception and Banquet, the Clean Lakes Classic, or explore some new ones – euchre anyone?

My year as president has passed in a blink and a lot happened at NALMS during that short time; but a lot is left to do. I am grateful to have had this opportunity to serve the NALMS community and I cherish all the contacts I’ve made. I value all the contributions and comments each of you passed on. Thank you.

I pass the NALMS helm to Frank Browne, a long-time – and original founding – member who decided to return for a turn as president. His long-time participation in NALMS should serve the organization well.

Stop to say hello in Denver, see you there.

Frank M. Wilhelm
President, 2016–17
On behalf of the 2017 host committee and the Colorado Lake and Reservoir Management Association (CLRMA), we welcome you to the 37th International Symposium in Colorado! The theme of this year’s symposium, Finding Balance, is key to managing our lakes, reservoirs, and watersheds while meeting ever-increasing demands. Water in the Centennial State is used for drinking, farming, ranching, fishing, mining, boating, snowmaking, brewing, and more. All of these uses are supported with a statewide annual average precipitation of just 17 inches. Additionally, our state’s approach to water rights also places unique constraints on how we manage water. Water law versus aquatic science. Water quantity versus water quality. Preservation versus development. Finding Balance among these and other competing demands is vital to ensuring sufficient water supply, protecting water quality, and managing lakes and reservoirs in our state.

Colorado and CLRMA are excited to welcome NALMS back to the headwaters state. Much has happened in Colorado in the 26 years since the 1991 symposium that was held in Denver. We’ve experienced droughts and floods, constructed new reservoirs, and watched our population grow by more than 2 million people. In 2015, Colorado finalized its first-ever state-wide water plan in response to the increasing demands and stresses placed on our limited supply of water from drought, fire, flood, climate change, and population growth. We look forward to sharing our stories and lessons learned from our efforts throughout the state in Finding Balance, and are eager to learn from the experiences of others from across the continent. We hope the workshops, presentations, and field trips spark meaningful discussions, promote the sharing of ideas and expertise, foster the development of new and existing relationships, and help us all find balance. Welcome!

Steve Lundt and Jean Marie Boyer
NALMS 2017 Host Committee Co-chairs
Symposium Host Committee

Jean Marie Boyer, Co-chair
Hydros Consulting Inc., Boulder, Colorado

Steve Lundt, Co-chair
Metro Wastewater Reclamation District, Denver, Colorado

Kelly DiNatale, Program Committee Co-chair
DiNatale Water Consultants, Boulder, Colorado

Chris Holdren, Program Committee Co-chair
Environmental Consultant, Littleton, Colorado

Jeff Schloss, NALMS Conference Advisory Chair
University of New Hampshire Cooperative Extension • Durham, New Hampshire

Philip Forsberg, NALMS Director of Programs and Operations
North American Lake Management Society, Boulder, Colorado

Alyssa Schulte, NALMS Director of Marketing and Membership
North American Lake Management Society, Madison, Wisconsin

Kelly Cline, Exhibitors and Fundraising Committee Co-chair
City of Westminster, Colorado

Laurie Rink, Exhibitors and Fundraising Committee Co-chair
Aqua Ria Ltd., Fruita, Colorado

Kelly Close, Local Events Committee Co-chair
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Colorado Department of Public Health & Environment, Denver, Colorado

Al Polonsky, Publicity Committee Co-chair
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Linda Rosales, Volunteer Committee Chair
Denver, Colorado

Nathan Jahns
GEI Consultants, Inc., Denver, Colorado

JoJo La
Denver, Colorado

David Leach
City of Thornton, Colorado

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Centennial Water and Sanitation District, Highlands Ranch, Colorado

Vic Lucero
Walsenburg, Colorado

Jared Mann
Parker Water and Sanitation District, Parker, Colorado

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Colorado Parks and Wildlife, Brighton, Colorado

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Metro Wastewater Reclamation District, Denver, Colorado

Paul Tedesco
City of Thornton, Colorado

Theresa Thom
National Park Service, Lake Mead NRA, Boulder City, Nevada

Craig Wolf
GEI Consultants, Inc., Denver, Colorado

Ian Babson
Denver Water, Denver, Colorado

Alfred Basile
US Environmental Protection Agency, Denver, Colorado

Kevin Bierlein
Hydros Consulting Inc., Boulder, Colorado

Cindy Brady
Denver Water, Denver, Colorado

Andy Cross
City of Westminster, Colorado

Ben Emerson
Parker Water and Sanitation District, Parker, Colorado

Mike Eytel
Colorado River Water Conservation District, Glenwood Springs, Colorado

Kindra Greentree
City of Arvada, Colorado

Christine Hawley
Hydros Consulting Inc., Boulder, Colorado
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Representing all members of NALMS
Sara Peel, CLM
Arion Consultants, Indianapolis, Indiana

Student At-large Director
Representing student members of NALMS
Sarah Burnet
University of Idaho, Moscow, Idaho
NALMS Committees

The success of the Society relies largely upon our dedicated volunteers, members, and leaders who give of their time to serve on our many important committees. Please see below for a list of our active committees, the members who chair them, and a brief snapshot of the role they play in NALMS operations. If you are interested in joining one (or more) of these committees, please visit the NALMS booth or contact us at info@nalms.org.

**Committees**

**Articles of Incorporation and Bylaws Committee**
Committee Chair: Chris Holdren
Objective: review the structure of the Society and to organize ideas and proposals for changes and present them at the Midterm Board Meeting.

**Conference Advisory Committee**
Committee Chair: George Antoniou
Objectives: work with Conference Coordinator, conference host committee, and NALMS staff to determine best strategies to make NALMS yearly symposiums successful.

**Communications Committee**
Committee Chair: Sara Peel
Objectives: regular and effective communications are essential to the functioning of a largely-volunteer organization like NALMS. The Communications Committee helps ensure that all communications coming from NALMS staff, officers, directors, committees, liaisons, and programs stay true to NALMS mission.

**Executive Committee**
Committee Chair: Frank Wilhelm, President
Objective: to provide leadership for the Society, the Board of Directors, and NALMS office staff. The Executive Committee is comprised of the NALMS President, Past President, President-Elect, Secretary, and Treasurer. Meet our current Executive Committee!

**Financial Advisory Committee**
Committee Chair: Michael Perry, Treasurer
Objective: to assist the President in preparing a budget for the next fiscal year, to provide investment alternative recommendations, and to monitor all investments.

**Grants, Marketing, and Fundraising Committee**
Committee Chair: Ellen Preece
Objectives: to improve the visibility of the Society in those areas where there is potential for developing financial support. The committee is also responsible for identifying and pursuing grants to carry out NALMS projects and activities and for fundraising for the Society, with assistance from office staff.

**Nominating Committee**
Committee Chair: George Antoniou
Objective: identifying active, dedicated leaders and encouraging them to seek positions of leadership within the Society.

**Outreach and Education Committee**
Committee Chair: Anna DeSellas
Objectives: aid the Society's goal in forging partnerships among citizens, scientists, and professionals to foster the ongoing management and protection of lakes and reservoirs. To do this, the Outreach and Education Committee promotes the awareness and appreciation of lakes, ponds, and reservoirs through various multi-media activities.
Activities: Lakes Appreciation Month, Jody Connor Student Awards, Student Travel Grants, etc.

**Policy Committee**
Committee Chair: Vacant
Objectives: establish guidance to ensure all activities of the Society are consistent with the purposes and objectives of the Society, as well as the operational aspects of NALMS set forth in the Bylaws. The committee is also expected to formulate recommendations on emerging policy questions.

**Publications Committee**
Committee Chair: Imad Hannoun
Objective: work to keep NALMS print and multimedia publications up-to-date and relevant.
NALMS Programs

Inland HAB Program

Harmful Algal Blooms (HABs) and cyanobacteria (blue-green algae) impact lakes and reservoirs around the world. Like you, NALMS is greatly concerned about HABs. In 2004 the NALMS Board adopted an initiative to take a leadership role in furthering the understanding and management of HABs and in educating people about them. With your help the Inland HAB Program can support resource managers, lake associations, local, state and provincial governments begin to address problems associated with HABs. These organizations need easily accessible, current information to make effective decisions and minimize human health risks. While research on the ecology, monitoring, and management of HABs exists, it is diffuse and not easy to find. Our goal is to solve these issues with the Inland HAB Program.

Lakes Appreciation Month

You work and play on them. You drink from them. But do you really appreciate them? Growing population, development, and invasive species stress your local lakes, ponds, and reservoirs. All life needs water; let’s not take it for granted.

NALMS inaugurated Lakes Appreciation Month as a means of focusing public attention on the state of lakes, reservoirs and watersheds in the US and Canada as well as their management. The public uses lakes for a variety of purposes: water supply for municipal, industrial and agricultural use; recreation; flood control; and aesthetic enjoyment. However, lakes are often considered as “free” resources by lake users and this can result in abuse and neglect.

Lakes Appreciation Month is in July of each year to coincide with Independence Day (July 4) in the U.S. and with Canada Day (July 1) in Canada. Both holidays provide people with the opportunity to get out and enjoy lakes. July is also when the Secchi Dip-in is held.

Professional Certification Program

The Certified Lake Manager/Professional (CLM/CLP) program has been established to aid in NALMS’ mission of gaining a better understanding of lakes, ponds, reservoirs, impoundments and their watersheds, through the identification of individuals who have exceptional training and experience in lake management. A lake manager is a person who is directly involved in the comprehensive management of ponds, lakes, reservoirs or other bodies of water and their watersheds and makes decisions that affect the quality and uses of the body of water. This person will be primarily responsible for implementing appropriate measures and/or for making recommendations to the governing management body. A CLM/CLP is an individual who has satisfied the NALMS requirements intended to properly prepare that person to perform the above duties with maximum competence. CLMs/CLPs establish themselves as both knowledgeable and experienced professionals by meeting the requirements.

The Secchi Dip-In

The Secchi Dip-In is a demonstration of the potential of volunteer monitors to gather environmentally important information on our lakes, rivers and estuaries.

The concept of the Dip-In is simple: individuals in volunteer monitoring programs take a transparency measurement on one day during the month of July. Individuals may be monitoring lakes, reservoirs, estuaries, rivers, or streams. These transparency values are used to assess the transparency of volunteer-monitored lakes in the United States and Canada. One of the goals of the Dip-in is to stimulate the development and growth of existing volunteer monitoring programs.

Student Programs

Here at NALMS, we believe that our students and emerging young professionals are not only the future of our Society, but the future of freshwater research and conservation, as well.

Student programs include sponsored student memberships, the Student Mentorship Program, Student Travel Grants, Student Video Series and the Jody Connor Student Awards. Ask us about the many exciting opportunities we offer our student members.
NALMS History

Presidents

2016-17  Frank Wilhelm  2003-04  Steve Heiskary  1990-91  Richard S. McVoy
2015-16  Julie Chambers  2002-03  Jeff Schloss  1989-90  William Norris
2014-15  Reed Green  2001-02  Steve Souza  1988-89  Matthew Scott
2013-14  Terry McNabb  2000-01  Steve Colvin  1987-88  Ron L. Raschke
2012-13  Ann Shortelle  1999-00  Larry Butler  1986-87  Richard Wedepohl
2010-11  Bev Clark  1997-98  Bill Jones  1984-85  William Funk
2009-10  Mark Hoyer  1996-97  Chris Holdren  1983-84  Eben Chesebrough
2008-09  Harry Gibbons  1995-96  Lisa Conley  1982-83  Bob Johnson

Symposium Locations

2016  Banff, Alberta, Canada  2003  Mashantucket, Connecticut  1990  Springfield, Massachusetts
2014  Tampa, Florida  2001  Madison, Wisconsin  1988  Saint Louis, Missouri
2013  San Diego, California  2000  Miami, Florida  1987  Orlando, Florida
2010  Oklahoma City, Oklahoma  1997  Houston, Texas  1984  McAffee, New Jersey
2008  Lake Louise, Alberta, Canada  1995  Toronto, Ontario, Canada  1982  Vancouver, British Columbia, Canada
2007  Lake Buena Vista, Florida  1994  Orlando, Florida  1981  None Held
2005  Madison, Wisconsin  1992  Cincinnati, Ohio

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Award Recipients

Secchi Disk Award
Bestowed upon the individual member considered to have contributed the most to the achievement of NALMS’ goals.

2016  John (Jack) R. Jones
2015  Eugene Welch
2014  G. Dennis Cooke
2013  Mark Hoyer
2012  Harry Gibbons
2011  Dick Osgood
2010  Roger Bachmann
2009  Steve Heiskary
2008  Tom Conry
2007  Tom Davenport
2006  Ann St. Amand
2005  Jeff Schloss
2004  Steve Colvin
2003  Ken Wagner
2002  Greg Searle
2001  Chris Holdren
2000  Bill Jones
1999  Jim Flynn
1998  Lisa Conley
1997  Jim Vennie
1996  Bruce Wilson
1995  Dan Canfield
1994  Jay Sauber
1993  Jim LaBounty
1992  Virginia Garrison
1991  Richard Wedepohl
1990  Bob Kirschner
1989  Garth Redfield
1988  Bill Funk
1987  Donna Sefton
1986  Eben Chesebrough
1985  Bob Johnson

2014  No award given
2013  No award given
2012  No award given
2011  No award given
2010  No award given
2009  Hach Hydromet
2008  USACOE, Waterways Experiment Station
2007  ENSR Corporation
2006  AW Research
2005  Osgood Consulting
2004  Princeton Hydro, LLC
2003  Sweetwater Technology
2002  No award given
2001  YSI, Inc.
2000  E.X. Browne, Inc.
1999  PhycoTech
1998  Ecosystems Consulting Service
1997  Hydrolab Corporation
1996  Aquarius Systems
1995  TVA
1994  Coastal Environmental Services
1993  ACRT, Inc.
1992  Aquarius Systems
1991  Baystate Environmental Consultants
1990  Judith Taggart & Associates
1989  General Chemical
1988  Aqua Technique
1987  Living Lakes
1986  Hydrolab
1985  Mudcat

Jim Flynn Outstanding Corporation Award
Given to the corporation considered to have contributed the most to NALMS’ goals.

2016  Abraxis, Inc.
2015  No award given

2014  No award given
2013  No award given
2012  No award given
2011  No award given
2010  No award given
2009  Hach Hydromet
2008  USACOE, Waterways Experiment Station
2007  ENSR Corporation
2006  AW Research
2005  Osgood Consulting
2004  Princeton Hydro, LLC
2003  Sweetwater Technology
2002  No award given
2001  YSI, Inc.
2000  E.X. Browne, Inc.
1999  PhycoTech
1998  Ecosystems Consulting Service
1997  Hydrolab Corporation
1996  Aquarius Systems
1995  TVA
1994  Coastal Environmental Services
1993  ACRT, Inc.
1992  Aquarius Systems
1991  Baystate Environmental Consultants
1990  Judith Taggart & Associates
1989  General Chemical
1988  Aqua Technique
1987  Living Lakes
1986  Hydrolab
1985  Mudcat

Friends of NALMS Award
Awarded to individuals or corporations making major contributions to NALMS. Recipients do not have to be NALMS members, and “contributions” extend beyond monetary donations.

2016  Pennsylvania Lake Management Society
2015  SUNY Oneonta Biological Field Station
2014  Lake George Association
2013  Linda Green
2012  Doug Knauer
Jim LaBounty Best Paper Award
This annual award established in 2003 recognizes the best paper published in Lake and Reservoir Management.

2016 Deriving nutrient criteria to minimize false positive and false negative water use impairment determinations
Eric Smeltzer, Neil C. Kamman, and Steven Fiske

2015 Regional distribution of Secchi disk transparency in waters of the United States

Leadership and Service – Volunteers
2016 No award given

2015 Penn State Extension Water Resources Team
Federation of Ontario Cottagers’ Associations
Michigan Natural Shoreline Partnership

Leadership and Service – Education and Outreach
2016 Beaver Watershed Alliance
2015  Indiana Clean Lakes Program
Aquatic Invasive Volunteer Monitoring Program

Leadership and Service – Other
2016  No award given
2015  No award given

Lake Management Success Stories
2016  Ducks Unlimited- Iowa
Lake Wallenpaupack, Pennsylvania
2015  Town of Barnstable, Massachusetts
Deer Lake Conservancy

Advancements in Lake Management Technologies
2016  Harvey Harper
2015  No award given

Technical Merit Awards
This award may be selected from four categories: Successful Projects, Volunteer Actions, Research Efforts and Public Education/Outreach

2014  Lake Griffin Nutrient Restoration Project (Projects)
Dr. John Little (Research Efforts)
Wabash River Watershed Sampling Blitz (Volunteer Actions)
Clean Lakes Alliance (Public Education & Outreach)
2013  Chicago Botanic Garden (Projects)
Deal Lake Commission (Projects)
Clear Choices Clean Water (Public Education & Outreach)
2012  Paradox Lake and Adirondack Ecologists LLC (Projects)
Lake of the Woods Water Sustainability Foundation (Volunteer Actions)
Extension Volunteer Monitoring Network (Public Education & Outreach)
2011  Dr. Barry Moore – Washington State University (Projects)
Dr. John (Jack) Jones – University of Missouri (Research)
Ontario Lake Partner Program (Volunteer Actions)
Fairfax County Watershed Plan (Public Education & Outreach)
2010  Wetland & Hydrologic Restoration of the Grand Prairie Site, Flying Eagle Wildlife Management Area, Southwest Florida WMD (Projects)
The Sugar Lake Association, Wright County, Minnesota (Volunteer Actions)
Dana Rizzo & Susan Boser – Pennsylvania State Coop. Extension (Public Education & Outreach)
J. Clark, B. Swistock, T. McCarty & M. Barkley – Penn State Cooperative Extension (Public Education & Outreach)
Dr. Robert Doyle (Public Education & Outreach)
2009  Long Pond, Towns of Brewster & Harwich, Mass. (Projects)
Town of Warrenton, Virginia (Projects)
Jane & Carroll Johnson (Volunteer Actions)
Woodridge Lake Property Owners Association (WLPOA) (Volunteer Actions)
2008  Alberta Lake Management Society (Volunteer Actions)
Bow River Basin Council (Public Education & Outreach)
Dick Lathrop (Research)
2007  Brian Kotak & Ron Zurawell (Research)
St. Johns Water Management District & Southwest Florida Water Management District (Research)
2006  Cobossee Watershed District (Public Education & Outreach)
Tennessee Valley Authority Stream, River & Tailwater Assessment (Public Education & Outreach)
2005  LakeSuperiorStreams.org (Public Education & Outreach)
Tennessee Valley Authority Spring Sportfish Survey (Public Education & Outreach)
2004  Lake Hopatcong Commission (LHC) (Public Education & Outreach)
Las Vegas Wash Coordination Committee (Volunteer Actions)
2003  Lake Mohawk Lake Community (Project)
Champlain 2000 (Public Education & Outreach)
Maine Lakes Conservancy Institute (Public Education & Outreach)
2002  Tennessee Valley Clean Marina Initiative (Public Education & Outreach)
Gertrud Nürnberg (Research)
2001  Chocorua Lake Project (Project)
White Meadow Lake Property Owners Association (Volunteer Actions)
2000  Mount Arab Preserve Association (Volunteer Actions)
Bhoj Wetland Project, India (Project)
2002  TVA Clean Marina Initiative (Project)
Third Lake Project – Mark Pfister, Leader (Project)
2001  Hartford Union High School Environmental Club (Volunteer Actions)
2000  Michael Martin (Public Education and Outreach)
Stafford Pond (Project)
2000  Lionel Dallas (Volunteer Actions)
Peter Siver (Research)
2000  Gordon Davis (Public Education and Outreach)
Sidney Post (Public Education and Outreach)
Scott Williams (Public Education and Outreach)  
WOW/Lake Access Team at University of Minnesota-Duluth (Public Education and Outreach)  
1999  
Steve LaMere (Public Education and Outreach)  
John Holz (Research)  
Madeleine Ducham (Volunteer Actions)  
Bass Bay/Big Muskego Lake Management District and Wind Lake Management District (Volunteer Actions)  
1998  
Robert Korth (Public Education and Outreach)  
Pine Lake Restoration Society, Alberta, Canada (Volunteer Actions)  
Paul Garrison (Research)  
James LaBounty (Research)  
1997  
Upper Tippecanoe Water Quality Project (Project)  
Oster Creek Community (TX) Environmental Action Network (Volunteer)  
1996  
Lake Shaokatan Restoration  
Lake Bemidji Watershed Management Project (Project)  
1995  
Steve Effler (Research)  
Friends of Menotomy Rocks Park (Volunteer)  
1994  
Wally Christiansen (Volunteer)  
Tom Murphy (Research)  
Terry Bovee (Volunteer)  
Patricia Chambers (Research)  
Interactive Lake Ecology (Project)  
Craig Heaton (Volunteer)  
1993  
Vadnais Lake/Lambert Creek Watershed Improvement Project (Project)  
John P. Smol and the Paleoecological Environmental Assessment & Research Laboratory (Research)  
John Barko (Research)  
Joanna Buehler (Volunteer)  
Florida Lake Watch (Project)  
1992  
Ellie Prepas (Project)  
Little Rock Lake, Whole Lake Acidification (Project)  
1991  
Lake Delavan (Project)  
Corps of Engineers WES (Research)  
Bruce Wilson (Research)  
1990  
Robert Munyon (Volunteer)  
Newroth/Welch/Peterson/Cooke (Research)  
Joe Shapiro (Research)  
1989  
Lake Summerset (Project)  
Lake Morey, VT (Project)  
1988  
David Sutton (Research)  
Ken Reckhow (Research)  
Bob Carlson (Research)  
Bill Walker (Research)  
1987  
Lake Jackson, FL (Project)  
1985  
Lake Geneva, WI (Project)  

**Jody Connor Student Awards**

These annual awards recognize the best student presentation and best student poster at the Annual Symposium.

2016  
Comparing Predictive Modeling Techniques for Cyanobacterial Abundance, Microcystin, and Geosmin in a Eutrophic Midwestern USA Drinking Water Supply Reservoir (Presentation)  
Ted Harris  
Cold Spots and Cold Moments: The Potential for Sediment Freezing to Depress Denitrification in Wetland Sediments (Poster)  
Kimberly Gilmour  
2015  
High Resolution Spatial and Temporal Data to Understand Nutrient Concentrations and Loads That Influence Algal Blooms in a Small Lake: How Much Data Do We Need? (Presentation)  
Trea LaCroix  
Three Lakes, One Management Plan (Poster)  
Maxine Verteramo  
2014  
Paleolimnological Assessment of Atmospheric Heavy Metal Deposition in Eastern Washington Lakes: Phase 1 – Chemical Analyses of Sediment Cores (Presentation)  
Andrew Child  
Determining Bioavailable Phosphorus in Lake Whatcom (Washington) Stormwater Using Dual Culture Diffusion Apparatus Bioassays (Poster)  
Jonnel Deacon  
2013  
Feeding Ecology of a Mixed Cold- and Warm-Water Fish Community Following Hypolimnetic Oxygenation in Mesotrophic Twin Lakes, WA (Presentation)  
Megan Skinner  
Sediment Properties Affecting Methane Storage and Ebulition in Southern California Lakes (Poster)  
Jacob Shiba  
2012  
Detection and Quantification of the Cyanotoxin, Microcystin, in Fish Muscle Tissues (Presentation)  
Ellen Preece  
Rapid Response to Control Myriophyllum spicatum in Blackhawk Lake, Wisconsin (Poster)  
Laura Sefton  
2011  
Remediation of Eutrophic Lakes: Is Iron Treatment Safe for Aquatic Invertebrates? (Presentation)  
Lindsey Wilson  
The Role of Insects in the Nutrient Budget of Spirit Lake, Mount Saint Helens, Washington (Poster)  
Katie Royer
<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Author</th>
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<tbody>
<tr>
<td>2010</td>
<td>The Impact of Alum Based Advanced Nutrient Removal Processes on Phosphorus Bioavailability (Presentation)</td>
<td>Bo Li</td>
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<td>2009</td>
<td>Long-term Trophic State Indicator Trends in Florida Lakes (Presentation)</td>
<td>Dana Bigham</td>
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<td>2008</td>
<td>Macroinvertebrate and Waterfowl Communities of Rotationally Grazed Temporary Prairie Pothole Wetlands (Presentation)</td>
<td>Carly Silver</td>
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<td>2006</td>
<td>Paleolimnological Assessment of Lake Geneserath, Beaver Island, Charlevoix County, Michigan Using Fossil Diatom Assemblage, Total Phosphorus and Chlorophyll (Presentation)</td>
<td>Jane Schild</td>
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<td>2005</td>
<td>Epilimnetic Bacterioplankton Communities Exhibit Interalannual Patterns of Composition and Succession in a Eutrophic Lake (Presentation)</td>
<td>Ashley Shade</td>
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<td>2004</td>
<td>Productivity and Growth Rates of Egeria densa in the Sacramento-San Joaquin Delta (Presentation)</td>
<td>Toni Pennington</td>
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<td>2003</td>
<td>Ecology of Lake Griffin, a Hypereutrophic Cyanobacteria-Dominated Lake in Central Florida (Presentation)</td>
<td>J. Frost</td>
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<td>Defining Reference Conditions for Measuring the Effects of Shoreline Development in Lakes in Maine (Poster)</td>
<td>Kristen Ness</td>
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<td>Phenology and Impacts of Egeria densa in a Drinking Water Reservoir (Presentation)</td>
<td>Toni Pennington</td>
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<td>Growth of Indicator Bacteria in Surface Waters (Poster)</td>
<td>Kristal Davis</td>
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<td></td>
<td>A Study of Bacterial Contamination in Ponds and Rivers in Myrtle Beach, South Carolina (High School Poster)</td>
<td>R. Cromer</td>
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<td>2001</td>
<td>Atmospheric Deposition of Phosphorus to Lake Tahoe (Presentation)</td>
<td>Marie Liu</td>
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<td></td>
<td>Students can Protect Lakes through Political Influence and Communications (High School Presentation)</td>
<td>Aris Severn</td>
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<td>Lake Classification in the Sand Hills Region of Nebraska (Poster)</td>
<td>Aris Severn</td>
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<tr>
<td>2000</td>
<td>Potential Biological Removal Mechanisms of Pathogens in Constructed Wetlands (Presentation)</td>
<td>Elena F. Proakis</td>
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Code of Conduct

The North American Lake Management Society commits to promoting a welcoming environment while fulfilling our mission of forging partnerships among citizens, scientists, and professionals to foster the management and protection of lakes and reservoirs. We intend to do this during daily operations, which includes the annual NALMS symposium, by fostering environments that are safe, collaborative, supportive, and productive for all members and attendees, including sponsors, exhibitors, guests of members, invited speakers, and members of the media. We intend to conduct our business in a fair, honest, and ethical manner that values the diversity of views, expertise, opinions, backgrounds, and experiences reflected among our membership and all conference and event attendees.

All attendees, speakers, sponsors and volunteers at our conference are required to abide by the following code of conduct. Organizers will be available for those that need to report an incident or concern. We expect cooperation from all participants to help ensure a safe, welcoming and inclusive environment for everyone.

Expected Behavior

• Treat everyone with respect.

• Communicate openly and thoughtfully and be considerate of varying views, opinions, levels of experience, and backgrounds.

• Be respectful in your critique of ideas and avoid personal attacks directed toward other attendees, participants, NALMS staff, sponsors, and vendors.

• Respect the rules and policies of the symposium venue, hotels, NALMS contracted facilities, or any other venue.

• Be mindful of your surroundings and fellow participants. Alert a NALMS staff member or designated contact person if you notice unacceptable behavior, a dangerous situation or someone in distress.

Unacceptable Behavior

• Harassment and intimidation, including any verbal, written, or physical conduct designed to threaten, intimidate, or coerce another attendee, speaker, volunteer, exhibitor, NALMS staff member, service provider or other meeting guest;

• Discrimination based on gender or gender identity, sexual orientation, age, disability, physical appearance, body size, race, religion, national origin, or culture; or

• Physical or verbal abuse of any attendee, speaker, volunteer, exhibitor, NALMS staff member, service provider or other meeting guest.

• Examples of unacceptable behavior also include, but are not limited to: inappropriate use of nudity and/or sexual images in public spaces or in presentations; threatening or stalking any NALMS symposium participant; or sexually harassing any NALMS symposium participant.

• Disruption of talks at oral or poster sessions, in the exhibit hall or at other events organized by NALMS at the meeting venue, hotels, or other NALMS contracted facilities is not allowed.

Consequences

• Anyone requested to stop unacceptable behavior is expected to comply immediately.

• NALMS staff (or their designee) or security may take any action deemed necessary and appropriate, including immediate removal from the meeting without warning and potentially without refund.

• NALMS reserves the right to prohibit attendance at any future meeting.

Reporting Unacceptable Behavior

• If you are the subject of unacceptable behavior or have witnessed any such behavior, please immediately notify a NALMS staff member or a designated contact person.

• Notification should be done by contacting a NALMS staff person or the designated contact persons on-site or by e-mailing your concern to one of the designated contact persons.

• Anyone experiencing or witnessing behavior that constitutes an immediate or serious threat to public safety at the symposium location or other NALMS event is advised to either tell a security guard or locate a house phone and ask for security.

• Reporting should never be done via social media.

Administration

• Any reports of unacceptable behavior will be handled on a case-by-case basis by one or more of the designated contact persons.

• The Code of Conduct, including contact information for the designated contact persons, will be made available to all members and conference attendees as follows: inserted into the conference program, posted to the NALMS website, and included in the NALMS Operations Manual and Strategic Plan.

• NALMS staff and designated contact persons will be introduced at the beginning of the conference and will make every effort to be visible and available to attendees at the annual symposium.

• The list of designated contact persons will be updated annually prior to publication in the conference program.

Code of conduct adapted from International Marine Conservation Congress (IMCC) and Ecological Society of America (ESA).

http://conbio.org/mini-sites/imcc-2016/registration-participation/code-of-conduct/

https://www.esa.org/esa/meetings/esa-meetings-code-of-conduct/

NALMS Meeting Code of Conduct approved by the Board on September 7, 2017
General Conference Information

Name Badges & Event Tickets
For most events and functions at the symposium, your name badge is your only ticket. Wear it to all activities during the Symposium. All individuals participating in Symposium events or activities must be registered and have a name badge.

Poster Session Set Up
All Posters will be on display from Tuesday morning through the end of sessions on Wednesday. If you are presenting a poster, please make sure that your poster is set-up on Monday, November 6, between the hours of 2:00 pm and 4:45 pm. The Poster Display Area will be located in the Westminster Foyer.

Message Board
Do you have a job listing you’d like to post? Are you looking to pass along other information (no advertising)? Post it on our message board located near the registration desk. Guests of attendees who wish to organize should use the message board to arrange a meeting location and time for daily excursions.

Hospitality
The NALMS Hospitality Room is open Tuesday and Wednesday nights (check daily schedules for times) and is located in the Flatirons / Long’s Peak Rooms on the second floor of the Westin Westminster. Relax with your NALMS friends, new and old.

Silent Auction
Be sure you stop by the Silent Auction tables, located in the Westminster Ballroom, during the conference. Many and varied items will be on display for your bid. All proceeds go to the Eberhardt Memorial Student Fund which provides support to NALMS’ Student members. Not only does the money raised go for a good cause, you won’t want to miss the exciting and unique items awaiting your bid. Bidding begins on Tuesday morning and ends at 3:30 pm on Wednesday. Winners may pay for and pick up their items at the registration desk on Thursday until 1:30 pm.

Photo Contest
Help pick the covers for upcoming issues of LakeLine Magazine! The 2017 NALMS Photo Contest entrants will be displayed near the registration desk. Cast your vote for your favorite photos. Winning entries may appear in your mailbox in the near future! Sponsored by Water Resource Services.

Special Opportunities for Students
We have a number of events and opportunities specifically for students attending the conference:

Student Luncheon, Resume Review and NALMS Student and New Author Workshop: How to Publish in Lake and Reservoir Management
Tuesday, November 7
Lake House
12:00 pm – 1:15 pm
Come enjoy a casual lunch, meet other students, and hear about what NALMS has to offer students like you! Additionally, the 3rd annual resume review will take place during the luncheon. The resume review allows students to get feedback on the strengths and weaknesses of their resumes from professionals in the field.

The luncheon will conclude with a presentation by Al Sosiak, Editor of the NALMS journal, Lake and Reservoir Management, who will provide tips to successfully publish in the Journal. His presentation will be followed by a question and answer period.

Please grab your lunch in the Westminster Ballroom and join us for lunch in the Lake House.

Student Presentation Awards
Student presenters are eligible to compete for the Jody Connor Student Awards! Awards will recognize the top two student oral and poster presentations. The awards are sponsored by SOLitude Lake Management.
Registration and Meal Functions

Registration
Located in the Westminster Foyer.

Hours:
- Monday, November 6: 7:00 am – 5:30 pm
- Tuesday, November 7: 7:00 am – 5:30 pm
- Wednesday, November 8: 7:00 am – 3:30 pm
- Thursday, November 9: 7:30 am – 1:30 pm

Meal Functions
Unless noted otherwise, all meals listed below are provided to all full conference registrants on Tuesday, Wednesday & Thursday. Daily registrants receive all meals on the day that they are registered for the conference.

* Available to workshop participants only.

Continental Breakfast
- *Monday, November 6: 7:30 am – 8:00 am Windsor
- Tuesday, November 7: 7:00 am – 8:30 am Westminster Ballroom
- Wednesday, November 8: 7:00 am – 8:30 am Westminster Ballroom
- Thursday, November 9: 7:30 am – 8:30 am Westminster Ballroom

Morning Break
- *Monday, November 6: 10:00 am – 10:30 am Windsor
- Tuesday, November 7: 10:00 am – 10:30 am Westminster Ballroom
- Wednesday, November 8: 10:00 am – 10:30 am Westminster Ballroom
- Thursday, November 9: 10:00 am – 10:30 am Westminster Ballroom

Lunch
- *Monday, November 6: 12:00 pm – 1:00 pm Lake House
- Tuesday, November 7: 12:00 pm – 1:30 pm Westminster Ballroom
- Wednesday, November 8: 12:00 pm – 1:30 pm Westminster Ballroom
- Thursday, November 9: 12:00 pm – 1:30 pm Westminster Ballroom

Afternoon Break
- *Monday, November 6: 3:00 pm – 3:30 pm Windsor
- Tuesday, November 7: 3:00 pm – 3:30 pm Westminster Ballroom
- Wednesday, November 8: 3:00 pm – 3:30 pm Westminster Ballroom

Exhibitors’ Reception and Poster Session
- Tuesday, November 7: 5:45 pm – 7:00 pm Westminster Ballroom / Foyer

NALMS Awards Reception & Banquet
*Tickets are required for this event. Tickets are free with a full conference registration or Wednesday-only registration, however, there are a limited number available.*

- Wednesday, November 8: 5:00 pm – 7:00 pm Reception at the Butterfly Pavilion
- 7:15 pm – 9:00 pm Banquet in the Westminster Ballroom
**Workshops**

**Alum for Phosphorus Control in Lakes and Ponds**  
Monday, November 6, 8:00 am – 5:00 pm | Meadowbrook II

*Sponsored by HAB Aquatic Solutions*

Alum (aluminum sulfate) is widely used for controlling phosphorus (P) in lakes and ponds. There is a large body of knowledge and wide experience using alum due to its efficacy, safety and cost-effectiveness. This workshop provides a systematic overview of the planning, diagnostic, monitoring, dosing and application technologies for using alum for P control. Alum use strategies for deep and shallow lakes include a) water column P stripping, b) P interception, c) maintenance dosing, d) sediment P inactivation and e) P control in ponds. We provide overviews of the history of alum use, long-term efficacy, aluminum chemistry, diagnostic and modeling tools, a decision matrix for the appropriate alum use strategy, dosing calculations, application technologies and monitoring requirements. As well, we provide updated information on other P precipitants and compare/contrast costs, efficacy, reliability, etc. We will discuss numerous case studies and welcome participants to present their lakes’ concerns. The workshop is interactive and there is ample time for discussion.

**Presenters**

Harry Gibbons has authored scientific articles, makes frequent presentations on lake management and participated in his first whole lake alum treatment in 1974 and has been actively involved in over 265 alum applications. He has served on the NALMS Board and as Past-President. Dick Osgood has conducted hundreds of diagnostic/modeling evaluations has authored numerous scientific articles, including design and implementation of alum treatments for lakes. He has served on the NALMS board as treasurer and as Past-President. Shannon Brattebo is an environmental engineer. Shannon's work has focused on lake and reservoir water quality, restoration, and management both in the Pacific Northwest and across the nation. Shannon has been a member of NALMS since 2001, is currently NALMS Region 10 Director and is a past board member of the Washington Lakes Protection Association. John Holz and Tadd Barrow are limnologists who own and operate HAB Aquatic Solutions, which specializes in conducting both small and large-scale alum applications. Both John and Tadd are longtime members of NALMS and John is a past regional director on the NALMS board.

**Collection, Identification, Ecology and Control of Freshwater Algae**  
Monday, November 6, 8:00 am – 5:00 pm | Standley I

*Sponsored by PhycoTech, Inc.*

Algae are an important part of a properly functioning natural aquatic system, but when algae become abundant, water uses and habitat are often impaired. Toxicity of algae has become a "hot button" issue, and other water quality implications and aesthetic considerations remain prominent issues. All algae were not created equal, however, and proper collection and identification are essential to selecting a management strategy. This workshop is intended to provide information on how to collect and recognize common genera within major groups of algae, with emphasis on taxonomic detail and identification approaches. Participants are encouraged to bring any algae samples with which they would like identification help. The workshop also covers basic algal ecology and the methods used to control algae, but with only 8 hours, we can only introduce participants to issues and options. The workshop is taught by Drs. Ken Wagner and Ann St. Amand, experienced algal taxonomists and ecologists working in applied fields. Collectively they have many years of experience assessing algal problems, evaluating impacts and causes of algal nuisances, and developing algal management programs.

**Presenters**

Ann St. Amand (co-chair) holds a Ph.D. in Aquatic Ecology from the University of Notre Dame. She has 31 years of experience identifying and enumerating over 39,000 algal samples from all over North America. Her company uses a unique proprietary mounting method, and custom software containing information on nearly 34,000 different aquatic organisms.

Ken Wagner (co-chair) holds a B.A. in Environmental Biology from Dartmouth College and M.S. and Ph.D. degrees in Natural Resource Management from Cornell University. He has taught an algal workshop in association with the North American Lake Management Society for 25 years, working cooperatively with expert phycologists and ecologists.

Barry Rosen has a B.S. in Botany from University of Connecticut, Storrs, M.A. in Biology from St. Cloud State University, Minnesota, and Ph.D. in Biology from Bowling Green State University, Bowling Green, Ohio. He has worked in algae in freshwater ecosystems for the past 40 years. He has been affiliated with several universities, the private sector, state and currently the federal government and the University of Central Florida. He has lived in several states including Virginia, Nebraska, Florida, Oregon, Vermont, Michigan, North Carolina and now Florida, working on HABs nationwide.

Andrew Chapman has been a phycologist with GreenWater Laboratories since its inception in 2001. He received his B.S. in Biology from Susquehanna University in 1990 and a M.S. in Botany from the University of Oklahoma in 1993. His master’s research was on freshwater dinoflagellates. Since moving to Florida in 1993 he has been particularly interested in the ecology and taxonomy of potentially toxic cyanobacteria.
Do-It-Yourself Lake, Shoreline, & Watershed Mapping: Telling Stories with Online Maps
Monday, November 6, 8:00 am – 12:00 pm | Library

The scientific, volunteer and lake management communities have historically invested significant time and money into collecting and analyzing data about lake characteristics. In spite of these vast efforts, a relatively small amount of time has been dedicated to finding compelling ways to present this information to the wide range stakeholders involved with and affected by lake issues. While standard graphs and tables in PDF reports and PowerPoint presentations may communicate information effectively to select groups, a far wider audience would be more responsive to stories, images, videos and maps that they can interact with on their own terms. Several approaches to online mapping have dramatically expanded the ability of people to present information in a compelling online format for free (or nearly so) without any coding knowledge. To harness the emerging capabilities of online mapping to the benefit of their lakes, participants in this session will learn how to use ArcGIS Online and Story Maps to create maps, share data and tell stories.

Presenter
Shane Bradt leads the geospatial technology outreach program for Cooperative Extension at the University of New Hampshire. He is responsible for developing, coordinating and leading a range of training opportunities on mapping topics, including desktop GIS, online mapping, storytelling with maps and mobile mapping. Shane coordinates the eXtension geospatial technologies community (Map@Syst) group, leading efforts to promote the use of mapping throughout Extension nationally. Shane is a professor in the Department of Biological Sciences at UNH, specializing in lake water quality and issues related to cyanobacteria, and is the co-lead of the NALMS Inland HAB’s Program.

Do-It-Yourself Lake, Shoreline, & Watershed Mapping: Collecting Field Data with Smartphones
Monday, November 6, 1:00 pm – 5:00 pm | Library

With the widespread availability of smartphones and tablets, identifying and mapping your lake and watershed should be easier than ever. However, instead of effectively using their phones to collect data, many people get caught up in the choices of which technology to use and how best to use it. This session will teach you to use a mobile device to collect data in the field and make a map using easy and inexpensive (or free) apps and software. We will start a review of the most capable mapping apps available for iOS and Android. We then get hands-on collecting data using mobile device. Once finished, each participant will use the data they just collected to make a map. Finally, we will learn how to upload data to the mobile device from a computer.

Presenter
Shane Bradt leads the geospatial technology outreach program for Cooperative Extension at the University of New Hampshire. He is responsible for developing, coordinating and leading a range of training opportunities on mapping topics, including desktop GIS, online mapping, storytelling with maps and mobile mapping. Shane coordinates the eXtension geospatial technologies community (Map@Syst) group, leading efforts to promote the use of mapping throughout Extension nationally. Shane is a professor in the Department of Biological Sciences at UNH, specializing in lake water quality and issues related to cyanobacteria, and is the co-lead of the NALMS Inland HAB’s Program.

Internal Phosphorus Loading
Monday, November 6, 8:00 am – 5:00 pm | Cotton Creek I

Internal phosphorus loading as phosphorus (P) released from anoxic sediment surfaces often represents the main summer P load to lakes. Because of its high biological availability, the lack of dilution, and the timing, it can have an immense effect on summer water quality of a lake, reservoir, or pond. However, depending on the stratification of the lake, it is not always easy to determine the quantity of internal load (especially in polymeric lakes), and it may be difficult to estimate the ultimate effect it may have on surface water quality (especially in stratified lakes).

This workshop presents a way of quantifying internal load in polymeric as well as stratified lakes. Considering lake characteristics and data availability, such quantification can be done in a step-wise fashion, where missing data may be predicted by subsidiary models. After the mere quantification of internal load the participant will learn how to combine it with external load in a simple mass balance model to predict seasonal phosphorus concentration. Knowing this, other water quality characteristics (algal biomass, bloom frequencies, Secchi disk transparency, and hypolimnetic anoxia) can be arrived at. Applications regarding lake quality assessment, nutrient criteria, total maximum daily load (TMDL) computations, and restoration options will be discussed.

Each workshop topic will include a description of the theory and presentation of case studies covering US, Canadian, and European lake assessment and restoration projects. Open discussion with attendees is encouraged, and comprehensive handouts and references will be provided. For preparation, see publications listed at http://www.fwr.ca, especially Nürnberg GK. 2009: Assessing internal phosphorus load – problems to be solved. Lake Reservoir Management 25:419–432.

Presenter
Gertrud K. Nürnberg, Ph.D. is an environmental scientist at Freshwater Research, a limnological company focusing on restoration and modeling of eutrophic lakes and reservoirs. She is specialized in internal processes in eutrophic lakes such as internal phosphorus loading and hypoxia and has more than 30 years of experience working with lake associations, governmental agencies, engineering companies and the private sector in the US, Canada, and Europe. She has published comparative research and empirical lake models on phosphorus, iron and anoxia and on lake management techniques in numerous scientific journals and was an associate editor of the NALMS Journal, Lake and Reservoir Management, in 1996–2014.

John Fielder Photography Workshop
Monday, November 6, 10:00 am – 5:00 pm | Standley II

This is your opportunity to learn landscape photography directly from Colorado’s premier nature photographer, John Fielder. Find out how John creates his award-winning images and gain a deeper understanding of the visual aspects of nature. In a comprehensive 2-hour slide show lecture learn how to improve your
compositions and get an insider’s look at professional techniques, including which bells and buttons you only really need to use on your camera. At the end of the lecture, John will discuss and demonstrate the most important tools used in the post-processing program Lightroom. Appropriate for all levels of photographers, beginner to advanced.

We will break for lunch then spend 4 hours at some of John’s favorite Denver area scenic open spaces and parks photographing side-by-side with John. He will show you his compositions in his LCD, and he will critique yours. Any type of digital camera, point & shoot or SLR, is appropriate. Limit 16 participants.

Presenter
John Fielder has worked tirelessly to promote the protection of Colorado’s ranches, open space, and wildlands during his 35-year career as a nature photographer and publisher. His photography has influenced people and legislation, earning him recognition including the Sierra Club’s Ansel Adams Award in 1993 and, in 2011, the Aldo Leopold Foundation’s first Achievement Award given to an individual. Over 40 books have been published depicting his Colorado photography. He lives in Summit County, Colorado, and operates a fine art gallery, John Fielder’s Colorado, in Denver’s Art District on Santa Fe. He teaches photography workshops to adults and children. His latest books are Colorado’s Yampa River: Free Flowing & Wild from the Flat Tops to the Green and Wildflowers of Colorado. Information about John and his work can be found at johnfielder.com.

Real Time Test Systems for Cyanotoxins
Morning Session
Monday, November 6, 8:00 am – 12:00 pm | Meadowbrook I

Afternoon Session
Monday, November 6, 1:00 pm – 5:00 pm | Meadowbrook I

Most of the harmful algae blooms in lakes throughout the world are due to cyanobacteria which include species that can produce toxins that are broadly called cyanotoxins. There is growing concern about the potential health and environmental effects of toxic blooms as cyanotoxins can cause illness and death of humans plus both domestic and wild animals. Children are at greater risk because of their smaller body size and the way they play in the water. The workshop is intended to provide approaches and examples for response protocols, risk assessment, monitoring programs and management options associated with harmful algae blooms and related cyanotoxins. The morning phase will present both historical background and an overview of rapid test methods and discuss the importance of sample collection, preparation, treatment, storage and transportation. Each participant will have an opportunity to conduct a semi-quantitative microcystins and/or cylindrospermopsin lateral flow, dipstick test. The afternoon phase will focus on participants conducting quantitative microtiter plate format analysis.

Attendees may register for either the morning or afternoon session, or for both sessions.

Presenter
Dave Deardorff holds a B.S. in Civil Engineering from Bucknell University and a MBA from the Wharton School. He is a retired Colonel, AUS, and is a licensed professional engineer with over forty years’ experience in environmental engineering. He has conducted over 100 installations and trainings of cyanotoxin systems globally for municipal, state and federal agencies.

The Role of Aeration/Oxygenation in Lake and Reservoir Management
Monday, November 6, 8:00 am – 5:00 pm | Cotton Creek II

Addition of air or oxygen is frequently used as a lake management option for lakes suffering from oxygen depletion. When used properly, aeration/oxygenation can increase oxygen concentrations in the water column, decrease sediment nutrient release, minimize iron and manganese concentrations, and prevent fish kills. These systems can be designed to provide complete mixing throughout the water column, increase oxygen concentrations in the hypolimnion without mixing the lake, or to aerate surface waters and provide aesthetic appeal. Improperly designed or installed aeration systems can increase algal growth and lead to decreased water clarity. The morning session of this workshop will discuss the pros and cons of aeration systems, describe factors that must be considered to properly design aeration/oxygenation systems, and present case studies for both successful and unsuccessful applications. The afternoon will include a tour of local reservoirs with different aeration systems.

Presenters
Chris Holdren is a Certified Lake Manager and has served as President, Treasurer, and Board member for NALMS, and also served on the Boards of the Pennsylvania Lake Management Society, the Virginia Lakes and Watersheds Association, and the Colorado Lake and Reservoir Management Association. He has over 40 years of experience with lake and watershed management projects.

Jim Ruane is the President of Reservoir Environmental Management, Inc. and has over 50 years of experience in water quality management for water resources, mathematical modeling, field assessments, and research. He specializes in the development and application of river and reservoir models for hydrodynamics, water quality, aeration, and operational strategies as well as development of water quality management strategies. Assessing oxygen demands and aeration alternatives often is a site-specific process. He has worked on 150 reservoir projects, primarily hydropower projects.

Bob Kortmann is the founder and principal investigator of Ecosystem Consulting Service, Inc. and directs all research, consulting, and implementation projects for that firm. He specializes in the design and installation of aeration systems, and his work has led to the development of new diagnostic techniques and innovative lake and reservoir restoration methods, including three US patents.

Alex Horne is an Emeritus Professor with the Department of Civil and Environmental Engineering at the University of California Berkeley and former NALMS Board member. He has studied lakes, reservoirs, streams, wetlands and oceans in Africa, Antarctica, Europe, the Middle East, Australia, Asia, and North and South America. He has been a Principal Investigator in over 100 funded research projects and served as a consultant for over 600 water-related projects throughout the world. His projects included additions of oxygen or air for fish health and eutrophication reversal, and TOC/DOC and taste and odor reduction in reservoirs.
Field Trips and Special Events

Tools for Water Quality Monitoring or Sondes and Suds
Monday, November 6, 8:30 am – 5:00 pm | Meet at the Conference Center Main Entrance

*Sponsored by In-Situ and YSI, Inc.*

Spend a day traveling along Colorado’s beautiful Front Range while learning about the manufacture and use of sensors for monitoring various water quality parameters. This all-day tour will visit OTT Hydromet and In-Situ, two leading manufacturers of sondes and sensors used to measure the health of lakes and streams. The tour will also visit with staff from the city of Westminster, who use a YSI profiling unit to monitor the reservoir that is the source of their drinking water. Participants will have time to compare and discuss the uses of different types of water quality sensors in different settings. Along the way, the group will stop for lunch, with the opportunity to sample craft beers.

NALMS New Member Reception
Monday, November 6, 5:00 pm – 6:00 pm | Lake House

*Sponsored by NorthEast Aquatic Research*

Are you a new NALMS member? Is this your first NALMS symposium? If so, please join us for a special welcome reception where you will have the opportunity to meet other first-timers, members of the NALMS Board of Directors and the Symposium Host Committee.

Brewery Tours
Monday, November 6, 6:00 pm – 10:00 pm | Meet at 5:45 pm at the Conference Center Main Entrance

*Sponsored by the Colorado Lake and Reservoir Management Association*

Did you know that beer is kind of a big deal in Colorado? Well, experience it yourself with brewery tours organized by NALMS. We will be taking 100 people to a selection of three breweries in your choice of Denver or Boulder (selected during registration). Price includes transportation from the Westin to the breweries and one beer at each brewery. Additional beer can be purchased at the breweries and food and alcohol consumption is allowed on the bus.

Yoga
Tuesday, November 7, 7:00 am – 8:00 am | $10 | Gray’s Peak

Wake up with an invigorating hatha yoga class — a potent alignment-oriented practice that emphasizes the forms and actions within yoga postures. We will draw upon a range of postures that build strength, flexibility, and highly-refined awareness in body and mind. Targeting the myofascial connections to correct postural imbalances, this class will focus on relieving the strain from occupation-related repetitive physical motions commonly used in office settings, such as sitting for long periods of time, typing, and forward head posture from peering at those pesky computer screens! Join us to relieve stress, focus on breath, and enjoy gentle movements that will open your body as well as your heart.

NALMS Membership Meeting
Tuesday, November 7, 5:00 pm – 5:45 pm | Cotton Creek

All NALMS members are encouraged to attend and participate in our annual membership meeting.

Exhibitors’ Reception and Poster Session
Tuesday, November 7, 5:45 pm – 7:00 pm | Westminster Ballroom / Westminster Foyer

NALMS, the Local Host Committee and our exhibitors invite you to join us in kicking off the symposium and welcoming attendees to Denver. Take time to relax, view the poster displays and visit with the exhibitors and fellow attendees.

Euchre Tournament
Tuesday, November 7, 8:00 pm – 11:00 pm | Flatirons / Long’s Peak

Have you always wondered what the big deal was with the euchre card game in the hospitality rooms? Beginners to experts are all welcome to play. This is a great time to learn the game, socialize with the experts (limnologists as well as euchre players), and enjoy the hospitality room. To understand how the tournament will work, check out www.euchrefun.com/2013/04/run-euchre-tournament.html.
Yoga
Wednesday, November 8, 7:00 am – 8:00 am | $10 | Gray's Peak

Wake up with an invigorating hatha yoga class — a potent alignment-oriented practice that emphasizes the forms and actions within yoga postures. We will draw upon a range of postures that build strength, flexibility, and highly-refined awareness in body and mind. Targeting the myofascial connections to correct postural imbalances, this class will focus on relieving the strain from occupation-related repetitive physical motions commonly used in office settings, such as sitting for long periods of time, typing, and forward head posture from peering at those pesky computer screens! Join us to relieve stress, focus on breath, and enjoy gentle movements that will open your body as well as your heart.

Clean Lakes Classic
Wednesday, November 8, 12:00 pm – 1:30 pm | Runners meet in the Conference Center Main Entrance at 11:45 am.

Sponsored by Wenck

The annual Clean Lakes Classic starts at mid-day from the Westin Westminster. The 5-kilometer run / walk takes participants on a route through Westminster City Park, located across the street from the Westin Westminster. You need not be a runner to participate! All pre-registered participants receive a t-shirt as part of the sign-up fee.

NALMS Awards Reception and Banquet
Wednesday, November 8
Pre-Banquet Reception, 5:00 pm – 7:00 pm | Butterfly Pavilion

Sponsored by GEI Consultants, Inc.

NALMS Awards Banquet, 7:15 pm – 9:00 pm | Westminster Ballroom

Join us for a special evening of food, fellowship and recognition. NALMS’ Awards Reception & Banquet is the culmination of the Society’s year. Our evening begins with a reception at the Butterfly Pavilion, located a short walk from the Westin Westminster. The Butterfly Pavilion is the first stand-alone nonprofit invertebrate zoo in the nation and is home to over 5,000 animals including butterflies, insects and aquatic invertebrates. Be sure to pay a visit to Rosie the tarantula! Our evening at the Butterfly Pavilion will include light hors d’oeuvres and beverages featuring a selection of craft beer from the Denver-Boulder area.

Following the reception, attendees are invited to reconvene at the Westin Westminster to enjoy the banquet and the NALMS Awards program. Awards are presented for Leadership and Service, Advancements in Lake Management Technologies, and Lake Management Success Stories, along with our special recognition awards: Friends of NALMS, the Jim LaBounty Best Paper Award, Jim Flynn Award (outstanding corporation) and the Secchi Disk Award. Our most prestigious award, the Secchi Disk Award, honors the NALMS member who has made the most significant contributions to the goals and objectives of the Society.

Maintaining Water Quality in a High-Altitude Reservoir
Friday, November 10, 8:30 am – 4:00 pm | Meet at the Conference Center Main Entrance

Take a trip up into the high country of Colorado and learn about the challenges of maintaining water quality in lovely Dillon Reservoir. Dillon is Denver Water’s largest storage reservoir and a key recreational asset in Summit County. Completed in 1963, the construction of this reservoir required relocating a small town. Maintaining its clear mountain appeal requires the cooperative work of multiple towns and agencies. Participants will hear from Lane Wyatt, coordinator for the Summit Water Quality Committee, on the many strategies employed by the SWQC to assure that Dillon meets standards imposed by the state of Colorado. These include an innovative phosphorus trading program, multiple commissioned routine and special studies, and promotion of BMPs on local construction sites.

Enjoy lunch at a local brewpub before the return trip to Denver.

Barr Lake Tour and BBQ
Friday, November 10, 10:00 am – 2:00 pm | Meet at the Conference Center Main Entrance

This is a great way to end the week. This special tour will take you to Barr Lake State Park to learn about the 100-year-old reservoir’s history. Barr Lake is known for its birds with more than 350 species of migratory and resident birds having been sighted in the park. The southern half of the lake is a wildlife refuge where bald eagles have been nesting for over 28 years. A barbecue lunch will be included at the newly-renovated Nature Center. Then for those that need a shuttle to the airport, the van can take people to Denver International Airport which is about 15 minutes from Barr Lake.
Exhibitors

Abraxis, Inc.
124 Railroad Drive
Warminster, PA 18974
215-357-3911
www.abraxiskits.com

Applied Biochemists, A Lonza Business
1200 Bluegrass Lakes Parkway
Alpharetta, GA 30004
800-558-5106
www.appliedbiochemists.com

Aqua Sierra, Inc.
9094 US Highway 285
Morrison, CO 80465
303-697-5486
www.aqua-sierra.com

Aquarius Systems
200 N Harrison Street
North Prairie, WI 53153
262-392-2162
www.aquarius-systems.com

Benthica
37500 Bluebird Lane
Elizabeth, CO 80107
303-646-0048
benthica.com

BioSafe Systems
22 Meadow Street
East Hartford, CT 06108
888-273-3088
www.biosafesystems.com

Canadianpond.ca Products Ltd.
513 Knowlton Road
Lac-Brome, QC J0E 1V0
Canada
450-243-0976
www.canadianpond.ca

Colorado Department of Public Health and Environment
4300 Cherry Creek South Drive
Denver, CO 80246
303-692-6343
www.colorado.gov/cdphe

Colorado Lake and Reservoir Management Association (CLRMA)
PO Box 9504
Denver, CO 80209
clrma.org

Cruise Planners
1 Locust Road
Portage, IN 46368
219-706-5137
www.sumactravelservices.com

Dredge America, Inc.
9555 NW Highway N
Kansas City, MO 64153
816-330-3100
www.dredgeamerica.com

EarthTec
113 SE 22nd Street, Suite 1
Bentonville, AR 72712
earthsciencelabs.com

Ecosystem Consulting Service, Inc.
30 Mason Street
Coventry, CT 06238
860-742-0744
ecosystemconsulting.com

Eureka Water Probes
2113 Wells Branch Parkway, Suite 4400
Austin, TX 78728
512-302-4333
waterprobes.com

Fluid Imaging Technologies
200 Enterprise Drive
Scarborough, ME 04074
207-289-3200
www.fluidimaging.com

Gold Systems, Inc. (AWQMS)
2121 S McClelland Street, Suite 204
Salt Lake City, UT 84106
412-491-9421
www.awqms.com

HAB Aquatic Solutions
5100 Van Dorn Street, Suite 6096
Lincoln, NE 68506
402-430-0352
habaquatics.com

Hydrotech
PO Box 5520
Round Rock, TX 78683
512-846-2893
www.hydrotechzs.com

In-Situ
221 E Lincoln Avenue
Fort Collins, CO 80524
800-446-7488
www.in-situ.com

Kasco Marine
800 Deere Road
Prescott, WI 54021
715-262-4488
www.kascomarine.com

Keeton Industries
1520 Aquatic Drive
Wellington, CO 80549
800-493-4831
www.keetonaquatics.com

KISTERS North America
7777 Greenback Lane, Suite 209
Citrus Heights, CA 95610
916-723-1441
www.kisters.net

Lake Bottom Blanket c/o Derma-Safe LLC
32 Juniper Road
Wayne, NJ 07470
973-839-6383
www.lakebottomblanket.com

NALMS 2018
PO Box 5443
Madison, WI 53705
608-233-2836
www.nalms.org/nalms2018

North American Lake Management Society (NALMS)
PO Box 5443
Madison, WI 53705
608-233-2836
www.nalms.org

OTT Hydromet
5600 Lindbergh Drive
Loveland, CO 80539
800-949-3766
www.ott.com

PhycoTech, Inc.
620 Broad Street, Suite 100
St. Joseph, MI 49085
269-983-3654
www.phycoTech.com
Premier Materials Technology, Inc.
7401 Central Avenue NE
Minneapolis, MN 55432
763-785-1411
www.premierwatertreatment.com

Princeton Hydro, LLC
1108 Old York Road, Suite 1
PO Box 720
Ringoes, NJ 08551
908-237-5660
www.princetonhydro.com

SePRO Corporation
11550 N Meridian Street, Suite 600
Carmel, IN 46032
800-419-7779
www.stewardsofwater.com

SolarBee/GridBee (Medora Corp.)
3225 Highway 22
Dickinson, ND 58601
701-225-4495
www.medoraco.com

SOLitude Lake Management
7000 N Broadway, Suite 108
Denver, CO 80221
303-442-2344
www.solitudelakemanagement.com

Taylor & Francis
530 Walnut Street, Suite 850
Philadelphia, PA 19106
215-625-8900
taylorandfrancis.com

Turner Designs
1995 N 1st Street
San Jose, CA 95112
408-749-0994
www.turnerdesigns.com

Vertex Water Features
2100 NW 33rd Street
Pompano Beach, FL 33069
754-307-9790
vertexwaterfeatures.com

Wenck
4025 Automation Way, Building E
Fort Collins, CO 80525
970-223-4705
wenck.com

Wildlife Supply Company
86475 Gene Lasserre Boulevard
Yulee, FL 32097
904-225-9889
wildco.com

YSI, A Xylem Brand
1725 Brannum Lane
Yellow Springs, OH 45387
937-767-7241
ysi.com
# Conference at a Glance

## Monday, November 6

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
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<tbody>
<tr>
<td>7:30 am – 8:00 am</td>
<td>Continental Breakfast – Workshop Participants Only <em>(Windsor)</em></td>
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<tr>
<td>8:30 am – 5:00 pm</td>
<td>Field Trip: Tools for Water Quality Monitoring or Sondes and Suds <em>(meet at the Conference Center Main Entrance)</em></td>
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<td><strong>Workshops</strong></td>
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<tr>
<td>8:00 am – 10:00 am</td>
<td>Alum for Phosphorus Control in Lakes and Ponds</td>
<td>Meadowbrook II</td>
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<td></td>
<td>Collection, Identification, Ecology and Control of Freshwater Algae</td>
<td>Standley I</td>
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<td>DIY Lake, Shoreline, &amp; Watershed Mapping: Collecting Field Data with Smartphones</td>
<td>Library</td>
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<td></td>
<td>Internal Phosphorus Loading</td>
<td>Cotton Creek I</td>
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<td>Real Time Test Systems for Cyanotoxins (Morning Session)</td>
<td>Meadowbrook I</td>
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<td>The Role of Aeration/Oxygenation in Lake and Reservoir Management</td>
<td>Cotton Creek II</td>
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<tr>
<td>10:00 am – 10:30 am</td>
<td>Refreshment Break – Workshop Participants Only <em>(Windsor)</em></td>
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<tr>
<td>10:00 am – 5:00 pm</td>
<td>John Fielder Photography Workshop <em>(Standley II)</em></td>
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<tr>
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<td>12:00 pm – 1:00 pm</td>
<td>Lunch – Workshop Participants Only <em>(Lake House)</em></td>
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<td><strong>Workshops</strong></td>
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<td>Alum for Phosphorus Control in Lakes and Ponds</td>
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<tr>
<td>3:00 pm – 3:30 pm</td>
<td>Refreshment Break – Workshop Participants Only <em>(Windsor)</em></td>
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<td>Real Time Test Systems for Cyanotoxins (Afternoon Session)</td>
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<tr>
<td>5:00 pm – 6:00 pm</td>
<td>NALMS New Member Reception <em>(Lake House)</em></td>
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<tr>
<td>6:00 pm – 10:00 pm</td>
<td>Brewery Tours <em>(meet at the Conference Center Main Entrance)</em></td>
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## Tuesday, November 7

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>7:00 am – 8:30 am</td>
<td>Continental Breakfast / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)</td>
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<tr>
<td>8:30 am – 10:00 am</td>
<td>Opening Plenary Session (Standley Ballroom)</td>
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<td>10:00 am – 10:30 am</td>
<td>Refreshment Break / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)</td>
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<tr>
<td>10:30 am – 12:00 pm</td>
<td>Concurrent Session A&lt;br&gt;Standley I, Standley II, Meadowbrook, Lake House, Cotton Creek&lt;br&gt;Western Issues, Alum, Paleolimnology, Drinking Water Reservoirs, Data Analysis</td>
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<tr>
<td>12:00 pm – 1:30 pm</td>
<td>Lunch / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)&lt;br&gt;NALMS Student Luncheon (Lake House)</td>
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<tr>
<td>1:30 pm – 3:00 pm</td>
<td>Concurrent Session B&lt;br&gt;Standley I, Standley II, Meadowbrook, Lake House, Cotton Creek&lt;br&gt;Climate Change, Chemical Treatment, Paleolimnology, Drinking Water Reservoirs, Data Analysis</td>
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<tr>
<td>3:00 pm – 3:30 pm</td>
<td>Refreshment Break / Exhibits Open / Poster Viewing (Westminster Ballroom)</td>
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<tr>
<td>3:30 pm – 4:40 pm</td>
<td>Concurrent Session C&lt;br&gt;Standley I, Standley II, Meadowbrook, Lake House&lt;br&gt;Climate Change, Monitoring, Paleolimnology, Drinking Water Reservoirs</td>
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<tr>
<td>5:00 pm – 5:45 pm</td>
<td>NALMS' Annual Membership Meeting (Cotton Creek)</td>
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<tr>
<td>5:45 pm – 7:00 pm</td>
<td>Exhibitors' Reception and Poster Session (Westminster Ballroom / Foyer)</td>
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<tr>
<td>8:00 pm – 11:00 pm</td>
<td>Hospitality / Euchre Tournament (Flatirons / Long's Peak)</td>
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### Concurrent Session A
- **Standley I**: Western Issues
- **Standley II**: Alum
- **Meadowbrook**: Paleolimnology
- **Lake House**: Drinking Water Reservoirs
- **Cotton Creek**: Data Analysis

### Concurrent Session B
- **Standley I**: Climate Change
- **Standley II**: Chemical Treatment
- **Meadowbrook**: Paleolimnology
- **Lake House**: Drinking Water Reservoirs
- **Cotton Creek**: Data Analysis

### Concurrent Session C
- **Standley I**: Climate Change
- **Standley II**: Monitoring
- **Meadowbrook**: Paleolimnology
- **Lake House**: Drinking Water Reservoirs

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**Join Us Next Year!**

October 30 – November 2, 2018

**NALMS 2018 Cincinnati, Ohio**
### Wednesday, November 8

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<td>Continental Breakfast / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)</td>
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<td>7:30 am – 8:30 am</td>
<td>NALMS Inland HABs Program Meeting (Westminster Ballroom)</td>
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<td>Aeration / Mixing</td>
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<td>10:00 am – 10:30 am</td>
<td>Refreshment Break / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)</td>
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<td>12:00 pm – 1:30 pm</td>
<td>Lunch / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)</td>
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<td></td>
<td>CLM / CLP Luncheon (Lake House)</td>
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<td>Clean Lakes Classic (Runners meet in the Conference Center Main Entrance at 11:45 am)</td>
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<tr>
<td>Volunteer Monitoring</td>
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<td>3:00 pm – 3:30 pm</td>
<td>Refreshment Break / Exhibits Open / Poster Viewing (Westminster Ballroom / Foyer)</td>
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<th>Time</th>
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<tbody>
<tr>
<td>5:00 pm – 7:00 pm</td>
<td>NALMS Awards Reception (Butterfly Pavilion)</td>
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<tr>
<td>7:15 pm – 9:00 pm</td>
<td>NALMS Awards Banquet (Westminster Ballroom)</td>
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<tr>
<td>9:00 pm – 12:00 am</td>
<td>Hospitality (Flatirons / Long's Peak)</td>
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### Thursday, November 9

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<th>Time</th>
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<tr>
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<td>Continental Breakfast / Exhibits Open (Westminster Ballroom / Foyer)</td>
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<td>Standley I</td>
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<td>National Lakes Assessment</td>
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<td>10:00 am – 10:30 am</td>
<td>Refreshment Break / Exhibits Open (Westminster Ballroom / Foyer)</td>
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<td>Data Management</td>
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Monday, November 6

Continental Breakfast – Workshop Participants Only
7:30 am – 8:00 am | Windsor

Workshop
Alum for Phosphorus Control in Lakes and Ponds
8:00 am – 5:00 pm | Meadowbrook II

*Sponsored by HAB Aquatic Solutions*
See page 20 for details.

Workshop
Collection, Identification, Ecology and Control of Freshwater Algae
8:00 am – 5:00 pm | Standley I

*Sponsored by PhycoTech, Inc.*
See page 20 for details.

Workshop
DIY Lake, Shoreline, & Watershed Mapping:
Collecting Field Data with Smartphones
8:00 am – 12:00 pm | Library

See page 21 for details.

Workshop
Internal Phosphorus Loading
8:00 am – 5:00 pm | Cotton Creek I

See page 21 for details.

Workshop
Real Time Test Systems for Cyanotoxins (Morning Session)
8:00 am – 12:00 pm | Meadowbrook I

See page 22 for details.

Workshop
The Role of Aeration/Oxygenation in Lake and Reservoir Management
8:00 am – 5:00 pm | Cotton Creek II

See page 22 for details.

Field Trip
Tools for Water Quality Monitoring or Sondes and Suds
8:30 am – 5:00 pm | Meet at the Conference Center Main Entrance

*Sponsored by In-Situ and YSI, Inc.*
See page 23 for details.

Refreshment Break – Workshop Participants Only
10:00 am – 10:30 am | Windsor

Workshop
John Fielder Photography Workshop
8:00 am – 5:00 pm | Standley II

See page 21 for details.

Luncheon – Workshop Participants Only
12:00 pm – 1:00 pm | Lake House

Exhibitor & Poster Display Set-up
12:00 pm – 4:45 pm | Westminster Ballroom / Westminster Foyer

Workshop
DIY Lake, Shoreline, & Watershed Mapping:
Telling Stories with Online Maps
1:00 pm – 5:00 pm | Library

See page 21 for details.
Monday, November 6

Workshop
Real Time Test Systems for Cyanotoxins
(Afternoon Session)
1:00 pm – 5:00 pm | Meadowbrook I

See page 22 for details.

Refreshment Break – Workshop Participants Only
3:00 pm – 3:30 pm | Windsor

Special Event
NALMS New Member Welcome Reception
5:00 pm – 6:00 pm | Lake House

Sponsored by NorthEast Aquatic Research

See page 23 for details.

Special Event
Brewery Tours
6:00 pm – 10:00 pm | Meet at 5:45 pm at the Conference Center Main Entrance

Sponsored by the Colorado Lake and Reservoir Management Association

See page 23 for details.
Plenary Session

8:30 am – 10:00 am | Standley Ballroom

Welcome to NALMS’ 37th International Symposium

Frank Wilhelm
President, North American Lake Management Society

Steve Lundt and Jean Marie Boyer
Denver Symposium Host Committee

Plenary Speaker

A Portrait of Colorado’s Lakes & Reservoirs…Then, Now, and in 2050!

John Fielder
Silverthorne, Colorado

John Fielder has spent the past 40 years exploring and photographing most of Colorado’s 66 million acres. He has assembled for this presentation iconic images of its lakes and reservoirs, from Highest Lake at 13,100 feet above sea level in Rocky Mountain National Park to Lake Pueblo at 4,890 feet. Included will be the 19th-century Colorado lake photos of W.H. Jackson side-by-side with Fielder’s repeat images made a century later.

Fielder will also discuss Colorado’s 2015 Water Plan. The state’s population will increase to 10 million by 2050 from its current 5.5 million. In the face of global warming, where will the water needed to accommodate these people come from and will Colorado’s natural environment, including its rivers and creeks, lakes and reservoirs, survive the outcome.

John Fielder has worked tirelessly to promote the protection of Colorado’s ranches, open space, and wildlands during his 35-year career as a nature photographer and publisher. His photography has influenced people and legislation, earning him recognition including the Sierra Club’s Ansel Adams Award in 1993 and, in 2011, the Aldo Leopold Foundation’s first Achievement Award given to an individual. Over 40 books have been published depicting his Colorado photography. He lives in Summit County, Colorado, and operates a fine art gallery, John Fielder’s Colorado, in Denver’s Art District on Santa Fe. He teaches photography workshops to adults and children. His latest books are Colorado’s Yampa River: Free Flowing & Wild from the Flat Tops to the Green and Wildflowers of Colorado. Information about John and his work can be found at johnfielder.com.

Photo: Craig McNeil
Tuesday, November 7

Yoga
7:00 am – 8:00 am | Gray's Peak
See page 23 for details.

Continental Breakfast / Poster Viewing / Exhibits Open
7:00 am – 8:30 am | Westminster Ballroom / Foyer

Opening Plenary Session (Details on page 33)
8:30 am – 10:00 am | Standley Ballroom

Refreshment Break / Poster Viewing / Exhibits Open
10:00 am – 10:30 am | Westminster Ballroom / Foyer

Session A1
Western Issues
10:30 am – 12:00 pm | Standley I

Sponsored by Leonard Rice Engineers, Inc.

Moderator
Kelly Close, Leonard Rice Engineers, Inc., Denver, Colorado

Presentations
Western Water Law and Impacts on Reservoir Management
Kelly DiNatale, DiNatale Water Consultants, Boulder, Colorado

Grand Lake Clarity Adaptive Management
Esther Vincent, Northern Water, Berthoud, Colorado

Collaborative Reservoir Operations to Achieve Water Supply, Irrigation, In-Lake and Streamflow Needs
Arista H. Shippy, DiNatale Water Consultants, Boulder, Colorado

Session A2
Alum
10:30 am – 12:00 pm | Standley II

Moderator
Melissa Laney, Indiana University, Bloomington, Indiana

Presentations
Geochemical Augmentation with Aluminum Salts for Control of Internal Nutrient Loading and Algae Blooms in Reservoirs, Lakes, and Ponds
David Austin, CH2M, Saint Paul, Minnesota

Soldiers Creek Regional Alum Treatment Nutrient Reduction Facility (NuRF) – An Innovative Partnership to Maximize Watershed Load Reductions
Harvey Harper, Environmental Research & Design, Inc., Orlando, Florida

Quarry Island Cove Phosphorus Inactivation and Water Column Clearing
Steven Patterson, Bio x Design, Poteau, Oklahoma

Effects of Nutrient Inactivation (Alum) on the Water Quality of a Shallow, Eutrophic Urban Lake: LeMay Lake, Minnesota
John Holz, HAB Aquatic Solutions, Lincoln, Nebraska

Session A3
Paleolimnology
10:30 am – 12:00 pm | Meadowbrook

Moderator
Thomas Whitmore, University of South Florida St. Petersburg, St. Petersburg, Florida

Presentations
Assessing Past Influences of Associated Wetlands on Water Quality in Shallow Florida Lakes, With Implications for Management
Thomas Whitmore, University of South Florida St. Petersburg, St. Petersburg, Florida

Paleolimnological Reconstruction of Lake Bonny, Florida USA: Wetland Destruction and Nutrient Loading as Important Drivers of Change
* Francesca Lauterman, University of South Florida St. Petersburg, St. Petersburg, Florida
Using Paleolimnology to Understand Historical Trends in Nutrients and Dissolved Oxygen in an Ontario Lake That Supports Lake Trout

*Clare Nelligan, Queen’s University, Kingston, Ontario, Canada*

A Multi-Proxy Paleolimnological Analysis of Long-Term Water Quality Trends in a Remote, Nutrient-Poor Lake Affected by Cyanobacterial Blooms

*Elizabeth Favot, Queen’s University, Kingston, Ontario, Canada*

**Session A4**
**Drinking Water Reservoirs**
10:30 am – 12:00 pm | Lake House

**Moderator**

*Diane Lauritsen, Mount Pleasant Waterworks, Mount Pleasant, South Carolina*

**Presentations**

The Balancing Act: Managing a Water Supply Reservoir for Other Benefits

*Cindy Brady, Denver Water, Denver, Colorado*

Becoming a Blended Water Provider

*Jamie Langer, Parker Water & Sanitation District, Parker, Colorado*

Integrated Passive Biological Selenium Treatment System: Results of a 1-year Pilot Study

*James Bays, CH2M, Tampa, Florida*

Proving Septic Tank Contamination of a Drinking Water Supply Lake Using Multiple Lines of Evidence

*Rob Zisette, Herrera Environmental Consultants, Seattle, Washington*

**Session A5**
**Data Analysis**
10:30 am – 12:00 pm | Cotton Creek

**Moderator**

*Jared Mann, Parker Water & Sanitation District, Parker, Colorado*

**Presentations**

Analyzing Lake Data – Finding Patterns and How to Avoid Being Led Down the Wrong Road

*Joan Marie Boyer, Hydros Consulting, Boulder, Colorado*


*Shelley Stanley, City of Northglenn, Colorado*

Effects of Informed Bias in Citizen Science: A Comparison or Variance Between Data Collected by an Informed Bias vs. Random Citizen Groups

*David Pfuhler, State University of New York Oneonta Biological Field Station, Cooperstown, New York*

Statewide Data Analysis to Identify Lake Chlorophyll a Endpoints and Nutrient Thresholds to Protect Beneficial Uses

*Rebecca Veiga Nascimento, Oklahoma Water Resources Board, Oklahoma City, Oklahoma*

**Lunch / Poster Viewing / Exhibits Open**
12:00 pm – 1:30 pm | Westminster Ballroom / Foyer

**NALMS Student Luncheon**
12:00 pm – 1:15 pm | Lake House

See page 18 for details.

**Concurrent Session B**

**Session B1**
**Climate Change**
1:30 pm – 3:00 pm | Standley I

**Moderator**

*Perry Thomas, Vermont Department of Environmental Conservation, Montpelier, Vermont*

**Presentations**

Climate Change in the Northeast: What Might It Mean to Water Quality Management?

*Bob Kortmann, Ecosystem Consulting Service, Inc., Coventry, Connecticut*

Extreme Event Monitoring; Ameliorating Climate Change Induced Impacts to Lakes and Reservoirs

*Stephen Souza, Princeton Hydro, LLC, Ringoes, New Jersey*

Managing Shallow Florida Lakes Under a Warming and More Variable Climate

*Melanie Riedinger-Whitmore, University of South Florida St. Petersburg, St. Petersburg, Florida*

Climate Change and Extreme Weather Events: Impact on Turbidity and NOM

*William Becker, Hazen and Sawyer, New York, New York and Columbia University, New York, New York*
Tuesday, November 7

Session B2
Chemical Treatment
1:30 pm – 3:00 pm | Standley II

Moderator
Amy Smagula, New Hampshire Department of Environmental Services, Concord, New Hampshire

Presentations
The Impact of Low Dose Fluridone Treatments on Non-Target Aquatic Plants
Ken Wagner, Water Resource Services, Wilbraham, Massachusetts

The Impact of Low Dose Fluridone Treatments on Aquatic Plant Richness
Ken Wagner, Water Resource Services, Wilbraham, Massachusetts

Control of HABs Through a More Rational Use of Copper: Deepening the Conversation About Cell Lysis and Cyanotoxins – What’s Really Happening?
David Hammond, Earth Science Labs, Inc., Berkeley, California

Targeting the “Bad Players”: Effective Cyanobacteria Management with Liquid Activated Peroxygen Algaecide/Cyanobacteriacide
Tom Warmuth, BioSafe Systems LLC, Winston Salem, North Carolina

Session B3
Paleolimnology
1:30 pm – 3:00 pm | Meadowbrook

Moderator
Francesca Lauterman, University of South Florida St. Petersburg, St. Petersburg, Florida

Presentations
Evaluating the Interface: Combining Limnology and Paleolimnology in Lake Management
Lisa Doner, Plymouth State University, Plymouth, New Hampshire

Extrinsic Versus Intrinsic Regimes Shifts in Shallow Lakes: Long-Term Response of Cyanobacterial Blooms to Historical Terrestrial Phosphorus Loading
Jesse Vermaire, Carleton University, Ottawa, Ontario, Canada

Assessing the Hierarchy of Environmental Controls on Aquatic Communities of Yellowstone National Park
Victoria Chraibi, Tarleton State University, Stephenville, Texas

Using Paleolimnology to Assess the Effects of Road Salt Application on Zooplankton and Diatom Assemblages in Jevins Lake in the Muskoka River Watershed, Ontario
★ Robin Valleau, Queen’s University, Kingston, Ontario, Canada

Session B4
Drinking Water Reservoirs
1:30 pm – 3:00 pm | Lake House

Moderator
Diane Lauritsen, Mount Pleasant Waterworks, Mount Pleasant, South Carolina

Presentations
The Influence of Reservoir Operations and Natural Reservoir Processes on Disinfection By-Product Speciation in a Drinking Water in SE Virginia
Gary Schafran, Old Dominion University, Norfolk, Virginia

Evaluation of External v. Internal Loading in Beaver Creek Reservoir, Crozet, Virginia
Alex Horne, Alex Horne Associates, El Cerrito, California

Survey of Drinking Water Reservoir Monitoring and Management Practices
Chris Newton, DiNatale Water Consultants, Boulder, Colorado

Evaluation of Management Methods for a System of Drinking Water Reservoirs in Virginia
Kelly DiNatale, DiNatale Water Consultants, Boulder, Colorado

Session B5
Data Analysis
1:30 pm – 3:00 pm | Cotton Creek

Moderator
Jared Mann, Parker Water & Sanitation District, Parker, Colorado

Presentations
1973–2014 Historical Review of the Water Quality of Rhodhiss Lake, North Carolina, with Emphasis on Nutrient Loading and Export
Jonathan Knight, Consultant, Mooresville, North Carolina

Reservoir DO Related to Inflow TP Concentration and Water Residence Time
Shannon Brattebo, Tetra Tech, Inc., Spokane, Washington

Comparison of Sub-Basin Characteristics Within Cassadaga Lakes Chautauqua County, New York
★ Joseph O’Reilly, State University of New York Oneonta, Oneonta, New York

Spatial Relationship Between Nutrient Availability and Sediment Particle Size in Willow Creek Reservoir, Heppner, Oregon
★ Sarah Burnet, University of Idaho, Moscow, Idaho
Session C1
Climate Change
3:30 pm – 4:40 pm | Standley I

Moderator
Perry Thomas, Vermont Department of Environmental Conservation, Montpelier, Vermont

Presentations
How will Intensified Water Management Affect Reservoir Food Webs and Fisheries?
Adam Hansen, Colorado Parks and Wildlife, Fort Collins, Colorado

Mysis diluviana Responses to Climate and Dam Operations in Three Mesotrophic Reservoirs
Brett Johnson, Colorado State University, Fort Collins, Colorado

Extended Discussion

Session C2
Monitoring
3:30 pm – 4:40 pm | Standley II

Moderator
Chris Mikolajczyk, Princeton Hydro, LLC, Ringoes, New Jersey

Presentations
Building a Reservoir Water Quality Monitoring Program from the Ground Up
Chris Newton, DiNatale Water Consultants, Boulder, Colorado

Did Monitoring Reduce the Phosphorus in Barr Lake?
Steve Lundt, Metro Wastewater Reclamation District, Denver, Colorado

US Bureau of Reclamation's Water Quality Monitoring Program Overview
Heidi McMaster, US Bureau of Reclamation, Boulder City, Nevada

Session C3
Paleolimnology
3:30 pm – 4:40 pm | Meadowbrook

Moderator
Thomas Whitmore, University of South Florida St. Petersburg, St. Petersburg, Florida

Presentations
A Comparison of Present-Day and Pre-Industrial Zooplankton Assemblages and Size Structure in Cottage and Reference Lakes in Algonquin Provincial Park, Ontario, Canada
*Anna DeSellas, Queen’s University, Kingston, Ontario, Canada

Paleolimnology Provides Early Warnings of Impacts from Eutrophication, Invasive Species and Climate Change
Euan Reavie, University of Minnesota Duluth, Duluth, Minnesota

Extended Discussion

Session C4
Drinking Water Reservoirs
3:30 pm – 4:40 pm | Lake House

Moderator
Diane Lauritsen, Mount Pleasant Waterworks, Mount Pleasant, South Carolina

Presentations
Investigating the Effects of Purified Water Discharges in Water Supply Reservoirs
Jeffery Pasek, City of San Diego Public Utilities Department, San Diego, California

A Rapid Shift from Oligotrophy to Eutrohpy: Water-Quality Trends in California’s Recently Constructed Diamond Valley Lake
Seyoum Gebremariam, Metropolitan Water District of Southern California, La Verne, California

Modeling of Purified Water Mixing in Lake Jennings, California
Li Ding, Flow Science Incorporated, Pasadena, California
NALMS’ Annual Membership Meeting
5:00 pm – 5:45 pm | Cotton Creek

All NALMS members are encouraged to attend and participate in our annual membership meeting.

Special Event
Exhibitors’ Reception and Poster Session
5:45 pm – 7:00 pm | Westminster Ballroom / Foyer

NALMS, the Symposium Host Committee and our exhibitors invite you to join us in kicking off the symposium and welcoming attendees to Denver. Take time to relax, view the poster displays and visit with the exhibitors and fellow attendees.

Poster Presentations

2D and 3D Numerical Modeling of Water Level and Temperature in Lakes and Reservoirs Based on the Numerical Scheme in CE-QUAL-W2: A Case Study

★ Hussein Al-Zubaidi, Portland State University, Portland, Oregon

The Cyanobacteria Monitoring Collaborative – An Evolving Approach to Cyanobacteria Monitoring

Shane Bradt, University of New Hampshire Cooperative Extension, Durham, New Hampshire

Applying Paleolimnological Techniques to Reservoirs in Arid Regions

Victoria Chraibi, Tarleton State University, Stephenville, Texas

Reduced Snowpack May Compound Effects of Climate Warming on High-Elevation Lakes

★ Kyle Christianson, Colorado State University, Fort Collins, Colorado

Public Outreach and Education – Don’t Go It Alone

Amy Conklin, Barr Lake and Milton Reservoir Watershed Association, Littleton, Colorado

New Data Portal for Global Environmental Monitoring

Steve Elgie, KISTERS North America, Sacramento, California

A Water Chemistry Regime Shift Associate with Zebra Mussel (Dreisseina polymorpha) Entrance into New York State Lakes

★ Leah Gorman, State University of New York College at Oneonta, Oneonta, New York

Advection and Nutrients Regulate Phytoplankton Dynamics in Tainter and Menomin Reservoirs, Wisconsin

William F. James, University of Wisconsin–Stout, Menomonie, Wisconsin

Management of Half Moon Lake, Wisconsin, for Native Macrophyte Community Re-Establishment

William F. James, University of Wisconsin–Stout, Menomonie, Wisconsin

Long-Term Endothall Control of Curly-Leaf Pondweed in Half Moon Lake, Wisconsin

★ Heidi Lieffort, University of Wisconsin–Stout, Menomonie, Wisconsin

Source Water Quality and Supply Challenges in the Houston, Texas Metropolitan Area: Assessing Baseline Data prior to an Interbasin Transfer into Lake Houston

Zalimar Lucena, U.S. Geological Survey, Houston, Texas

Implementing Monitoring Techniques of Hydrilla verticillata in the New Jersey Delaware and Raritan Canal

★ Emily Mayer, University of Florida & Solitude Lake Management, Hackettstown, New Jersey and Amanda Mahaney, Solitude Lake Management, Shrewsbury, Massachusetts

Use of Aquatic Filter Barriers to Control Water Quality Impacts from Concentrated Nonpoint Sources

Andrew McCusker, Mackworth-Enviro, Scarborough, Maine

Utilization of Aquatic Barriers to Protect Fish Populations from Reservoir Management Activities

Andrew McCusker, Mackworth-Enviro, Scarborough, Maine

Application of Iron Filings to Reduce Internal Phosphorus Loading in Lakes

Poornima Natarajan, University of Minnesota, Minneapolis, Minnesota

A Survey of Cottagers’ Perceptions in Ontario, Canada, Regarding Algae and Impacts to Recreational Enjoyment

★ Carmen Pereira, Queen’s University, Kingston, Ontario, Canada

Differences and Similarities in Perceived Threats to North American Lakes by Scientists, Managers, and Stakeholders

★ Melanie Perello, Indiana University-Purdue University Indianapolis, Indianapolis, Indiana

Reducing Surface Accumulation of Aphanizomenon flos-aquae by Increasing Cellular Turgor Pressure and Disrupting Buoyancy Control Using Wetland Water and Ion Additions

★ Arick Rouhe, Portland State University, Portland, Oregon

A Five-Year Recreational Water Microbiome

★ Sydney Rudko, University of Alberta, Edmonton, Alberta, Canada

Urban Phosphorus Runoff and Loading to Half Moon Lake, Wisconsin

★ Mai Lia Vang, University of Wisconsin–Stout, Menomonie, Wisconsin

Engaging Indigenous People in Alberta’s Regional Lake Monitoring Program – A Case Study

Zoey Wang, Government of Alberta, Edmonton, Alberta, Canada

Working with Landowners to Improve Water Quality in the White River and Richland Creek Watersheds of Northwest Arkansas

Melissa Welch, Beaver Watershed Alliance, Springdale, Arkansas

Internal Phosphorus Loading in Bone Lake, Wisconsin

★ Amanda Wilson, University of Wisconsin–Stout, Menomonie, Wisconsin

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Zoey Wang, Government of Alberta, Edmonton, Alberta, Canada

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Melissa Welch, Beaver Watershed Alliance, Springdale, Arkansas

Internal Phosphorus Loading in Bone Lake, Wisconsin

★ Amanda Wilson, University of Wisconsin–Stout, Menomonie, Wisconsin
Hospitality Reception and Euchre Tournament
8:00 pm – 11:00 pm | Flatirons / Long’s Peak

Hospitality Reception Sponsored by Cherry Creek Basin Water Quality Authority (CCBWQA)

See page 23 for details.
Wednesday, November 8

Yoga
7:00 am – 8:00 am | Gray’s Peak
    See page 24 for details.

Continental Breakfast / Poster Viewing / Exhibits Open
7:00 am – 8:30 am | Westminster Ballroom / Foyer

NALMS Inland HABs Program Meeting
7:30 am – 8:30 am | Westminster Ballroom

Concurrent Session D

Session D1
Aeration / Mixing
8:30 am – 10:00 am | Standley II

Moderator
David Rosenthal, City of Norfolk, Virginia

Presentations
Hypolimnetic Aeration System is "Breathing New Life" Into Aurora Reservoir
    Pamela Benskin, City of Aurora, Colorado

Managing Taste, Odor, and Manganese in a Small Alpine Lake One Year Later
    Paul Gantzer, Gantzer Water Resources Engineering, LLC, Kirkland, Washington

Eliminating Scouring Problems on a Side Stream Saturation Oxygenation System
    Mark Mobley, Mobley Engineering, Norris, Tennessee

Extended Discussion

Session D2
HABs / Algal Dynamics
8:30 am – 10:00 am | Standley I

Moderator
Laurie Rink, Aqua Ria Ltd., Fruita, Colorado

Presentations
Comparison of Classification Strategies for Algal Data Collected with Imaging Flow Cytometry for Both Live and Preserved Samples with an Emphasis on HAB Taxa

HAB Potential in Colorado Lakes
    James Saunders, University of Colorado, Boulder, Colorado

A Review of Cyanobacteria Harmful Algae Blooms Education, Outreach and Monitoring Programs in the USA
    Ellen Preece, Robertson Bryan Inc. Elk Grove, California

HAB Monitoring with FlowCam Cyano in Recreational Lakes to Facilitate Management Decisions by Maine DEP
    Frances Buerkens, Fluid Imaging Technologies, Scarborough, Maine

Session D3
Invasive Species
8:30 am – 10:00 am | Meadowbrook

Moderator
Chris Holdren, Environmental Consultant, Littleton, Colorado

Presentations
Where's the Body? Water Testing for Dreissenid Mussels and the Value of eDNA
    Denise Hosler, Bureau of Reclamation, Denver, Colorado

Improvement of Methods for Detection of Dreissenid Mussels by Microscopy and Polymerase Chain Reaction
    *Jacquie Keele, Bureau of Reclamation, Denver, Colorado

Rapidly Responding: Montana’s Invasive Mussel Detections
    Stephanie Hester, Montana Department of Natural Resources and Conservation, Helena, Montana

Eyes on the Lake: How 24 Million Annual Visitors Can Protect Tahoe While They Play
    Jesse Patterson, League to Save Lake Tahoe, South Lake Tahoe, California
Session D4
Public Outreach
8:30 am – 10:00 am | Lake House

Moderator
Jojo La, Denver, Colorado

Presentations
Public Outreach and Education – Don't Go It Alone
  Amy Conklin, Barr Lake and Milton Reservoir Watershed Association, Littleton, Colorado

Minnesota Lake Associations Survey: Identifying Demographics, Activities, and Concerns
  ★ Benjamin Bjertness, Concordia College, Moorhead, Minnesota

Scaling Up Local Lake Stewardship: Benefits and Challenges of Countywide Lake Assessments, Planning, and Implementation
  Nancy Turyk, University of Wisconsin–Stevens Point, Wisconsin

Extended Discussion

Session D5
Watershed Management
8:30 am – 10:00 am | Cotton Creek

Moderator
Sara Peel, Arion Consultants, Indianapolis, Indiana

Presentations
Performance Characteristics of a Cold-Climate Constructed Stormwater Treatment Wetland
  Alan Heyvaert, Desert Research Institute, Reno, Nevada

Source Water Protection Program Overview and Case Study
  Bradley Hufhines, Beaver Water District, Lowell, Arkansas

Successful Control of Algal Biomass Through Reductions in Watershed Phosphorus Inputs
  Todd Tietjen, Southern Nevada Water Authority, Las Vegas, Nevada

Extended Discussion

Refreshment Break / Poster Viewing / Exhibits Open
10:00 am – 10:30 am | Westminster Ballroom / Foyer

Concurrent Session E

Session E1
Aeration / Mixing
10:30 am – 12:00 pm | Standley II

Moderator
Melissa Laney, Indiana University, Bloomington, Indiana

Presentations
Prevention of Cyanobacteria Blooms by Destratification Aeration: Evidence from Continuous Vertical Profile Monitoring in C.W. Bill Young Reservoir, Tampa Bay Water
  David Austin, CH2M, Saint Paul, Minnesota

Savannah Harbor Dissolved Oxygen Supplementation Through SuperOxyg enation
  David Clidence, ECO2 Oxygen Technologies, LLC, Indianapolis, Indiana

TIBEAN Deep Water Hypolimnetic Aerator: 3 Case Studies
  Stefan Bruns, Polyplan GmbH, Bremen, Germany

The Effects of Diffused Aeration on Fish Habitat in Small Scale Ponds
  Elizabeth Edgerton, Kasco Marine, Prescott, Wisconsin

Session E2
HABs / Algal Dynamics
10:30 am – 12:00 pm | Standley I

Moderator
Jared Mann, Parker Water & Sanitation District, Parker, Colorado

Presentations
Spatiotemporal Phytoplankton Community Dynamics and Toxin Production in Jordan Lake, North Carolina
  ★ Dan Wiltsie, North Carolina State University, Raleigh, North Carolina

Reducing Surface Accumulation of Aphanizomenon flos-aquae by Increasing Cellular Turgor Pressure and Disrupting Buoyancy Control Using Wetland Water and Ion Additions
  ★ Arick Rouhe, Portland State University, Portland, Oregon

Advection and Nutrients Regulate Phytoplankton Dynamics in Tainter and Menomin Reservoirs, Wisconsin
  William F. James, University of Wisconsin–Stout, Menomonie, Wisconsin

Monitoring Harmful Algal Blooms in Arkansas
  Brie Olsen, Arkansas Department of Environmental Quality, Little Rock, Arkansas
Wednesday, November 8

Session E3
Invasive Species
10:30 am – 12:00 pm | Meadowbrook

Moderator
Sarah Powers, Indiana University, Bloomington, Indiana

Presentations
Successful Long-Term Control of *Myriophyllum spicatum* in Blackhawk Lake, Wisconsin
  Donna Sefton, CORRE, Inc., Madison, Wisconsin

Control of Zebra and Quagga Mussels with a More Rational Use of Copper
  David Hammond, Earth Science Labs, Inc., Berkeley, California

Potash Dose Responses for Open-Water Treatment of Invasive Mussels
  Scott O’Meara, Bureau of Reclamation, Denver, Colorado

Prevention and Management of Invasive Species: Vulnerability Assessment of the Rueter-Hess Reservoir
  Lisa Scurlock, Parker Water and Sanitation, Parker, Colorado

Session E4
Public Outreach
10:30 am – 12:00 pm | Lake House

Moderator
Amy Conklin, Barr Lake and Milton Reservoir Watershed Association, Littleton, Colorado

Presentations
The Social Issues of Big Bowman Pond, Rensselaer County, New York with the Construction of a Management Plan
  George Smith, State University of New York Oneonta, Oneonta, New York

Guardians of the Grande: A Multi-Pueblo Water Quality Sampling Event Focused on Data Quality, Standardization, and Sharing
  Alex Heppner, Gold Systems, Inc., Salt Lake City, Utah

Why Crowdsourcing Data Gets You More Bang for Your Buck
  K. Kelly Close, Leonard Rice Engineers, Inc., Denver, Colorado

Extended Discussion

Session E5
Watershed Management
10:30 am – 12:00 pm | Cotton Creek

Moderator
Jojo La, Denver, Colorado

Presentations
Engaging with Water Utilities to Enhance Lake Management: A Triple Bottom Economic Analysis of Beaver Water District’s Source Water Protection Program
  Chi Ho Sham, Eastern Research Group, Lexington, Massachusetts

Lake & Reservoir Watershed Management – An Interactive Web-Based System
  Jeff Boeckler, Northwater Consulting, Springfield, Illinois

Why is Watershed Phosphorus Loading So Stubbornly Persistent?
  Joe Bischoff, Wenck Associates, Inc., Golden Valley, Minnesota

Impacts of Wetland Phosphorus Export on Lake Minnetonka
  Brian Beck, Wenck Associates, Golden Valley, Minnesota

Luncheon / Poster Viewing / Exhibits Open
12:00 pm – 1:30 pm | Westminster Ballroom / Foyer

Attendees of the Certified Lake Manager / Professional Luncheon should get their buffet lunch in the Westminster Ballroom and take it to the Lake House.

Special Event
Clean Lakes Classic 5k Run / Walk
12:00 pm – 1:30 am | Runners meet at the Conference Center Main Entrance at 11:45 am

*Sponsored by Wenck*

See page 24 for details.
Concurrent Session F

Session F1
Volunteer Monitoring
1:30 pm – 3:00 pm | Standley II

Moderator
Jeff Schloss, University of New Hampshire Cooperative Extension, Durham, New Hampshire

Presentations
CSLAP in the Finger Lakes: Volunteer Monitoring on Large, High Profile Lakes with Multiple Stakeholders
Nancy Mueller, New York State Federation of Lake Associations, Inc., LaFayette, New York

The Cyanobacteria Monitoring Collaborative: Working with Citizen Scientists, Trained Professionals and the Public to Identify and Monitor Cyanobacteria
Linda Green, University of Rhode Island Watershed Watch, Kingston, Rhode Island

The New Hampshire Lakes Lay Monitoring Program’s Quest for a Better Lake Report
Shane Bradt, University of New Hampshire Cooperative Extension, Durham, New Hampshire

Lake Observer: A Mobile App for Recording Lake and Water Quality Observations Across the Globe
Lisa Borre, Cary Institute of Ecosystem Studies, Annapolis, Maryland

Session F2
HABs / Algal Dynamics
1:30 pm – 3:00 pm | Standley I

Moderator
Ellen Preece, Robertson Bryan Inc. Elk Grove, California

Presentations
Assessing N and P Sources in Nantucket Ponds to Manage Cyanobacteria
Emily Molden, Nantucket Land Council, Nantucket, Massachusetts

Freshwater Microcysts Contaminate Marine Mussels: Tales of Future Past
Barry Moore, Washington State University, Pullman, Washington

A Rare Uroglena Bloom in Beaver Lake, Arkansas
Reed Green, US Geological Survey Lower Mississippi-Gulf Water Science Center, Little Rock, Arkansas

Understanding the Effectiveness of Artificial Mixing for Harmful Algal Bloom Control
Tarek Aziz, North Carolina State University, Raleigh, North Carolina

Session F3
Invasive Species
1:30 pm – 3:00 pm | Meadowbrook

Moderator
Al Basile, US Environmental Protection Agency, Denver, Colorado

Presentations
Achieving Ecosystem Balance Through Food Web Manipulation and Trophic Cascade: Top-Down Control of an Invasive Landlocked Alewife (Alosa pseudoharengus) Population via Walleye (Sander vitreus) Stocking and the Associated Limnological Changes (Otsego Lake, New York)
Holly Waterfield, SUNY College at Oneonta Biological Field Station, Cooperstown, New York

Reexamining the Balance of a Percid Fishery Over the Course of Two Decades
Justin Hulbert, State University of New York College at Oneonta, Oneonta, New York

Effects of Introduced Blueback Herring (Alosa aestivalis) on a Landlocked Southeastern US Reservoir
Dennis DeVries, Auburn University, Auburn, Alabama

Evaluation of the Effects of Ultraviolet Light Treatment on Quagga Mussel Settlement and Veliger Survival at Davis Dam
Sherri F. Pucherelli, Bureau of Reclamation, Denver, Colorado

Session F4
Remote Sensing
1:30 pm – 3:00 pm | Lake House

Moderator
Chris Mikolajczyk, Princeton Hydro, LLC, Ringoes, New Jersey

Presentations
A Comparative Study of Deep-Water Sampling with an Unmanned Aerial Water Sampling System (UAWSS) to Traditional Sampling Methods: A Case Study from Dillon Reservoir, Summit County, Colorado
Brian Straight, University of Colorado, Boulder, Colorado

Using Real-Time High-Frequency Monitoring to Study Regional Heterogeneity in an Oligotrophic Lake
Michael Kelly, IBM Research, Yorktown Heights, New York

Predicting Water Quality from Satellite Observations of the Watershed
Josh Weiss, Hazen and Sawyer, Baltimore, Maryland

Extended Discussion
Session F5
Internal Loading / In-Lake Treatment
1:30 pm – 3:00 pm | Cotton Creek

Moderator
Frank Wilhelm, University of Idaho, Moscow, Idaho

Presentations
28 Years of Impact from Central Basin Hypoxia and Internal Phosphorus Loading on North Shore Water Quality in Lake Erie
Gertrud Nürnberg, Freshwater Research, Baysville, Ontario, Canada

Application of Iron Filings to Reduce Internal Phosphorus Loading in Lakes
Poornima Natarajan, University of Minnesota, Minneapolis, Minnesota

Whole Lake Combined PAC-Phoslock Treatment to Manage Eutrophication and Cyanobacteria
Maïra Mucci, Wageningen University, Wageningen, The Netherlands

Restoration of a Eutrophic Hard-Water Lake by Applying an Optimum Dosage of Poly-Aluminum Chloride: Reasons, Results, Problems
Peter Kasprzak, Leibniz-Institute of Freshwater Ecology & Inland Fisheries, Berlin, Neuglobsow, Germany

Refreshment Break / Poster Viewing / Exhibits
Open
3:00 pm – 3:30 pm | Westminster Ballroom / Foyer

Session G2
Fisheries Management
3:30 pm – 5:00 pm | Standley I

Moderator
Mark Hoyer, University of Florida, Gainesville, Florida

Presentations
Long-Term Patterns in Water Temperature Downstream of a Large Reservoir in Southeastern Idaho
John McLaren, Indiana University School of Public and Environmental Affairs, Bloomington, Indiana

Ryan Elliott, State University of New York College at Oneonta, Oneonta, New York

Bayesian Analysis of Proportional Size Distribution Indices in Recreational Fisheries
Dan Stich, State University of New York College at Oneonta, Oneonta, New York

Utilization of Aquatic Barriers to Protect Fish Populations from Reservoir Management Activities
Andrew McCusker, Mackworth-Enviro, Scarborough, Maine

Session G1
Voice of Experience
3:30 pm – 5:00 pm | Standley II

Moderator
Ken Wagener, Water Resource Services, Inc., Wilbraham, Massachusetts

Presentations
Working at One Place for 38 Years: A Career of Opportunities
Steven Heiskary, Minnesota Pollution Control Agency (Retired), St. Paul, Minnesota

From Civil Engineering to Limnology to NALMS
Frank Browne, F.X. Browne, Inc., Lansdale, Pennsylvania

Reflecting on Lakes
Harry Gibbons, Lake Advocates, Bainbridge Island, Washington

Panel Discussion

Session G3
Urban Lakes
3:30 pm – 5:00 pm | Meadowbrook

Moderator
Al Polonsky, City and County of Denver, Colorado

Presentations
Physicochemical and Biological Impacts of Road Salts on Urban Lakes
Isabelle Fournier, Université Laval et Centre d’études nordiques, Québec, Québec, Canada

Managing Multi-Use Reservoirs: How Reservoir Fill Rates May Affect Swim Beach Bacteria Levels
Kate Dunlap, City of Boulder Public Works, Boulder, Colorado

TMDL Compliance as an Opportunity for Park and Habitat Enhancement
Michael Whelan, Anchor QEA, LLC, Lakewood, Colorado

Achieving Lake TMDL Goals with Innovative Urban BMPs
Jacob Newhall, WSB & Associates, Minneapolis, Minnesota
Session G4
Phoslock
3:30 pm – 5:00 pm | Lake House

Moderator

Miquel Lurling, Wageningen University, Wageningen, The Netherlands

Presentations

Managing Eutrophication in Lakes and Ponds with the Lanthanum-Modified Clay Phoslock

Miquel Lurling, Wageningen University, Wageningen, The Netherlands

Preventative Phosphorus Management to Maintain the Mesotrophic State of an Irregularly Mixed Lake

Tim Sebastian Epe, Institut Dr. Nowak, Ottersberg, Germany

Application of Phoslock to a Water-Supply Reservoir in Northeastern Brazil: Lower Phosphorous and Cyanobacterial Concentrations Have Resulted in Reductions in Annual Treatment Costs

Patrick Van Goethem, Institut Dr. Nowak, Ottersberg, Germany

Water Quality After Treatment with Lanthanum-Modified Clay (Phoslock) of Urban Henderson Lake, Alberta

Gertrud Nürnberg, Freshwater Research, Baysville, Ontario, Canada

Session G5
Modeling & Monitoring
3:30 pm – 5:00 pm | Cotton Creek

Moderator

Jeff Schloss, University of New Hampshire Cooperative Extension, Durham, New Hampshire

Presentations

Long-Term Monitoring of Stream Integrity in Rocky Mountain National Park: In situ Water Chemistry and Bioassessment Set the Context for Restoration Success

Erin Borgman, National Park Service, Fort Collins, Colorado

A Simple, User-Friendly Index for Assessing the Sensitivity of Lakes to Increased Nutrient Loading

Andrew Paterson, Ontario Ministry of the Environment and Climate Change, Dorset, Ontario, Canada

Advantages of Monitoring Phosphorus Trends with Sediment Traps

Stephen Klein, Benthica LLC, Elizabeth, Colorado

Investigating the Use of Active Fluorescence in Determining Condition of Deep-Water Cyanobacteria Stratifications

* Sabina Perkins, University of New Hampshire, Durham, New Hampshire

Special Event
NALMS Awards Reception and Banquet
Pre-Banquet Reception, 5:00 pm – 7:00 pm | Butterfly Pavilion

Sponsored by GEI Consultants, Inc.

NALMS Awards Banquet, 7:15 pm – 9:00 pm | Westminster Ballroom

See page 24 for details.

Hospitality Reception
9:00 pm – 12:00 am | Flatirons / Long's Peak
Thursday, November 9

Continental Breakfast / Exhibits Open
7:30 am – 8:30 am | Westminster Ballroom / Foyer

Concurrent Session H

Session H1
National Lakes Assessment
8:30 am – 10:00 am | Standley I

Moderator
Eugene Braig, Ohio State University Extension, Columbus, Ohio

Presentations
Title TBD
Amina Pollard, US Environmental Protection Agency, Washington, District of Columbia

Phytoplankton and Zooplankton Data from the 2012 National Lakes Assessment Reflect Ecoregion and Biogeography
John Beaver, BSA Environmental Services, Inc., Beachwood, Ohio

Networked Lake Science: How GLEON’s Global Network is Using the National Lakes Assessment Database for Research and Graduate Student Training
Kathleen Weathers, Cary Institute of Ecosystem Studies, Millbrook, New York

The Importance of Lake-Specific Characteristics for Water Quality Across the Continental United States
Jennifer Brentrup, Miami University, Oxford, Ohio

Session H2
Modeling
8:30 am – 10:00 am | Standley II

Moderator
Trea Nance, City of Westminster, Colorado

Presentations
Balancing Water-Supply Constraints and Water-Quality Objectives
Taylor Adams, Hydros Consulting, Boulder, Colorado

Water-Quality Modeling in Chehalis River Basin, Washington State
Robert Montgomery, Anchor QEA, Seattle, Washington

Modeling Summertime Cyanobacteria Blooms in a Polymictic Reservoir
Christine Hawley, Hydros Consulting, Boulder, Colorado

Extended Discussion

Session H3
PAHs
8:30 am – 10:00 am | Meadowbrook

Moderator
Bill Wilber, US Geological Survey (retired), Reston, Virginia

Presentations
Coal-Tar-Based Pavement Sealants – A Potent Source of PAHs
Barbara Mahler, US Geological Survey, Austin, Texas

Trends and Sources of PAHs to Urban Lakes and Streams
Peter Van Metre, US Geological Survey, Austin, Texas

Acute Lethality of Runoff from Coal Tar Sealcoat to Aquatic Animals, and Prevention by Green Stormwater Infrastructure
Jennifer McIntyre, Washington State University, Puyallup, Washington

Reducing PAHs in Urban Waters and Sediments in Minnesota and the Great Lakes Region
Al Innes, Minnesota Pollution Control Agency, St. Paul, Minnesota

Session H4
Managing Shallow Lakes
8:30 am – 10:00 am | Cotton Creek

Moderator
Dick Osgood, Lake Advocates, Duluth, Minnesota

Presentations
Aeration of a Shallow Eutrophic Lake: What to Expect
Patrick Goodwin, State University of New York at Oneonta, Oneonta, New York

A Restoration Project in Lake Apopka, Florida, USA, Using a Laminar Flow Aeration System to Reduce the Hypereutrophic State
Jennifer Jermalowicz-Jones, Restorative Lake Sciences, Spring Lake, Michigan
Effects of Solar-Powered Circulators on Turbulence and Stratification in a Shallow Embayment of Jordan Lake, North Carolina

Robyn Smyth, Bard College, Annandale-on-Hudson, New York

The Challenges, Rewards, and Results of Managing a Private Shallow Lake

Sonja Wixom, State University of New York at Oneonta, Oneonta, New York

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Sonja Wixom, State University of New York at Oneonta, Oneonta, New York

Denotes that the lead author is a student.
Thursday, November 9

Luncheon / Exhibits Open
12:00 pm – 1:30 pm | Westminster Ballroom / Foyer

Concurrent Session J

Session J1
Data Management
1:30 pm – 3:00 pm | Standley I

Moderator
Kelly Close, Leonard Rice Engineers, Inc., Denver, Colorado

Presentations
New Data Portal for Global Environmental Monitoring
Steve Elgie, KISTERS North America, Sacramento, California

High-Frequency Limnological Data Collection: Utility and Challenges
Kiyoko Yokota, State University of New York College at Oneonta, Oneonta, New York

Harnessing Open Source to Collect and Manage Your Data Better and Cheaper
K. Kelly Close, Leonard Rice Engineers, Inc., Denver, Colorado

Session J2
Aquatic Plant Management
1:30 pm – 3:00 pm | Cotton Creek

Moderator
Bob Kirschner, Chicago Botanic Garden, Glencoe, Illinois

Presentations
Balancing Target and Non-Target Impacts of Macrophyte Management in Paradox Lake, New York
Alexa Tumbarello, SUNY Oneonta Biological Field Station, Cooperstown, New York

The Role of Aquatic Plant Harvesting in Lake Management
Ken Wagner, Water Resource Services, Wilbraham, Massachusetts

Assessment of New Zealand Lakes Using Submerged Plants as Bio-Indicators
Tracey Burton, NIWA, Hamilton, Waikato, New Zealand

Mesocosm Evaluation of Multiple Invasive Watermilfoils Response to PROCELLACOR – A Novel Herbicide Technology
Mark Heilman, SePRO Corporation, Carmel, Indiana

Session J3
Lake Management
1:30 pm – 3:00 pm | Meadowbrook

Moderator
Steve Lundt, Metro Wastewater Reclamation District, Denver, Colorado

Presentations
Lake Management Adrift
Dick Osgood, Lake Advocates, Duluth, Minnesota

Advanced Sediment Management – Adjustable and Continuous
Michael Detering, DB Sediments GmbH, Duisburg, Germany

Operation and Effects of an Intake Barrier Curtain in Iron Gate Reservoir on Downstream Water Quality in the Klamath River, California
Demian Ebert, Pacific Power, Portland, Oregon

Use of Aquatic Filter Barriers to Control Water Quality Impacts from Concentrated Nonpoint Sources
Andrew McCusker, Mackworth-Enviro, Scarborough, Maine
Friday, November 10

Field Trip
Maintaining Water Quality in a High-Altitude Reservoir
8:30 am – 4:00 pm | Meet at the Conference Center Main Entrance

See page 24 for details.

Field Trip
Barr Lake Tour and BBQ
10:00 am – 2:00 pm | Meet at the Conference Center Main Entrance

See page 24 for details.
Session A1: Western Issues
10:30 am – 12:00 pm | Standley I

Western Water Law and Impacts on Reservoir Management
Kelly DiNatale
DiNatale Water Consultants, Boulder, Colorado

The system of water law and the allocation of water supply in much of the western U.S. differ significantly from the riparian system of the eastern U.S. Water law in the Colorado River basin states and in the southwest U.S. was developed in response to the unique climatic and geographic conditions in these areas. Except for high mountain elevations, the southwest has a semi-arid to arid climate with average annual precipitation ranging from 20 inches to less than 10 inches in many areas. The limited rainfall results in the inability to reliably grow crops without supplemental irrigation. In response to the scarcity of precipitation, a different means to allocate water supply was needed to provide for development of the southwest. As the appropriation of river flows exceeded the available supply, reservoirs were constructed to capture and store flow during times of high flow and/or low demand for later release. Western water laws for management of reservoirs has evolved into a complex system that has direct impacts on the operations of reservoirs and the ability to manage reservoirs for water quality.

Grand Lake Clarity Adaptive Management
Esther Vincent
Northern Water, Berthoud, Colorado

Grand Lake, the largest natural lake in Colorado, is an integral part of the Colorado-Big Thompson (C-BT) Project that supplies water to Northern Colorado for agricultural, municipal and industrial uses. It serves as a conveyance facility as water moves from west of the Continental Divide to the Northern Colorado Front Range.

Clarity in Grand Lake is significantly less than it was before construction of the C-BT Project and has been an on-going concern of local stakeholders and agencies.

In 2008, the Colorado Water Quality Control Commission (WQCC) was petitioned to consider the adoption of a clarity standard for Grand Lake, a first in Colorado. It adopted a 4-meter clarity standard with a delayed effective date along with a narrative standard aiming at the “highest attainable” clarity without adverse impacts to water rights and aquatic life.

In January 2016, Northern Water, Reclamation, Grand County, NWCCOG and the River District signed an agreement that memorialized an adaptive management approach to improve clarity in Grand Lake. The WQCC subsequently adopted the adaptive management framework as an implementation vehicle for the narrative standard.

The agreement sets numeric clarity goals (not standards) and lays out the terms of collaboration and consultation between the parties regarding C-BT operations.

In June 2016, the Parties began implementing the adaptive management process. This presentation will discuss how the process has unfolded thus far, tools and technical analyses used to support the process, lessons learned and challenges encountered.

Collaborative Reservoir Operations to Achieve Water Supply, Irrigation, In-Lake and Streamflow Needs
Arista H. Shippy
DiNatale Water Consultants, Boulder, Colorado

The Rio Grande Reservoir is located on the headwaters of the Rio Grande in Colorado, and is owned and operated by the San Luis Valley Irrigation District (District). Built from 1907-1912, the reservoir is over 100 years old. Aging infrastructure and operational constraints threaten the District’s ability to store water for irrigation needs and several other uses.

The District studied and analyzed infrastructure improvements required to provide a multi-use facility that would meet the permanent storage needs of many entities throughout the Rio Grande Basin. A plan for rehabilitation was finalized in 2011 and rehabilitation of the dam was completed in 2013.

Over the past several years the District, Colorado Parks and Wildlife, and the Colorado Water Conservation Board have developed the Rio Grande Cooperative Project to re-operate the Rio Grande Reservoir to maximize the benefit of water deliveries for public and private water users. Trout Unlimited was also a consulting partner.

The Cooperative Project’s primary objectives are to store and regulate water rights to better meet water demands of the San Luis Valley and the upper Rio Grande basin including: permanent fisheries pool within the reservoir, in-stream flow enhancement, channel maintenance, recreation, terrestrial and aquatic wildlife habitat, irrigation, augmentation, municipal and industrial, and other beneficial water uses including Compact compliance. This presentation will discuss how reservoir operations have evolved from a few specific users to multiple water users and several operational objectives.
Abstracts

Session A2: Alum
10:30 am – 12:00 pm | Standley II

Geochemical Augmentation with Aluminum Salts for Control of Internal Nutrient Loading and Algae Blooms in Reservoirs, Lakes, and Ponds

David Austin¹, Estell Johnson², and Howard Partington³
¹CH2M, Saint Paul, Minnesota; ²CH2M, Wichita, Kansas; ³City of Great Bend, Kansas

Coagulant dosing of aluminum salts is used to control internal phosphorus loading; a leading cause of phytoplankton blooms in reservoirs, lakes, and ponds. Coagulation entails charge neutralization, which is not necessary to bind low phosphate concentrations. We define geochemical augmentation as dosing of metal salts below both charge neutralization and chronic toxicity concentrations. This definition avoids confusion with coagulation dosing criteria.

Veteran’s Lake in the City of Great Bend, Kansas is a 5.7 ha, 2.4 m deep lake in a former sand quarry that receives urban stormwater runoff. It was in the Kansas of Environmental Health (KDEH) cyanotoxin warning list 2010–2015.

April to July 2015, 39 m³ of alum were metered into the lake. An additional dose of 20 m³ of alum was added in spring 2016 at approximately the same rate. Alum was injected into bubble plumes to disperse in solution throughout the lake. Median post dosing surface TP of 70 µg/L (JUL15–MAY17) was significantly lower (p < 0.0001) than the pre-dosing median of 180 µg/L (SEP14–JUN15). In August 2015 KDEH removed Veteran’s Lake from the cyanotoxin warning list.

The average alum dose corresponded to approximately 460 µg Al L/d. In lake water total hardness of 148 mg/L, chronic Al toxicity per water effect ratios is 2,344 µg/L.

Geochemical augmentation proved a practical, low-cost means of water quality remediation in Veteran’s Lake. It is probably best constrained by chronic toxicity criteria. Widespread application of this method motivates better characterization of site-specific Al aqueous geochemistry to design dosing rates.

Soldiers Creek Alum Treatment Regional Nutrient Reduction Facility (NuRF) – An Innovative Partnership to Maximize Watershed Load Reductions

Harvey Harper¹, Kim Ornberg², and Shannon Wetzel³
¹Environmental Research & Design, Inc., Orlando, Florida; ²Watershed Management Division, Seminole County, Sanford, Florida

Soldiers Creek is an ephemeral creek, located in Seminole County, Florida, which receives inflows from a 525-acre urban watershed consisting of residential and wetland areas. Discharges through Soldiers Creek are highly colored and poorly buffered with elevated levels of dissolved phosphorus. The Creek discharges ultimately to Lake Jesup, an 8,037-acre hyper-eutrophic lake and contributes approximately 11% of the annual runoff volume and 10% of the annual TP loading to Lake Jesup.

During 2013, the Florida Department of Transportation (FDOT) conducted a design for a roadway expansion of US 17-92 through a densely developed commercial corridor in lower portions of the Soldiers Creek watershed. The required stormwater ponds for the roadway would require more than $7 million in land acquisition to provide stormwater treatment for approximately 10 acres of roadway area with an estimated load reduction to Lake Jesup of 2–3 kg TP/yr. FDOT and Seminole County entered into a unique partnership where FDOT agreed to use the $7 million allocated for land acquisition to fund a regional treatment facility, in lieu of the proposed roadway stormwater ponds, with a potential to enhance the overall load reduction to Lake Jesup. A site was selected at an existing stormwater pond adjacent to Soldiers Creek. A diversion weir was constructed on the Creek to force water through a box culvert into the pond. Alum is added to the incoming flow, and the floc is collected in a linear trough and pumped to the sanitary sewer system, on-site storage tanks, or directly into a tanker truck for off-site disposal. The system is capable of treating flows up to 50 cfs which is sufficient to capture 85% of the annual discharge through the Creek, approximately 6,637 ac-ft/yr. When operated at full capacity annual alum use will be 277,000 gallons/yr with floc generation of 26,626 gallons/day. The Soldiers Creek NuRF is expected to remove 969 kg TP/yr compared with the 2–3 kg TP/yr for the roadway ponds. This project demonstrates a unique and innovative approach to maximizing watershed load reductions using existing resources.

Quarry Island Cove Phosphorus Inactivation and Water Column Clearing

Steven D. Patterson
Bio x Design, Poteau, Oklahoma

In August 2014 and July 2016, the Poteau Valley Improvement Authority applied approximately 16,000 pounds of liquid alum (aluminum sulfate) and 8,000 pounds of liquid sodium aluminate to 100 surface acres of Quarry Island Cove in Lake Wister, a 6,300-acre flood control, recreation, and water supply reservoir in LeFlore County, eastern Oklahoma. This pilot project was undertaken for multiple purposes: to reduce the concentration of mobile phosphorus levels in cove sediments, to attempt reduce the concentrations of disinfection by-products (DBPs) in treated water, and to explore the potential of a whole-reservoir alum application. The application was intended to reduce the concentration of cyanobacteria in Quarry Island Cove at the time of year when those concentrations are at their highest. Other attempts to flocculate and settle cyanobacteria blooms using clays and various other materials have shown variable results, apparently effective in some cases and ineffective in others. This was the first large scale alum application in Oklahoma and the first in a US Army Corps of Engineers managed reservoir. The application was made safely and successfully, without adverse impacts to fish or significant alteration of pH or alkalinity. Cyanobacteria cell counts were reduced 80% in 2014 and 24% in 2016. Sediment cores taken before and after application showed a 70–90% reduction in phosphorus release under anoxic conditions and a 50% reduction in potential mobile phosphorus in the top 10 cm of sediments.
Abstracts

Effects of Nutrient Inactivation (Alum) on the Water Quality of a Shallow, Eutrophic Urban Lake: LeMay Lake, Minnesota

John Holz1, Eric Macbeth2, Joe Bischoff3, Brian Beck4, and Tadd Barrow5

1HAB Aquatic Solutions, Lincoln, Nebraska; 2City of Eagan, Eagan, Minnesota; 3City of Eagan, Eagan, Minnesota; 4Wenck Engineering, Golden Valley, Minnesota

LeMay Lake is a 13-ha urban lake (mean depth = 1.6 m) located in Eagan, Minnesota and has 518-ha watershed. Historically, LeMay has been eutrophic (mean summer TP = 74 ppb; mean summer Secchi Disk depth = 1.6 m; mean summer chl-a = 26 ppb) and was placed on Minnesota’s Section 303(d) List of Impaired Waters for elevated concentrations of nutrients in 2014. The 2015 TMDL for LeMay called for 52% reduction in internal phosphorus loading from the lakebed to achieve a water column TP goal of ≤ 60 ppb. In the fall of 2015, a buffered alum application (9,853 gallons of alum and 4,927 gallons of sodium aluminate) was conducted to inactivate available sediment P. Post-project sampling shows that mean water column TP was reduced by 74% to 19 ppb, mean Secchi disk depth increased by 1.1 m to 2.7 m, mean chlorophyll a decreased by 73% to 7 ppb, and the lake is now meeting water quality goals and standards.

Session A3: Paleolimnology

10:30 am – 12:00 pm | Meadowbrook

Assessing Past Influences of Associated Wetlands on Water Quality in Shallow Florida Lakes, With Implications for Management

Thomas J. Whitmore, Zachary Leyton Rivera-Reed, Francesca M. Lauterman, Daniel Franklin, and Melanie A. Riedinger Whitmore
University of South Florida St. Petersburg, St. Petersburg, Florida

Florida USA represents a lake district of approximately 8000 natural lakes. The majority of Florida lakes are shallow solution basins, most of which were associated with wetlands prior to human disturbance. Florida wetlands were reduced from ~8.2 to 4.6 million hectares during the last 200 years because of development. Paleolimnological studies have played an important role in helping to define past limnetic nutrient concentrations and appropriate TMDL objectives for lake restoration and management programs in Florida. Few studies have addressed impacts on water quality and lake processes resulting from altered chemistry, hydrology, and water color caused by destruction of associated wetlands. Our studies have consistently shown that acidic, low-productivity waters and organic-rich deposits indicative of wetland influence are found at the base of sediment cores prior to the late 1800s, which preceded logging and drainage of swamps, water-level alterations, and urban and agricultural encroachment on wetlands. Changes in DOC and color resulted, and their potential effects on light limitation are well established. We present biological and chemical evidence from paleolimnological studies of multiple lakes to show how the loss of associated wetlands and humic acids led to progressive alkalization, and discuss how the reduction of water color and DOC, along with increased nutrient loading, likely contributed to increased phytoplankton production, and to alteration of aquatic plant communities. Nutrient mitigation efforts alone sometimes fail to adequately reduce algal production and to restore lakes. Our studies suggest that restoration of associated wetlands would contribute to more effective management strategies.

Paleolimnological Reconstruction of Lake Bonny, Florida, USA: Wetland Destruction and Nutrient Loading as Important Drivers of Change

Francesca M. Lauterman1, Thomas J. Whitmore1, Melanie A. Riedinger Whitmore1, Kendall Jackson2, Zachary Leyton Rivera-Reed1, Daniel Franklin1, Handong Yang3, and Jason H. Curtis4

1University of South Florida St. Petersburg, St. Petersburg, Florida; 2University of South Florida, Tampa, Florida; 3University College London, London, United Kingdom; 4University of Florida, Gainesville, Florida

Paleolimnology has a well-established role in ecosystem management because it provides long-term environmental information that is often undocumented. We applied paleolimnological methods to sediment cores from Lake Bonny, Polk County, Florida to infer past water-quality conditions, and to document the timing and nature of changes in the lake.

Nutrient accumulation rates increased in sediments after the late 1800s. Phosphorous accumulation was highest in the 1950s to 1980s, probably due to local phosphate mining. Eutrophic and hypereutrophic diatoms increased in the 1900s because of greater nutrient loading. Acidic diatom taxa at the core base transitioned to more alkaline taxa over time. Cyanobacterial pigments were present at low levels in the predisturbance period, but blooms became more frequent after ca. 1940. δ13N values indicated cyanobacterial proliferation after ca. 1950. δ15N versus C/N ratios documented changing sources of carbon deposited in lake sediments. Invasive macrophytes, including Hydrilla, became well established in the late 1900s.

Pollen of Taxodium and other swamp taxa were present at the base of the core, indicating wetland presence prior to disturbance. Wetland loss was concurrent with the historical change in pH, and would have caused reductions in DOC and water color. Clearer water and increased nutrients contributed to increases in planktonic and epiphytic algae, and proliferation of submerged invasive plants. As a step towards better-integrated restoration and management, we recommend reconstruction of fringe wetlands, including reestablishment of Taxodium, to restore water color and pH, and to moderate nutrient loads by reducing water clarity.

Using Paleolimnology to Understand Historical Trends in Nutrients and Dissolved Oxygen in an Ontario Lake that Supports Lake Trout

Clare Nelligan1, Adam Jeziorski1, Kathleen M. Rühland1, Andrew M. Paterson1, and John P. Smol1

1Queen’s University, Kingston, Ontario, Canada; 2Ontario Ministry of the Environment and Climate Change, Dorset Environmental Science Centre, Dorset, Ontario, Canada

Lake Trout (Salvelinus namaycush) are a valuable natural resource found in many lakes across Canada and the northern United States. Prolonged periods of hypolimnetic dissolved oxygen (DO) depletion threaten many Lake Trout populations as they
Finding Balance

Denotes that the lead author is a student.

1Queen's University, Kingston, Ontario, Canada; 2Ontario Ministry of the Environment and Climate Change, Dorset, Ontario, Canada

Abstracts

A Multi-Proxy Paleolimnological Analysis of Long-Term Water Quality Trends in a Remote, Nutrient-Poor Lake Affected by Cyanobacterial Blooms

*Elizabeth Favot1, Kathleen Rühland1, Andrew Paterson2, and John Smol1*

1Queen's University, Kingston, Ontario, Canada; 2Ontario Ministry of the Environment and Climate Change, Dorset, Ontario, Canada

Pollution of freshwater ecosystems by nuisance algal blooms has amassed public concern worldwide. Over the past two decades, there have been purported increases of cyanobacterial blooms in Ontario lakes. Many of these lakes are nutrient poor or have not experienced changes in nutrient status in recent years, suggesting nutrient fertilization is not the primary trigger. These blooms occur during some of the warmest air temperatures on record and may be associated with recent climate change. Dickson Lake, located in Algonquin Provincial Park, is a remote, low-nutrient lake where cyanobacterial blooms (genus *Pseudanabaena*) were reported for the first time in the fall of 2014 and late spring of 2015. To investigate potential environmental triggers, we examined long-term trends in water quality using a multi-proxy paleolimnological approach, examining sedimentary diatoms, chironomids, and chlorophyll *a* preserved in a 210Pb-dated core. Changes in diatom assemblage composition over the past ~200 years are minimal, suggesting that environmental thresholds have not yet been surpassed, or that the cause(s) of recent cyanobacterial blooms have not registered in the diatom record. Chironomid compositional changes are more pronounced, and a shift towards warm-water taxa occurs ~1950, consistent with a response to regional warming. The highest levels of sedimentary chlorophyll *a* are observed in the uppermost core intervals indicating a recent rise in whole-lake primary production that is temporally consistent with the onset of cyanobacterial blooms.

Sedimentary cladocerans and akinetes are used as additional proxies, to examine long-term changes in the grazing community and to indicate presence or absence of cyanobacteria, respectively.

Session A4: Drinking Water Reservoirs

10:30 am – 12:00 pm | Lake House

The Balancing Act: Managing a Water Supply Reservoir for Other Benefits

Cindy Brady

Denver Water, Denver, Colorado

How Denver Water strives to manage one of its water supply reservoirs, Dillon, using operational flexibility for other uses. These uses include: water supply, on-reservoir boating and downstream water management for fishing, rafting and managing high flows.

Becoming a Blended Water Provider

Jamie Langer

Parker Water & Sanitation District, Parker, Colorado

Established in 1962, Parker Water & Sanitation District (PWSD) has relied solely on groundwater to serve its customers. Groundwater is a nonrenewable source of drinking water that is being depleted as a result of aquifer overuse and steady population increase in the region. To establish long-term drinking water security for its customers, PWSD has implemented a multifaceted approach to reduce the reliance on nonrenewable groundwater. In 2012, PWSD completed construction of the Rueter-Hess Reservoir which is filled with a combination of renewable Cherry Creek surface water and reclaimed water flows from PWSD’s two water reclamation facilities. The Rueter-Hess Reservoir has a capacity of 75,000 acre-ft which feeds PWSD’s first surface water treatment facility, Rueter-Hess Water Purification Facility (RHWPF). The RHWPF began distributing drinking water on July 23, 2015, officially marking the transition of PWSD to a blended water provider. The RHWPF uses three main treatment processes: Actiflo Turbo (high rate clarification), Actiflo Carb (powder activated carbon system), and ceramic membrane technology (ultrafiltration). The RHWPF represents the first municipal application of ceramic membranes in North America.

This presentation will illustrate the triumphs and challenges of bringing a state-of-the-art technology to North America and how PWSD has adapted to transitioning from a strictly groundwater to a blended water provider. This presentation will highlight how PWSD teamwork in the development of a surface water monitoring program has enhanced the treatment and operation of the RHWPF.
Abstracts

Integrated Passive Biological Selenium Treatment System: Results of a One-Year Pilot Study

James Bays¹, Sarah Foster², Patrick Mulhern³, Chelsea Ransom⁴, Robert C. Thomas⁵, and Luis Tovar⁶
¹CH2M, Tampa, Florida; ²CH2M, Englewood, Colorado; ³Mulhern MRE, Englewood, Colorado; ⁴CH2M, San Francisco, California; ⁵CH2M, Atlanta, Georgia

Mining, power, water treatment, petrochemical and agricultural industry wastewaters may include selenium, a regulated contaminant. Treatment advances over the past thirty years have demonstrated that biologically-mediated transformation of oxidized selenium to reduced inorganic selenium offers effective treatment. Typically characterized as "active" or "passive", biological treatment uses engineered media reactors to create anaerobic environments for microbial reduction of selenate and selenite to elemental selenium, selenide and organic selenium. More land-intensive than active treatment systems, passive biological systems can be less expensive to operate and manage because of lower or negligible energy or chemical inputs. In 2016, the Cottonwood Water & Sanitation District (CWSD) in Parker, Colorado demonstrated passive treatment of selenium in reverse osmosis (RO) concentrate from municipal potable water supply wells using a two-train pilot study. The system was comprised of downflow organic compost-based biochemical reactor followed by a vertical upflow biochemical reactor composed of a peat/sawdust mixture, a polishing cell comprised of either a proprietary media or zero-valent iron, and an aerobic, gravel media polishing cell. The system was monitored at approximately weekly frequencies at inlet and outlet stations over three Phases for changes in total selenium, nitrate-nitrogen, and phosphorus. Inflow selenium ranged from 30 to 110 µg/L, and average concentrations from both trains met or remained below the 30-day average discharge limit criterion of 4.6 µg/L. Total phosphorus, nitrogen species, oxidized metals, divalent inorganic cations, micro-pollutants, and toxicity exhibited consistent and significant reductions through the biological treatment system. Planning for a full-scale biological treatment system is currently underway.

For each event, septic inputs were first detected in observed drainages to and within the lake using continuous, real-time measurements of fluorescence by an optical brightener meter having a low detection limit (0.6 µg/L). Hot spots were successfully identified from the field and bacteria results to direct sampling and analysis of chemical and molecular parameters. Results of two Bacteroidetes human biomarker analyses successfully detected moderate to high concentrations of either biomarker at 6 of 20 discharges and at one lake station along the study shoreline. The combination of field fluorescence and human biomarker analysis techniques proved to be most effective for identifying septic system inputs to Lake Whatcom.

Session A5: Data Analysis

Analyzing Lake Data – Finding Patterns and How to Avoid Being Led Down the Wrong Road

Jean Marie Boyer, Christine Hawley, Taylor Adams, and Kevin Bierlein
Hydros Consulting, Boulder, Colorado

The analysis of field and lab data is a very important part of lake management. Sometimes, taking raw data at face value can lead to drawing the wrong conclusions. Decades of experience in lake and reservoir data analysis have resulted in several examples where digging deep into the data was needed to understand actual lake water-quality dynamics and to recommend successful management actions. Data sleuthing techniques to find important patterns and issues associated with lake data will be described and discussed.

Collecting, Analyzing, and Statistically Evaluated, Now What? Putting Water Quality Data to Work

Shelley Stanley¹ and Trea Nance²
¹City of Northglenn, Colorado; ²City of Westminster, Colorado

Croke Canal (Canal or Croke) is one of three earthen ditches that delivers raw water from Clear Creek to Standley Lake (Standley), the drinking water supply for approximately 250,000 people. Along its 21-mile journey, suspended sediment loading increases two-fold. This sediment carries nutrients and other, sorbed pollutants to Standley. During anoxia, additional sorbed pollutants are released. The other two earthen delivery ditches do not show a similar increase in total suspended solids as they travel downstream. What is causing this phenomenon? Where along the Canal is sediment loading occurring? Why is sediment loading in Croke Canal so much different than the Farmer’s Highline Canal, which essentially follows the same path as Croke? This presentation examines potential sediment inputs along the Canal Zone, identifies resuspension locations and explores entrainment and transport mechanisms. Armed with a better understanding, options to address sediment loading will be developed and presented to the Farmer’s Reservoir and Irrigation Company, owner of the Canal. Improving the quality of water delivered to Standley is protective of this important water resource.
Effects of Informed Bias in Citizen Science: A Comparison or Variance Between Data Collected by an Informed Bias vs. Random Citizen Groups

David Pfuhler
State University of New York Oneonta Biological Field Station, Cooperstown, New York

Data collected by citizen scientists is often used by management agencies for its value as a source for long-term information that is difficult to collect over large areas. Varieties of environmental and scientific groups and organizations collect this data leading to a broad range of skill level amongst volunteers. These can ultimately be defined into two groups, an informed bias population who know a system well and a random sampling group with little knowledge of the specific area. Crumhorn Lake in Milford, New York offers a rich source of data from each of such groups. Lake residents provide an informed bias for surveys while the Boy Scout camp along the eastern shore of the lake provide a source of random data collection. This project will aim to look into the differences of simulated variation of data amongst informed samples in comparison to data that is inherently random. The investigation of model strength will be through the lens of fisheries data collected by each of these groups. Random effect is difficult to quantify statistically in ecological situations that are not well understood, like many small private lakes, and the ability to compare variance in two different data sets is a unique perspective into the investigation of citizen data.

Statewide Data Analysis to Identify Lake Chlorophyll a Endpoints and Nutrient Thresholds to Protect Beneficial Uses

Michael J. Paul1, Diane Allen1, Rebecca Veiga Nascimento2, and Monty Porter2
1Tetra Tech, Inc. Center for Ecological Sciences, Research Triangle Park, North Carolina; 2Oklahoma Water Resources Board, Oklahoma City, Oklahoma

Many Oklahoma lakes are nutrient rich and exhibit poor water quality due to high algal biomass, low dissolved oxygen, and harmful algal blooms. These poor conditions impact beneficial uses including Public Water Supply, Aquatic Life, and Recreation. Identifying nitrogen and phosphorus numeric thresholds related to desired water quality and protection of beneficial uses is a management goal for the state. An analysis of Oklahoma's extensive statewide water chemistry and phytoplankton/zooplankton datasets (N = 550 – 12,000) explored relationships of nutrients to chlorophyll, chlorophyll to dissolved oxygen (DO) and nuisance algae, and zooplankton-cyanobacteria relationships. Analysis demonstrated a significant relationship between both TN and TP and chlorophyll a (p < 0.05). Lake DO decreased with increasing chlorophyll a concentration and at 10 µg/L chlorophyll a the probability that 50% of hypolimnetic DO samples were less than 4 mg/L and 2 mg/L DO exceeded 80 and 70 percent, respectively. Analysis of chlorophyll a and cyanobacteria biovolume found that growing season average chlorophyll a concentration of 10 µg/L related to a 1% probability of exceeding a cyanobacteria human health guideline, and the probability increase sharply above 10. Finally, further analysis revealed that at a chlorophyll a concentration of 10 µg/L (growing season mean) there is approximately a 70% probability of having less than 40% combined Daphnia and Ceriodaphnia relative abundance. This statewide analysis supports the conclusion that a chlorophyll a endpoint of 10 µg/L (growing season mean) is protective of multiple beneficial uses and can be linked to lake TN and TP concentrations.

Session B1: Climate Change
1:30 pm – 3:00 pm | Standley I

Climate Change in the Northeast: What Might It Mean to Water Quality Management?

Robert W. Kortmann and Elizabeth Cummins
Ecosystem Consulting Service, Inc., Coventry, Connecticut

Winters are becoming more extreme, with some years providing record snowfall and others recording the warmest temperatures on record. Lakes and reservoirs of the Northeast are behaving more like the monomictic lakes and reservoirs further south (e.g., the Carolinas) in response to mild winters with little or no ice-cover. With these mild winters, the timing of phytoplankton seasonal succession is altered, prolonging summer stratification, increasing the anoxic factor and internal nutrient loading while increasing cyanobacteria growth. Even the composition of the phytoplankton appears to be influenced with more southern genera. Water treatment plants now need to deal with increased raw water concentrations of geosmin, MIB, anaerobic respiration products, turbidity, high TOC content, high UV254 (suggesting a reactive TOC, and requiring higher coagulant dose), and DBP precursors during summers following very mild winters.

How a reservoir or lake responds to the changing winter conditions depends on the nature of the specific lake-watershed ecosystem. In large and deep reservoirs, early and extended duration of thermal stratification results in more anaerobic respiration, resulting in higher concentrations of anaerobic respiration products (Fe, Mn, Sulfide) and greater internal nutrient loading of Phosphorus and Nitrogen. An early diatom peak often results in more cyanobacteria later in the summer. In smaller reservoirs and lakes with a large bottom area in the trophogenic zone, early growth of littoral macrophytes or benthic cyanobacteria can result. In reservoirs, annual water level fluctuation often limits rooted vegetation, which favors benthic cyanobacteria over rooted vegetation.

Growing Degree Days (GDD) are used in agriculture to predict growth and maturity of crops. Applying GDD to algae growth during the winter-spring-summer transitions can help a utility anticipate source water changes, and respond with appropriate management strategies. Source water management strategies can help to adapt to variable winter and spring weather patterns. Several examples of managing reservoir systems in response to the early growing season are described, including:

- Extending the spring diatom peak by artificial circulation
- Scheduling of transfers between reservoirs by GDD or other “triggers”
- Scheduling of alternative reservoir sources, or intakes, by water quality parameters
Abstracts

- Managing stratification structure and respiration pathways by circulation or aeration
- Anticipating necessary reservoir treatments such as peroxhydrate and copper sulfate

Our climate in the Northeast appears to be shifting, reservoirs are adjusting to the new seasonal conditions, so must the water supply manager.

Extreme Event Monitoring: Ameliorating Climate Change Induced Impacts to Lakes and Reservoirs
Stephen Souza
Princeton Hydro, LLC, Ringoes, New Jersey

Climate change has led to severe swings in weather patterns ranging from exceptionally intense storm events to prolonged droughts. These extreme events pose critical challenges to the sustainable management of the water quality as well as the ecological and human services and functions of lakes and reservoirs. However, with proper planning the severity of these events on the long term management and maintenance of a waterbody can be anticipated and their impacts minimized. This paper reviews the measures that can be put into place to maximize water storage and water quality, while simultaneously decreasing flooding, pollutant transport and the development hazardous algae blooms triggered by climate change induced extreme weather events. The Extreme Event Monitoring (EEM) approach entails the development and utilization of detailed bathymetric, water quality, hydrologic, pollutant loading and trophic state data to anticipate and temper the impacts of extreme weather events and actually create opportunities to increase the resiliency of waterbodies to the impacts of EEMs. This presentation presents the EEM approach and demonstrates its application in the long term management of a major drinking water reservoir and a large recreational lake both located in northern New Jersey.

Managing Shallow Florida Lakes Under a Warming and More Variable Climate
Melanie Riedinger-Whitmore
University of South Florida St. Petersburg, St. Petersburg, Florida

The predicted rise in global air temperatures in coming decades is expected to impact surface water temperatures and the thermal regime of freshwater lakes. Long-term temperature data from across the globe document rapid changes since the 1980s in lake surface water temperatures in some regions, and corresponding changes in water column biological and chemical properties as a result of increasing temperatures. Shallow lakes are predicted to be strongly impacted by future climate change, experiencing greater fluctuations in water levels, mixing patterns, community structure, seasonal variability, and nutrient/chemical processes. Thermal changes pose a significant challenge to lake management, since temperature directly affects many processes that influence water quality and other management concerns. The majority of Florida’s 8,000 lakes are shallow, and many of these lakes are managed for nutrient loading, water level, algal productivity, and recreation. Shallow Florida lakes typically are warm polympictic with stratification easily broken by wind and storm activity. Heat stored in sediments is an important influence on sediment/water interface processes and water column temperature profiles. Long-term daily temperature profiles are lacking for most shallow Florida lakes, but archived databases from central and southwest Florida of surface water temperatures (0–1 m) and periodic temperature-depth profiles can be used to examine how these subtropical lakes have responded to increases in air temperature and climate variability in recent decades. Patterns revealed from analyses of these data can be used to amend lake management plans to include potential climate change impacts on lake thermal regimes and associated in-lake processes.

Climate Change and Extreme Weather Events: Impact on Turbidity and NOM
William Becker1,2, Ben Wright3, and Steven Schindler4
1Hazen and Sawyer, New York, New York; 2Columbia University, New York, New York; 3Hazen and Sawyer, Baltimore, Maryland; 4New York City Department of Environmental Protection, New York, New York

Climate change and extreme weather-related events are of primary concern to drinking water utilities in that they affect both the quantity and quality of drinking water. In addition to spikes in water quality that occur during storm events, there are more subtle long-term changes in baseline water quality that are also occurring. The two water quality parameters of primary concern to most utilities are turbidity and natural organic matter (NOM). In addition to being a surrogate for pathogens, raw water turbidity is a major design and operational parameter for water treatment facilities. Turbidity affects whether filtration is needed (there are still several major unfiltered supplies in the US including New York City, Boston, Portland, Seattle, and San Francisco), the type of water treatment process used (e.g., direct filtration, sedimentation, dissolved air flotation, etc.), and has a big impact on operational costs associated with residuals handling and disposal. NOM is present in all surface waters and is the major precursor to disinfection byproducts. The changes in raw water turbidity levels and in the character and concentration of NOM that can occur as a result of climate change and extreme weather events and wildfires can have a significant impact on a utility’s ability to produce high quality finished water that meets all regulatory requirements and consumer’s expectations. The purpose of this paper is to present results from a Water Research Foundation study that evaluated the effect of climate change and extreme weather events on raw water quality and treatability.

Session B2: Chemical Treatment
1:30 pm – 3:00 pm | Standley II

The Impact of Low Dose Fluridone Treatments on Non-Target Aquatic Plants
Toni Stewart, Kenneth Wagner, and Maxine Verteramo
Water Resource Services, Wilbraham, Massachusetts

Fluridone has been used extensively for control of invasive species in the northern USA, particularly Eurasian watermilfoil (Myriophyllum spicatum, EWM). Over several decades, the most common strategy for EWM control with fluridone has evolved into longer exposure times (2–4 months) to relatively
low concentrations (< 10 ppb). Using monitoring data from 177 treatments of 95 lakes, we examined the response of non-target plant species 1–6 years after treatment comparing pre-treatment and post-treatment data for frequency. These are empirical data from actual treatments, where many factors other than treatment itself can have effects, but the range of responses provides insights to what can be expected when fluridone treatment is conducted in lakes with known plant assemblages.

The Impact of Low Dose Fluridone Treatments on Aquatic Plant Richness
Maxine Verteramo, Kenneth Wagner, and Toni Stewart
Water Resource Services, Wilbraham, Massachusetts

Fluridone has been used extensively for control of invasive species in the northern USA, particularly Eurasian watermilfoil (Myriophyllum spicatum, EWM). Over several decades, the most common strategy for EWM control with fluridone has evolved into longer exposure times (2–4 months) to relatively low concentrations (< 10 ppb). Using monitoring data from 177 treatments of 95 lakes, we examined species richness before and after treatment for a period of up to 6 years post-treatment. These are empirical data from actual treatments, where many factors other than treatment itself can affect richness, most notably monitoring approach, but the data provide insights into how species richness responds to low-dose fluridone treatment.

Control of HABs Through a More Rational Use of Copper: Deepening the Conversation About Cell Lysis and Cyanotoxins – What’s Really Happening?
David Hammond1 and Fred Singleton2
1Earth Science Labs, Inc., Berkeley, California; 2Earth Science Labs, Inc., Jacksonville, Florida

Frequency and severity of Harmful Algae Blooms (HABs) across the U.S. have increased markedly in recent years, affecting plant operations and even forcing temporary closure of several WTPs as a result of taste and odor issues and/or fear of cyanotoxins. Copper-based algaecides have been an important tool for many decades in management of source water – to the extent that in some jurisdictions copper has been over-used and there has been a backlash against it. But recent advances have led to more efficient formulations of copper, permitting superior performance with less chemical applied and less impact on the environment. Data from real world case studies will be presented, illustrating that a formulation of liquid copper delivered as cupric ions yields superior results, superior pest control, and better cost-effectiveness at lower doses of active ingredient. The data to be presented suggest that in most instances, facilities switching from conventional copper to liquid copper are able to achieve similar results by applying only 20% of the elemental copper previously applied, reducing cost and the impact on the environment. One such liquid copper product, EarthTec, has also been reported by some municipalities to reduce taste and odor by directly removing or degrading the compounds responsible, especially geosmin, and data from these municipalities will be presented along with a discussion of possible mechanisms for the chemical destruction or conversion to less offensive compounds. Copper also has bactericidal properties and aids in disinfection of drinking water without contributing to disinfection by-products. There has been much debate and controversy around the topic of cyanotoxins and the role of cell lysis in determining threats to human health. The latest data and microscopy-based evidence of the consequences from treating HABs will be presented, helping to answer the critical and timely question of “when should I treat and when should I not?”

Targeting the “Bad Players”: Effective Cyanobacteria Management with Liquid Activated Peroxygen
Tom Warmuth1, Hugh Dalton2, and Tom McNabb3
1BioSafe Systems LLC, Winston Salem, North Carolina; 2Santa Cruz Water Laboratory, Santa Cruz, California; 3Clean Lakes, Incorporated, Martinez, California

Effective copper alternative treatments for cyanobacterial management are emerging as a needed option as the threat to our waters by these organisms becomes more realized and understood. The development of effective treatments for the “Bad Players,” or what are identified as cyanobacteria that are known to produce harmful toxins or even taste and odor compounds, has never been more imperative. Santa Cruz Water Laboratory, through a program of monitoring, sampling, algal enumeration and development of an algaecide treatment regime with Clean Lakes, Inc. (Santa Cruz’s contracted California Certified Pest Control Advisor and licensed aquatic applicator) has delivered effective control of cyanobacteria throughout the season using GreenClean Liquid 2.0, a NSF/ANSI 60 Certified, liquid activated peroxygen algaecide, in their reservoir. Peroxide based algaecides have been identified as effective in selective treatments for cyanobacteria, where it is not greatly effecting the population of beneficial green algae/phytoplankton. The more commonly known use and delivery of “granular peroxide”, SCP – Sodium Carbonate Peroxyhydrate, can have challenges not only in the delivery of the treatment to the water, but also in effectively controlling the target organism depending on where it may be in the water strata. The chemistry of GreenClean Liquid 2.0 has shown to be effective, while also being easier to apply than SCP and having the ability to be more effectively applied near the surface as well as at variable depths and temperatures in the reservoir where the target cyanobacteria are found. This all leading to a better potable water source through better control of target cyanobacteria while preserving the phytoplankton. An overall healthier and productive algal population while limiting the input of copper based algaecides to the system.
Lake sedimentary deposits have been used for many purposes over the last 50 years, generally through use of proxy indicators of water quality and climate. Using radiometric dating, these paleolimnological records can often be tied to known local-to-regional events that aid in the interpretation of the data, including periods of European settlement, deforestation and development, large floods and fires, and water pollution. Where historic records aren’t available, changes in the various biogeochemical characteristics of lake sediment samples can be interpreted through use of modern analogs.

The modern analog method uses calibration data sets gathered through lake, watershed and climate monitoring to create a logical link between biological, chemical and particulate characteristics and the environmental processes that created them. For trends, this technique has proven very useful. Much uncertainty exists, however, in identifying high impact, short-term events, like tropical storm flooding, from repeated, low-impact events, such as a “wetter than usual season.”

Thanks to seven New England lake associations partially funding development of a paleolimnological “baseline” of their lakes in the last few years, opportunity now exists to use data from dated sediment cores alongside data from water quality monitoring to compare and assess regional trends in climate and land use change since the early Colonial period. This paper describes that effort and the patterns that are beginning to emerge from the results.

Sediment cores from all seven lakes have been $^{210}$Pb-dated and some have $^{14}$C dates. Other analytical results they share include particle-size, ICP-OES geochemistry, magnetic susceptibility, and organic content. Preliminary diatom counts from vertical plankton collections, sediment traps and sediments and biweekly measurements of thermal structure and water chemistry have been done on a few of the lakes. Two of the lakes have year-round temperature profiles, one since 2014, the other since 2015.

This presentation pulls together the commonalities in the paleo records from these different sites and uses them to examine modern water quality trends.

Regime shifts add complexity to lake management and restoration because they are difficult to predict, hard to reverse, and often involve a transformation to an undesirable state. A common thread among recent studies of regime shifts is the idea that an ecosystem undergoes a critical transition in response to either extrinsic (abrupt change in an environmental driver) or intrinsic (crossing an internal threshold in response to gradual environmental change) processes. To evaluate the relative influence of intrinsic and extrinsic paradigms on ecosystem dynamics we examined the algal response from two shallow lakes (Roxton Pond and Lake Petit Saint-François; PSF) to historical catchment phosphorus loading using a paleolimnological approach. Specifically, we tested whether cyanobacteria concentration measured as echinenone pigments showed an abrupt, nonlinear response to changes in the historical terrestrial phosphorus load index to the lakes. While Lake PSF is presently turbid, paleolimnological analyses indicated that the lake was once in the clear-water state, and that nonlinear increases in catchment phosphorus index resulted in an abrupt extrinsic transition to a cyanobacteria-dominated state. Roxton Pond, on the other hand, experienced a delayed response to external forcing but pre-impact dynamics differed between both lakes. These results suggest that cyanobacteria dominance in shallow lakes can display either extrinsic or intrinsic response to catchment phosphorus loading depending on the antecedent conditions or the resilience of the ecosystem and the magnitude for the external forcing.

Environmental conditions fundamentally determine ecological resilience, which we define as an ecosystem’s ability to maintain structure and function during disturbance. Lacustrine sediment cores from Yellowstone National Park were characterized for structure using fossil diatom assemblages and for function using algal and geochemical proxies of productivity. In one study, climate was the primary environmental control on community assemblage and productivity via its interaction with lake hydrology. Lakes with snow-fed hydrological budgets showed significant changes over the past century, whereas lakes with groundwater-linked hydrology did not. In either case,
lakes showed more sensitivity to climate and hydrology than to assumed trophic cascade effects imposed by introducing fish to naturally fishless lakes. A second study underlines that climate impacts may be mediated by environmental conditions in complex ways. Over the past ~ 30 years, researchers have observed significant decreases in mean cell size of centric diatoms in over 250 lakes in the Northern Hemisphere and attributed these changes to temperature increase. Indeed, a common centric diatom in the modern Yellowstone dataset showed the same trend in size diminution. However, we tested the temperature-diminution hypothesis in the region during the Holocene Insolation Maximum, an interval of conditions warmer than today that occurred ~ 10,000 years ago, and found that earlier fossil diatom records showed no evidence of size diminution. While the modern trend may be due in part to a changing climate and longer summer stratification, there may also be other factors at play; notable possibilities include increasing nitrogen, salinity, and alkalinity. Overall, climate exerts a primary environmental control on lake ecosystems, while catchment processes exert a secondary environmental control. Understanding the relative hierarchy of environmental controls on a specific region or water body can inform prioritization of management strategies.

Using Paleolimnology to Assess the Effects of Road Salt Application on Zooplankton and Diatom Assemblages in Jevins Lake in the Muskoka River Watershed, Ontario

Robin Valleau1, Andrew Paterson2, and John Smol3
1Queen’s University, Kingston, Ontario, Canada; 2Dorset Environmental Science Centre (DESC) Ministry of the Environment and Climate Change, Dorset, Ontario, Canada; 3Paleoecological and Environmental Assessment and Research Laboratory (PEARL) Department of Biology, Queen’s University, Kingston, Ontario, Canada

To promote safe road conditions, road salt is commonly used as a de-icing agent for winter road maintenance. Of the several compounds that can be used for this purpose, sodium chloride (NaCl) is the most commonly used in Canada. In North America, the use of road salt as a de-icing agent began in 1940 and was in widespread use by the 1950s. While it is undeniable that road salt reduces road accidents it may also have adverse effects on surface water. Because of their conservative nature and relatively high solubility, almost all chloride ions from road salts eventually find their way into waterways downstream. Jevins Lake, located in the Muskoka River Watershed and within sight of a major twinned highway, has the highest recorded chloride concentration of lakes in the Muskoka region of south-central Ontario (84 mg/L). To assess whether biological changes have occurred in this “worst-case” lake, coincident with historical road salt applications, high-resolution cladoceran and diatom records from 210Pb-dated sediment cores were examined from the lake. Biological changes in Jevins Lake, including a notable shift in PCA Axis 1 scores of cladoceran assemblages in the late 1950s, suggest that road salt application may have been a trigger for recent changes. Specifically, an increase in the relative abundance of Alona cicutumfimbriata occurred near the onset of road salt applications in the region. This taxon is known to be relatively saline tolerant. Salinity has also been shown to be an important variable controlling diatom assemblages in lakes in the region, and so diatom records from Jevins Lake will be used to corroborate the changes seen in the zooplankton assemblages, and to explore effects across trophic levels.

Session B4: Drinking Water Reservoirs
1:30 pm – 3:00 pm | Lake House

The Influence of Reservoir Operations and Natural Reservoir Processes on Disinfection By-Product Speciation in a Drinking Water in SE Virginia

Gary Schafran1, Chris Mihalkovic1, Peter Pommerenk2, David Rosenthal1, and Bob Cox3
1Old Dominion University, Norfolk, Virginia; 2Virginia Beach Public Utilities, Virginia Beach, Virginia; 3Norfolk Utilities Department, Norfolk, Virginia

Observations in recent years of an increasing ratio of brominated trihalomethanes to total trihalomethanes in drinking water in Norfolk and Virginia Beach, Virginia prompted an investigation into factors causing this multi-year trend. Trihalomethanes are formed from the chlorination of water during drinking water treatment and result from chlorine reacting with natural organic matter (NOM) and bromide present in water. Trihalomethanes are known or suspected carcinogens and some brominated THMs have a higher cancer potency.

Norfolk provides treated drinking water to its residents and Virginia Beach primarily utilizing three water supply reservoirs in a rural-agricultural region. The reservoirs receive water from adjacent watersheds as well as interbasin transfer at up to 60 million gallons per day. Examination of changes in treatment conditions over the past 17 years showed no change in treatment to explain the change in both drinking water THM concentrations and speciation, thus the causative factor was believed to be changes in reservoir water composition.

Reservoir monitoring data from the City of Norfolk were examined relative to the distribution system data to discern the role of reservoir composition on drinking water THM concentrations and whether natural processes and/or reservoir operational decisions were influencing THM speciation. Of particular interest was determining whether the interbasin transfer of water from a lake located downstream from coal-fired power plants where waters elevated in bromide are known to be discharged had an influence on THM speciation. Variation in NOM concentrations in the reservoirs appears to be the primary factor controlling drinking water distribution THM speciation and NOM variations are strongly influenced by natural processes.

Evaluation of External v. Internal Loading in Beaver Creek Reservoir, Crozet, Virginia

Alex Horne1, Kelly DiNatale3, Chris Newton1, and Andrea Terry3
1Alex Horne Associates, El Cerrito, California; 2DiNatale Water Consultants, Boulder, Colorado; 3Rivanna Water and Sewer Authority, Charlottesville, Virginia

Beaver Creek Reservoir is a 40 ha (100-acre) impoundment owned and operated by Rivanna Water and Sewer Authority (RWSA) as a drinking water supply. The reservoir was built in
Evaluation of Management Methods for a System of Drinking Water Reservoirs in Virginia

Kelly DiNatale1, Alex Horne2, Chris Newton1, and Andrea Terry3

1DiNatale Water Consultants Inc., Boulder, Colorado; 2Alex Horne Associates, El Cerrito, California; 3Rivanna Water and Sewer Authority, Charlottesville, Virginia

The Rivanna Water and Sewer Authority (RWSA) is a wholesale water utility that owns and operates five reservoirs that hold drinking water supply for Albemarle County, Virginia. The reservoirs have experienced problems with algae blooms, which have historically been managed by the application of copper sulfate based algacides. RWSA has chosen to investigate proactive methods of management to address water quality issues at the source.

A comprehensive monitoring program was instituted and began collecting data in 2015 and monitoring is still ongoing. Based on the data from the initial year of monitoring, several initial management options were recommended for each reservoir. Each reservoir in the system is unique, and management methods could not be broadly applied. Continued monitoring and additional studies have allowed for refinement of the initial recommendations. We present an evaluation of potential management methods and supporting data for select reservoirs in the system, focusing on those reservoirs with the greatest water quality issues.

Survey of Drinking Water Reservoir Monitoring and Management Practices

Chris Newton1, Kelly DiNatale1, and Andrea Terry2

1DiNatale Water Consultants Inc., Boulder, Colorado; 2Alex Horne Associates, Mooresville, North Carolina

Many drinking water utilities in the United States that utilize surface water supplies have reservoirs as part of their water supply. Reservoirs may serve as drought supply, intakes for diversions to water treatment plants, and/or redundant water sources if direct river diversions are unavailable due to water quality concerns. A survey of nine drinking water utilities using reservoirs was conducted on behalf of the Rivanna Water and Sewer Authority (RWSA). The goal of the survey was to inform RWSA of water quality concerns, monitoring programs, and reservoir management methods, both successful and unsuccessful that have been used by other drinking water utilities.

This presentation shows the similarities, differences, and effectiveness of different monitoring programs and management methods used by various utilities. Water quality concerns included aquatic nuisance species, dissolved iron and manganese, taste and odor compounds, and excessive or harmful algae blooms. Frequency of water quality monitoring, field and lab sampling approaches, and parameters sampled were catalogued. Allowed recreational uses ranged from complete closure to the public to hiking, fishing, and boating. Reservoir management methods for many utilities have evolved over time and include algacide applications, water level drawdown, aquatic plant harvesting, hypolimnetic oxygenation/aeration, mixing, and several other methods. The utilities provided their evaluation of the success of the management methods used.

Session B5: Data Analysis

1:30 pm – 3:00 pm | Cotton Creek

1973–2014 Historical Review of the Water Quality of Rhodhiss Lake, North Carolina, with Emphasis on Nutrient Loading and Export

Jonathan (Jon) Knight
Consultant, Mooresville, North Carolina

Rhodhiss Lake is the second most upstream reservoir on the Catawba River. Located between Lakes James and Hickory, Rhodhiss Lake was impounded in 1925 following the completion of Rhodhiss Dam and Powerhouse. Historically, Duke Energy used the hydropower station to generate electricity during periods of peak electrical demand and/or during periods of adequate inflows to maintain target lake elevations. In addition to hydropower production, the lake provides drinking water to the municipalities of Granite Falls, Morganton, Lenoir and Valdese. Morganton, Lenoir and Valdese also discharge treated municipal wastewater into the lake or its tributaries. The lake is popular among fishermen and boaters.

Since 1950, Rhodhiss Lake has experienced degraded water quality with periodic taste and odor problems reported in the drinking water originating from Rhodhiss. By 2004, with six of seven water quality parameters identified as lake stressors (percent saturation DO, algae, chlorophyll a, pH, sediment, and taste and odor), NCDWQ reported that Rhodhiss Lake suffers from eutrophication and was impaired in its support of aquatic...
life. In 2008, the North Carolina 303(d) list was updated to include Rhodhiss Lake for exhibiting high pH values (NCDWQ 2008).

Recognizing a lack of hard, comprehensive data collection to calculate the various sources of phosphorus, nitrogen, and sediment into Rhodhiss Lake, Carolina Land and Lakes RC&D, Inc. applied for and received a 319 grant to measure the comprehensive yearly nutrient loads to Rhodhiss Lake. Since water quality data had been collected by various groups since 1973, the results of the loading study were used to evaluate historical water quality trends in Lake Rhodhiss.

This report describes the historical water quality trends compared to North Carolina lake water quality standards as a function of hydraulic retention times, lake stratification, nutrient sources and subsequent loading, nutrient export, and biological activity.

Based upon many nutrient loading models, Lake Rhodhiss should be extremely eutrophic (very high chlorophyll concentrations) since its phosphorus loading rate was 5.4 g/m²/yr and nitrogen loading was 43.7 g/m²/yr. These values were 27 times and 15 times higher, respectively, than the permissible levels of nutrient loading described by the models. Clearly, these models do not apply to Lake Rhodhiss and/or the plankton community was limited by other factors. The autotrophic phytoplankton in Lake Rhodhiss exhibited a diverse assemblage of nearly all taxonomic groups typically found in temperate lakes. The taxonomic diversity as well as the specific population levels (algae densities) was a response to specific requirements for light, temperature, nutrients (macro and micro), buoyancy regulation, competition, productivity, generation times, and predation.

Reservoir DO Related to Inflow TP Concentration and Water Residence Time

Shannon Brattebo¹, Gene Welch², and Harry Gibbons²

Lake Spokane, a large main-stem reservoir, has remained borderline meso-oligotrophic during the past seven years with seasonal mean, whole-reservoir, epilimnetic total phosphorus (TP), chlorophyll (chl) and transparency at 11 µg/L ± 5%, 4 µg/L ± 20% and 4.8 m ± 20%, respectively. Mean chl has decreased 80% and transparency doubled since the reservoir’s near hypereutrophic state prior a reduction in wastewater TP in 1977 resulting in an 84% reduction in inflow TP concentration, which is currently 15 µg/L. Mean, volume-weighted, minimum DO increased from 1.4 mg/L before to 4.5 soon after TP reduction to 6.2 mg/L the last seven years, during which there has been no trend, despite additional reduction in wastewater TP. Minimum DO has apparently reached a “floor,” which will probably not decrease further, but nevertheless has varied year-to-year with water residence time (r² 0.85), rather than with inflow TP (11–20 µg/L), over the past seven years. Areal hypolimnetic deficit rate has also decreased from 70–90%, is consistent with mean chl, and will probably not decrease further. These results show that main-stem reservoir trophic state and DO resources are related directly to inflow TP concentration despite their reputation of higher water and nutrient loading and inherently higher trophic state and lower DO than natural lakes.

Comparison of Sub-Basin Characteristics Within Cassadaga Lakes Chautauqua County, New York

Joseph O’Reilly
State University of New York Oneonta, Oneonta, New York

Multi-basin lakes have the potential to require more-intensive monitoring of limnological parameters than single-basin lakes if individual basins change in different ways throughout the year. As the number of sub-basins in a lake increases, the number of sampling and monitoring locations increase as well, multiplying the time and energy needed to accurately study the lake. The need for sampling in individual sub-basins is rarely validated in practice. Cassadaga Lakes in Chautauqua County, New York, is an interconnected chain of lakes. The lake itself has three primary basins: Upper Cassadaga, Middle Cassadaga, and Lower Cassadaga lakes. Among the three basins are a total of seven distinct sub-basins. The objective of this study was to determine whether or not differences in key limnological parameters (e.g., temperature and dissolved oxygen) could be detected in seasonal measurements within these sub-basins. General linear models were used to test for effects of primary basins and sub-basins on limnological parameters of interest while accounting for differences in depth and seasonal variability. Preliminary results indicate that if statistical differences in measurements between sub-basins or primary basins do exist, then they are beyond our ability to detect them based on precision of measurement. These results underscore the importance of validating assumptions associated with annual lake monitoring, and indicate that sampling intensity in Cassadaga Lakes can likely be reduced without losing important information about seasonal changes collected through limnological monitoring.

Spatial Relationship Between Nutrient Availability and Sediment Particle Size in Willow Creek Reservoir, Heppner, Oregon

Sarah Burnet and Frank Wilhelm
University of Idaho, Moscow, Idaho

For many lakes, internal loading of phosphorus (P) from bottom sediments has been calculated to be a large fraction of the annual phosphorus budget and has been identified to significantly delay improvements of water quality after reducing external sources of P. To understand the dynamics of the potential release of P from bottom sediments, we will focus on the particle size composition from 30 cores collected from Willow Creek Reservoir, in northeastern Oregon. We aim to test the hypothesis that the amount of reactive P is directly related to particle size, and the abundance of binding sites presented by the presence of iron (Fe), manganese (Mn), and aluminum (Al) in the sediments. The amount of reactive P will be compared to previously measured sediment release rates from the same reservoir. If relationships exist between the two methods, then analysis of reactive P in cores could serve to replace time-consuming incubations to measure P release from sediment cores. It would also allow more expansive sampling at a lower cost to better understand the spatial distribution of P stored in sediments which is important to managers constructing a nutrient mass balance, or attempting to identify ‘hotspots’ that should be prioritized for any in-lake
Abstracts

3:30 pm – 4:40 pm | Standley I

Session C1: Climate Change

How will Intensified Water Management Affect Reservoir Food Webs and Fisheries?
Adam Hansen
Colorado Parks and Wildlife, Fort Collins, Colorado

Reservoir ecosystems are sensitive to climate warming, water use, and other natural or human disturbances. A warming climate, extended drought, and continued human development have increased burden on water storage reservoirs, particularly in the arid west. As a result, the magnitude and variability of fluctuations in reservoir surface elevation have increased, and will likely continue to intensify. Yet, the effects of alternative water management regimes on reservoir biota and implications for the conservation of sensitive coldwater species and valuable sport fisheries remain distinctly underappreciated and understudied despite decades of water manipulation and use. Exploring how variability in water management of decades past shaped reservoir food webs and species interactions could inform the implications of intensified water use in the decades to come. Here, I present two cases studies evaluating the effects of variable water level fluctuations on reservoir biota and food web interactions. The first within the context of native coldwater species conservation, and the second within the context of maintaining economically important sport fisheries. I conclude by discussing implications for the cooperative management of water and fisheries and outline future research needs.

Mysis diluviana Responses to Climate and Dam Operations in Three Mesotrophic Reservoirs
Brett Johnson, Douglas Silver, William Pate, and Kyle Christianson
Colorado State University, Fort Collins, Colorado

Mysis diluviana (Opossum Shrimp) introductions have proven detrimental to fish populations and have altered zooplankton grazing and nutrient cycling in lakes and reservoirs throughout western North America. As cold stenotherms, Mysis should be sensitive to climatic conditions and dam operations that affect thermal stratification. A standardized Mysis diluviana monitoring program at three coldwater reservoirs during 1991–2016 allowed us to examine responses of Mysis populations to climate and dam operations. Average Mysis density was 236–498 mysids/m² over the 26 years of the study. In 2003, reservoir content decreased by as much as 80% after two successive years of severe drought. Mysis density in 2003 (≤ 30 mysids/m²) was the lowest observed in the period of record at the two reservoirs with the most severe drawdowns. We hypothesized that Mysis may be sensitive to climate-induced changes to reservoir content, epilimnetic temperature and hypolimnetic dissolved oxygen. In this presentation we will evaluate the evidence for this hypothesis.

Session C2: Monitoring

3:30 pm – 4:40 pm | Standley II

Building a Reservoir Water Quality Monitoring Program from the Ground Up!
Andrea Terry¹, Kelly DiNatale², Chris Newton³, and Alex Horne³
¹Rivanna Water and Sewer Authority, Charlottesville, Virginia; ²DiNatale Water Consultants, Boulder, Colorado; ³Alex Horne Associates, El Cerrito, California

The Rivanna Water and Sewer Authority (RWSA) owns and operates five drinking water reservoirs, serving Albemarle County, Virginia. Several of these reservoirs have experienced water quality issues over the past 40 years and one reservoir has been recently enlarged and will have new water sources in the future. Historically there has been minimal water quality monitoring in reservoirs except for some 208 studies in the late 1970s and early 1980s. Some of the water quality issues have been excessive algae blooms, including cyanobacteria. RWSA has historically relied on copper sulfate applications to manage algae blooms. An aeration system installed in one reservoir in the early 1980s was abandoned within ten years and never replaced. RWSA determined that it should examine alternative lake management methods to the current practice of copper sulfate applications. A consulting team was retained and a monitoring program developed.

This presentation covers the trials and tribulations of starting a monitoring program from the ground up and will describe the monitoring parameters, equipment, staffing, financial and sampling challenges. An adaptive sampling approach has been used in response to these challenges.

Did Monitoring Reduce the Phosphorus in Barr Lake?
Steve Lundt
Metro Wastewater Reclamation District, Denver, Colorado

The obvious answer to the title question is no. However, a person that closely monitors a lake over a long period of time can easily feel a false sense of accomplishment that the lake is getting better because of the monitoring.

Barr Lake, a 115-year-old irrigation reservoir downstream of Denver, was ignored for 70+ years. Then in the past 20 years, a year-round monitoring program focused on phosphorus and the cultural eutrophication process. Recent data are finally starting to show signs of phosphorus reduction. Can these reductions be explained? Did a more intense monitoring program have an influence on the data? When a lake has been given a large amount of attention, will it always show signs of improvement?
This presentation will cover the historical record of phosphorus concentrations in Barr Lake and how monitoring, studies, lake management, public education, and natural disasters have all played a role in the always changing eutrophication process.

**US Bureau of Reclamation’s Water Quality Monitoring Program Overview**

Heidi McMaster¹ and Janet Kirsch²

¹US Bureau of Reclamation, Boulder City, Nevada; ²Retired, Boulder City, Nevada

Under the Colorado River Basin Salinity Control Act of 1974, Public Law 93-320, the Bureau of Reclamation (Reclamation) is authorized to enhance and protect the quality of water in the Colorado River and its tributaries. Reclamation’s Lower Colorado Regional Office (LCRO) has currently four programs established to manage these water quality objectives. The Colorado River Water Quality Improvement Program (CRWQIP) performs ongoing monitoring of the river and its tributaries. The Environmental Compliance Group’s Invasive Species program protects and monitors the environment in order to determine and mitigate impacts from invasive species and to reduce their spread to other ecosystems. To accomplish the goals of these programs, Reclamation collects water samples from its Colorado River reservoirs on a regular basis for nitrate/nitrite (as N), ammonia (as N), phosphorus (total and ortho-), chlorophyll (a, b, c and pheophytin), silica, chloride, selenium (total), total suspended solids (TSS), boron (total), chromium (total), hexavalent chromium, and mercury. Additionally, phytoplankton, zooplankton, and algal toxins are analyzed for some sampling events. Lake Mead is sampled each year on a quarterly basis at up to 22 stations. Lake Havasu is sampled each year on a quarterly basis at up to 7 stations (previously bi-monthly). The Las Vegas Wash is sampled each year on a quarterly. The Lower Colorado River Contaminant Monitoring Program (LCR CMP) samples the Colorado River 2 times a year in August and December (high and low flow periods). Reclamation coordinates with multiple agencies (Federal, State and Local) and Indian tribes to accomplish the various sampling events. Transparency and collaboration has enhanced the program and continued efforts by all interested parties will benefit all users on the Colorado River.

**Paleolimnology Provides Early Warnings of Impacts from Eutrophication, Invasive Species and Climate Change**

Euan D. Reavie¹, Elizabeth E. Alexson¹, Lisa R. Estepp¹, Gerald V. Sgro¹, Andrew J. Bramburger¹, Mei Cai¹, Robert W. Pillsbury³, and Victoria L. Shaw Chraïbi⁴

¹University of Minnesota Duluth, Duluth, Minnesota; ²John Carroll University, University Heights, Ohio; ³University of Wisconsin Oshkosh, Oshkosh, Wisconsin; ⁴Tarleton State University, Stephenville, Texas

Multiple stressors need management options in the Laurentian Great Lakes and paleolimnology provides tools to track changing conditions and predict future impairments. We can provide early data reflecting aquatic impacts before they are realized in higher trophic levels, thereby predicting future conditions. Here are two examples of how paleolimnology is being used to inform management decisions for the Great Lakes. (1) The RAP for the St. Louis River requires removal of beneficial use impairments associated with nutrients. Sediment cores were analyzed for physical, chemical and biological remains and long-term changes in fossil algae provided evidence that some areas have improved since nutrient abatement. However, nearshore areas show increasing nutrients and algal abundance, likely due to stressors that are not fully understood (climate change, sediment nutrients). Recommendations for delisting and future studies are forthcoming. (2) A diatom-based paleolimnological study has revealed the first biological effects of climate change on the base of the food webs in all five Great Lakes: an increasing relative abundance of *Cyclotella sensu lato*. Atmospheric warming is the strongest correlate with these changes, and recommendations are made regarding the eventual impacts on food webs throughout the Great Lakes system.

**Session C3: Paleolimnology**

3:30 pm – 4:40 pm | Meadowbrook

A Comparison of Present-Day and Pre-Industrial Zooplankton Assemblages and Size Structure in Cottage and Reference Lakes in Algonquin Provincial Park, Ontario, Canada

Anna DeSellas¹, Andrew Paterson², and John Smol¹

¹Queen’s University, Kingston, Ontario, Canada; ²Ontario Ministry of the Environment and Climate Change, Dorset, Ontario, Canada

Algonquin Provincial Park in south-central Ontario, Canada, has a high number of headwater and Lake Trout lakes, and the province has a mandate to protect these resources. Algonquin Park is also one of only two provincial parks in Ontario that allows leases for private cottages, dating back to the 19th century. However, a scarcity of long-term water chemistry and biological data for lakes within the Park makes it challenging for resource managers to discern what impact, if any, cottage development and other anthropogenic stressors are having on lake health. Zooplankton remains from the order Cladocera preserve well in lake sediments and have been used worldwide as a tool to understand changes in lake biology and water quality, such as declines in calcium concentrations, acidification, predation shifts (e.g., those caused by invasive species), and eutrophication. In this study, we examine cladoceran assemblages from the surface sediments of 54 lakes (22 with cottage-leases and 32 reference lakes). We extend the zooplankton monitoring record to a period prior to European human (pre-impact sediments) disturbance and use multivariate statistical methods to evaluate temporal and spatial variation in community assemblages. We also tease apart assemblage changes caused by local stressors (e.g., cottages, campgrounds, highway corridors), regional anthropogenic stressors (e.g., climate change, calcium decline) and natural variability. The cladoceran data examined here complement other paleolimnological research from the same study lakes, providing an integrated record of food web and other biological changes over time.
Abstracts

Session C4: Drinking Water Reservoirs
3:30 pm – 4:40 pm | Lake House

Investigating the Effects of Purified Water Discharges in Water Supply Reservoirs

Jeffery Pasek¹ and Imad Hannoun²
¹City of San Diego Public Utilities Department, San Diego, California; ²Water Quality Solutions, McGeahysville, Virginia

In southern California, there are many reservoirs that were constructed to serve municipal water systems. These reservoirs are managed to provide a reliable and high-quality water supply for domestic, industrial, and agricultural uses. Persistent droughts in the southwest and future climate change could further amplify the important roles of these reservoirs. One approach for maximizing water resources is to implement potable reuse through reservoir augmentation, whereby highly treated wastewater is added to water supply reservoirs on a big scale. Due to large variations in water quality between the highly-treated wastewater and historical water inflows, the reservoirs may experience significant changes in water quality, including changes in temperature, salinity, and algal productivity. An important question is how to assess and predict potential changes to the reservoir water quality and devise updated management techniques.

The City of San Diego Public Utilities Department (City) is considering multiple projects for recycling highly treated wastewater – which the City refers to as purified water – for potable reuse. As a first step, the City is implementing a potable reuse project whereby 33,000 AF (acre-feet) per year of purified water will be added to Miramar Reservoir, a 6,000 AF impoundment. The City is considering similar projects at several of its other reservoirs. In this presentation, the effects of potable reuse through reservoir augmentation on a reservoir’s water quality – including salinity, algae, nutrients, dissolved oxygen, and pathogens – are discussed and evaluated through modeling.

A Rapid Shift from Oligotrophy to Eutrophpy: Water Quality Trends in California's Recently Constructed Diamond Valley Lake

Seyoum Gebremariam, Paul McCormick, and Paul Rochelle
Metropolitan Water District of Southern California, La Verne, California

Diamond Valley Lake, Southern California’s largest lake, was constructed in the late 1990s and completely filled by 2002. The lake remained oligotrophic for the first 9 years before showing signs of rapid eutrophication in 2011. Since then, anoxia and cyanobacterial blooms in summer and autumn, nutrient recycling, and the production of sulfides and dissolution of metals into the water column have become routine and pose challenges for drinking-water treatment. We analyzed long-term environmental, chemical and flow data, conducted a hydrographic survey, and developed a hydrodynamic model to identify the factors that contributed to the shift in trophic state of the lake and to evaluate different management strategies that might be pursued. Our findings indicate that inherent morphometric features such as lake-form type and large relative depth make the lake less resilient to changes in source-water nutrient levels and accentuate water-quality problems caused by increased nutrient loading. Light prevailing winds and unfavorable morphometric conditions impede deep mixing and upwelling in the water column, and a stable stratification that lasts up to 10 months makes the lake susceptible to hypolimnetic anoxia. Increased influent nutrient levels in recent years caused increased cyanobacterial productivity in surface waters, which accelerated oxygen consumption in the hypolimnion and subsequent formation of nutrient recycling and a shift in lake trophic status. Water quality modeling results indicate that hypolimnetic oxygenation is more efficient solution to ameliorate the lake’s water quality problems than alum treatments. Other management options are less feasible because of high cost or other technical issues.

Modeling of Purified Water Mixing in Lake Jennings, California

Li Ding¹, Ben Martin¹, J.P. Semper², Paige Russell², Seval Sen³, and Brian Olney⁴
¹Flow Science Incorporated, Pasadena, California; ²Brown and Caldwell, San Diego, California; ³Padre Dam Municipal Water District, Santee, California; ⁴Helix Water District, La Mesa, California

Padre Dam Municipal Water District (PDMWD) partnered with Helix Water District (HWD), County of San Diego, and City of El Cajon on the East County Advanced Water Purification Program (Program). The objective of the Program is to diversify the local water supply and reduce the region’s dependence on imported water by creating a new source of local sustainable water supply using state-of-the-art technology to purify East San Diego County’s recycled water (i.e., purified water). One strategy the Program is considering for implementing potable reuse is through surface water augmentation (SWA) at the Lake Jennings Reservoir (approx. volume of 9,800 acre-feet). Determining the feasibility of using Lake Jennings under the emerging California Division of Drinking Water’s (DDW) SWA Regulations was an important step in verifying the future size and capacity of the Program. A three-dimensional hydrodynamic model of Lake Jennings has been developed to evaluate the viability of using Lake Jennings for receiving potable reuse water with utmost consideration to public health and safety. The model was calibrated and validated using field data in the lake and was subsequently used to predict the dilution and mixing of the purified water in Lake Jennings under two future operating scenarios: Routine Operations and Boundary Condition Operations. The modeling results indicates that using Lake Jennings for the East County AWP Program meets the emerging SWA requirements and can be a viable way to produce a safe and reliable, locally sustainable water supply for the region.
**Poster Session**
5:45 pm – 7:00 pm | Westminster Foyer

**2D and 3D Numerical Modeling of Water Level and Temperature in Lakes and Reservoirs Based on the Numerical Scheme in CE-QUAL-W2: A Case Study**

*Hussein A. M. Al-Zubaidi and Scott A. Wells*
Portland State University, Portland, Oregon

A two and three-dimensional hydrodynamic and temperature numerical model were developed and calibrated for Laurnace Lake, Oregon, USA. The 3D hydrodynamic governing equations of continuity, free surface equation, and momentum were solved numerically based on the numerical scheme in the 2D laterally averaged hydrodynamic and water quality model, CE-QUAL-W2. The new 3D model employed higher order schemes for mass and heat transport in the solution of the transport governing equation. The numerical formulation of the 3D scheme was done in which the final numerical solution of the free surface has a tri-diagonal matrix form rather than a penta-diagonal matrix form. This new 3D numerical scheme reduced the numerical computations since there is no need to solve a penta-diagonal matrix form. Both 2D and 3D model were run depending on the same input meteorological data, boundary conditions of flow and temperature, and surface heat exchange algorithm. Comparisons in water surface levels and temperature vertical profiles between 3D model predictions and data were performed. The 3D model matched data with good error statistics. Additionally, the 3D model results were compared to the 2D model, CE-QUAL-W2, and recommendations were made on when 2D versus 3D models should be used.

**The Cyanobacteria Monitoring Collaborative – An Evolving Approach to Cyanobacteria Monitoring**

*Shane Bradt1, Linda Green2, Hilary Snook3, Betty Kreakie4, Jeff Hollister5, and Jasper Hobbs6*

1University of New Hampshire Cooperative Extension, Durham, New Hampshire; 2University of Rhode Island, Kingston, Rhode Island; 3US Environmental Protection Agency Region 1, Chelmsford, Massachusetts; 4US Environmental Protection Agency Atlantic Ecology Division, Kingston, Rhode Island; 5US Environmental Protection Agency Atlantic Ecology Division, Narragansett, Rhode Island; 6New England Interstate Water Pollution Control Commission, Lowell, Massachusetts

Starting in 2013, the New England Cyanobacteria Monitoring Workgroup was created to collaboratively address issues related to cyanobacteria in lakes and rivers. The workgroup spent several years developing standardized monitoring methods which could be used across the region to address both short-term cyanobacteria bloom events and long-term monitoring of dynamic cyanobacteria populations. During the past three summers, over one hundred waterbodies across the region have been sampled for cyanobacteria utilizing these protocols and the data shared among workgroup participants. In late 2016, the workgroup officially transitioned to the Cyanobacteria Monitoring Collaborative (CMC). The name change reflects the changing nature of the group, both in approach and scope. The CMC has put increasing effort into collaboration with the goal of furthering the understanding and monitoring of cyanobacteria populations and blooms. In addition, collaborators have grown to include people and organizations outside New England, now ranging from coast to coast in the United States with additional interest from abroad.

A newly redesigned website (https://cyanos.org) provides access to news on the monitoring programs and activities, allowing interested groups and individuals to discover, learn about, and collaborate with the CMC. The CMC’s three monitoring programs (bloomWatch, cyanoScope and cyanoMonitoring) are described in detail on the website including links to the materials and methods necessary to participate. In addition to this new virtual presence, the CMC offers training using a mobile lab in New England and virtual and site trainings beyond the group’s home region.

**Applying Paleolimnological Techniques to Reservoirs in Arid Regions**

*Victoria L.S. Chraibi*
Tarleton State University, Stephenville, Texas

Arid regions, such as Texas and the American southwest, are currently experiencing drastic changes in hydrology and biotic structure due to decreasing precipitation, changing seasonality, and human activities like impoundment, diversion, and irrigation. Using reservoirs for paleolimnological analysis addresses the lack of natural lakes from which to procure long-term sediment cores. However, there is a need to experimentally develop best practices for obtaining and analyzing sediment cores from these non-traditional sites. Fortunately, there is the potential to synchronize paleolimnological studies with modern limnological processes that are monitored in reservoirs in order to better understand how reservoir-specific hydrological and limnological processes are reflected in longer-term records. This will strengthen the ability to core reservoirs and obtain useful records of recent climatic, hydrological, and biological shifts in arid areas to inform water management.

**Reduced Snowpack May Compound Effects of Climate Warming on High Elevation Lakes**

*Kyle Christianson, Brett Johnson, and Douglas Silver*
Colorado State University, Fort Collins, Colorado

Changes in climate are expected to have the greatest effect on high elevation and high latitude systems. In the Southern Rocky Mountains, > 90 percent of an estimated 2,000 natural lakes are located at high elevations (> 2,700m). Analysis of historical temperature measurements from > 300 of these lakes demonstrated a signal of surface warming since 1940. A mechanistic one-dimensional lake thermal model, General Lake Model (GLM, v3.1.14), was used to capture contemporary dynamics and predict the effects of lake-specific characteristics on thermal structure given future environmental change. We found that lake size, water clarity, inflow, and weather all affected individual lake thermal responses. Environmental change, such as reduced snowpack and climate warming, alter the thermal structure of high elevation lakes. Stratification developed more rapidly and was more intense under environmental change, increasing the potential for hypoxia to develop. Interactive effects
of climate change and lake-specific characteristics have important implications for habitat suitability for coldwater stenotherms such as salmonids currently inhabiting high elevation lakes in the Southern Rocky Mountains.

Public Outreach and Education – Don’t Go It Alone

Amy Conklin1 and Susan Thornton2
1Barr Lake and Milton Reservoir Watershed Association, Littleton, Colorado; 2Susan Thornton Associates, Littleton, Colorado

The Barr Lake and Milton Reservoir Watershed Association (BMW) using an Urban Waters grant from the US Environmental Protection Agency convened a diverse group of stakeholders to develop messaging around clean water. We first completed research on past and current water awareness campaigns, then hired outside firms to conduct focus groups and develop messages. We partnered with students in marketing classes at Metro State University and the Greenway Foundation to evaluate results of surveys of Denver residents’ water awareness. We leveraged work being done by others, specifically a statewide awareness survey conducted by the Colorado Water Conservation Board to help inform the messages. We also conducted focus groups in both English and Spanish to test the messages. We prepared the messaging files in both English and Spanish, loaded them on flash drives and distributed them widely. Ideally, the messages would be used in a statewide water awareness campaign. This proved much harder to accomplish. Our research showed that in Colorado’s history there has only ever been one statewide campaign, from 1999 to 2001, run by the League of Women Voters. We included some of their messages in the packet of messages we developed. The messages are currently in use by a number of Denver Metro area organizations.

New Data Web Portal for Global Environmental Monitoring

Steve Elgie1, Jens Proche2, and Frank Schlaeger3
1KISTERS North America, Sacramento, California; 2KISTERS North America, Denver, Colorado; 3KISTERS Aachen, Aachen, North Rhine – Westphalia, Germany

The United Nations Global Environmental Monitoring System (GEMS) Water Programme is dedicated to providing environmental water quality data (sample results and continuously measured data) of the highest quality, integrity, accessibility and interoperability. This data is provided to the public via the GEMStat website to be used in water assessments and capacity building initiatives. The water quality data currently includes more than 3,000 stations, over 100 parameters, almost four million sample records and is submitted to GEMStat by national focal points of governmental agencies.

In March 2014, the hosting of the GEMStat component was taken over by the German Federal Institute of Hydrology (FIH). The FIH completely redesigned the data storage and management component as well as the representation of data, including the data download portal.

The data storage, management and analysis system was replaced by the KISTERS water quality module KiWQM. This module was specifically designed to manage, validate and analyse discrete sampling data along with continuously measured real time sensor data. As KiWQM is fully integrated into the WISKI system it takes advantage of features such as flexible data structuring, powerful calculations, scripting and graphing functionalities.

The KISTERS Web Interoperability Solution (KiWIS) will provide environmental monitoring data to the public and allow specialists to easily download the data as required. The KiWIS solution is a single framework for multiple web service types and serves several data sources at one time such as HTTP GET/POST KVP services (KiQS, SOS1/2) and SOAP (WaterOneFlow, SOS2). The KiWIS supports user authentication and authorization for members to view and download their data but restricts guest users from accessing. In addition to powerful web services, KiWIS provides WISKI data for specific web widgets such as creating dynamic time series graphs or displaying descriptive station metadata. The GEMS portal will be set up by applying this functionality and overlaying with mapping capabilities.

The project for redesigning the new GEMStat portal started in September 2015. The final portal will be presented during the 10th annual National Water Quality Monitoring Conference.

A Water Chemistry Regime Shift Associated with Zebra Mussel (Dreissena polymorpha) Entrance into New York State Lakes

Leah Gorman and Daniel Stich
State University of New York College at Oneonta, Oneonta, New York

Three decades of limnological data were collected by the Citizen Statewide Lake Assessment Program on DeRuyter Reservoir, Madison County, New York. Trends in pH, conductivity, Secchi transparency, and chlorophyll a suggest a regime shift correlated with the introduction of Dreissena polymorpha (zebra mussels) into the lake. Piecewise regression models were specified to determine the year (2004) in which the shift in water quality trends occurred and to help predict future water quality trends. Significant differences were noted between regimes occurring from 1988 to 2004 and from 2004 to 2015 for Secchi depth (increase) and chlorophyll a (decrease). Similar models will be used to determine if similar trends are occurring in lakes across New York State. Though there are arguably no successful strategies to manage zebra mussels, understanding how they have altered water quality can help inform long-term whole lake management decisions.

Advection and Nutrients Regulate Phytoplankton Dynamics in Tainter and Menomin Reservoirs, Wisconsin

William F. James1, Rachel Fleck2, Heidi Lieffort1, Lyndsey Provos1, Miranda Vandenberg1, and Amanda Wilson
1University of Wisconsin–Stout, Menomonie, Wisconsin; 2Iowa State University, Ames, Iowa

Tainter and Menomin Lakes are a series of rapidly flushed hydropower impoundments located near the base of the Red Cedar River watershed in west-central Wisconsin. Ranked as among the most severely impaired, hypereutrophic systems in the state, mean summer total P and chlorophyll typically exceed...
Management of Half Moon Lake, Wisconsin, for Native Macrophyte Community Re-Establishment

William F. James1, Jordan Bauer1, Rachel Fleck1, Heidi Lieffort1, Evan Native Macrophyte Community Re-Establishment Management of Half Moon Lake, Wisconsin, for
1University of Wisconsin–Stout, Menomonie, Wisconsin; 2Iowa State growing non-native species such as Potamogeton crispus productivity and decreasing light penetration. Invasion by rapidly growth and community diversity by stimulating excessive algal shallow aquatic ecosystems. Eutrophication can negatively impact biological community dynamics and limnological conditions of Submersed macrophytes play an important structuring role in watersheds will be challenging.

Submersed macrophytes play an important structuring role in biological community dynamics and limnological conditions of shallow aquatic ecosystems. Eutrophication can negatively impact growth and community diversity by stimulating excessive algal productivity and decreasing light penetration. Invasion by rapidly growing non-native species such as Potamogeton crispus (CLP) can also exacerbate declines in native populations by forming a dense canopy in early summer that attenuates light. For eutrophic systems that have become light-limited by algal-induced light attenuation, direct biomass control of CLP may not be sufficient to restore native macrophyte communities, particularly meadow-forming species, in areas they previously inhabited. Additional management may be needed to reduce algal biomass to improve the underwater light climate for re-establishment of native submersed macrophytes. Alum was applied to shallow eutrophic Half Moon Lake, Wisconsin, in 2011 to reduce internal P loading, limit algal growth, and increase PAR penetration. Mean summer Secchi transparency increased to near the lake bottom, while PAR attenuation decreased, during the first 3 summers post-treatment. These variables then declined in 2014–15 in conjunction with decreased alum P binding efficiency, increased internal P loading, and higher summer chlorophyll. There was linear relationship between native biomass and frequency versus Secchi transparency (positive) or PAR attenuation (negative), suggesting PAR attenuation was ultimately limiting native submersed macrophyte growth in the lake. Results suggested that the native macrophyte community was very sensitive to underwater light habitat. A second alum treatment is scheduled for 2017 to control algal-mediated PAR attenuation.

Long-Term Endothall Control of Curly-Leaf Pondweed in Half Moon Lake, Wisconsin

Heidi Lieffort and William F. James
University of Wisconsin–Stout, Menomonie, Wisconsin

The macrophyte community of eutrophic Half Moon Lake, a shallow oxbow located in Eau Claire, Wisconsin, has been dominated by nearly 100% coverage of invasive curly-leaf pondweed (CLP, Potamogeton crispus) for decades. Efforts to manage the system for native macrophyte re-establishment included an alum treatment in 2011 to improve underwater light habitat and annual early spring, low-dose Endothall treatments. Successive annual whole lake herbicide treatments at 0.7 to 1.0 mg/L ae were conducted between Spring 2009 and 2013 to deplete the sediment turion bank and control populations. A point-intercept grid (~150 points) was established to determine germinated turions in late April and CLP biomass in early June and August every year using a rake sampling technique. Late April germinated turions occurred at a frequency of 80% and averaged 40 turions/m2 in 2009 before the start of herbicide treatment and declined to a frequency of < 20% with an average < 6 turions/m2 by year 5. Summer CLP frequency of occurrence and biomass were generally < 10% and < 5 g/m2 during the summers of treatment years. Cessation of herbicide treatment in 2014 was accompanied by a surprisingly pronounced rebound in CLP frequency of occurrence to 40% and average June biomass of 20 g/m2. A second 5-year series of annual early spring treatments were initiated in 2015 and will end in 2019. Results suggested that long-term herbicide applications (on the order of 10 y or more) may be needed to deplete viable turions residing in sediment from decades of CLP dominance.

Source Water Quality and Supply Challenges in the Houston, Texas Metropolitan Area: Assessing Baseline Data Prior to an Interbasin Transfer into Lake Houston

Zulimar Lucena
US Geological Survey, Houston, Texas

The Houston, Texas metropolitan area has a population of over 6 million people. Resulting water supply challenges have led to the development of various management strategies to ensure future water availability. In 50 years, population is expected to increase in the region by almost 50 percent resulting in the need to increase water supplies and avoid future shortages. Land-surface subsidence, driven by excessive groundwater withdrawals, has led to regulations forcing municipalities to convert to surface water sources. One project designed to increase surface water supply in the Houston region is the Luce Bayou Interbasin Transfer (LBIT), which will convey water from the Trinity River into Lake Houston, the main drinking water reservoir in the region located in the San Jacinto River Basin. The US Geological Survey, in cooperation with the City of Houston (COH), has collected water-quality and streamflow data in Lake Houston and the San Jacinto River Basin since 2005. In 2012, this monitoring effort was expanded to include the Trinity River Basin to obtain baseline data before the LBIT is initiated. Developing water-quality trends from continuous monitoring and discrete sampling data collected in Lake Houston and the Trinity River are presented and...
Abstracts

37th International Symposium of the North American Lake Management Society

**Abstracts**

**Implementing Monitoring Techniques of *Hydrilla verticillata* in the New Jersey Delaware and Raritan Canal**

*Emily Mayer*¹ and *Amanda Mahaney*²

¹University of Florida & Solitude Lake Management, Hackettstown, New Jersey; ²Solitude Lake Management, Shrewsbury, Massachusetts

The Delaware and Raritan Canal serves as a potable water resource, in addition to being utilized for irrigation and cooling water. Managed by the New Jersey Water Supply Authority, the 60-mile canal also serves as a registered historical site, New Jersey state park, and is a navigable waterway, heavily used for recreational purposes. As a raw water transmission system, thick growth of submerged aquatic vegetation (SAV) is detrimental to the water quality and velocity of delivering water on a daily basis. In 2016, Hydrilla (*Hydrilla verticillata*) was discovered in the canal. In response to the discovery, this prompted the New Jersey Water Supply Authority to retain an aquatic consultant to conduct SAV monitoring, using modified Point Intercept Methods (PIM), in order to support the Hydrilla control program. The three year Hydrilla control program includes a low dose herbicide injection system up to 120 days. Extensive SAV monitoring and mapping of the entire canal will be conducted, in addition to the 2016 monitored areas. Herbicide residue analysis and Hydrilla tuber monitoring are being utilized for the management of hydrilla and nuisance vegetation.

**Use of Aquatic Filter Barriers to Control Water Quality Impacts from Concentrated Nonpoint Sources**

Andrew J. McCusker¹, Melissa Hamlin¹, Jaret Johnson², and Chris Guelke³

¹Mackworth-Enviro, Scarborough, Maine; ²Mackworth-Enviro, Chapel Hill, North Carolina; ³Mackworth-Enviro, Clinton, Connecticut

Aquatic filter barriers (AFBs) have been used to protect the water quality of lakes and reservoirs since the late 1990s. These full-depth, bottom-sealed underwater curtains have protected the drinking water supply of New York City from airport runoff, the drinking water supply of Boston from stormwater flows, Northeast and northern Midwest lakes from elevated nutrient loading, and a recreational lake in New Hampshire from toxic algae blooms. Each AFB application for lake protection has been a relatively novel and new approach to water quality protection, and the technology is not yet widely known, especially among inland, managed western waters and fisheries.

Each application of the AFB for lake protection has been individually designed for the specific location and goals. Characteristics of the physical water body, its natural or managed elevations and flows, short- and long-term goals and many other factors all become part of an AFB’s design basis. This site-specific adaptability has allowed for the AFB’s use for a wide variety of environmental circumstances and for a breadth of knowledge to be gained about its capabilities.

The presentation will discuss AFB design considerations, successes and lessons learned, and applicability within managed reservoir environments to protect lake water quality for drinking water and other uses.

**Utilization of Aquatic Barriers to Protect Fish Populations from Reservoir Management Activities**

Andrew J. McCusker¹, Melissa Hamlin¹, Jaret Johnson², and Chris Guelke³

¹Mackworth-Enviro, Scarborough, Maine; ²Mackworth-Enviro, Chapel Hill, North Carolina; ³Mackworth-Enviro, Clinton, Connecticut

Aquatic barriers have been used to protect fish populations from various threats since the late 1990s. These full-depth underwater curtains have protected Alaskan salmon populations from dredging operations, estuarine fish from industrial intakes in New York and Massachusetts, and fishing reservoir populations from a dam outlet in Kansas. Each aquatic barrier application for the protection of fish has been a relatively novel and new approach to conservation, and the technology is not yet widely known, especially among inland, managed western waters and fisheries.

Each new application of the aquatic barrier for the protection of fish populations has been individually designed for the specific location and goals. Characteristics of the physical water body, its natural or managed elevations and flows, the type and size of organism to protect, short- and long-term goals and many other factors all become part of an aquatic barrier’s design basis. This site-specific adaptability has allowed for the aquatic barrier’s use for a wide variety of environmental circumstances and for a breadth of knowledge to be gained about its capabilities.

The presentation will discuss aquatic barrier design considerations, successes and lessons learned, and applicability within managed reservoir environments to protect fish populations for conservation and fishing uses.

**Application of Iron Filings to Reduce Internal Phosphorus Loading in Lakes**

Poornima Natarajan¹, John S. Gulliver¹, and William A. Arnold²

¹University of Minnesota, Minneapolis, Minnesota; ²Department of Civil, Environmental and Geo-Engineering, University of Minnesota, Minneapolis, Minnesota

High internal phosphorus loading in lakes can impede restoration efforts and must be addressed to reduce algal blooms. In this study, addition of zero-valent iron filings to control phosphorus (P) release from lake sediments was investigated. Sediment cores collected from two Minnesota lakes were set up for laboratory mesocosm studies, and the effects of increasing iron supply in the sediment determined under controlled oxic and anoxic conditions. At doses greater than 0.05 g iron/cm², the sediment-P flux, pore water P concentrations and water column P concentrations were found to decrease by 75 to 96%, even
under anoxic conditions. The effect of iron filings addition on the redox-sensitive P in the sediment was also determined. This study demonstrates that iron filings application could be a potential treatment technology to sequester phosphorus in lake sediments.

A Survey of Cottagers’ Perceptions in Ontario, Canada, Regarding Algae and Impacts to Recreational Enjoyment

★ Carmen Pereira1, Andrew M. Paterson2, John P. Smol1, Claire Holeton3, Michelle Palmer3, Terry Rees1, Deanne Panitz4, Christy Doyle5, Rebecca Willison4, and Dan Walters6
1Paleoecological Environmental Assessment and Research Laboratory, Department of Biology, Queen's University, Kingston, Ontario, Canada; 2Ontario Ministry of the Environment and Climate Change, Dorset Environmental Science Centre, Dorset, Ontario, Canada; 3Ontario Ministry of the Environment and Climate Change, Toronto, Ontario, Canada; 4Federation of Cottagers' and Associations, Peterborough, Ontario, Canada; 5Muskoka Watershed Council, Bracebridge, Ontario, Canada; 6Nipissing University, North Bay, Ontario, Canada

Algal blooms have numerous impacts on lake water quality, and can negatively impact recreational activities and enjoyment for lake users. In 1986, the Ontario Ministry of the Environment and Climate Change (MOECC) conducted a study to determine if residents’ and cottagers’ perceptions may allow for the accurate identification of lakes with filamentous and taste and odour-producing algae. Additionally, the study endeavoured to gather data on these algae, and explore the significance they may have on residents’ recreational activities. In 2017, we repeated this survey, and updated it to include questions on cyanobacteria (blue-green algae), and emerging stressors including climate change. The survey was administered in June 2017 and responses were collected until November. Our goals are threefold: 1) to determine if property owners’ perceptions can accurately identify lakes with known filamentous, taste-and-odour producing, or cyanobacterial blooms; 2) if so, to assess if the spatial extent of blooms have changed in Ontario over the last 30 years; and 3) to assess whether lake user perceptions regarding algae have changed over time. In addition to benchmarking and documenting current attitudes of residents to water quality issues, our survey will help identify the current health of the lakes and chart the progression of these algae. The perspectives gathered in this survey will help government and management agencies evaluate key issues relevant to improving or maintaining the quality of recreational lakes.

Differences and Similarities in Perceived Threats to North American Lakes by Scientists, Managers, and Stakeholders

★ Melanie Perello1, Robyn Smith2, Karen Baumert2, Alicia Caruso2, Chelsea Weirich1, Sarah Bartlett1, and Lisa Borre1
1Indiana University-Purdue University Indianapolis, Indianapolis, Indiana; 2Bard College, Annandale-on-Hudson, New York; 3University of Wisconsin-Milwaukee, Milwaukee, Wisconsin; 4Cary Institute of Ecosystem Studies, Millbrook, New York

The Reservoirs and Lake Management Working Group of the Global Lake Ecological Observatory Network (GLEON) developed an online State of the Lakes survey to assess perceptions of ecological threats and management of lakes globally. The survey was distributed to GLEON members and affiliates in February 2016 yielding assessments of 146 lakes on 6 continents. Climate change (CC) was the most commonly perceived threat followed by eutrophication, harmful algal blooms, and invasive species. The threat of CC was more often perceived by respondents that identified themselves as scientists (87% affirmative) while only 70% of managers and 58% of stakeholders perceived CC as a threat to their specific lake. Managers and stakeholders more often perceived eutrophication and invasive species to be threats to lakes than CC, but were they a small number of total respondents. To further explore differences in threat perception between scientists, managers, and stakeholders, we distributed the survey through NALMS in October 2016 and received 104 responses for North American lakes. NALMS respondents perceived eutrophication and invasive species to be threats more often than CC. Both GLEON and NALMS respondents concerned with CC were most concerned with increasing surface water temperatures followed by changes in the intensity and frequency of precipitation. Ecologically, GLEON respondents were most concerned with changes in aquatic community structure while NALMS respondents cited increasing nutrient and sediment pollution with precipitation changes. Such differences in CC threat perception have been found in other contexts and may have important implications for lake management and CC resiliency planning.

Reducing Surface Accumulation of Aphanizomenon flos-aquae by Increasing Cellular Turgor Pressure and Disrupting Buoyancy Control Using Wetland Water and Ion Additions

★ Arick Rouhe and John Rueter
Portland State University, Portland, Oregon

Harmful algal blooms of cyanobacteria (CyanoHABs) have become an increasing problem worldwide, primarily due to species from the following genera: Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya, Microcystis, Nodularia, Oscillatoria, Plankthothrix, Synechococcus, and Trichodesmium. Species from these genera use a variety of different characteristics to exploit aquatic systems, but they all share one common characteristic: buoyancy control using gas vesicles. In this study, we mixed a buoyant Cyanobacteriota, Aphanizomenon flos-aquae, in small-scale microcosms and lakeside mesocosms with varying percentages of wetland water and addition of sodium, potassium, and calcium to investigate the effects of wetland water on surface accumulation and buoyancy control. The results indicate a target mixture of wetland water that reduces surface accumulation, increases cellular turgor pressure (a measure of the ability of gas vesicle forming cells to control buoyancy), and decreases the position of suspended cells in the water column. By adding ions at same concentration as target wetland mixture, similar results were found. This research could represent the basis of a possible new strategy for mitigating surface blooms of CyanoHABs in lakes using wetland water and/or ion additions.
A Five-Year Recreational Water Microbiome

*Sydney P. Rudko1, Yuanyuan Qui2, Xiaoxli Pang3, and Patrick C. Hanington2*

1School of Public Health University of Alberta, Edmonton, Alberta, Canada; 2Provincial Laboratory, Alberta Health Services, Edmonton, Alberta, Canada

Pigeon Lake is a shallow, eutrophic lake in Alberta, Canada. The watershed surrounding the lake has a significant human footprint, boasting a number of bustling residential villages. The lake annually experiences cyanobacterial blooms, that typically exceed recreational water quality guidelines for cyanobacteria cell count sometime in June. In addition to being potentially harmful to human and animal health, cyanobacteria blooms also alter the biotic and abiotic freshwater environment. They can harm plant and fish species, and the increase organic matter results in oxygenation, phosphorous loading of sediment, and nitrification.

Bacteria are critically important to nutrient cycling and the health of aquatic ecosystems; and bacterial communities respond to biotic and abiotic changes in the freshwater environment, thus there is precedence for understanding how cyanobacteria blooms may alter the microbial ecosystem of freshwater lakes.

Utilizing a bank of samples collected from Ma-Me-O beach on Pigeon Lake during the summers between 2012–2016, we have evaluated changes in the microbial ecosystem across this period using 16S rRNA targeted microbiome sequencing. We have assessed changes in microbial community structure, and have correlated these changes with cyanobacteria abundance, cyanotoxin amount, and other abiotic factors, such as nitrogen (nitrate and nitrite) and phosphorous concentrations, dissolved oxygen concentrations, conductivity, chlorophyll a, and pH. Our goal is to understand how various abiotic and biotic factors interact temporally during periods of cyanobacterial blooms.

Urban Phosphorus Runoff and Loading to Half Moon Lake, Wisconsin

*Mai Lia Vang and William F. James*

University of Wisconsin–Stout, Menomonie, Wisconsin

Half Moon Lake, a shallow oxbow, is located in the heart of Eau Claire, Wisconsin. Since the lake loses water volume from seepage, shallow groundwater from the Chippewa River is pumped in to maintain pool elevation. Other hydrological inputs to the lake include urban runoff from storm sewers draining ~ 15 subwatersheds that surround the lake. While internal P loading dominates the P budget, there is concern that P inputs from urban runoff could stimulate algal growth after alum treatment to control internal P loading. Efforts and BMPs have been implemented throughout the city to increase infiltration and reduce urban P loading to the lake. The objectives of this research were to examine flow, P concentrations and P loading from one of the storm sewer inputs in 2017 for comparison with a long-term data base to evaluate the potential impacts of BMPs on urban loading to the lake. Storm samplers (ISCO 6700) and area-velocity probes (ISCO 750) were deployed to capture flow (5-min intervals) and samples (15-min intervals) for total P and soluble P analysis between May and September 2017. Overall, numerous large and small precipitation events resulted in runoff to the lake and flow-weighted concentrations averaged ~ 0.10 mg/L total P and 0.018 mg/L soluble reactive P between 2012 and 2017. These mean summer concentrations were lower than those estimated in 1999 (0.15 mg TP/L and 0.05 mg SRP/L), suggesting that implementation of BMPs post-1999 have led to reduced P loading from this subwatershed.

Engaging Indigenous People in Alberta’s Regional Lake Monitoring Program – A Case Study

Ziyun (Zoey) Wang1, Gilman Cardinal2, Tracy Howlett1, Krista Tremblett1, and Ron Zurawell1

1Government of Alberta, Edmonton, Alberta, Canada; 2Bigstone Cree Nation, Wabasca, Alberta, Canada

In Alberta and across Canada, community involvement in water monitoring is gaining momentum. In 2016, Alberta appointed its first Chief Scientist and since then public participation in monitoring has become a departmental priority.

Alberta Environment and Parks (AEP), in collaboration with the Bigstone Cree Nation (BCN), engaged in a project to monitor water quality on North and South Wabasca Lakes. Water quality data was collected over five seasonal sampling trips by AEP field staff and the BCN Land Officer. AEP scientists worked with BCN to interpret data and generate a results report that could be presented to the community.

This project has resulted in the collection of technically and socially credible data, and is helping to build a respectful relationship between AEP scientists and BCN. The project has fulfilled a need for scientific data collection, and is helping to address community concerns about local lake water quality. BCN demonstrated interest and commitment in the lake monitoring program throughout the season and for these reasons we consider this project a success.

The process and approach applied in this project is serving as a model for the Province to work with interested Indigenous groups. Keys to our success have included setting common goals; ensuring open, and constant communication; acknowledgement and attribution of local knowledge; and respect for cultural and science protocols. Our hope is to create more opportunities for Indigenous and public participation in environmental monitoring, so that the data gathered can become increasingly relevant, and technically and socially credible.

Working with Landowners to Improve Water Quality in the White River and Richland Creek Watersheds of Northwest Arkansas

Melissa Welch, John Pennington, and Becky Roark

Beaver Watershed Alliance, Springdale, Arkansas

The White River and Richland Creek Watersheds are a diverse group of subwatersheds of Beaver Lake, the drinking water source for 500,000 Arkansans. The Headwaters of the White River is highly rural with forest and pasture covering most of the landscape, but land use change is occurring due to rapid population growth in the Northwest Arkansas metropolitan area. The Beaver Watershed Alliance (BWA), formed in 2011, has been conducting successful outreach and education programs in other subwatersheds of Beaver Lake to establish working relations with landowners and communities to identify potential water quality
improvement projects to help prevent water quality degradation as the area continues to grow. BWA was awarded a FY2017 319(h) grant through the Arkansas Natural Resources Commission and US Environmental Protection Agency to work with streamside landowners in the White River-Richland Creek Watersheds to voluntarily adopt riparian best management practices (BMPs). In the first few months of the project, BWA conducted 29 landowner visits with interested landowners and has implemented 114 BMPs including working with an open-space neighborhood to develop an open space plan. Over the next two years BWA will continue to work with landowners, encourage best management practices and identify water quality improvement opportunities in the watershed.

**Internal Phosphorus Loading in Bone Lake, Wisconsin**

* Amanda Wilson and William F. James  
University of Wisconsin–Stout, Menomonie, Wisconsin

Bone Lake (Polk County) is a 721-ha eutrophic, polymictic drainage lake (13 m max depth 6.7 m mean depth) that exhibits late summer algae blooms. Soluble P increases in the anoxic hypolimnion due to sediment internal P loading may be entrained into the epilimnion during late summer for algal uptake and growth. The objectives of this research were to quantify diffusive P flux from anaerobic sediment and examine vertical variations in sediment mobile P fractions in order to evaluate the role of internal P loading in the P budget of the lake and estimate alum dosage required to control sediment P release. Intact sediment cores collected from the north, central, and south basins of the lake were incubated under laboratory-controlled anaerobic conditions. Increases in soluble P in the overlying water column of incubation systems over time were used to estimate rates of diffusive P flux (mg/m² d). Vertical variations in sediment loosely-bound P, iron-bound P, and labile organic P were examined to further assess P recycling and burial characteristics. Summer internal P loading (mg/m² y) estimated from these approaches were compared with mass balance estimates to evaluate sediment-derived contributions to the P budget of the lake.
Wednesday, November 8

Session D1: Aeration / Mixing
8:30 am – 10:00 am | Standley II

Hypolimnetic Aeration System is “Breathing New Life” into Aurora Reservoir

Pamela Benskin, Mark H. Mobley, David Austin, Steve Fiori, Kevin Linder, Paul Swaim, and Chris Conte
1City of Aurora, Aurora, Colorado; 2Mobley Engineering, Inc., Norris, Tennessee; 3CH2M, Mendota Heights, Minnesota; 4CH2M, Englewood, Colorado

The presence of seasonal anoxia in bottom waters at Aurora Reservoir (Aurora, Colorado), and the resulting decline in water quality due to internal nutrient loading, prompted Aurora Water to initiate a capital project to evaluate options for additional aeration at the reservoir. Seasonal treatment issues associated with the use of Aurora Reservoir as a source water included elevated manganese, increasing total organic carbon levels and algal related issues including Geosmin taste and odor events during the summer of 2014 and 2015. Maintaining high quality water in Aurora Reservoir is mission critical to Aurora Water and is the key to ensuring Aurora Reservoir is a consistent primary source water for the 50 MGD Direct Filtration Wemlinger WPF as well as a reliable back up source for the 80 MGD Direct Filtration Wemlinger WPF.

Aurora Water staff worked closely with CH2M to review existing reservoir conditions, set goals for the project, collect necessary data and finally evaluate alternatives that would meet the desired goals in a cost-effective manner. The system chosen for installation is a Mobley Engineering, liquid oxygen based system that utilizes a single 2300-foot linear diffuser line to deliver a maximum oxygen flow of 42 SCFM directly to the hypolimnion of the reservoir.

This presentation will include information on the history of the reservoir, the evaluation and design process as well as include water quality results from the first year of operation.

Managing Taste, Odor, and Manganese in a Small Alpine Lake, One Year Later

Paul Gantzer, Stephen McCord, and Kimi Johnson
1Gantzer Water Resources Engineering, LLC, Kirkland, Washington; 2McCord Environmental Inc, Davis, California; 3Lake Alpine Water Company, Bear Valley, California

Bear Lake is a small alpine lake located in the Sierra Mountains of California, with a permanent residence of 150 people. The lake serves as a water supply maintained by the Lake Alpine Water Company (LAWC). Despite having a pristine water source from snow melt, Bear Lake has experienced taste and odor issues as well as elevated Mn levels in their drinking water supply. A small hypolimnetic oxygenation system (HOS) was designed and installed early June 2016 to address these issues associated with hypolimnetic anoxia. The oxygenation system is supplied by a small on-site oxygen generator with a line diffuser located along the deepest part of the reservoir and has been operated continuously since installation sans a week or two for maintenance. Prior to HOS installation, the LAWC were approaching exceeding running annual average limits reported for color and Mn. Additionally, plant staff was consumed with constant monitoring of the membrane treatment process because of raw water quality issues. Since installation, the LAWC has experienced a remarkable improvement in water quality. This presentation provides a follow up to HOS operation and the corresponding raw water quality improvement that has resulted in essentially eliminating taste, odor, algae, and Mn issues for this small alpine water supply.

Eliminating Scouring Problems on a Side Stream Saturation Oxygenation System

Mark Mobley, Terry Palmer, Paul Gantzer, and David Clidence
1Mobley Engineering, Norris, Tennessee; 2City of Barberton, Norton, Ohio; 3Gantzer Water Resources Engineering, Kirkland, Washington; 4ECO Oxygen Technologies, LLC, Indianapolis, Indiana

Wolf Creek Reservoir is a 196-acre reservoir in Norton, Ohio and is the only lake in Summit County used for water supply. This shallow, approximately 23 ft maximum depth, eutrophic reservoir provides drinking water to the City of Barberton. The treatment plant was previously upgraded from sand filtration to membranes. As a result of this upgrade, increased manganese (Mn) levels in the raw water were observed to cause problems with the membrane filters. With increased manganese (Mn) levels at the treatment plant, the City of Barberton researched options to minimize soluble Mn in the reservoir. Oxygenation of bottom waters in the reservoir was identified as the most viable management strategy. A Side Stream Saturation Oxygenation System (SSS) was installed in Wolf Creek Reservoir in 2015. The installed SSS system consists of two raw water intakes, two water pumps, two ECO2 Speece cones, and four oxygenated water distribution lines that extend approximately 800 feet upstream and downstream of the facility. Initial operation of the SSS revealed major scouring of bottom sediments resulting in resuspension as well as exacerbated Mn levels, completely opposite of the designed outcome. In May 2017, the distribution header was modified to eliminate scouring and sediment resuspension. Initial operation showed a dramatic improvement in dissolved oxygen levels within the first seven days of operation, increasing from <1 mg/l to over 10 mg/l in the bulk hypolimnion. This presentation provides the opportunity to share the initial failed experience, what was learned, and how the situation was corrected.
Abstracts

Session D2: HABs / Algal Dynamics
8:30 am – 10:00 am | Standley I

Comparison of Classification Strategies for Algal Data Collected with Imaging Flow Cytometry for Both Live and Preserved Samples with an Emphasis on HAB Taxa

Ann St. Amand, Denise Clark, Kam Truhn, and Joseph St. Amand

Multiple strategies were compared to classify algal images collected from several lakes and seasons with an Imaging Flow Cytobot (IFCB) configured for freshwater use. IFCB image data (300,000+ images) were analyzed using multiple platforms and models. Platforms included MatLab, R and WEKA. Models included treebagger (random forest classification), multilayer perceptron (MLP), Bayes classifier, and sequential minimal optimization (SMO), among others. Identification accuracy was assessed for 78-170 species groups/classes separated on the basis of taxonomy and functional group. Preserved samples present several challenges (detrimental material, clumping) that are avoided in live material. There was reliable separation among many morphologically distinct HAB taxa (e.g., Microcystis, Dolichospermum, and Aphanizomenon), but closely related HAB taxa were not as easily distinguished (Aphanizomenon flos-aquae, Chrysochromulina ovalisporum) without decision capability incorporated into the classification model, such as presence/absence of akinetes, etc. Classifier accuracy for HAB taxas was generally not sensitive to preservation. General water quality indicators (e.g., Ceratium, Dinobryon, Cryptomonas and Euglena) were classified more accurately in live versus preserved material, e.g. Ceratium, Dinobryon, Cryptomonas and Euglena) were classified more accurately in live versus preserved material. There was reliable separation among many morphologically distinct HAB taxa (e.g., Microcystis, Dolichospermum, and Aphanizomenon), but closely related HAB taxa were not as easily distinguished (Aphanizomenon flos-aquae, Chrysochromulina ovalisporum) without decision capability incorporated into the classification model, such as presence/absence of akinetes, etc. Classifier accuracy for HAB taxa was generally not sensitive to preservation. General water quality indicators (e.g., Ceratium, Dinobryon, Cryptomonas and Euglena) were classified more accurately in live versus preserved material, primarily due to aggregation in the preserved samples. Numeric feature variables were assessed for importance in the different classiers as well.

HAB Potential in Colorado Lakes

James Saunders¹, Amanda Jensen², Sarah Wheeler³, and James McCutchan¹
¹University of Colorado, Boulder, Colorado; ²Colorado Department of Public Health and Environment, Denver, Colorado

Like most states, Colorado is working to address concerns about HABs and cyanotoxin levels in lakes. Monitoring all lakes, even infrequently, would be challenging in Colorado, where thousands of lakes are spread over a broad geographic area, parts of which are not readily accessible. We consider how monitoring effort for HABs can be optimized on the basis of statewide patterns in the composition of phytoplankton communities. We evaluated an extensive record of phytoplankton data collected by the Water Quality Control Division over many years as part of routine water quality monitoring. The phytoplankton data set, which is unusual in having maintained consistent methods and taxonomic continuity, includes many bloom-forming species. The lakes present a broad spectrum of environmental conditions, especially on gradients of elevation and nutrients. The data are evaluated from a regulatory perspective, acknowledging that a limited budget requires balancing monitoring effort against water quality risks and potential threats to beneficial uses that are not the same in all parts of the state.

A Review of Cyanobacteria Harmful Algae Blooms Education, Outreach and Monitoring Programs in the USA

Ellen Preece¹ and F. Joan Hardy²
¹Robertson Bryan Inc. Elk Grove, California; ²Washington Department of Health (retired), Seattle, Washington

While numerous strategies have been used to educate and notify the public about potential hazards from exposure to cyanobacteria harmful algae blooms (CHABs), at present there are no national guidelines regarding outreach approaches. Recent unprecedented large-scale HAB outbreaks throughout the United States seriously impacted drinking water (Ohio 2014) and resulted in the declaration of a state of emergency in four counties in Florida (2016). Such outbreaks indicate the need for effective and standardized outreach methods at a national level. To identify current efforts at the state and regional levels, we identified CHAB education efforts and compiled strategies used to notify the public of CHAB issues in recreational and drinking waters. We also identified inland CHAB monitoring efforts to determine which states or regions have active programs. Using this information we identified methods that were most successful and developed a general framework for CHAB outreach including specific notification strategies. We also indicate potential future directions for outreach at the local, state and regional levels so that available information can be used to communicate efforts for activities such as toxin-contaminated water for irrigation, consumption of toxin-contaminated food, and outreach and education to protect pets and wildlife.

HAB Monitoring with FlowCam Cyano in Recreational Lakes to Facilitate Management Decisions by Maine DEP

Frances Buerkens¹, Michaela Oberkfell², Brenda Fekete³, Logan Parker³, and Harry Nelson³
¹Fluid Imaging Technologies, Scarborough, Maine; ²Colby College, Waterville, Maine; ³Maine Lakes Resource Center, Belgrade Lakes, Maine

Harmful algae blooms are increasing in frequency and intensity each season in the Belgrade Lakes, a popular chain of recreational lakes in central Maine. The Maine Department of Environmental Protection requires reliable and timely data from the Maine Lakes Resource Center (Colby College) to make informed decisions concerning lake conservation, remediation and recreational safety. The FlowCam Cyano detects and monitors cyanobacteria and other algae, identifying taxa to the genus level and tracking concentration. The FlowCam combines digital imaging, flow cytometry and microscopy to measure the size and shape of plankton in a water sample. Methods for characterizing nuisance algae, HABs and general algae productivity will be shared, along with data and insights into interpreting the data for reports provided to the Maine DEP.
Where is the Body? Water Testing for Dreissenid Mussels and the Value of eDNA

Denise M. Hosler  
Bureau of Reclamation, Denver, Colorado

The Bureau of Reclamation has been monitoring the waters in the western US since 2006 for the presence of dreissenid mussels. Currently, Reclamation has evaluated over 15,000 raw water samples representing over 400 western water bodies. This body of data includes water bodies where mussels had invaded and western US waters for the purposes of tracking the dreissenid mussel invasion. Utilizing the US Army Corps of Engineers program for zebra mussel detection, Reclamation developed a protocol for testing plankton tow net water samples for determination of dreissenid mussel presence. The test protocol included cross polarized microscopy and DNA testing, initially requiring the detection of a larval body. Due to the occasional microscopic detections, it was decided to perform all tests on water bodies where a veliger or larval mussel had been detected. The mixed results of testing clashed with definitions, and triggered concerns for costly false positives that round robin testing did not substantiate. Initially, a clear understanding of the conflicting test results was not available for the stakeholders and partners participating in the mussel detection program. Over time, the large body of data revealed some unique information on the invasion of mussels in the western US; from the way samples were collected and preserved, to the slower than anticipated spread. The Reclamation Detection Laboratory for Exotic Species (RDLES) conducted research looking more closely at the science involved in the detection of invasive mussels in raw water plankton tow net samples. As research revealed information about the lack of microscopic findings, the value of E-DNA findings for invasive species and mission essential projects became apparent. This presentation presents an overview of the development of the Reclamation invasive mussel program. Focusing on RDLES research developments that have far-reaching applications for future management activities and decisions, the many of the lessons learned from this large body of data and produced a related discovery of benefits of E-DNA testing for numerous species of concern.

Improvement of Methods for Detection of Dreissenid Mussels by Microscopy and Polymerase Chain Reaction

Jacquie Keele1, Jamie Carmon2, and Denise Hosler1  
1US Bureau of Reclamation, Denver, Colorado; 2GEI Consultants Inc., Denver, Colorado

Reclamation Detection Laboratory for Exotic Species (RDLES) has been doing research to understand the factors that affect the analysis of environmental samples for the detection of Dreissena polymorpha (zebra mussel) and Dreissena rostriformis (quagga mussel). RDLES uses both cross polarized light microscopy and DNA analysis to assess water samples from across the Western United States for the presence of these invasive mussels. This data is used to track the spread and distribution of the mussels in the West. Research at RDLES has focused on the best methods for preserving and processing the water samples so that if there are Dreissenid veligers present it is possible to detect these organisms. The use of polymerase chain reaction (PCR) to detect the mussel DNA has been technically more difficult than the microscopy testing because of the many different factors that can affect the PCR testing. To understand these factors, a series of experiments were performed to gain a better understanding of why the PCR testing is not always consistent. These studies looked at preservation methods (buffer and alcohol concentrations), the DNA extraction kits, and presence of inhibitors in the water sample. One major finding was that without proper buffering the Maltese cross that is diagnostic for veligers under cross polarized light microscopy disappears, but the DNA is still present and can be detected. This is a major issue because to meet state regulations that consider a water body positive for these invasive mussels it is necessary to have both the body and DNA. By performing experiments to understand the behavior of Dreissenid DNA in environmental samples, RLDES has been able to improve its detection methods and sensitivity. The lessons learned from the analysis of raw water samples for the detection of Dreissenid environmental DNA can be extended to other invasive and endangered organisms.

Rapidly Responding: Montana's Invasive Mussel Detections

Stephanie Hester  
Montana Department of Natural Resources and Conservation, Helena, Montana

Montana has been monitoring for aquatic invasive species for more than a decade and coordinating with the region on perimeter defense. The state's aquatic invasive program includes an extensive education and outreach program focused on prevention using the Clean, Dry, Drain message. In 2016, Montana Fish, Wildlife, & Parks operated 17 stations and inspected more than 37,000 watercraft.

In November 2016, the state had its first positive detection of invasive mussels at Tiber Reservoir in the Missouri River watershed on the eastside of the Continental Divide. The State of Montana has made its response a priority at the highest levels. Governor Steve Bullock issued an executive order November 30, 2016, declaring a statewide natural resource emergency for Montana water bodies due to the detection of invasive aquatic mussel larvae.

Montana's Mussel Response Team was formed to rapidly assess the extent and severity of the mussel incident impacting Montana's waterways. The team developed a coordinated response and long-term strategy in order to mitigate economic and ecological damage. To accomplish this, the team consulted with experts and collected data and information in order to make informed decisions, contain and control affected areas, and develop procedures to prevent future contamination risks.

The team is now implementing the long-term strategy developed during the initial response. The latest information on Montana's mussel response will be provided, as well as the state's long-term strategy for managing invasive mussels in Montana.
**Eyes on the Lake: How 24 Million Annual Visitors Can Protect Tahoe While They Play**

**Jesse Patterson**  
League to Save Lake Tahoe, South Lake Tahoe, California

Lake Tahoe is one of America’s most pristine water bodies, as well as one of the most visited. Over 24 million people visit Lake Tahoe annually to enjoy the cobalt blue waters and white sand beaches. This extensive use has brought the unintended introduction of aquatic invasive species (AIS), which are rapidly colonizing and spreading throughout the Lake, changing its ecology, water quality and famed clarity. In 2008 the Lake Tahoe AIS Program was launched to prevent new introductions of AIS into the Lake and to manage existing populations. Much of the program’s public funding is dedicated to prevention through comprehensive boat inspections, with the remaining supporting control of priority species (primarily two species of aquatic plants and Asian clams). There remains little funding for monitoring of spread or new introductions. Enter Tahoe’s 24 million annual visitors, many of whom spend a portion of their visit at the Lake. Eyes on the Lake (EOL) is a citizen science monitoring program that trains water recreationists to identify, survey and report on the presence/absence of aquatic invasive plants and Asian clams while out playing at Lake Tahoe. In just four years EOL has certified 349 volunteers who have completed 712 surveys from 132 unique sites and identified five previously undocumented infestations of aquatic invasive plants in the Lake. EOL volunteers removed two of those infestations. The program’s success has resulted in its formal incorporation into the Lake Tahoe AIS Management Plan and its inclusion in NPDES permit requirements for Tahoe’s marinas.

**Session D4: Public Outreach**  
8:30 am – 10:00 am | Lake House

**Public Outreach and Education – Don’t Go It Alone**

**Amy Conklin**1 and **Susan Thornton**2  
1Barr Lake and Milton Reservoir Watershed Association, Littleton, Colorado;  
2Susan Thornton Associates, Littleton, Colorado

The Barr Lake and Milton Reservoir Watershed Association (BMW) using an Urban Waters grant from the US Environmental Protection Agency convened a diverse group of stakeholders to develop messaging around clean water. We first completed research on past and current water awareness campaigns, then hired outside firms to conduct focus groups and develop messages. We partnered with students in marketing classes at Metro State University and the Greenway Foundation to evaluate results of surveys of Denver residents’ water awareness. We leveraged work being done by others, specifically a statewide awareness survey conducted by the Colorado Water Conservation Board to help inform the messages. We also conducted focus groups in both English and Spanish to test the messages. We prepared the messaging files in both English and Spanish, loaded them on flash drives and distributed them widely. Ideally, the messages would be used in a statewide water awareness campaign. This proved much harder to accomplish. Our research showed that in Colorado’s history there has only ever been one statewide campaign, from 1999 to 2001, run by the League of Women Voters. We included some of their messages in the packet of messaged we developed. The messages are currently in use by a number of Denver Metro area organizations.

**Minnesota Lake Associations Survey: Identifying Demographics, Activities, and Concerns**

**★ Benjamin Bjertness, Matthew Zabel, Michelle Marko, and Mona Ibrahim**  
Concordia College, Moorhead, Minnesota

Lake associations are groups of volunteer citizens with a mutual goal to protect and maintain lake ecosystems. Most members are waterfront property owners or regular lake-goers, resulting in a strong familiarity with issues surrounding lake management. Due to the complexity of lake ecosystems, human intervention is necessary for managing unpredictable changes that may occur and the respective ecological responses. Little is known about the demographic composition, activities, and concerns of Minnesota lake associations. Some lake associations have yet to even be identified. Increasing our knowledge of lake associations, would make it possible to involve them more in decision making and to help increase their capacities for lake conservation work.

The goal of this study was to quantify the demographic makeup of Minnesota’s lake associations, assess the projects they undertake, determine their financial contributions, and understand the crucial work they do in areas such as water quality testing, aquatic invasive species prevention, and wildlife conservation. To obtain this information, a survey was developed and piloted on 60 lake associations. Results were used to refine the pilot survey and to improve its reliability and validity. The revised survey was then administered to a population of 500+ Minnesota lake associations. Case studies were conducted on a few highly engaged associations. Results from the survey and cases studies are important to help understand who the Minnesota lake associations are, their impact on water quality, and their concerns for the protection of these important resources.

**Scaling Up Local Lake Stewardship: Benefits and Challenges of Countywide Lake Assessments, Planning, and Implementation**

**Nancy Turyk**  
University of Wisconsin-Stevens Point, Wisconsin

Countywide lake assessments and planning can dramatically enhance lake protection and improvement efforts by developing and strengthening community knowledge and partnerships. The assessments provide a county-scale view of lake health to guide science-based decisions for lake management, prioritization and work planning for county and state staff, and development of support for lakes by elected officials. The assessment and planning processes take place years. During this time, community discussions about lake health evolve, strategies are developed, and partnerships begin to solidify.

Particularly in states with thousands of lakes, there is a need for many parties to be involved for successful lake management and protection. Gaps exist between what can be accomplished by state staff, what volunteers can or are willing to accomplish, and what is needed. In many cases, counties can fill some of these
gaps. Since 2002, staff at the Center for Watershed Science and Education have assisted counties with scientific lake assessments, outreach, and planning processes for 88 lakes. The chemical, physical and biological conditions of the lakes ranged in trophic state, presence and vulnerability to AIS, habitat abundance, biota, development, and shoreland disturbance. Social conditions have also varied in terms of capacity, sophistication of organizations, technical knowledge of agency staff, and political support. Many of the benefits of countywide processes exceed those derived by discrete lake planning efforts. Examples of county-scale data will be presented with discussion about their use in lake management and implementation.

Session D5: Watershed Management
8:30 am – 10:00 am | Cotton Creek

Performance Characteristics of a Cold-Climate Constructed Stormwater Treatment Wetland

Alan Heyvaert¹ and Robert Qualls²
¹Desert Research Institute, Reno, Nevada; ²University of Nevada, Reno, Nevada

Reducing nutrient and sediment loads is one of the primary strategies for improving lake water quality, and constructed stormwater wetlands are one of many structural best management practices (BMPs) available for mitigating water quality impacts. The overall effectiveness of such wetlands is not well documented, especially in colder climates with snow-covered conditions during runoff. A wetland retention basin designed to remove sediment, nutrients and other pollutants from stormwater runoff in the Lake Tahoe Basin reached its useful end-of-life after 16 years of continuous service. Along with water quality monitoring during that period, several sediment cores were extracted from the basin prior to its excavation to assess the accretion rates of major nutrients, sediment and metals. Results showed the wetland basin accreted 3.2 cm of depth per year, and 7.0 kg m⁻² yr⁻¹ of inorganic material. Average annual accretion of C, N, P and sediment was comparable to most non-wastewater treatment wetlands and was relatively efficient for a stormwater treatment wetland. Comparison of particle size distributions between sediment cores and suspended solids in stormwater runoff indicated the wetland was efficient in trapping fine silt and clay-sized particles. The accretion of most metals and P was attributed to allochthonous material, while over half the accretion of C and N could be attributed to accumulation of autochthonous organic matter from net primary production. This BMP efficiently combined the physical properties of a retention basin with the biological characteristics of a wetland to provide effective treatment with minimal maintenance over its lifetime.

Successful Control of Algal Biomass Through Reductions in Watershed Phosphorus Inputs

Todd Tietjen
Southern Nevada Water Authority, Las Vegas, Nevada

In 2001 Lake Mead had a significant algal bloom (Pyramichlamys) as a result of a combination of environmental and urban influences. While the ultimate prioritization of drivers of the bloom was not resolved, several key parameters were identified; warm overflowing waters from the urban Las Vegas Wash, warm spring weather, and seasonally high nutrient loading. Regional wastewater treatment plants operated under discharge permits that permitted higher nutrient loading outside of the algal growing season, which included the start of the bloom period. Following this bloom, the loading from wastewater sources was reduced year-round by consent of the municipalities. While this urban based loading was a small proportion of the total phosphorus load to the reservoir, it was a significant portion of the bioavailable phosphorus. Since these voluntary reductions have been implemented chlorophyll concentrations have decreased and remained low, generally 1 – 2 µg/L in the open waters of the reservoir. These low chlorophyll conditions have persisted through an extended period of drought and the introduction of quagga mussels to the system. Lake Mead is unique as regulation of inputs from urban Las Vegas are the only watershed factors that can be manipulated. In this case the maintenance of the reservoirs strong nitrogen limitation through reductions in nutrient loading have resulted in the desired oligo/mesotrophic levels of productivity without in-lake management.

Source Water Protection Program Overview and Case Study

Bradley Hufhines¹ and Byron Winston²
¹Beaver Water District, Lowell, Arkansas; ²AECOM, Houston, Texas

More than 220 million North Americans receive drinking water from surface water sources that are under constant threat of water quantity and quality degradation. Examples of these threats can include increased sediment load, changes in hydrology due to increased impervious surfaces in the watershed, climate change, chemical spills, point source contamination, and agricultural runoff. Source Water Protection (SWP) programs seek to protect source water from these threats using a holistic, collaborative approach involving water utilities, lake managers, stakeholders, and citizen groups. A SWP program characterizes water quantity, water quality, and identifies potential sources of contamination within the watershed. This information leads to the development of water quantity and/or quality goals and an action plan to achieve these goals. Internal water quality issues are best addressed by lake managers while watershed and urban best management practices (BMP) are typically addressed by citizen groups or watershed organizations. A SWP program must include monitoring so that changes in quantity or quality can be realized and the SWP plan can be updated, thus making SWP an adaptive management strategy. Because a SWP program is not mandated by federal or state/provincial government there is a lack of a sustained funding mechanism. Therefore funding for SWP programs has to be passed on to stakeholders (i.e. water meter fee, water usage, recreational fee). We will present the 6 components that constitute a SWP program and then examine a case study of a successful SWP program that is protecting human health by protecting source water.
Abstracts
Session E1: Aeration / Mixing
10:30 am – 12:00 pm | Standley II

Prevention of Cyanobacteria Blooms by Destratification Aeration: Evidence from Continuous Vertical Profile Monitoring in C.W. Bill Young Reservoir, Tampa Bay Water

David Austin1, Ed Davis2, Randy Bushey3, and Christine Owen4
1CH2M, Saint Paul, Minnesota; 2CH2M, Orlando, Florida; 3CH2M, Gainesville, Florida; 4Tampa Bay Water, Clearwater, Florida

Continuous Vertical Profile Monitoring in C.W. Bill Young Reservoir and at a site near Hutchinson Island, a 4100-acre estuarine complex near the city of South Beach, Florida, was conducted by continuous water sampling using AEXO2 vertical profilers. The system was used to monitor both epilimnion and hypolimnion profiles and to record the vertical oxygen profiles of the water column. In late April 2016, intense thermal stratification created a "super" epilimnion in the top ten feet, thermally isolated from the rest of the epilimnion. RFU rose from 1.5 to the 4–6 range in this zone. Signs of incipient bloom development were observed in the field on May 5. Fluorescence dissolved organic matter, turbidity, conductivity, and pH corroborated these observations.

The HA system was shut down and the DA system began operation on May 6. Affect was immediate, reducing RFU to less than 1.5 in a day. Diurnal oscillation to higher RFU values ceased by May 13. These results corroborate key findings by Jef Huisman et al. for the first time in the US at full scale on control of cyanobacteria ecology by increasing turbulent diffusivity over critical values.

TIBEAN Deep Water Hypolimnetic Aerator: Three Case Studies

Stefan Bruns
Polyplan GmbH, Bremen, Germany

Deep water aeration where the hypolimnion is not destratified, is a well-known and serious solution for Lake Remediation. Polyplan has developed the TIBEAN deep water hypolimnetic aerator, field tested in Europe for over 20 years.

Based on 3 examples the effect of hypolimnetic water aeration will be shown:

Example 1: Lake Großkayna: Deep water aeration provides enough oxygen to enhance microbiologic activity in the hypolimnetic water body for microbial removal of nutrients leaching from the submerged municipal disposal site.

Example 2: A lake in Vienna: Oligotrophication of a 10 ha. lake in Vienna by operating an hypolimnetic aerator.

Example 3: Reservoir Ennepetal: Reducing treatment costs of potable water treatment from the reservoir Ennepetal by implementing an hypolimnetic aerator.

Finally, the hypolimnetic aeration technology and its viability in specific cases will be discussed in further detail. New application for winter aeration without ice opening will also be discussed as a viable technology to reduce winter fish kill while keeping ice surfaces safe.

Savannah Harbor Dissolved Oxygen Supplementation Through SuperOxygenation

David Clidence
ECO2 Oxygen Technologies, LLC, Indianapolis, Indiana

The completion of the new Panama Canal locks will allow passage of new larger Panamax size container ships from Asia. The Port of Savannah must deepen its harbor from 42 to 47 feet in order to accommodate these larger fully loaded ships. In order to move forward with the Savannah deepening, the US Army Corps of Engineers developed an Environmental Impact Study. This study concluded that 40,000 pounds per day of dissolved oxygen (DO) must be supplemented to the harbor to compensate for the deeper depth. The Corps hired a consulting firm to study 25 different oxygen supplementation technologies to determine which was most appropriate for the task. It was concluded that pure oxygen dissolved in large, conical shaped oxygen transfer reactors called "Speece Cones" was the best fit for the application. A pilot demonstration of this technology was then conducted in 2007 which successfully supplemented 20,000 pounds of dissolved oxygen per day for a 30-day period. The final design for this first of its kind application will incorporate four (4) 12-foot diameter by 20-foot-high oxygenation cones at a site on Hutchinson Island near the convention center and 8 more of these cones at an upriver site near Georgia Powers Plant McIntosh.

The system is under construction and the downriver site should be completed and operational by fall 2017. The results of the system startup and initial operation will be presented along with background information included herein.

The Effects of Diffused Aeration on Fish Habitat in Small-Scale Ponds

Elizabeth Edgerton
Kasco Marine, Prescott, Wisconsin

Small-scale ponds are increasingly popular features on private property, providing recreation, aesthetic value, and irrigation. These ponds experience many of the same issues as larger lakes like stratification, excess nutrients, and unwanted algae blooms. Stratification can be especially problematic in ponds that are used for fishing. As stratification occurs, fish habitat can be greatly decreased as the anoxic hypolimnion forms at the bottom of the pond and they become limited to the warmer, oxygen-rich epilimnion. Additionally, hot summer temperatures cause excessively high water temperatures in the upper portion of the water column, resulting in fish stress or die-off. Thoroughly mixing the water column eliminates stratification, providing
better habitat for fish. Here, we look at a case studies where diffused aeration was used to improve water quality and eliminate thermal stratification, with the goal of improving fish habitat in these small-scale ponds.

**Session E2: HABs / Algal Dynamics**
10:30 am – 12:00 pm | Standley I

**Spatiotemporal Phytoplankton Community Dynamics and Toxin Production in Jordan Lake, North Carolina**

* Dan Wiltse1, Jason Green2, Mark Vander Borgh1, Elizabeth Fensin2, and Astrid Schnetter2

1North Carolina State University, Raleigh, North Carolina; 2North Carolina Department of Environmental Quality, Division of Water Resources, Raleigh, North Carolina

Changes in water quality can propagate the growth of algae, possibly leading to the formation of harmful algal blooms (HABs). Cyanobacterial (blue-green algae) blooms (CyanoHABs) are becoming more widespread and common in freshwater systems. These blooms can lead to serious problems, including the production of toxins that are harmful to other organisms and humans. While there is a significant amount of research conducted, a lack of understanding about the specific factors leading to their formation in a given system prevents effective measures for management. This study focuses on a six-year data set from Jordan Lake, a large artificial reservoir that provides water for over 300,000 residents in central North Carolina. Phytoplankton community shifts, with a focus on cyanobacteria, are linked to pertinent physical, chemical, and hydrological parameters to determine which are most influential for bloom development. Temporal trends, as well as spatial patterns, are discussed and relationships between toxin detection and environmental conditions are examined.

**Reducing Surface Accumulation of *Aphanizomenon flos-aquae* by Increasing Cellular Turgor Pressure and Disrupting Buoyancy Control Using Wetland Water and Ion Additions**

* Arick Rouhe and John Rueter

Portland State University, Portland, Oregon

Harmful algal blooms of cyanobacteria (CyanoHABs) have become an increasing problem worldwide, primarily due to species from the following genera: *Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya, Microcystis, Nodularia, Oscillatoria, Planktothrix, Synechococcus,* and *Trichodesmium.* Species from these genera use a variety of different characteristics to exploit aquatic systems, but they all share one common characteristic: buoyancy control using gas vesicles. In this study, we mixed a buoyant CyanohAB taxa, *Aphanizomenon flos-aquae,* in small-scale microcosms and lakeside mesocosms with varying percentages of wetland water and addition of sodium, potassium, and calcium to investigate the effects of wetland water on surface accumulation and buoyancy control. The results indicate a target mixture of wetland water that reduces surface accumulation, increases cellular turgor pressure (a measure of the ability of gas vesicle forming cells to control buoyancy), and decreases the position of suspended cells in the water column. By adding ions at same concentration as target wetland mixture, similar results were found. This research could represent the basis of a possible new strategy for mitigating surface blooms of CyanoHABs in lakes using wetland water and/or ion additions.

**Advection and Nutrients Regulate Phytoplankton Dynamics in Tainter and Menomin Reservoirs, Wisconsin**

William F. James1, Rachel Fleck2, Heidi Lieffort1, Lyndsey Provos1, Miranda Vandenberg1, and Amanda Wilson1

1University of Wisconsin–Stout, Menomonie, Wisconsin; 2Iowa State University, Ames, Iowa

Tainter and Menomin Lakes are a series of rapidly flushed hydropower impoundments located near the base of the Red Cedar River watershed in west-central Wisconsin. Ranked as among the most severely impaired, hypereutrophic systems in the state, mean summer total P and chlorophyll typically exceed 0.10 mg/L and 60 µg/L, respectively, and the phytoplankton community is dominated by *Microcystis aeruginosa.* Although P can largely limit phytoplankton growth in freshwater systems, advective flow and high flushing rate can also regulate bloom frequency in reservoirs via algal washout in excess of growth and doubling time. The objective of this research was to examine seasonal variations in reservoir phosphorus and chlorophyll in relation to hydrodynamics and nutrient (primarily phosphorus) availability. Research conducted between 2014–2016 found that the mean summer soluble reactive P (SRP) loading (62 T) accounted for ~50% of the total P input to the reservoirs with flow-weighted concentrations exceeding 0.08 mg/L. During periods of high inflow and elevated loading, SRP was very high in the reservoirs but rapid flushing resulted in low chlorophyll due to washout of the phytoplankton community. As flow subsided and residence time increased more than cellular doubling rates, SRP declined rapidly in conjunction with substantial increases in chlorophyll. Subsequent storm-related high inflows reset this pattern. Thus, phytoplankton growth can be limited by advection and transport in rapidly flushed reservoirs even though phosphorus concentrations are high and available for phytoplankton uptake. Management and reduction of SRP loading from this large watershed will be challenging.

**Monitoring Harmful Algal Blooms in Arkansas**

Brie Olsen

Arkansas Department of Environmental Quality, Little Rock, Arkansas

In 2015 a Harmful Algal Bloom (HAB) Workgroup was created in Arkansas consisting of members specializing in water resources and public health. Goals of the HAB Working Group include developing a statewide standard for cyanobacteria and cyanotoxins, establishing a response plan to HAB events, and promoting a monitoring system on lakes prone to cyanobacterial blooms. One of the greatest limitations to properly achieving these goals is a lack of long-term water quality data on lakes. Statewide monitoring on susceptible waterbodies is an essential part of predicting, preventing and responding to cyanobacterial
Abstracts

Successful Long-Term Control of *Myriophyllum spicatum* in Blackhawk Lake, Wisconsin

Donna Sefton¹ and Laura Spears²

¹CORRE, Inc., Madison, Wisconsin; ²DFS Conservation Consulting, Mineral Point, Wisconsin

Three colonies of *Myriophyllum spicatum* (EWM) were found in Blackhawk Lake, a popular recreation destination in southwestern Wisconsin, in 2006. Blackhawk Lake is an 89-ha impoundment with a maximum depth of 13.7 m, mean depth of 4.5 m, and a 3958 ha watershed. The colonies were manually removed by a scuba diver. By 2007, EWM had spread around the lake. Many of the colonies were spot treated with 2,4-D granular; some were manually harvested. EWM was reduced in high density areas, but still found in scattered locations post-treatment. No EWM was found in 2008 when heavy spring runoff reduced the mean spring Secchi to 1.5 m. (It is normally 6 m). In 2009, EWM was abundant in a 2-ha area at depths between 1.2 m and 3.7 m. Application of 2,4-D granular at a rate of up to 218 kg/ha effectively controlled it. One colony of EWM was found near the original infestations and the colonies were manually harvested. In June 2010, EWM was abundant in a 2-ha area at depths between 1.2 m and 3.7 m. Application of 2,4-D granular effectively controlled it. One colony of EWM was found near the original infestations and the colonies were manually harvested.

Potash Dose Responses for Open-Water Treatment of Invasive Mussels

Scott O’Meara, Denise Hosler, Sherri Pucherelli, and Diane Mench

Bureau of Reclamation, Denver, Colorado

Potash (KCl) treatments have been used as an effective tool for open-water management of invasive dreissenid mussels. Several factors have been documented to influence the toxic effects of potassium to invasive mussels, such as water temperature and ion concentrations. This objective of this study was to determine site-specific dose-exposure mortality curves for zebra mussels (*Dreissena polymorpha*) treated with MOP in a central California reservoir. Two water temperatures (12 °C and 22 °C) and five potassium concentrations (0, 25, 50, 100, and 200 ppm potassium) were examined with five replicates for each treatment combination. Experimental units consisted of jars containing 10 live zebra mussels under aeration with daily water changes. Mussels were observed daily over a 45-day period; suspected dead mussels were placed in untreated water for 72 hours to confirm mortality. Temperature, dissolved oxygen, and pH were also recorded at each observation. Potassium concentration and water temperature both had considerable effects on mussel mortality. All mussels in control treatments survived the duration of the study. 25 ppm treatments at both temperatures reached 2% mortality by the end of the study. 50 ppm treatments resulted in 100% mortality by day 36 at 22 °C, but only 42% mortality at 12 °C after 45 days. All mussels treated with 100 or 200 ppm potassium reached 100% mortality, requiring 25/17 days at 12 °C and 8/6 days at 22 °C for 100/200 ppm treatments, respectively.
Prevention and Management of Invasive Species: Vulnerability Assessment of the Rueter-Hess Reservoir
Lisa Scurlock
Parker Water and Sanitation, Parker, Colorado

Parker Water and Sanitation District (PWSD) owns and manages the Rueter-Hess Reservoir located in Parker, Colorado. This is the newest drinking water reservoir on the Front Range and it is now in the infant stages of becoming a recreation destination. The recreational component may pose a risk for the introduction of invasive species. A significant level of effort is dedicated to forecasting and prevention of unwanted species invasion.

As a utility, the primary focus is the protection of reservoir water quality as well as the state of the art ceramic membrane filtration treatment facility. With this focus, it is necessary to evaluate all risks, including invasive species infestation.

Veligers have been found in Colorado water bodies, but no adult mussel populations have developed. Invasive mussel species do exist outside of the Colorado borders and strict management practices are essential to prevent the introduction into our reservoirs.

In an effort to prevent future infestations, Parker Water and Sanitation is working diligently with RNT Consulting, Inc. to develop a vulnerability assessment so present and future risks can be evaluated and addressed.

Areas of consideration include water quality, vectors of introduction, monitoring plans for early detection and long-term management, potential impacts, eradication and control strategies.

With a clear vulnerability assessment and strict reservoir management practices, the goal is to nearly eliminate the risk introduced by recreation and keep invasive species out of the Rueter-Hess Reservoir.

Guardians of the Grande: A Multi-Pueblo Water Quality Sampling Event Focused on Data Quality, Standardization, and Sharing
Alex Heppner1 and Scott Bulgrin2
1Gold Systems, Inc., Salt Lake City, Utah; 2Pueblo of Sandia Water Quality Program, Bernalillo, New Mexico

In February 2017, the Pueblo of Sandia Water Quality Program initiated a New Mexico Tribal Water Quality Working Group. The purpose of this working group is to convene the New Mexico pueblo and tribal water quality programs on a quarterly basis to discuss issues they face and foster tribal partnerships. The group has proposed a joint sampling event for all the pueblos and tribes on the Rio Grande in order to provide a contiguous picture of the river’s water quality. The coordinated sampling event will focus on a common set of water quality parameters using common collection and analytical methods in order to make the data comparable across the programs. The data will be commonly available via a web based data management and analysis system called the Ambient Water Quality Monitoring System (AWQMS). Use of AWQMS will allow all participants to have access to, analyze, and even map the data. The data potentially may also be submitted from AWQMS to the EPA’s Water Quality eXchange (WQX) and be made available via the National Water Quality Portal.

Why Crowdsourcing Data Gets You More Bang for Your Buck
K. Kelly Close
Leonard Rice Engineers, Inc., Denver, Colorado

Today, it's all about data – to effectively and successfully understand, protect, preserve, manage and regulate our lakes and reservoirs, we need constantly up to date information about them, and it's never been cheaper or easier to collect environmental data. But it's not THAT cheap or easy, and limited resources usually prevent us from gathering all we want or using it the way we should. That's where crowdsourcing comes in.

Crowdsourcing isn't just for Kickstarter and Google – it can work for you too, filling in gaps in your monitoring program and providing analytics and perspectives you don't have time to develop. And depending on the kinds of uses you have for your data, it can serve as just a modest supplement to a more rigorously controlled data collection process, or it can be the cornerstone of your watershed group's data management program - or anything in between.
Come see real examples of how crowdsourcing is being put to use in our industry now. We'll discuss pros and cons, compare various approaches, and even look at costs. This is a fairly non-technical discussion of this topic. Pair this session with Harnessing Open Source to Collect and Manage Your Data Better and Cheaper to learn about technical side of crowdsourcing in the booming world of Open Source software.

Session E5: Watershed Management
10:30 am – 12:00 pm | Cotton Creek

Engaging with Water Utilities to Enhance Lake Management, a Triple Bottom Line Economic Analysis of Beaver Water Districts Source Water Protection Program
Chi Ho Sham¹, Bradley Hufhines², Robert Morgan³, Richard Krop⁴, and Jaime Rooke⁵
¹Eastern Research Group, Lexington, Massachusetts; ²Beaver Water District, Lowell, Arkansas; ³Arkansas Forest and Drinking Water Collaborative, Springdale, Arkansas; ⁴The Cadmus Group, Santa Monica, California

Source water protection (SWP) programs and projects enhance water quality for drinking water utilities. Research into SWP efforts indicates that the economic benefits can be substantial under specific circumstances (e.g., New York City). However, statistical analyses have failed to consistently demonstrate the relationship between SWP and economic benefits. Confounding factors associated with watershed conditions, ecology, landform, hydrology, and development history make simple analysis difficult to interpret. In other words, each SWP program should be considered on its own merit. Since 2006, Beaver Water District (BWD) has implemented a SWP program to protect its source water – Beaver Lake. This effort has fallen short of full implementation. Increasing the effort to meet the goals of the program, required an informative analysis to support decision making by the BWD Board. This project analyzed the feasibility of expanding watershed protection efforts in the Beaver Lake watershed. The project team conducted a triple bottom line analysis (economic, environmental, and societal) of BWD’s source water program including, a baseline analysis; the costs of inaction; a gap analysis; the costs for full implementation; cost effectiveness of measures; BWD’s ability to leverage funding; and a sensitivity analysis. Based on the analysis, the BWD’s SWP program is shown to be cost-effective. The strategy returns roughly $125 million to the community above the costs. Thus, BWD implemented a dedicated source water protection fund of $0.04 per 1000 gallons sold. The fund would support partner organizations in the watershed. The process for conducting the analysis and final findings will be presented.

Lake and Reservoir Watershed Management – An Interactive Web-Based System
Jeff Boeckler
Northwater Consulting, Springfield, Illinois

In almost all cases, lake and reservoir quality is directly tied to inputs from the contributing watershed. Effective watershed management begins with a sound understanding of basin dynamics followed by focused implementation and the execution of a comprehensive strategy.

A Watershed Implementation Plan was recently completed for the Lake Springfield watershed. Lake Springfield is the largest municipally owned public water supply reservoir in Illinois. The roughly 4,000-acre reservoir drains almost 170,000 acres, the vast majority in row crop agriculture. The plan details watershed characteristics, annual runoff, spatially explicit nutrient and sediment loading, and site specific Best Management Practices (BMPs) to address loading to the lake. A watershed plan however is only useful if it can be translated into action on-the-ground. To facilitate this action, an interactive web-based system was developed for watershed managers at City Water Light and Power, the City utility responsible for managing the lake. This system allows users to navigate their watershed and interact with various components of the watershed plan. Functionality includes: the ability to view watershed map layers such as streams, watershed boundaries, imagery, and other custom layers; the ability to view and query spatially explicit runoff volumes and nutrient and sediment loading; capability to issue user names and passwords; ability to navigate to planned or proposed BMPs query their expected load reductions; a watershed management dashboard for tracking progress; the ability for users to generate and save their own map layers; and the ability to trace a custom area and generate the loadings for that area, apply a BMP and tabulate load reductions. The presentation will highlight key components of the Lake Springfield plan and demonstrate functionality of the web-based management system.

Why is Watershed Phosphorus Loading So Stubbornly Persistent?
Joe Bischoff⁶, Eric Macbeth⁷, Kelly Dooley⁸, Yvette Christianson⁹, Brian Beck⁷, and Bill James⁴
⁶Wenck Associates, Inc., Golden Valley, Minnesota; ⁷City of Eagan, Eagan, Minnesota; ⁸Minnehaha Creek Watershed District, Minnetonka, Minnesota; ⁹University of Wisconsin-Stout, Menomonie, Wisconsin

The traditional paradigm for reducing watershed phosphorus loading to lakes is to settle particulate phosphorus in stormwater ponds and wetlands. One of the primary assumptions in this approach is that phosphorus is permanently sequestered once it reports to pond or wetland sediments. Furthermore, this phosphorus accumulates in pond and wetland sediments building a legacy phosphorus pool in the watershed that only increases over time. Recent evidence for both stormwater ponds and wetlands suggest that sediments expected to permanently sequester settled phosphorus are becoming saturated and are releasing phosphorus to surface waters, offsetting new efforts aimed at reducing watershed phosphorus loading. Further exacerbating the problem, legacy phosphorus is released in a dissolved form that is not removed by traditional stormwater
Impacts of Wetland Phosphorus Export on Lake Minnetonka

Brian Beck¹, Kelly Dooley¹, Sarah Nalven¹, Joe Bischoff¹, and Anna Brown¹
¹Wenck Associates, Golden Valley, Minnesota; ²Minnehaha Creek Watershed District, Minnetonka, Minnesota;

Six Mile Marsh is a ditched wetland that lies between the headwaters of Minnehaha Creek and Lake Minnetonka’s westernmost bay (Halsted Bay). Historically, Six Mile Marsh has received high nutrient loads from watershed runoff. The traditional paradigm in wetland management for stormwater is that wetlands act as sinks of phosphorus. Over the three years studied (2013–2015), there was a net total phosphorus (TP) removal of 115 pounds in Six Mile Marsh, which fits the traditional paradigm. However, analysis of orthophosphorus (Ortho-P) loading indicates that Six Mile Marsh gross ortho-P export averaged 1,295 pounds per year. Six Mile Marsh’s role as a transformer rather than a sink of phosphorus has serious implications for Halsted Bay, which is already impaired for excess nutrients. First, Ortho-P release occurs during the summer growing season, just as water bodies downstream are most sensitive to Ortho-P loads. So even if Six Mile Marsh is a TP sink on an annual basis, summer Ortho-P release could still result in excessive algal blooms in Halsted Bay. Second, the processes controlling settling and release of phosphorus from Six Mile Marsh are largely independent. Therefore, reducing the external TP load to Six Mile Marsh will not affect Ortho-P export from Six Mile Marsh. Furthermore, reducing the sediment Ortho-P release from the wetland complex would satisfy more than half of the required phosphorus reductions for Halsted Bay.

Session F1: Volunteer Monitoring
1:30 pm – 3:00 pm | Standley II

CSLAP in the Finger Lakes: Volunteer Monitoring on Large, High-Profile Lakes of Variable Trophic Status

Nancy Mueller¹, Scott A. Kishbaugh², Aimee Clinkhammer³, Lewis McCaffrey¹, David Matthews⁴, and Gregory Boyer⁵
¹New York State Federation of Lake Associations, Inc., LaFayette, New York; ²New York State Department of Environmental Conservation, Albany, New York; ³New York State Department of Environmental Conservation, Syracuse, New York; ⁴Upstate Freshwater Institute, Syracuse, New York; ⁵SUNY College of Environmental Science & Forestry, Syracuse, New York

The Finger Lakes of Central, New York are large, high profile lakes with a wide range of water quality characteristics. The lakes have been the subject of many water quality investigations by multiple researchers, but there are still large data gaps and a lack of ELAP certified laboratory data upon which to base regulatory and management decisions. In recent years, harmful algal blooms on some of the lakes have created additional concerns resulting in the establishment of a New York State Department of Environmental Conservation (NYS DEC) Finger Lakes HUB to coordinate management activities and research on the lakes. One of the first efforts, was to obtain funding that would allow all 11 Finger Lakes to participate in the Citizens Statewide Lake Assessment Program (CSLAP) coordinated by NYS DEC and New York State Federation of Lake Associations. Since the lakes don’t fit the typical CSLAP lake profile, coordination with lake associations, government agencies, various watershed groups, and academic researchers was required. While the initial response to participation was enthusiastic, the development of a volunteer monitoring program on a group of large lakes brought its own unique challenges. The data set obtained through CSLAP will be utilized to complete water quality assessments for each lake and determine lake management strategies.

The Cyanobacteria Monitoring Collaborative: Working with Citizen Scientists, Trained Professionals and the Public to Identify and Monitor Cyanobacteria

Linda Green¹, Hilary Snoonk², and Shane Bradt³
¹University of Rhode Island Watershed Watch, Kingston, Rhode Island; ²US Environmental Protection Agency, Chelmsford, Massachusetts; ³University of New Hampshire, Durham, New Hampshire

Since 2013 a broad, dedicated group of stakeholders has met at the US Environmental Protection Agency (EPA) Region 1 lab in Massachusetts to collaboratively address concerns about cyanobacteria in New England’s lakes and rivers. We developed a region-wide cyanobacterial monitoring strategy with consistent methods that mesh well with existing efforts and enhance understanding. The cyanobacterial monitoring workgroup has grown to ~100 member organizations—federal, tribal, regional, state, local agencies, academics, limnology professionals, water suppliers, and lake and watershed organizations and has become the Cyanobacteria Monitoring Collaborative (CMC.).
The CMC has collaboratively developed, tested, evaluated, refined, and implemented a uniform and consistent regional approach to cyanobacteria monitoring in a cost-effective manner and appropriate to a wide range of expertise. EPA leadership has been crucial to this process. This presentation will discuss the triad of CMC approaches, bloomWatch, cyanoScope and cyanoMonitoring, all of which can be found at www.cyanos.org. There’s a wealth of practical information, including University of New Hampshire’s on-line “dirty dozen” cyanobacteria reference key. The CMC smart phone bloomWatch app enables anyone to photograph and report blooms. CyanoScope uses smartphones connected to field microscopes to uploading of algae images to a central database, with crowd-sourced identification. The relatively inexpensive CyanoMonitoring kits engage volunteer monitors and professionals alike in collecting water samples and uses a relatively inexpensive fluorometer to ascertain phycocyanin and chlorophyll pigment levels in whole water with a unique separator and concentrator to fractionate components. Although CMC has gone national, and even international, ground truthing of procedures, data, results and information still takes place in New England.

The New Hampshire Lakes Lay Monitoring Program’s Quest for a Better Lake Report

Shane Bradt1, Jeff Schloss1, Bob Craycraft1, James Haney2, and Linda Schier3
1University of New Hampshire Cooperative Extension, Durham, New Hampshire; 2University of New Hampshire, Durham, New Hampshire; 3Acton Wakefield Watersheds Alliance, Union, New Hampshire

The New Hampshire Lakes Lay Monitoring Program (LLMP) is a long-standing volunteer lake monitoring program run by the University of New Hampshire Cooperative Extension. Over the nearly three decades of its existence, the LLMP has produced annual lake reports to share information gained about each lake in the program with the lake associations involved in the monitoring efforts.

For most of the history of the program, these reports followed a standard report format, including large blocks of text and numerous pages of tables and graphs. Starting in 2012, the LLMP decided to re-evaluate the way in which data were shared with lake associations through the development of a lake highlight report. In contrast to the comprehensive approach of the annual lake reports, the highlight report attempted to distill the most important information available on a lake that year and present it with a few selected graphics and small amounts of text.

Over the past year, the LLMP worked intensively with the Acton Wakefield Watershed Alliance (AWWA) and the town of Wakefield, New Hampshire to refine the highlight report even further with the goal of producing a report which was both scientifically accurate, topically relevant, and provided useful and usable information for community decision-makers. This presentation will describe the journey of lake reports in the LLMP, will detail the current version of the highlight report, and list lessons learned over the past year of work with AWWA and the town of Wakefield.

Lake Observer: A Mobile App for Recording Lake and Water Quality Observations Across the Globe

Kathleen C. Weathers1, Holly A. Ewing2, Kenneth Chiu3, Lisa Borre4, and Michael Forcella5
1Cary Institute of Ecosystem Studies, Millbrook, New York; 2Bates College, Lewiston, Maine; 3Binghamton University, Binghamton, New York; 4Cary Institute of Ecosystem Studies, Annapolis, Maryland; 5State University of New York New Paltz, New Paltz, New York

Mobile apps are rapidly gaining ground as effective tools for collection and display of scientific and environmental monitoring data. The Lake Observer app project began in 2010 as a partnership among computer, ecosystem, and citizen scientists working with the Global Lake Ecological Observatory Network (GLEON) and Lake Sunapee Protective Association (LSPA). Project partners were interested in developing a tool that allows for easy submission of geo-referenced lake data by research scientists and citizen scientists using a smartphone or tablet. The Lake Observer mobile app was developed for global use and is now available for Android and iOS mobile devices. The app allows users to record and submit data on water quality, Secchi depth, ice cover, cyanobacteria, and aquatic vegetation while working in the field.

In 2016, GLEON teamed up with the North American Lake Management Society as part of the White House Water Summit to make the app available for use in the annual Secchi Dip-In and partnered with the US Environmental Protection Agency to make collected data publicly available for the first time via the Water Quality Portal. Beta testing of the Lake Observer app for the Secchi Dip-in began in Indiana in 2015, accounting for 14% of the observations that year. These data already have been used for research published in a peer-reviewed scientific journal. App use was extended to all Secchi Dip-In participants beginning in 2016 and is planned for the Canadian Lake Pulse project beginning in 2017. Recent results will be shared along with a demonstration of the app’s main features.

Assessing N and P Sources in Nantucket Ponds to Manage Cyanobacteria

Emily Molden1 and Kenneth J. Wagner2
1Nantucket Land Council, Nantucket, Massachusetts; 2Water Resource Services, Wilbraham, Massachusetts

Nantucket Island lies 30 miles out to sea, south of Cape Cod Massachusetts, and was formed by the action of the last continental glacier. Over 30 water bodies are scattered across the island, some fresh, some salty, and some of which are seasonally opened to the ocean. Many of these systems are highly valued for recreation and suffer from eutrophication and harmful algae blooms (HABs). Studies have taken place to assess the sources of N in many of these water bodies, and a recent study has also begun to better identify the sources of P in two systems, Hummock and Miacomet Ponds. Hummock Pond is intentionally opened to the ocean twice a year for anadromous fish, but the breaching of Miacomet Pond ceased a decade ago. A combination
of internal loading and watershed inputs of N and P affect these ponds. Here we evaluate the role that internal recycling of nutrients plays in the water quality of these two water bodies and consider the relationship this has with their salinity. Competing coastal stewardship needs must be evaluated and prioritized to develop management programs, and this effort must be supported by data sufficient to draw clear conclusions.

**Freshwater Microcystins Contaminate Marine Mussels: Tales of Future Past**

Barry C. Moore¹, Ellen Preece², Joan Hardy¹, and Danna L. Moore¹
¹Washington State University, Pullman, Washington; ²Robinson-Bryan, Inc., Elk Grove, California; ³Washington State Department of Health (Retired), Seattle, Washington

For well over a half-century, lake restoration scientists have focused much of their “blood and treasure” on understanding, cleaning up, and preventing cyanobacterial blooms and other water quality problems associated with anthropogenic eutrophication. Unfortunately, cyanobacterial blooms in lakes have often been treated by regulatory and funding programs as localized phenomena. In recent years, massive blooms, such as in Lake Erie, along the Florida coast, and in marine waters of Chile, have seemed to verify predictions that algae problems are likely to be more widespread, more frequent, and more intense with changing climate and increasing human populations. Consequent economic disruptions have stimulated more public scrutiny and governmental attention to the problem. Scientists and the media now tend to use more generic term, Harmful Algae Blooms (HABs), which encompasses waters of all salinities and a wider range of causative organisms. Recently, our research demonstrated freshwater to marine transfer of microcystins (MC) into Puget Sound, with subsequent MC bioaccumulation by mussels. ELISA analysis estimated maximum MC concentrations in source lakes of 2700 μg/L, up to 0.34 μg/L in marine waters, and 6.5 μg/kg in mussels. Confirmatory analyses by LC-MS/MS on water and mussel samples identified MC-LA as the major toxin. Freshwater to marine toxin transport has been documented in other parts of the world, this is the first such demonstration in the northwestern US. While North American Lake Management Society scientists understand the connectedness of land and water resources, we discuss many of the vast future implications for human health, for environmental protection and regulation.

**A Rare Uroglena Bloom in Beaver Lake, Arkansas, Spring 2015**

Reed Green¹ and Brad Hufhines²
¹US Geological Survey Lower Mississippi-Gulf Water Science Center, Little Rock, Arkansas; ²Beaver Water District, Lowell, Arkansas

A combination of factors triggered a *Uroglena volvox* bloom and taste and odor event in Beaver Lake, a water-supply reservoir in northwest Arkansas, in late April 2015. Factors contributing to the bloom included increased rainfall and runoff containing increased concentrations of dissolved organic carbon, followed by a stable pool, low nutrient concentrations, and an expansion of lake surface area and littoral zone. This was the first time *U. volvox* was identified in Beaver Lake and the first time it was recognized as a source of taste and odor. Routine water quality samples happened to be collected by the US Geological Survey and the Beaver Water District throughout the reservoir during the bloom. Higher than normal rainfall in March 2015 increased the pool elevation in Beaver Lake by 2.3 m (by early April), increased the surface area by 10%, and increased the littoral zone by 1214 ha; these conditions persisted for 38 days, resulting from flood water being retained behind the dam. Monitoring programs that cover a wide range of reservoir features, including dissolved organic carbon, zooplankton, and phytoplankton, are valuable in explaining unusual events such as this *Uroglena* bloom.

**Understanding the Effectiveness of Artificial Mixing for Harmful Algal Bloom Control**

Tarek N. Aziz¹, Yue Han¹, Jeremy Smithheart¹, Alexandre Mangot¹, Robyn Smyth¹², and Daniel R. Obenour¹
¹North Carolina State University, Raleigh, North Carolina; ²Bard College, Annandale-on-Hudson, New York

Harmful cyanobacteria blooms are increasingly recognized as a threat to the integrity of freshwater reservoirs, diminishing their value as water supplies, wildlife habitats, and recreational areas. While research on cyanobacterial blooms is not new, our ability to predict and mitigate the formation of these blooms remains limited. For decades, artificial mixing has been used to manage reservoir water quality, but its efficacy for controlling harmful algal blooms remains unclear. Our ongoing research focuses on linkages between blooms, artificial mixing, and climate variability; as understanding these relationships is critical to cyanobacteria management.

Based on thermal regime data and meteorological inputs, we have developed a mechanistic turbulent diffusion model that we applied to estimate temperature and vertical mixing rates throughout time in multiple southeastern reservoirs. Furthermore, we have developed a multi-level statistical model to explore relationships among cyanobacteria, mixing, and other biophysical factors. Finally, we have built and tested novel experimental water-column reactors to explore the interplay of light and mixing on phytoplankton community structure. Current results indicate that vertical mixing may play an important role in modulating cyanobacteria dominance, though additional data and modeling are required to better isolate the different mechanisms affecting bloom formation. In this presentation, we will provide a summary of our ongoing research efforts, insights gained, and our future direction.
Achieving Ecosystem Balance through Food Web Manipulation and Trophic Cascade: Top-down Control of an Invasive Landlocked Alewife (*Alosa pseudoharengus*) Population via Walleye (*Sander vitreus*) Stocking and the Associated Limnological Changes (Otsego Lake, New York)

Holly Waterfield, Matt Albright, Bill Harman, and Dan Stich
State University of New York College at Oneonta Biological Field Station, Cooperstown, New York

Alewife were introduced to Otsego Lake, New York in 1986 and were the dominant forage fish by 1991. While alewife provided beneficial forage for native lake trout during the winter months, they ultimately threatened lake trout habitat due to the associated cascading trophic effects of decreased cladoceran mean size, increased algal biomass, and depletion of hypolimnetic oxygen. Despite the lack of documented success in other lakes, a walleye stocking program was initiated in 2000 and continued through 2015 in an attempt to reduce alewife abundance. A compensatory reproductive response to the increased predation was evident in acoustic abundance estimates, spawning adult abundance, and population age structure. Alewife abundance has declined substantially from an estimated 11,000 fish/ha in fall 2002 to less than 100 fish/ha in fall 2012, based on hydroacoustic surveys. No alewife have been physically collected since 2012. Data suggest that the decline of alewife can be attributed to the combined pressure of predation by walleye and lake trout. Lake whitefish and rainbow smelt, planktivores which were previously outcompeted by alewife, have increased in abundance and appear to be rebounding. Balance in the food web is most notably evidenced by a more robust zooplankton community with increased mean cladoceran size and abundance, decreased chlorophyll *a* concentrations, and the lowest AHOD rates observed since 1988.

Reexamining the Balance of a Percid Fishery Over the Course of Two Decades

* Justin R. Hulbert and Daniel S. Stich
State University of New York College at Oneonta, Oneonta, New York

Proportional size distribution (PSD) indices were developed for quantifying length frequency data and estimating size structure of fish populations. Length categories for PSD indices are based on percentages of world record length for each fish species. Stock density indices have been correlated with population dynamics (recruitment, growth, mortality) for many game fish populations, several methods have been used in analyzing PSD index data to improve inferences on size structure and explain the variability in the relationships. In Canadarago Lake, New York walleye (*Sander vitreus*) have been stocked for the dual purpose of supporting recreational fisheries and biocontrol of invasive alewife (*Alosa pseudoharengus*) for more than two decades. We constructed binomial models to estimate the proportion of stock length fish from each population that were also of quality length. In general, the PSD of yellow perch (*Perca flavescens*) and the size structure of walleye increased from 1991 to 2010. The predator to prey ratio of walleye and yellow perch in Canadarago Lake, New York was trending toward a range described as a fishery with over populated, small-bodied yellow perch that interfered with predator reproduction. We surmise that the trends in predator-prey PSD relationship and walleye populations are primarily related to recruitment. Future work will investigate how proportional size distribution indices change at regional and statewide scales, and will include data collected from 2011 to 2017.

Effects of Introduced Blueback Herring (*Alosa aestivalis*) on a Landlocked Southeastern US Reservoir

Dennis R. DeVries1, Gary Lee Grove2, and Russell A. Wright1
1Auburn University, Auburn, Alabama; 2Florida Fish and Wildlife Conservation Commission, West Palm Beach, Florida

Introductions of invasive species can have many effects on resident fishes, potentially including both positive and negative impacts. Blueback herring (*Alosa aestivalis*) were first discovered in Lewis Smith Lake, Alabama in 2010 and it is unclear what their overall effect will be on native species. Responses elsewhere have demonstrated that blueback herring can compete with other fishes for zooplankton at multiple life stages. Alternately, introductions might increase prey availability for piscivores, increasing piscivore growth and condition. We sampled all life stages of blueback herring and resident sport fishes in Lewis Smith Lake over 2 years (2013–2014). Blueback herring consumed significantly more zooplankton than did larval *Lepomis spp.* or adult threadfin shad (*Dorosoma pentenense*), as well as consuming significantly larger zooplankton than either species or what was found in the environment. High diet overlap of blueback herring and both larval *Lepomis spp.* and adult threadfin shad for zooplankton prey suggests a potential for competition at multiple life stages. In contrast, relative weights of adult Alabama bass (*Micropterus henshalli*) and largemouth bass (*Micropterus salmoides*) increased significantly (as well as a non-significant increase for striped bass (*Morone saxatilis*)), suggesting positive effects for these piscivores. Hydroacoustic sampling supported that blueback herring have become abundant in the lake. The overall impact of blueback herring will ultimately be a complex mix of positive and negative effects.

Evaluation of the Effects of Ultraviolet Light Treatment on Quagga Mussel Settlement and Veliger Survival at Davis Dam

Sherri F. Pucherelli1 and Renata Claudi2
1Bureau of Reclamation, Denver, Colorado; 2RNT Consulting, Inc., Picton, Ontario, Canada

Dreissenid mussels are aggressive biofoulers that threaten water delivery and hydropower reliability. The use of medium pressure UV systems to control dreissenid mussel settlement in industrial cooling water systems is a desirable alternative to chemical treatments. This paper summarizes two experiments, carried out over two years, using a proprietary medium pressure UV system. The first experiment tested veliger settlement after exposure to doses of 50, 40 and 20 mJ/cm2. The second experiment tested
settlement after exposure to 100 mJ/cm², and examined veligers behavior and direct mortality post exposure to UV doses of 100, 50, 40 and 20 mJ/cm². All doses tested in the first experiment resulted in settlement reduction between 88 and 99%. The 100 mJ/cm² dose reduced settlement by 99%. In the second experiment delayed veliger mortality was observed after every UV level tested. Mortality varied based on UV dose, ambient water temperature, and veliger size.

**Session F4: Remote Sensing**

1:30 pm – 3:00 pm | Lake House

**A Comparative Study of Deep-Water Sampling with an Unmanned Aerial Water Sampling System (UAWSS) to Traditional Sampling Methods: A Case Study from Dillon Reservoir, Summit County, Colorado**

Brian Straight, Devin Castendyk, Brandon Ransom and Pierre Filiatreault

1University of Colorado, Boulder, Colorado; 2Hatch Associates Consultants, Fort Collins, Colorado; 3Denver Water, Denver, Colorado; 4Hatch Associates Consultants, Sudbury, Ontario, Canada

Unmanned Aerial Systems, commonly known as drones provide an innovative approach to sample the water column in a lake setting. An unmanned aerial water sampling system (UAWSS) has been developed and used to sample Dillon Reservoir in Summit County, Colorado. The UAWSS currently consists of a hexacopter UAV that can be equipped with a conductivity, temperature and depth (CTD) probe or 1.2 L water sampler. This emerging technology was first tested on September 20, 2016 at Dillon Reservoir. The test flight profiled Dillon Reservoir with the CTD and collected a water sample from 25 m depth. The CTD profile showed a possible layer of surface water inflow from the Snake River. The next test flight conducted at Dillon Reservoir was on April 12, 2017. The accuracy of in-flight procedures to collect a sample at a specific depth was examined by using a pressure transducer attached to the Niskin bottle. Depth measurements taken with the UAS ground station were within ± 1.5 m of depths measured with the pressure transducer. Procedural protocol for the UAWSS involves profiling the water column with the CTD profiler before water sampling, profiling identifies depths of stratified layers which are targeted for sampling. In this presentation, we provide a comparative study of water samples collected from Dillon Reservoir at the same depths and same day using traditional methods verses the UAWSS. Analyses of cations, anions, conductivity, pH and trace elements will be compared. The goal is to validate that UAWSS methods provide identical results as traditional methods.

**Using Real-Time High-Frequency Monitoring to Study Regional Heterogeneity in an Oligotrophic Lake**

Michael R. Kelly and Harry R. Kolar

IBM Research, Yorktown Heights, New York

Lake George is a freshwater oligotrophic lake in upstate New York with generally deep Secchi transparency (~9m). Extensive study of the lake and its watershed aided by a new observational sensor and intelligent computing network is underway. This effort complements ongoing traditional scientific experimentation and data collection, and integrated computer modeling of weather, runoff, circulation, and the food web. Better understanding of the regional differences resulting from processes around and within the lake will enable more informed decision making and long term preservation of this valuable resource.

High-frequency weather, vertical profiler, and acoustic Doppler current profiler data sets are examined to reveal unique physical, chemical, and biological characteristics across separate regions within the lake over multiple time scales. Our investigation includes the examination of lake-wide differences of temperature, chlorophyll, pH, and other parameters measured throughout a season.

**Predicting Water Quality from Satellite Observations of the Watershed**


Hazen and Sawyer, Baltimore, Maryland; 2Hazen and Sawyer, New York, New York; 3Hazen and Sawyer, San Francisco, California; 4Hazen and Sawyer, Cincinnati, Ohio; 5National Aeronautics and Space Administration, Pasadena, California

Despite the strong influence of watershed conditions on source-water quality, most water utilities do not currently have the capability to monitor watershed sources of contamination with great temporal or spatial detail. Typically, knowledge of source-water quality is limited to the treatment plant intake and periodic grab samples. While important, such observations do not provide enough information for proactive watershed or source-water management. Satellite remote-sensing data can provide a snapshot of an entire watershed at regular intervals, helping utility analysts characterize watershed conditions and identify trends that could signal changes in source-water quality.

Funded by National Aeronautics and Space Administration's ROSES program, our team is investigating correlations between satellite remote-sensing observations of watersheds and source-water quality, at a variety of spatial and temporal scales and lags. Predictor variables under evaluation include parameters that describe vegetative conditions; parameters that describe climate/weather conditions; and non-remote sensing, in situ measurements. Predictands under investigation include nitrogen, phosphorus, organic carbon, and turbidity. In this presentation, we will describe results of statistical analyses and discuss how these results are being used to inform development of a desktop decision-support tool to support predictive application of remote-sensing data.
Abstracts

Session F5: Internal Loading / In-Lake Treatment
1:30 pm – 3:00 pm | Cotton Creek

28 Years of Impact from Central Basin Hypoxia and Internal Phosphorus Loading on North Shore Water Quality in Lake Erie
Gertrud K. Nürnberg1, Todd Howell1, and Michelle Palmer2
1Freshwater Research, Baysville, Ontario, Canada; 2Ontario Ministry of the Environment and Climate Change, Toronto, Ontario, Canada

We hypothesized that north shore water quality of Lake Erie’s Western and Central Basins is impacted by Central Basin hypoxia and related internal phosphorus (P) loading. First, we quantified Central Basin hypoxia from published information of annual hypoxic (<2.0 mg/L dissolved oxygen) areal extent and duration as hypoxic factor (HF, the number of days in August – September that a sediment area equal to the Central Basin surface area was hypoxic). 1985 to 2012 HF values averaged 15.2 d/yr and ranged between 0 (1996) and 34.3 d/yr (2012, year of extended fishkill along the north shore). Internal load was estimated from an areal release rate multiplied by HF and averaged 122 mg/m²/yr for 1985–2012. Second, we analyzed phosphorus (P) and chlorophyll (chl) data at 2 north shore sites, Leamington (Western) and Port Stanley (Central) provided by the Great Lakes Intake Program. Central Basin HF and internal loading were significantly correlated with summer dissolved reactive P and August–October chl concentrations at Port Stanley, but not Leamington. These correlations may be causal because summer Central Basin hypolimnetic currents are directed towards the north shore. They support our hypothesis that Central Basin north shore water quality is impacted by Central Basin hypoxia.

Application of Iron Filings to Reduce Internal Phosphorus Loading in Lakes
Poornima Natarajan1, John S. Gulliver2, and William A. Arnold2
1University of Minnesota, Minneapolis, Minnesota; 2Department of Civil, Environmental and Geo-Engineering, University of Minnesota, Minneapolis, Minnesota

High internal phosphorus loading in lakes can impede restoration efforts and must be addressed to reduce algal blooms. In this study, addition of zero-valent iron filings to control phosphorus (P) release from lake sediments was investigated. Sediment cores collected from two Minnesota lakes were set up for laboratory mesocosm studies, and the effects of increasing iron supply in the sediment determined under controlled oxic and anoxic conditions. At doses greater than 0.05 g iron/cm², the sediment-P flux, pore water P concentrations and water column P concentrations were found to decrease by 75 to 96%, even under anoxic conditions. The effect of iron filings addition on the redox sensitive-P in the sediment was also determined. This study demonstrates that iron filings application could be a potential treatment technology to sequester phosphorus in lake sediments.

Whole Lake Combined PAC-Phoslock® Treatment to Manage Eutrophication and Cyanobacteria
* Maira Mucci1, Guido Waajen1,2, Elisabeth Faassen1, and Miquel Lüring1,3
1Wageningen University, Wageningen, The Netherlands; 2Water Authority Brabantse Delta, Breda, The Netherlands; 3Netherlands Institute of Ecology, Wageningen, The Netherlands

Lake de Kuil (The Netherlands, 6.7 ha, maximum depth 9 m) suffered from cyanobacterial blooms since the early 1990s as a consequence of eutrophication. Point source reduction did not yield improved water quality due to high internal loading. To control internal loading and cyanobacteria the lake was treated with a low dose of flocculent (4 tons of iron chloride) and a solid phase phosphate sorbent (42 tons of Phoslock®) in May 2009. The treatment aimed to target both dissolved and particulate phosphate, and to block P release from the sediment. The treatment was successful in reducing total phosphate, chlorophyll a and increasing water quality. Ongoing diffuse P inputs, however, have gradually moved the lake back towards a eutrophic state. Thus, a re-application of flocculent and Phoslock® was done in May 2017. We have been monitoring the lake before, during, and after the application. Water samples over depth were taken to analyze nutrients, chlorophyll a, turbidity, cyanotoxins and pH. In situ, Secchi depth, oxygen and light profiles were made. On May 8, 8 tons of Phoslock® were applied to the lake (30 mg/L) as ballast to sink the algae. The day after six tons of Polyaluminium chloride was applied (2.1 mg Al/L) to flocculate the cells, while on May 10, 23 tons of Phoslock® was injected in the hypolimnion layer (4–5 meters) only in the deeper part of the lake to target the internal loading. The results of the monitoring will be presented shedding light on the efficacy of the treatment.

Restoration of a Eutrophic Hard-Water Lake by Applying an Optimum Dosage of Poly-Aluminum Chloride: Reasons, Results, Problems
Leibniz-Inst. of Freshwater Ecology & Inland Fisheries, Berlin, Dept. of Experimental Limnology, Neuglobsow, Germany

Lake Feldberger Haussee (NE Germany) was polluted for almost a century. During the late 1980s the nutrient input approached 1.9/11.5 g TP/TN m⁻² yr⁻¹. As a result, the lake developed into a hypertrophic ecosystem and had largely lost its recreational value. In 1980 the sewage discharge was stopped decreasing the external loading by about 90%. Because of vast amounts of phosphorus stored in the sediment, the lake TP concentration remained until 1985 (1 mg L⁻¹). To accelerate recovery, biomanipulation had been applied from 1985–2002 but was successful to only a minor extent. Eventually, due to sediment sequestration and discharge to downstream lakes, the TP spring maximum (2006–2010) had dropped to 0.11 – 0.08 mg L⁻¹. However, given the trend it was obvious that it would take another 10–15 years until the concentration would approach the desired mesotrophic level. Thus, it was suggested to treat the lake using poly-aluminum chloride as precipitant. To ensure good water quality, a target concentration of ≤ 0.035 mg TP L⁻¹ had been intended. The objective was to achieve this result by optimizing the amount of aluminum being applied (as much
as needed, as little as possible). As a prerequisite, the status of the lake was carefully studied; whereby external phosphorus loading and the amount of mobile phosphorus stored in the sediment were of specific interest. Laboratory experiments and field observations eventually resulted in a dosage of 27 g Al m⁻² (Al/P 12). Subsequent to the treatment in April 2011, changes of prime water quality parameters showed two opposing trends. TP concentration immediately dropped below the restoration target (0.025 mg L⁻¹). Primary production and phytoplankton biomass declined substantially. However, water clarity did not improve for another four years. The likely reason for the delay was the structure of the phytoplankton community. It was dominated by cyanobacteria having the potential to trigger intensive calcite precipitation and thus impair transparency. In spring 2016 the cyanobacteria suddenly disappeared and transparency increased significantly. We speculate that the modification of the algal community shifted the ratio of assimilation and respiration in favor of the latter. This allowed an increase of free CO₂ (dissolved CO₂ & dissociated carbonic acid) shifting the carbonate buffering system and thus halting the formation of calcite crystals. Also, the phytoplankton, now represented by small readily ingestible taxa, promoted a flourishing Daphnia population inflicting heavy grazing losses. During the years 2015–2017 a summer clear water phase was observed (maximum Secchi transparency 3.7 – 4.2 m).

Summarizing we conclude that a drastic decrease of phosphorus grazing losses. During the years 2015–2017 a summer clear water phase was observed (maximum Secchi transparency 3.7 – 4.2 m). Summarizing we conclude that a drastic decrease of phosphorus availability in concert with structural and functional changes of the plankton community eventually improved the water quality of the Haussée significantly. The lake is now in a mesotrophic status, well in accordance with the aim of the restoration project.

**Reflecting on Lakes**

Harry Gibbons  
Lake Advocates, Bainbridge Island, Washington

Lakes are wonderful reflections of life on Earth. They are diverse, reactive, supportive of life, unique, and ever changing. William Barry, my first limnology professor, taught me: to understand lakes you must develop a passion for science; because without this passion you will not be able to continue to learn about how lakes are the expressed equilibrium of the physical, chemical, and biological interactions and energy driven dynamics that change with changing conditions. It has been my good fortune to have worked with colleagues that have continuously enabled me learn and to always put science first. By exploring and working together I have learned from my mistakes and my successes. Friends have empowered me to engage in many different ecosystems and management approaches, from my better half, Maribeth, to fellow graduate students, my graduate students, consultants and my staff, clients and government scientists, all my friends that have opened doors for me to learn and try to make a difference. They have helped me understand and design habitat and treatment wetlands, bioswales, infiltration systems and other water shed BMPs, as well as, AIS management, nutrient inactivation, dredging, aeration/circulation, hypolimnetic aeration and more. All of these activities helped me gain knowledge and understanding of ecological science. Now we must work together to build scientific understanding to allow for the survival of uniquely wonderful lake ecosystems and life on Earth they represents. Only by working together with science can we avoid extinction for human-kind and all life on our planet.
Long-Term Patterns in Water Temperature Downstream of a Large Reservoir in Southeastern Idaho

*John McLaren1, Todd V. Royer1, Rob Van Kirk2, and Melissa Muradian2*

1Indiana University School of Public and Environmental Affairs, Bloomington, Indiana; 2Henry’s Fork Foundation, Ashton, Idaho

Water temperature influences aquatic organism growth and development, including economically important cold-water sport fish. Large irrigation storage reservoirs in the western US tend to release hypolimnetic water, cooling and moderating water temperature in the tailwater to the benefit of these sport fish. Drought induced water shortage may change the expected water temperature regime in these regulated systems. We examined water temperature over the past two decades in the Henry’s Fork River, which supports a world-renowned sport fishery in southeastern Idaho, downstream of Island Park Reservoir, an 8000-acre reservoir storing 135,000 acre-feet of irrigation water. We found long-term drought events resulted in warmer river water temperatures. Long-term drought events trigger high irrigation water demand in conjunction with low reservoir inflow. High rates of release drain the hypolimnion faster than replacement by cool snowmelt- and spring-fed inflow, allowing warm epilimnion water to mix to greater depths and be released through the dam. In the extreme drought year of 2016 reservoir stratification broke down rapidly and river water temperatures below the dam increased 5–10 °C over a short period of time. In April through July—peak fish and insect development—this temperature shift results in the accumulation of up to 300 extra degree-days. Our research indicates reservoirs can magnify the effects of drought, and creative management may be needed to preserve water quality for tailwater sport fishing while simultaneously providing sufficient water supply for irrigators.

Bayesian Analysis of Proportional Size Distribution Indices in Recreational Fisheries

Dan Stich and Justin Hulbert
State University of New York College at Oneonta, Oneonta, New York

Proportional size distribution (PSD) is a size structure index that is widely used in fisheries management to assess freshwater fish populations. It is estimated as the proportion of fish of creelable size that also achieve some larger size of interest. Traditionally, PSD has been described as a unitless measure, usually expressed in whole numbers between zero and 100. However, this has the potential to confuse analysis and interpretation of the index. Arguably, this has resulted in a relatively limited context for thought about the metric, although some notable exceptions exist. Robust methods for estimating PSD, and for assessing changes at both the individual and population levels has the potential to promote further development of this important tool. Furthermore, simplification of estimating confidence intervals associated with derived quantities (e.g., spatial or temporal changes) has the potential to improve utility. This study used a combination of real and simulated data to demonstrate formulation and application of Bayesian analyses of trends in PSD. The results demonstrate the utility of this method and build naturally on previously proposed methods for estimation. Implications for use with long-term monitoring and data-limited situations are discussed.

Utilization of Aquatic Barriers to Protect Fish Populations from Reservoir Management Activities

Andrew J. McCusker1, Melissa Hamlin1, Jaret Johnson2, and Chris Guelke3

1Mackworth-Enviro, Scarborough, Maine; 2Mackworth-Enviro, Chapel Hill, North Carolina; 3Mackworth-Enviro, Clinton, Connecticut

Aquatic barriers have been used to protect fish populations from various threats since the late 1990s. These full-depth underwater curtains have protected Alaskan salmon populations from dredging operations, estuarine fish from industrial intakes in New York and Massachusetts, and fishing reservoir populations from a dam outlet in Kansas. Each aquatic barrier application for the protection of fish has been a relatively novel and new approach to conservation, and the technology is not yet widely known, especially among inland, managed western waters and fisheries.
Each new application of the aquatic barrier for the protection of fish populations has been individually designed for the specific location and goals. Characteristics of the physical water body, its natural or managed elevations and flows, the type and size of organism to protect, short- and long-term goals and many other factors all become part of an aquatic barrier’s design basis. This site-specific adaptability has allowed for the aquatic barrier’s use for a wide variety of environmental circumstances and for a breadth of knowledge to be gained about its capabilities.

The presentation will discuss aquatic barrier design considerations, successes and lessons learned, and applicability within managed reservoir environments to protect fish populations for conservation and fishing uses.

**Session G3: Urban Lakes**
3:30 pm – 5:00 pm | Meadowbrook

**Physicochemical and Biological Impacts of Road Salts on Urban Lakes**
★ Isabelle Fournier, Rosa Galvez, and Warwick F. Vincent
Université Laval et Centre d’études nordiques, Québec, Québec, Canada

In the province of Quebec, Canada, some 1.5 million tons of salt (mostly NaCl) are spread on roads during winter to ensure driver safety. Half of this salt eventually leaks into surface waters with snowmelt runoff. To better understand the impacts of salt contamination of lake ecosystems, major ion concentrations and associated limnological variables were measured throughout the year in the inflows and main basin of Lake St-Charles, the drinking water reservoir for Quebec City. We observed that rivers crossing more urbanized territories carried a higher chloride charge (by up to a factor 5) than those crossing forested regions. This road-derived chloride entered the lake as early as January, with peak concentrations and loading in March. The maximum chloride concentrations were an order of magnitude lower than the chronic aquatic life limit recommended by the Canadian Council of Ministers of the Environment, however this water quality criterion does not take into account potential effects on planktonic food webs. Modification of plankton community structure could potentially affect ecosystem functioning and biogeochemical cycles. To examine this question, an experiment was undertaken with water sampled from Lake St-Charles in winter. This natural community was exposed in the laboratory to spring-like conditions (in terms of temperature, photoperiod and irradiance), with and without added NaCl. After only two weeks of incubation, the salt-exposed community differed from the control, suggesting the influence of road salt on freshwater plankton, even at low concentrations.

**Managing Multi-Use Reservoirs: How Reservoir Fill Rates May Affect Swim Beach Bacteria Levels**
Kate Dunlap and Candice Owen
City of Boulder Public Works, Boulder, Colorado

Reservoirs throughout the west are often multi-use, serving as managed drinking water supplies and recreational destinations with public swim beaches. Beach closures due to elevated *E. coli* levels can be costly, result in event cancellations, and the perception of bacteria closures on a drinking water reservoir are less than ideal. Boulder Reservoir, a City of Boulder recreational destination and drinking water supply, experienced an unprecedented four-day swim beach closure in 2016. This presentation describes our analyses to determine the sources of *E. coli* and factors contributing to the exceedances, as well as the management approaches implemented to control *E. coli* levels at the swim beach.

Geese appear to be the primary source, with a significant portion of *E. coli* likely harbored in the beach sands. A significant positive correlation between reservoir fill rate and swim beach bacteria levels suggests that when the reservoir is filled at higher rates to meet drinking water needs, *E. coli* are released from the inundated beach sands, triggering an exceedance. City staff are working with the entity that manages reservoir fill rates and timing to make operational adjustments to minimize swim beach closures. The city is also implementing new strategies to control the goose population including: installing light beacons and mechanically removing goose poop from the beach, and sampling a stormwater drainage inlet near the swim beach. This presentation will include updates from the 2017 swim season.

**TMDL Compliance as an Opportunity for Park and Habitat Enhancement**
Michael Whelan
Anchor QEA, LLC, Lakewood, Colorado

This presentation discusses a recently completed project in Southern California that dealt simultaneously with several variables typically affecting lake and reservoir systems. Sediment dredging was needed to address total maximum daily load (TMDL) compliance and achieve the following additional goals:

- Create enhanced shallow-water habitat suitable for mitigation credits banking
- Regrade the shoreline to improve public access and promote native vegetation

Colorado Lagoon in Long Beach, California, is an inland waterbody with restricted tidal exchange, subject to TMDL criteria for water, sediment, and fish tissue. Early sediment removal actions and stormwater input controls reduced contaminant loads, but significant dredge residuals remained, affecting TMDL compliance. A subsequent and recently completed phase of the restoration effort allowed several opportunities to improve the site. First, hydraulic dredging was combined with sediment filling to create shallow benches to support shallow water habitat, leaving a sediment surface that improved water quality needs while providing a valuable habitat bank for the City of Long Beach. Second, in-water and shoreline regrading allowed upland features to be transformed by adding walking trails, a bioswale to manage runoff, and landscaping to restore native, drought-resistant species.

This presentation will describe the project and explore its relevance to other lake settings, particularly those that are publicly accessible and in chemically impacted watersheds.
Abstracts

Achieving Lake TMDL Goals with Innovative Urban BMPs

Jacob Newhall1, Bill Alms1, Daryl Jacobson2, and Jay Hartman2
1WSB & Associates, Minneapolis, Minnesota; 2City of Burnsville, Burnsville, Minnesota; 3City of St. Anthony Village, St. Anthony Village, Minnesota

Recently high efficiency and high value regional stormwater BMPs were implemented in fully urbanized areas to achieve TMDL loadings for four separate municipalities and four different lakes. Phosphorus reduction goals were achieved by following:

• City of Burnsville – Keller Lake
• City of St. Anthony – Silver Lake
• City of Robbinsdale – Crystal Lake
• City of St. Louis Park – Bass Lake

Innovative regional BMPs were implemented to achieve the necessary phosphorus removals for each water body. Innovative practices include:

• In-lake active alum treatment plant
• Active alum treatment system within regional stormwater pond
• Invasive species management
• Underground storage vault with extended detention and active infiltration or filtration for secondary treatment

Presentation will touch on the lake benefits as well as planning, design, and construction challenges and lessons learned from each of the BMPs.

Session G4: Phoslock
3:30 pm – 5:00 pm | Lake House

Managing Eutrophication in Lakes and Ponds with the Lanthanum-Modified Clay Phoslock

Miquel Lurling1, Maira Mucci1, Guido Waajen2, Natalia Noyma2, Leonardo de Magalhães3, Marcela Miranda4, Vera Huszar5, Marcelo Miquel Lurling1, Maíra Mucci1, Guido Waajen2, Natalia Noyma3, the Lanthanum-Modified Clay Phoslock
1HydroScience Consultoria e Restauração Ambiental, Florianópolis, Brazil; 2Institut Dr. Nowak, Ottersberg, Germany; 3Phoslock Water Solutions, Sydney, Australia

Eutrophication is the main water-quality issue worldwide. The lanthanum-modified clay Phoslock became available as a eutrophication-management product on the European market in 2006. The clay has been tested from laboratory and enclosure studies to whole-lake scales. In this overview the strong phosphate (P) immobilisation and reduced sediment P-release from Phoslock treated sediments from freshwater and brackish water systems will be presented. Results of large compartments constructed in urban ponds revealed that Phoslock can be as effective as dredging in controlling eutrophication. Whole-lake experiments showed that lakes can be moved from a eutrophic to an oligo-mesotrophic state and kept in the desired state for years. In lakes with ongoing diffuse P-loading, however, regularly repeated low-dose maintenance interventions are required. Despite the obvious efficacy of Phoslock in mitigating eutrophication, it should only be applied if a system analysis – a diagnosis – of the lake, which reveals the main water and nutrient flows and the biological structure of the waterbody, has indicated high internal P load. In those situations, as indicated by a wealthy body of cases, Phoslock may be a powerful supplement to existing catchment and biomanipulation measures for eutrophication management.

Preventative Phosphorus Management to Maintain the Mesotrophic State of an Irregularly-Mixed Lake

Tim Sebastian Epe
Institut Dr. Nowak, Ottersberg, Germany

The excavated lake “Waidsee” (area 0.24 km²; mean depth 13.5 m; max depth 28 m) is situated in the upper Rhine valley, Germany. It is of high recreational value and intensively used for swimming, fishing, diving and sailing. In recent decades, nutrient and phytoplankton concentrations have increased, threatening the ecological structure and functions, and thereby the ecosystem services of the lake.

Five in situ P-precipitation systems were installed in 2002 to control most of the annual phosphorus (P) inputs. These systems, which operate 9 months / year, use iron hydroxide granules to bind P in lake water. As the lake has a small surface area in relation to its depth, deep water is only circulated irregularly. Thus, the P concentrations in the deep water have increased gradually in recent years, mainly due to internal P-loading. To target this deep-water P-reservoir and the releasable P in the nutrient rich sediments, 94 t of lanthanum modified bentonite (LMB) were applied to the lake in February 2016.

This presentation will present data from pre- and post-treatment monitoring of the lake and outline the preventative strategies which have been implemented to maintain P concentrations within a mesotrophic state, thereby ensuring ecosystem functioning and the unrestricted recreational use of the lake. Furthermore, this recent example will be compared with long-term data of a restoration with LMB conducted in 2009. This comparison will illustrate limits, chances and perspectives following internal restoration measures.

Application of Phoslock to a Water Supply Reservoir in Northeastern Brazil: Lower Phosphorous and Cyanobacterial Concentrations Have Resulted in Reductions in Annual Treatment Costs

Tiago Finkler Ferreira1, Rafael Schmitt2, Julia Costa Silva1, Said Yasseri2, Patrick Van Goethem3, and Nigel Traill3
1HydroScience Consultoria e Restauração Ambiental, Florianópolis, Brazil; 2Institut Dr. Nowak, Ottersberg, Germany; 3Phoslock Water Solutions, Sydney, Australia

The Joanes 1 Reservoir supplies approximately 50% of the potable water supply to the City of Salvador, the capital of the State of Bahia in the northeast of Brazil. The reservoir is relatively shallow,
with an area of 110 ha and a volume of 5,500,000 m³. In recent decades, the system has suffered from cyanobacterial blooms and other symptoms associated with eutrophication, leading to higher chemical costs for water treatment plants.

In 2015, the water company for the State of Bahia, EMBASA decided to use Phoslock for eutrophication control. A total of 125 tonnes of Phoslock were applied in 3 applications over a 12-month period. The dose was derived from the total P concentrations in the water column and sediments of the reservoir and the mobile P pool in the sediments was only determined accurately after Psenner analysis was performed during the treatment. This analysis showed that the applied dose underestimated the mobile P in the sediments by approximately 50% and that an additional dose would be required to completely immobilize the reservoir's internal P pool. Despite the fact that the initial dose was an underdose, the applications resulted in a significant improvement in the water quality of the system. Total Phosphorus was reduced by 80% after the first two applications and cyanobacteria subsequently dropped by between 85% to 99%. Cyanobacterial concentrations were reduced to below 1000 cel/mL, enabling the company to save over USD 1.7 million in chemical costs in the six months after the commencement of the treatment. As the initial treatments were acknowledged to have been insufficient to fully immobilize the internal P load and as external P inputs into the reservoir continue, the Project has been extended and an additional 186 tonnes will be applied to the reservoir during 2017.

**Water Quality After Treatment with Lanthanum-Modified Clay (Phoslock) of Urban Henderson Lake, Alberta**

**Gertrud K. Nürnberg**

Freshwater Research, Baysville, Ontario, Canada

Highly eutrophic Henderson Lake, Lethbridge, Alberta (25.8 ha) was treated with 64 tonnes of Phoslock at a rate of 2.5 metric tonnes/ha in April 2016. Total phosphorus (P) concentration decreased from above 0.20 to below 0.03 mg/L (130 samples at 5 stations, surface and bottom depths, City of Lethbridge monitoring data), effectively rendering Henderson lake mesotrophic. Similarly, phytoplankton, including cyanobacteria biomass and chlorophyll concentration, was much reduced, and Secchi disk transparency was elevated according to a Lethbridge College Report. A multitude of restoration measures had been conducted for several years in Henderson Lake. To predict treatment effect and help distinguish the effects of various restoration techniques a P mass balance model was employed. External load, assessed from watershed characteristics and P export, and pre-treatment internal load predicted a TP concentration of 0.20 mg/L before the Phoslock treatment and 0.10 mg/L after the treatment for zero internal load. Explanations for the much lower observed post-treatment TP concentration of 0.03 mg/L will be presented and the importance of informed pre-treatment water quality assessment discussed. Scenario modeling of the two largest external loads suggests the importance of future monitoring of water fowl abundance and golf course management.

**Session G5: Modeling & Monitoring**

**Long-Term Monitoring of Stream Integrity in Rocky Mountain National Park: *in situ* Water Chemistry and Bioassessment Set the Context for Restoration Success**

**Erin M. Borgman, E. William Schweiger, and Kirk Sherrill**

National Park Service, Fort Collins, Colorado

The US National Park Service (NPS) protects cherished places like Rocky Mountain National Park (ROMO) in Colorado. However, the integrity of parks’ natural resources can be affected by events beyond their control. For example, the Grand Ditch on the west side of ROMO, which diverts water from the Colorado River for irrigation, breached in 2003 depositing extensive debris downstream. ROMO is restoring the system’s ecological integrity. The Inventory & Monitoring program of the NPS conducts long-term monitoring of streams in ROMO and other parks to determine status and trend over time and can provide valuable data to park management to determine the effectiveness of restoration. Here we focus on *in situ* water chemistry monitoring in the context of biological and habitat response using long-term continuously deployed sondes.

The upper Colorado River site includes paired sample reaches that bracket the debris flow created by the breach. Preliminary results from 2010–2015 suggest the upper reach was usually colder and had higher dissolved oxygen levels. Maximum temperature (17 °C, based on salmonid viability) was exceeded 1–5 weeks during 4 of 5 summers. Dissolved oxygen levels were usually above the base flow threshold (6 mg/L) at both sites although late summer levels at the lower reach were often low. There were higher dissolved solutes and turbidity and more acidic pH at the lower reach. These results provide a useful context for more synthetic biological and habitat parameters. Using monitoring data, we are able to provide baselines that will help determine whether restoration activities improve conditions.

**A Simple, User-Friendly Index for Assessing the Sensitivity of Lakes to Increased Nutrient Loading**

**Andrew Paterson¹, Eleanor Stainsby¹, Victor Castro¹, Tammy Karst-Riddoch², and Neil Hutchinson²**

¹Ontario Ministry of the Environment and Climate Change, Dorset, Ontario, Canada; ²Hutchinson Environmental Sciences Ltd., Kitchener, Ontario, Canada; ³Hutchinson Environmental Sciences Ltd., Bracebridge, Ontario, Canada

Planning decisions regarding residential shoreline development must be evidence-based and defensible. Thus, simple, quantitative tools for assessing development impacts may be of broad interest to lake managers and environmental planners. In Ontario, Canada, the Lakeshore Capacity Model (*i.e.*, the Dillon-Rigler model) has been used for decades at a lake or watershed scale to predict how human inputs of phosphorus (P) may alter the trophic status of lakes, and to make recommendations regarding the number of new lots that should be approved along a lake's shoreline. However, its application across the province has been hampered by high errors in predicted P in some lake types (*e.g.*,...
Abstracts

dystrophic lakes), and emerging evidence that P from well-designed septic systems may be significantly retained in well-oxygenated, sandy, acidic soils that are typical of the Precambrian Shield.

We explore an alternative use for the Lakeshore Capacity Model; that is, to develop and calibrate a simple, regression-based index for assessing the sensitivity of lakes to P inputs. We define lake sensitivity as a lake’s responsiveness to a human P load, regardless of its source, relative to a natural, background load. For hundreds of lakes in Ontario, we calculated sensitivity using P loading levels that were calibrated to measures of social crowding: 1) one development per 1.6 ha of lake area; 2) one development per 45 m (150 ft) of shoreline; and 3) one development per 60 m (200 ft) of shoreline. Using multiple regression analysis, model outputs (e.g., the percent change in lake P concentrations relative to background) were compared to commonly recorded lake and watershed variables (the number of upstream lakes, watershed area, lake area, % watershed wetland area, mean annual runoff, the background TP load) to develop a predictive index. Model predictions resulted in \( r^2 \) values > 0.90, suggesting that a simple, proactive index can be developed to help inform decision making about shoreline development.

Advantages of Monitoring Phosphorus Trends with Sediment Traps

Stephen Klein
Benthica LLC, Elizabeth, Colorado

Monitoring phosphorus loading to lakes and reservoirs is essential to determine the success of programs to manage nutrients in the watershed. Frequent water sampling and analysis is costly in terms of time, equipment and analyses, but provides good loading data. Although bottom sediment provides an archive of historical trends for many substances, including phosphorus, its ability to record short-term trends (e.g., annual) is quite limited due to vertical mixing of the sediment column. Sediment traps can provide much higher temporal resolution of phosphorus deposition than bottom sediment, and unlike periodic discrete water samples, sediment traps continuously integrate the P loading. Deployment periods can range from weeks to years. In addition to monitoring trends, data from traps can provide gross and net fluxes of P, N, C and other substances to the sediment, as well as mineralization rates, which is essential to mechanistic predictive water quality models.

Investigating the Use of Active Fluorescence in Determining Condition of Deep-Water Cyanobacteria Stratifications

Sabina Perkins1 and Jeffrey A. Schloss2
1University of New Hampshire, Durham, New Hampshire; 2University of New Hampshire Cooperative Extension, Durham, New Hampshire

Toxigenic cyanobacteria blooms are an increasingly apparent human health risk in lakes all over the world. Understanding the formation of these blooms and factors affecting the toxicity are vital to inform effective monitoring, detection, and management of lakes. Under favorable conditions, cyanobacteria have been shown to form deep-water layers in some lakes, often in oligo-
Session H1: National Lakes Assessment
8:30 am – 10:00 am | Standley I

Title TBD
Amina Pollard
US Environmental Protection Agency, Washington, District of Columbia

Abstract TBD

Phytoplankton and Zooplankton Data from the 2012 National Lakes Assessment Reflect Ecoregion and Biogeography
John R. Beaver1, Claudia E. Tausz1, Kyle C. Scotese1, Thomas R. Renicker1, and Amina Pollard2
1BSA Environmental Services Inc., Beachwood, Ohio; 2US Environmental Protection Agency, Washington, District of Columbia

Phytoplankton biovolume and zooplankton biomass (crustaceans, rotifers) data from the 2012 National Lakes Assessment were analyzed in the context of geographic and water quality variables using Canonical Correlation Analysis (CCA). Biomass and biovolume data were standardized, and a Bray-Curtis resemblance matrix was created for all three groups. Sample-matched, normalized matrices of environmental variables including Secchi depth, latitude, elevation, total phosphorus, total nitrogen, water temperature and chlorophyll (only for zooplankton CCAs) was analyzed against the biomass/biovolume resemblance matrices. Following the CCAs, samples were plotted onto ordination diagrams using the first two canonical axes. Ordinations for all three groups showed separation amongst the nine agglomerated level-III ecoregions (Herlihy et al. 2008). For all three groups, strong correlations with canonical axes (> 0.45) were observed for latitude and elevation. These results indicate that distinct geographical distributions exist amongst phytoplankton and zooplankton in lakes of the continental United States, oftentimes regardless of water quality. As a general pattern, highest zooplankton biomass and highest phytoplankton biovolume was observed in the Northern Plains and Temperate Plains ecoregions. Crustacean species were largely grouped by body size, with large species occurring in the western U.S. at high elevations and smaller species occurring primarily at lower elevations. Potentially toxic cyanobacterial genera exhibited unique relationships with different water quality variables. Data from this analysis may be useful to lake managers for the purpose of characterizing planktonic communities in local and regional systems and for predicting potential biological invasions.

Networked Lake Science: How GLEON's Global Network is Using the National Lakes Assessment Database for Research and Graduate Student Training
Kathleen C. Weathers1 and Paul C. Hanson2
1Cary Institute of Ecosystem Studies, Millbrook, New York; 2University of Wisconsin–Madison, Center for Limnology, Madison, Wisconsin

The Global Lake Ecological Observatory Network (GLEON) is a grassroots network of more than 600 members in 50+ countries conducting innovative science to understand, predict, and communicate the role and response of lakes in a changing global environment (www.gleon.org). GLEON’s international team of researchers, managers, and citizens collect, share, and interpret large datasets, with the goal of advancing lake ecology and informing sound freshwater stewardship. Although the network operates at a global scale, understanding regional to continental to cross-continental scale ecological processes is at GLEON’s core. The 2007 and 2012 National Lakes Assessments (NLA) conducted by the US Environmental Protection Agency have proven to be a rich dataset for scientific synthesis and for training the next generation of scientists while producing results that are relevant for the policy and management communities. For this talk, we will describe some of the ways GLEON researchers are using NLA data to advance our understanding of the ecology of lakes and their watersheds. NLA data have been used to better understand the: (1) importance of lake-specific characteristics for water quality, (2) interaction between climate warming and eutrophication to promote cyanobacteria, and (3) role of anthropogenic land use associated with N-fixing cyanobacterial dominance in lakes across the continental U.S. GLEON research teams are already working with the 2012 database released in December 2016 to conduct comparative analyses that are possible with the two distinct datasets. GLEON’s global network has also facilitated the transfer of experience with the NLA to inspire similar assessments now underway in Canada and Europe.
Abstracts

The Importance of Lake-Specific Characteristics for Water Quality Across the Continental United States

Emily K. Read1, Samantha K. Oliver2, Vijay Patil2, Amy L. Hetherington3, Jennifer A. Brentrup2, Jacob A. Zwart5, Kirsten M. Winters2, Jessica R. Corman6, Emily R. Nodine7, R. Iestyn Woolway8, Hilary A. Dugan1, Aline Jaimes9, Arianto B. Santoso2, Grace S. Hong10, Luke A. Winslow2, Paul C. Hanson11, and Kathleen C. Weathers14

1US Geological Survey, Middleton, Wisconsin; 2University of Wisconsin, Madison, Wisconsin; 3Alaska Science Center US Geological Survey, Anchorage, Alaska; 4Cornell University, Ithaca, New York; 5Miami University, Oxford, Ohio; 6University of Notre Dame, South Bend, Indiana; 7Oregon State University, Corvallis, Oregon; 8Rollins College, Winter Park, Florida; 9University of Reading, Reading, United Kingdom; 10University of Delaware, Newark, Delaware; 11Indonesian Institute of Sciences, Jakarta, Indonesia; 12University of Florida, Gainesville, Florida; 13Rensselaer Polytechnic Institute, Troy, New York; 14Cary Institute of Ecosystem Studies, Millbrook, New York

Lake water quality is affected by local and regional drivers, including lake physical characteristics, hydrology, landscape position, land cover/use, geology, and climate. Here, we demonstrate the utility of hypothesis testing within the landscape limnology framework using a random forest algorithm on a national-scale, spatially explicit dataset, the United States Environmental Protection Agency 2007 National Lakes Assessment. For 1026 lakes, we tested the relative importance of water quality drivers across spatial scales, the importance of hydrologic connectivity in mediating water quality drivers, and how the importance of both spatial scale and connectivity differ across response variables for five important in-lake water quality metrics (total phosphorus, total nitrogen, dissolved organic carbon, turbidity, and conductivity). By modeling the effect of water quality predictors at different spatial scales, we found that lake-specific characteristics (depth, sediment area-to-volume ratio) were important for explaining water quality (54–60% variance explained), and that regionalization schemes were less effective than lake specific metrics (28–39% variance explained). In some cases, hydrologic connectivity mediated the effect of regional-scale water quality drivers. The current regulatory practice of using regionalization schemes to guide water quality criteria could be improved by consideration of lake-specific characteristics, which were the most important predictors of water quality at the continental US scale. The spatial extent and high quality of contextual data available for this analysis makes this work an unprecedented application of landscape limnology theory to water quality data. The importance of lake morphology over other controls on water quality is relevant to both aquatic scientists and managers.

Session H2: Modeling

8:30 am – 10:00 am | Standley II

Balancing Water-Supply Constraints and Water-Quality Objectives

Taylor Adams
Hydros Consulting, Boulder, Colorado

Reservoir operations are often determined by water-supply constraints, such as the demands of water users, physical limitations, legal obligations, and many more. These constraints do not always fully determine system operations, however, resulting in the flexibility to adjust operations for water-quality objectives. Simulation of water quality-responsive operations is complicated, because most modeling frameworks are primarily focused on simulation of either reservoir operations or water-quality dynamics, with minimal crossover. A methodology for simulation of water quality-responsive reservoir operations is demonstrated for the Three Lakes System in Colorado, using a RiverWare reservoir operations model, and a CE-Qual-W2 model.

Water-Quality Modeling in Chehalis River Basin, Washington State

Robert Montgomery1, Binglei Gong2, Sarah Van Giubt1, Chris Berger3, Scott Wells4, and Paul J. Pickett4

1Anchor QEA, Seattle, Washington; 2Anchor QEA, Boston, Massachusetts; 3Portland State University, Portland, Oregon; 4Washington State Department of Ecology, Olympia, Washington

The Chehalis Basin is the second largest river basin within the State of Washington and drains an area of approximately 2,700 square miles. The Chehalis River flows approximately 125 miles north-northwesterly from the Willapa Hills to Grays Harbor and the Pacific Ocean. The Chehalis Basin has experienced both major flooding damage and substantial degradation of aquatic species habitat. These issues have persisted for almost 100 years without a comprehensive response. The State of Washington is leading a planning effort named the Chehalis Basin Strategy to address these issues in a comprehensive manner.

Water-quality models were developed to assist in the design and environmental review of proposed projects to reduce flood damage and restore aquatic species. Those projects include the construction of a flood-retention dam in the upper Chehalis Basin as well as riparian and floodplain restoration. Two options for a flood-retention dam were analyzed; a dam with a temporary reservoir during flood events (65,000 acre-feet) and a dam with a permanent reservoir pool (130,000 acre-feet).

The hydrodynamic and water-quality model CE-Qual-W2 was applied to the proposed reservoir area and to an 88-mile long reach of the Chehalis River downstream of the dam. Operational scenarios were modeled to develop recommendations for design of outlets and flow releases to meet water-quality standards for temperature. The analyses were completed using both current and future (with climate change) conditions. The Chehalis River model was developed by Portland State University and the reservoir model by Anchor QEA, both under the direction of Washington State Department of Ecology.
Session H3: PAHs
8:30 am – 10:00 am | Meadowbrook

**Coal-Tar-Based Pavement Sealants – A Potent Source of PAHs**

Barbara Mahler and Peter Van Metre
US Geological Survey, Austin, Texas

Pavement sealants are applied to the asphalt pavement of many parking lots, driveways, and even playgrounds in North America. Sealant products used commercially in the central, eastern, and northern United States typically are coal-tar-based, whereas those used in the western United States typically are asphalt-based. Coal tar (and coal-tar pitch) are known human carcinogens, and coal-tar-based pavement sealant products contain, on average, about 70,000 mg/kg polycyclic aromatic hydrocarbons (PAHs), on the order of 1,000 times higher than asphalt-based products. PAH concentrations in stormwater runoff from coal-tar-sealed pavement are highest in the months following sealant application and decrease with time, but even years after application PAH concentrations remain much higher than those in runoff from unsealed pavement. Additionally, pavement sealant is worn by vehicle tires into a fine powder that collects on pavement surfaces and at curbs and is readily transported by runoff down storm sewers. PAH-contaminated sediment that is not trapped by stormwater ponds can be transported to streams and lakes. The contribution of coal-tar-based sealant to PAHs in lake sediment has been evaluated by a variety of approaches, including environmental forensics, microscopic identification of particles, and land-use analysis. Independent research by scientists and engineers from academic institutions and government agencies demonstrates that coal-tar-based sealant is a potent source of PAHs to water, and to stream and lake sediment.

**Trends and Sources of PAHs to Urban Lakes and Streams**

Peter Van Metre and Barbara Mahler
US Geological Survey, Austin, Texas

Over the past few decades, concentrations of polycyclic aromatic hydrocarbons (PAHs) have been increasing in the sediments of many U.S. urban lakes and streams, however, understanding the causes of trends in PAHs is complicated by their many natural and anthropogenic sources. A breakthrough in identifying urban PAH sources occurred in 2003, when scientists with the City of Austin, Texas, noted that local streams with elevated PAH concentrations were immediately downstream from parking lots coated with coal-tar-based pavement sealcoat. Coal tar and coal-tar pitch, which are used in coal-tar sealcoat, consist of about 50 percent or more PAHs and are known human carcinogens. To date, multiple studies have identified coal-tar-based sealcoat as a PAH source to near-by water bodies, soils, and air. The consensus that has emerged is that coal-tar-sealcoat use accounts for roughly 50 percent to as much as 90 percent of the PAHs in urban streams, lakes, and stormwater ponds studied in the central and eastern United States. In one of these studies, we evaluated sources of PAHs in sediments from 40 lakes in urban areas across the United States using a contaminant mass-balance (CMB) receptor model and found that about one-half of the PAHs, on average, were from sealcoat. The model was used to calculate temporal trends in PAH sources to eight of the 40 lakes and in seven of the lakes, sealcoat was the largest source of PAHs since the 1960s.

**Acute Lethality of Runoff from Coal-Tar Sealcoat to Aquatic Animals, and Prevention by Green Stormwater Infrastructure**

Jennifer K. McIntyre1, Jay W. Davis2, John D. Stark3, and Nathaniel L. Scholz4

Stormwater runoff from pavements coated with coal-tar-based sealcoat contain a complex mixture of contaminants including a wide variety of polycyclic aromatic hydrocarbons (PAHs). Many PAHs are acutely harmful to aquatic animals, resulting in cardiovascular toxicity and even death. We simulated runoff events on an asphalt surface treated with a commercially available coal-tar-based sealcoat. Runoff was collected during four discrete simulated rain events that were separated by intervals of natural weathering conditions (1 wk to 7 mo). Runoff was collected untreated and also treated by filtering through experimental soil bioretention columns containing 60% sand : 40% compost by volume. Juvenile coho salmon (Oncorhynchus kisutch), zebrafish embryos (Danio rerio), and the waterflea, Ceriodaphnia dubia,
were exposed to untreated runoff or bioretention treated runoff and monitored for acute lethality and sublethal effects. Both the concentration of PAHs and toxicity to aquatic test animals decreased rapidly as a function of time since sealcoat application. Untreated runoff was highly toxic to aquatic organisms, producing acute lethality in coho and C. dubia and severe sublethal toxicity in zebrafish. For all exposure trials, bioretention treatment successfully reduced or eliminated lethal and sublethal effects of the PAH-rich sealcoat runoff.

**Reducing PAHs in Urban Waters and Sediments in Minnesota and the Great Lakes Region**

Al Innes
Minnesota Pollution Control Agency, St. Paul, Minnesota

Research findings linking increasing PAH concentrations in sediments of urban lakes, to stormwater runoff from asphalt surfaces covered with coal-tar sealant have been a significant concern in Minnesota. After more than 20 years of service, stormwater catchments in many cities are filling with PAH-contaminated sediment reducing their ability to capture both runoff and contaminants. Minnesota has developed its municipal separate storm sewer system (MS4) which requires cities to monitor and clean out stormwater ponds. Management of sediment with high concentrations of PAHs can cost cities $50 per cubic yard, up to 3 times the cost of onsite management. Some cities maintain dozens of catchments; the total statewide is in the thousands, so the individual and cumulative burden of clean-out spurred policy and prevention responses. In 2011, the Minnesota Pollution Control Agency teamed with agencies in Wisconsin and Michigan to support a coal-tar sealcoat pollution prevention project for the purpose of educating users and providers across the Great Lakes Region on tools that could reduce the use of coal-tar sealcoats, thereby reducing PAH loadings to surface waters and sediments.

The study concluded that, given conducive supporting conditions, voluntary pollution prevention initiatives can produce local pollutant reductions and build the case for wider scale (e.g., statewide) prevention efforts or restrictions on sales and use. If there is little local awareness, education can spur local government and retailer action to eliminate use, particularly where stakeholders are motivated to protect a local natural resource perceived to hold high value.

**A Restoration Project in Lake Apopka, Florida, USA, Using a Laminar Flow Aeration System to Reduce the Hypereutrophic State**

Jennifer L. Jermalowicz-Jones
Restorative Lake Sciences, Spring Lake, Michigan

Lake Apopka is a 12,500 ha (30,888 acre) hypereutrophic lake located in central Florida approximately 32 km northwest of Orlando, Florida. The lake has been the focus of intense restoration efforts over the past few decades due to excessive nutrient inputs that have devastated the aquatic ecosystem and have transitioned the lake from a clear macrophyte-dominated system to a turbid phytoplankton-dominated system.

A laminar flow aeration system was installed as a pilot project in the area known as Magnolia Park located on Lake Apopka between mid-July and mid-August of 2015. The official start-up of the technology began in mid-August of 2015. The pilot area consisted of a 250-acre parcel at the northeast quadrant of Lake Apopka. A total of 15 treatment and 8 control sites were monitored for multiple water quality parameters over a two-year period. Significant reductions in water column nutrients such as nitrogen, phosphorus, and in sediment ammonia nitrogen were noted in the treatment area. Some of these results were also noted in the control area and may indicate that the aeration system had impacts beyond the intended aeration zone. Other positive findings included the emergence of elodea and benthic biota not previously found in the aeration zone. Laminar flow aeration may be a useful tool for overcoming some of the effects of hypereutrophication, especially in regards to harmful algal blooms (HABs), taste and odor issues, and water clarity. An evaluation of this technique was conducted on Lake Mohegan, a shallow (3.7 m) 100-acre lake, located in the suburbs of northern Westchester County, New York. Even with the operation of an aeration system, Lake Mohegan exhibited weak to strong (episodic) stratification and anoxia at the sediment-water interface, HABs, poor zooplankton community composition, and poor transparency. Some of these results were possibly caused and exacerbated by inadequate mixing/design of the system. Other, more explainable factors were due to lake characteristics (i.e., iron deficiencies and mixing depth). However, the aeration approach did result in some benefits. Increased zooplankton abundance, improved fish habitat, Nitrate to Ammonium ratios, and changes in phytoplankton species composition suggested direct benefits of aeration. Modifications of the aeration approach, maximizing benefits while minimizing impacts, offer substantial improvement potential. This presentation will discuss aeration as a management approach and its applicability to Lake Mohegan and other problematic lakes.

Aeration is a commonly recommended management technique used to meet a variety of lake management goals including: 1) habitat improvement by eliminating thermal gradients and improving water chemistry, which allows for a more diverse and robust food web, and/or 2) reducing symptoms associated with eutrophication, especially in regards to harmful algal blooms (HABs), taste and odor issues, and water clarity. An evaluation of this technique was conducted on Lake Mohegan, a shallow (3.7 m) 100-acre lake, located in the suburbs of northern Westchester County, New York. Even with the operation of an aeration system, Lake Mohegan exhibited weak to strong (episodic) stratification and anoxia at the sediment-water interface, HABs, poor zooplankton community composition, and poor transparency. Some of these results were possibly caused and exacerbated by inadequate mixing/design of the system. Other, more explainable factors were due to lake characteristics (i.e., iron deficiencies and mixing depth). However, the aeration approach did result in some benefits. Increased zooplankton abundance, improved fish habitat, Nitrate to Ammonium ratios, and changes in phytoplankton species composition suggested direct benefits of aeration. Modifications of the aeration approach, maximizing benefits while minimizing impacts, offer substantial improvement potential. This presentation will discuss aeration as a management approach and its applicability to Lake Mohegan and other problematic lakes.

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Effects of Solar-Powered Circulators on Turbulence and Stratification in a Shallow Embayment of Jordan Lake, North Carolina

Robyn Smyth¹, Jeremy Smithheart¹, Yue Han¹, Tarek Aziz², and Daniel Obenour²
¹Bard College, Annandale-on-Hudson, New York; ²North Carolina State University, Raleigh, North Carolina

Artificial mixing is increasingly used to address water quality impairment from eutrophication and harmful algal/cyanobacterial blooms at considerable energy costs. Solar-powered circulators (SPCs) offer a low carbon alternative to aerators and pumps but there is very limited information available, especially in the peer-reviewed literature, on the conditions under which SPCs can effectively achieve water quality goals. In a 2015–16 demonstration project, arrays of SPCs failed to improve water quality in two shallow embayments of Jordan Lake, a large eutrophic reservoir in central North Carolina. A temperature gradient microstructure profiler (SCAMP from PME, Inc.) was used to estimate turbulence parameters (dissipation and diffusivity) in proximity to and away from the SPCs in Jordan Lake under different conditions during the summers of 2015 and 2016. Physical effects of the SPCs had a limited spatial extent and turbulence intensity in close proximity to the SPCs was consistently less than values observed following routine storm events. Findings from Jordan Lake will be compared to measurements from a nearby reservoir with an aeration system. Implications for artificial mixing for eutrophication management will be discussed.

The Challenges, Rewards, and Results of Managing a Private Shallow Lake

Sonja Wixom
State University of New York College at Oneonta, Oneonta, New York

Koinonia is a Lutheran campground located in Sullivan County, New York. The camp was settled in the early 1960s, shortly after a small dam was constructed to deepen the bodies of water on site, previously known as Mud Pond and Beaver Pond. Collectively, these bodies of water are now considered one and are known as Koinonia Lake (surface area = 0.341 km², mean depth = 1 m, maximum depth = 2 m). Koinonia Lake’s watershed is 6.008 km² and is primarily forested (88.2%, 5.3 km²). Coniferous species are the dominant trees within the watershed creating a dystrophic regime within the shallow lake. The majority of data will be collected during the 2017 summer focusing on an ecological approach and understanding. Site preservation of native species and ecological function as well as the abundance of a nuisance species, Utricularia spp., will be the focus of the management plan based on stakeholders’ primary concerns. Data to be analyzed consists of water quality parameters, as well as aquatic macrophyte, invertebrate, zooplankton, and fish community compositions.

Session I1: National Lakes Assessment
10:30 am – 12:00 pm | Standley I

Using National Lakes Assessment Results to Inform Lake-Protection Policies and Actions in Vermont, USA

Perry Thomas, Kellie Merrell, and Amy Picotte
Vermont Department of Environmental Conservation, Montpelier, Vermont

Data from the National Lakes Assessment (NLA) helped convince the Vermont legislature to enact shoreline protection measures, including new regulatory and training programs. Since 2014, the Vermont Lakes Program has been working to implement these measures. This presentation describes NLA-related findings that helped drive legislation and steps Vermont has taken to promote lake-friendly shoreline development and restoration since these findings were shared with the legislature and public.

The 2007 NLA showed Vermont trailing behind other states in the ecocregion and nation in protecting lakeshores. The low percentage of Vermont lakes categorized as “Good” was disappointing for a state that is home to the Green Mountains. Furthermore, since the 2007 NLA identified lakeshore disturbance as a major stressor, Vermont’s degraded shorelines were clearly a serious environmental concern. Two additional Vermont studies helped convince the Vermont legislature to act: 1) a Vermont-based study showed that replacing native shoreline vegetation with lawns and impervious surfaces dramatically reduced the quality of littoral habitat; and 2) a study in Maine of littoral habitat adjacent to developed sites that met Maine’s mandatory Shoreland Protection Act (in place since the early 1970s) found it was possible to develop a lakeshore and protect aquatic habitat and biota.

Vermont’s 2014 Shoreland Protection Act not only mandated a permit for new construction but also created a voluntary training program for contractors and landscapers working on shorelands. In 2016 the Lakes Program offered nine sessions of the newly developed Natural Shoreland Erosion Control Certification course to a total of 288 participants. Now, in 2017, we review lessons learned as Vermont attempts to both promote restoration of degraded lakeshore and prescribe protection of Vermont’s remaining healthy lakeshore habitat.

National Lake Assessment Overview for Indiana – 2012 Results and a Decade of Trends

Melissa Laney
Indiana University, Bloomington, Indiana

The National Lakes Assessment (NLA) is part of US Environmental Protection Agency’s (EPA) National Aquatic Resource Surveys, which are collaborative programs between EPA, states, and tribes to assess the quality of the nation’s coastal waters, lakes and reservoirs, rivers and streams, and wetlands using a statistical survey design. Some states, including Indiana, expanded on the NLA to statistically survey the condition of the state’s lakes, ponds, and reservoirs. The survey is designed to address three primary questions: 1) What is the condition of Indiana Lakes? 2) What are the key problems? 3) How widespread
Abstracts

are the problems? This talk will introduce you to the NLA design and results. While focusing on the 2012 survey results, this talk will illustrate trends from 2007 through 2017 for Indiana.

Understanding the Condition of Lakes in Minnesota Through Sampling Intensification as Part of the Environmental Protection Agency’s National Lakes Assessment Survey

Lee Engel and Jesse Anderson
Minnesota Pollution Control Agency, St. Paul, Minnesota

A primary program emphasis for the Minnesota Pollution Control Agency’s (MPCA) Water Quality Monitoring Unit in 2017 was to participate in the US Environmental Protection Agency’s (EPA) National Lake Assessment (NLA) Survey. The Survey’s random statistical design will complement the MPCA’s lake monitoring efforts used to assess lake water quality conditions and identify trends within Minnesota’s lakes. The NLA survey allows a unique opportunity to collect data that is not part of Minnesota’s routine monitoring efforts. Collection for these chemical and biological constituents provides data to analyze concentrations and species populations representative of Minnesota’s lakes and how they change over time. MPCA has used supplemental funds to intensify the survey since its inception, adding parameters and in collaboration with agency partners during the 2007, 2012, and 2017 surveys. In 2017, collection of chemical and biological parameters such as pesticides, Glyphosate, zooplankton, algal toxins, sediment, and contaminants of emerging concern (CECs) were collected for comparison to past and future surveys.

Session I2: Modeling

10:30 am – 12:00 pm | Standley II

Empirical Modeling of Periphyton Biomass Accrual in Ultra-Oligotrophic Reservoirs of Northern Vancouver Island, Canada

Chris Perrin1, Jennifer Harding2, Morgan Hocking3, Todd Hatfield4, Jim Meldrum5, and Jonathan Abell6
1Limnotek Research and Development, Inc., Vancouver, British Columbia, Canada; 2Limnotek Research and Development, Inc., Whitehorse, Yukon, Canada; 3Ecofish Research Ltd, Victoria, British Columbia, Canada; 4Laich-Kwil-Tach Environmental Assessments LP, Campbell River, British Columbia, Canada

Statistical and digital elevation models (DEM) were developed and linked to explore effects of variation in littoral area and habitat attributes on periphyton biomass accrual in two ultra-oligotrophic reservoirs on northern Vancouver Island, Canada. Littoral area was a function of water surface elevation that varied according to water management rules. Depth of the littoral zone was where photosynthetically active radiation (PAR) occurred at greater than 1% of surface irradiance. Periphyton biomass accrual culminating in peak biomass (PB) was measured over three months on substrata installed at multiple depths and replicate stations in each of summer and fall periods in the two reservoirs. Nutrient concentrations, temperature, and PAR were measured at each substratum to obtain detailed and accurate relationships between PB and those determinants of periphyton accrual. The models having strong fits to the data and the DEM facilitated simulations of change in PB with variation in habitat attributes and water surface elevation. Results can be used as a decision support tool in planning water management strategies for the reservoirs, wherein periphyton is the basis of the littoral food web.

Using AEM3D to Monitor the Effects of the Las Vegas Wash in Boulder Basin, Lake Mead

Deena Giffen and Todd Tietjen
Southern Nevada Water Authority, Las Vegas, Nevada

Baselflow in the Las Vegas Wash (the Wash) is approximately 90% highly treated effluent from wastewater treatment plants in the Las Vegas Valley, but less than 5% of the water entering Lake Mead. The Wash enters through Las Vegas Bay, flowing to Boulder Basin, where it mixes with the Colorado River water that dominates the reservoir. Despite the relatively small percentage of input from the Wash to Lake Mead, the inflow is significant as a source of nutrients for Boulder Basin. Routine water-quality sampling is conducted at dynamic sites along Las Vegas Bay and in Boulder Basin for NPDES permit compliance. Sampling locations were determined over 15 years ago, before record drought had reduced the reservoir volume by over 60%, to assess dilution of nutrients and to limit algal growth. The 3-D hydrodynamic and water quality model AEM3D was used to determine the dilution of the Wash water and nutrients at required sampling distances as lake levels decline from full pool to below forecasted future levels. As the southwest is experiencing prolonged drought conditions, the goal of this study is to determine the need to reconsider permit requirements necessary to maintain high quality water in a dramatically different system. Once dilution factors are determined for the range of lake surface elevations, regulators will have better information to revise treatment levels and sampling requirements.

Using Probabilistic Inflow Forecasts to Optimize the Operation of New York City Water-Supply Reservoirs

Simon Draijer and Michael Thiemann
RTI International, Fort Collins, Colorado

The City of New York obtains its drinking water mainly from six reservoirs. Water is transported from these storage locations to the city through two aqueducts. Because of the quality of the water, the city has been granted a filtration waiver from the US Environmental Protection Agency that imposes strict requirements on the water’s turbidity. Of the six reservoirs, four are in the Delaware River headwaters that are constrained by environmental regulations, minimum releases, and requirements of the downstream users. The two remaining reservoirs are in the Catskills and are impacted by sediment loading under large precipitation events. The City developed an Operation Support Tool (OST) that allows them optimize the operation of their water supply system to meet the turbidity requirements while still providing a reliable water supply to the city. The OST requires forecasted inflows into each of the reservoirs, which are derived from probabilistic forecasts provided by the National Weather Service (NWS) at nearby stream gages using a General Linear
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Finding Balance

Denotes that the lead author is a student.

Ecosystem Consulting Service, Inc. Coventry, Connecticut
Bob Kortmann
Management Link

Lake Ecosystem Energetics: The Missing

Simon Draijer1 and Johnny Cuevas2
1RTI International, Fort Collins, Colorado; 2Autoridad del Canal de Panamá, Balboa, Ancón, Panama

aspects of lake ecosystem structure and function offer substantial phytoplanktonic autotrophy (algae growth). However, many other lake management because it most often limits the degree of photophosphorylation. It is a role which no other atom needs on the Canal.

trans-basin imports to supplement water supply and navigation needs on the Canal.

Managing Interconnected Lakes to Supply the Panama Canal

The Panama Canal watershed includes two lakes that provide the water to operate the locks in the Panama Canal. A large part of the passage through the Canal is through Gatun Lake. Lake Alajuela is upstream of Lake Gatun and is used to control flows on the Chagres River and to serve as additional water supply for Lake Gatun. In addition, both lakes are also used for hydropower generation and water supply; the growing population in the area and increased electricity use put additional demands on the lakes that need to be balanced with the water requirements for operating the canal. The Panama Canal is an important driver of the local economy; operating the locks and providing sufficient draft for the vessels going through the canal is essential. To meet the increased demands of the lakes, including the recently completed canal expansion, the Panama Canal Authority upgraded their hydrologic forecast and management system. The new system shows all observations, including precipitation, flow, and reservoir levels in a single platform, including automated water balance calculations previously performed manually or by spreadsheet. In addition, the integrated ensemble forecast system provides long term probabilistic lake inflow forecasts that can be used in planning studies and to determine the refilling strategy of the lake during the wet season. This presentation will describe how the precipitation forecasts and joint operation tools help manage the use of the reservoirs as considerations are made for trans-basin imports to supplement water supply and navigation needs on the Canal.

Session 13: Lake Management
10:30 am – 12:00 pm | Meadowbrook

Lake Ecosystem Energetics: The Missing Management Link

Bob Kortmann
Ecosystem Consulting Service, Inc. Coventry, Connecticut

Phosphorus plays a central role in the bioenergetics of organisms and ecosystems (recall Adenosine Triphosphate [ATP], substrate level phosphorylation, cyclic and noncyclic photophosphorylation). It is a role which no other atom can duplicate. Phosphorus is of paramount importance in lake management because it most often limits the degree of phytoplanktonic autotrophy (algae growth). However, many other aspects of lake ecosystem structure and function offer substantial promise for the future of lake management and restoration. One such aspect, ecosystem energetics, is too often neglected or misunderstood by the lake manager.

There are fundamental differences between autotrophication and allotrophication, trophic and detrital dynamic structures, eutrophication and lake succession, and how these ecosystem components and processes can be effectively managed. An understanding of the nitrogen, sulfur, iron, and phosphorus cycles of lakes yields insight into new restoration technologies (e.g., alum surrogates, anaerobic aeration, biomanipulation) and potential long-term impacts of existing methods (sulfate loading, copper sulfate, aluminum sulfate). Methods to control eutrophication, and its in-lake consequences, are directly related to the energetics of a lake ecosystem, as are treatments of symptoms. Lakes are complex ecosystems in which all living organisms interact collectively with physical and chemical processes of the environment. Understanding a lake ecosystem is understanding nature, and will lead to more effective stewardship of the ecosystem in which we play a major role. This introduction to lake ecosystem energetics is intended to illustrate some fundamental relationships among biology, ecology, physics, chemistry, and lake management.

Data and Science to Support Water-Quality Management Balance in the Cherry Creek Basin, Colorado

Harry Gibbons1, Julie Vlier2, Shannon Brattebo3, and Chuck Reid4
1Tetra Tech, Inc., Seattle, Washington; 2Tetra Tech, Inc., Denver, Colorado; 3Tetra Tech, Inc., Spokane, WA, USA; 4Cherry Creek Basin Water Quality Authority, Greenwood Village, Colorado

Since 1987 the Cherry Creek Basin Water Quality Authority (Authority) has collected data to inform managers and regulators on the condition of the Cherry Creek Reservoir and its watershed and provide a scientific basis to water quality management decisions. The watershed/reservoir management program includes monitoring of physiochemical and biological parameters of streams, BMPs, groundwater and reservoir conditions. Data and science support actions to promote water quality protection and the Authority is actively exploring watershed and reservoir management alternatives to achieve their goals. Steps to date have been taken to control nutrient sources in the watershed, including point source controls and implementation of BMPs that both enhance habitat and improve water quality. In addition, in-reservoir aeration alternatives continue to be implemented and evaluated.

However, some phosphorus inflows remain high at over 250 µg/L, resulting in phosphorus retention within the reservoir of 2500 kg of P and 9500 kg of N per year. This contributes to internal loading and the total nutrient availability has resulted in growth season chlorophyll average concentrations ranging from 12 to over 31 µg/L for the past 25 years. The challenges associated with keeping a reservoir system in balance – improving water quality, preserving and enhancing beneficial uses of the reservoir and its basin, and economic realities are the subject of this case study on the dynamic and adaptive effort being pursued by the Authority.
Grand Lake is the largest natural lake in Colorado, and an important component of the Colorado-Big Thompson (C-BT) Project. It was also the first lake in the state to have a site-specific clarity standard. Natural hydrology and C-BT operations can both have significant impacts on clarity in Grand Lake, as water-quality data and analyses conducted over the past decade have shown.

Adaptive management for clarity in Grand Lake began in 2016, with the goal of satisfying the clarity standard while simultaneously protecting water rights and aquatic life. Based on the current conceptual understanding of Grand Lake and the rest of the west-slope C-BT system, several water-quality monitoring criteria and thresholds were identified and used to inform the adaptive management process. These criteria were based on clarity in Grand Lake, as well as water quality in Shadow Mountain Reservoir, which is connected to Grand Lake. Following the initial year of adaptive management, the criteria and thresholds were reevaluated after incorporating additional data from 2016.

This presentation describes the initial development of the adaptive management monitoring criteria, highlights the importance of reevaluating monitoring criteria as part of the adaptive management process, and emphasizes the importance of a thorough analysis of real-time monitoring data.

### Dilution of Moses Lake for Forty Years: Hypereutrophic to Mesotrophic

**Gene Welch, Shannon Brattebo, Harry Gibbons, and Chris Overland**

1Lake Advocates, Seattle, Washington; 2Lake Advocates, Spokane, Washington; 3Moses Lake Irrigation and Rehabilitation District, Moses Lake, Washington

Beginning in 1977, Moses Lake has been consistently diluted with large quantities of low nutrient (20 µg/L) Columbia River Water (CRW) for 40 years. Inputs of CRW during April-June averaged 130 × 10⁶ m³/yr from 1977–1988 when total phosphorus (TP) averaged 69 µg/L – 56% less than predilution 1969–1970 when CRW input was at only 5 × 10⁶ m³/yr. The increased input represented 1.7 volumes of the most input-affected lake. Inputs of CRW continued through the mid 1990s at twice that rate, but have averaged even higher since 2000 (320 × 10⁶ m³/yr) – replacing over 4 volumes of affected lake, resulting in much lower average TP (22 µg/L) – 56% less than predilution 1969–1970 when CRW input was at only 5 × 10⁶ m³/yr. The increased input represented 1.7 volumes of the most input-affected lake. Inputs of CRW continued through the mid 1990s at twice that rate, but have averaged even higher since 2000 (320 × 10⁶ m³/yr) – replacing over 4 volumes of affected lake, resulting in much lower average TP (22 µg/L). Dilution water is low in specific conductance (SC), which can be traced in the lake. Thus, lake SC was inversely related to CRW input (r² = 0.73). Nitrate-N:SRP (soluble reactive P) ratio has increased since 2000, averaging 7, compared to the ratio in 1977–1988 (1.5), due to halving of SRP concentration. That indicates less severe N limitation of growth rate than in the initial dilution years, with possibly less advantage to N-fixing cyanobacteria. Chlorophyll has likely decreased from early dilution years (19 µg/L), in relation to decreased TP, to about 6 µg/L, assuming a constant chl:TP ratio. This ongoing control of eutrophication by dilution was possible because of the lake’s proximity to the Columbia Basin Irrigation Project managed by the US Bureau of Reclamation.

### Session 14: Managing Shallow Lakes

**Shallow Lake Restoration in a Highly-Altered Landscape: Results and Management Implications from Iowa**

**Michelle B. Balmer**

Iowa Department of Natural Resources, Des Moines, Iowa

Shallow lakes and wetlands once dominated the landscape throughout the prairie pothole region in the Midwestern United States. Since European settlement began, much of the region has been altered to make way for intensive agricultural production, resulting in altered hydrology throughout the region and the net loss of wetlands and shallow lakes from the landscape. In Iowa, over 97% of the land use has been transformed over the last 200 years, resulting in the loss of over 99% of the wetlands and shallow lakes from the Des Moines Lobe, the prairie pothole region of the state. The remaining shallow lakes have become highly degraded due to stabilized water levels and altered hydrology, nutrient loading from the watershed, and internal loading associated with the introduction of rough fish and intensive boating.

Efforts to restore shallow lakes in Iowa began in the mid-2000s through the installation of water control structures, removal of rough fish, and partial or complete drawdowns to allow for the consolidation of sediments and germination of emergent aquatic vegetation. Following restoration, lakes have “flipped” from a turbid to a clear water state and aquatic vegetation has re-established throughout the basins. Changes in water clarity, nutrient concentrations, and the aquatic community have also been observed. Water quality and aquatic biology data in pre- and post-restoration lakes were examined to establish benchmarks and thresholds for managers to use when making decisions about future management action.

**Influence of Land Use and Climate Variability on Nutrient Concentrations in Florida Lakes**

**Chao Xiong and Mark V. Hoyer**

University of Florida, Gainesville, Florida

Geology and physiographic characteristics can determine background nutrient concentrations in lakes. This research examined the impact of land use type (agriculture, urban, forest and wetland) on nutrient concentrations (total phosphorus and total nitrogen) in Florida lakes, after accounting for local geology. Static relations between land use type and nutrient concentrations were examined for 87 lakes within individual phosphorus zones (TP zones established for Florida’s numeric nutrient criteria) for two discrete time periods (1989/1990 and 2009/2010). Agriculture and wetland, showed significant positive correlations with nutrient concentrations within each period. Surprisingly, urban land use showed significant negative relations. Forest
cover showed significant negative correlations with nutrients. Examination of concurrent changes in nutrients and land use over time (1889/1990 to 2009/2010) showed only two significant positive relations (one each with agriculture and wetland) out of a possible 24 comparisons. Adjusted cumulative rainfall deviation (ACRD) was significantly correlated with nutrient concentrations within individual lakes over time. Multiple significant negative (seven for TP and 11 for TN) and positive (25 for TP and 11 for TN) relations were found between nutrient concentrations and ACRD. Discovery of both positive and negative correlations between rainfall and lake nutrient concentrations over time suggests that multiple mechanisms related to cumulative rainfall influence lake nutrient concentrations. This research suggests that land use and other factors can impact nutrient concentration in Florida lakes and a thorough investigation of individual lakes must be considered before adopting a nutrient management plan.

**Session J1: Data Management**

1:30 pm – 3:00 pm | Standley I

**New Data Web Portal for Global Environmental Monitoring**

Steve Elgie¹, Jens Proche², and Frank Schlaeger³

¹KISTERS North America, Sacramento, California; ²KISTERS North America, Denver, Colorado; ³KISTERS Aachen, Aachen, North Rhine - Westphalia, Germany

The United Nations Global Environmental Monitoring System (GEMS) Water Programme is dedicated to providing environmental water-quality data (sample results and continuously measured data) of the highest quality, integrity, accessibility and interoperability. This data is provided to the public via the GEMStat website to be used in water assessments and capacity building initiatives. The water-quality data currently includes more than 3,000 stations, over 100 parameters, almost four million sample records and is submitted to GEMStat by national focal points of governmental agencies.

In March 2014 the hosting of the GEMStat component was taken over by the German Federal Institute of Hydrology (FIH). The FIH completely redesigned the data storage and management component as well as the representation of data, including the data download portal.

The data storage, management and analysis system was replaced by the KISTERS water-quality module KiWQM. This module was specifically designed to manage, validate and analyse discrete sampling data along with continuously measured real time sensor data. As KiWQM is fully integrated into the WISKI system it takes advantage of features such as flexible data structuring, powerful calculations, scripting and graphing functionalities.

The KISTERS Web Interoperability Solution (KiWIS) will provide environmental monitoring data to the public and allow specialists to easily download the data as required. The KiWIS solution is a single framework for multiple web service types and serves several data sources at one time such as HTTP GET/POST KVP services (KiQS, SOS1/2) and SOAP (WaterOneFlow, SOS2). The KiWIS supports user authentication and authorization for members to view and download their data but restricts guest users from accessing. In addition to powerful web services, KiWIS provides WISKI data for specific web widgets such as creating dynamic time series graphs or displaying descriptive station metadata. The GEMS portal will be set up by applying this functionality and overlaying with mapping capabilities.

**High-Frequency Limnological Data Collection: Utility and Challenges**

Kiyoko Yokota and Paul H. Lord

State University of New York College at Oneonta / Biological Field Station, Oneonta/Cooperstown, New York

Modern advances in limnological data collection technologies provide an unprecedented amount of high-frequency data that reveal previously unnoticed spatial and temporal patterns in physical, chemical and biological processes in lakes and reservoirs. Some of these technologies have become much more affordable in recent years, while more expensive and sophisticated technologies may still be cost-effective when they provide highly informative data for high-stake management decisions. We present a case study from Otsego Lake, a glacial mesotrophic lake in Central New York State, where we started to collect high-frequency lake data as part of the Global Lake Ecological Observatory Network (GLEON) with a series of simple temperature and light loggers, which is now being upgraded to an automated buoy system funded by the National Science Foundation. Examples of system configuration, cost, collected data, and data analysis methods as well as our experience with planning, deployment, and maintenance will be presented.

**Harnessing Open Source to Collect and Manage Your Data Better and Cheaper**

K. Kelly Close

Leonard Rice Engineers, Inc., Denver, Colorado

We are collecting more data than ever before, in the interest of managing and protecting our precious lakes and reservoirs. But the costs of collecting and managing all that data add up, and it is expensive to review all of that data, understand it and make good use of it. Don't forget the very critical need to then communicate the information contained in that data to non-technical audiences such as regulators, educators, and stakeholders. How can we find the money to make all this happen?

Free and Open Source software can help. Not only are the modern tools developed under free and open source programs more advanced than many of the proprietary tools we've used for decades, these new tools are usually web-based, intuitive for end users to navigate, and there has been so much work done with them now throughout the world that chances are, what you need has already been built!

Come see live examples of Free and Open Source tools that are currently being put to work collecting, managing, and displaying water quality and other environmental data. Learn about how to stand on the shoulders of others and save time and money by building your own tools from similar open source tools others have already been finished. This will be a technical talk, and we'll discuss the most useful and reliable open source projects and programming languages available to you now.
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Session J2: Aquatic Plant Management
1:30 pm – 3:00 pm | Cotton Creek

Balancing Target and Non-Target Impacts of Macrophyte Management in Paradox Lake, New York
★ Alexa Tumbarello
State University of New York Oneonta Biological Field Station, Cooperstown, New York

Paradox Lake is a dual‐basin, meso‐oligotrophic lake in Essex County, New York. In 2008, Eurasian watermilfoil (Myriophyllum spicatum) was identified in the upper basin near a public boat launch. Stakeholders immediately established the goal of preventing spread into the larger, lower basin of the lake which supports regionally popular fisheries for a variety of species. Like many lake associations, the Paradox Lake Association (PLA) has struggled to balance target and non-target results of macrophyte management. Since its introduction, annual hand harvesting of Eurasian watermilfoil has kept it from establishing in the lower basin. Although the original goal of containing the Eurasian watermilfoil to the upper basin has been maintained, stakeholders are now faced with an unintended consequence of harvesting – lower water clarity and increased algal growth in the upper basin. I will discuss the history behind plant management in this system, the challenges with macrophyte management in multi‐basin lakes, and how stakeholders expect to achieve some balance between plant coverage and increasing algal growth.

The Role of Aquatic Plant Harvesting in Lake Management
Kenneth J. Wagner, Maxine Verteramo, and Toni Stewart
Water Resource Services, Wilbraham, Massachusetts

Mechanical harvesting of aquatic plants has been practiced for more than half a century, with a variety of technological and operational advances and a range of experience that should provide a fairly reliable assessment of potential benefits and limitations. Yet there are few peer reviewed papers and much speculation in presentations about the role of this technique in lake management. Here we examine the control of rooted aquatic plants and removal of nutrients with mechanical harvesting in the context of a decade of experience at Morses Pond in Wellesley, Massachusetts.

Assessment of New Zealand Lakes Using Submerged Plants as Bio-Indicators
Tracey Burton
NIWA, Hamilton, Waikato, New Zealand

Submerged aquatic plants are increasingly being used in New Zealand as biological indicators to monitor change and assess lake ecological condition using the LakeSPI survey method. LakeSPI (Lake Submerged Plant Indicators) is a management tool that has been used to assess more than 280 New Zealand lakes. It uses key features of aquatic vegetation structure and composition to generate three LakeSPI indices: a Native Condition Index which characterises the status and quality of native vegetation within a lake, an Invasive Impact Index which captures the degree of impact from invasive weed species and an overall LakeSPI Index that provides an overall indication of lake ecological condition. Conceptionally, it was designed on the principles that high biodiversity and extent of native submerged vegetation indicates good ecological condition, whilst increasing replacement by invasive weed species or decline in vegetation presence signals worsening condition. LakeSPI results are being used to report on the status of lakes at an individual, regional or national level, monitor changes occurring within a lake or group of lakes over time and to prioritise lake management initiatives (e.g., protection, monitoring, weed surveillance). LakeSPI results are supported by a web-reporting service at www.lakespi.niwa.co.nz.

Mesocosm Evaluation of Multiple Invasive Watermilfoils Response to PROCELLACOR – A Novel Herbicide Technology
Mark Heilman1, Michael Netherland2, Jens Beets3, and Chetta Owens4
1SEPRO Corporation, Carmel, Indiana; 2US Army Corps of Engineers, Gainesville, Florida; 3University of Florida, Gainesville, Florida; 4US Army Corps of Engineers, Lewisville, Texas

Hybrid lineages of Eurasian Watermilfoil (Myriophyllum spicatum - EWM) crossed with native Northern watermilfoil (M. sibiricum) are a growing challenge to freshwater sites throughout North America. Recent studies in the laboratory and in the field have documented that hybrid watermilfoils (HWM) may be more aggressive than EWM and display less response to a variety of different management strategies including reduced efficacy of typical rates / use patterns of multiple currently registered aquatic herbicides. PROCELLACOR™ is a novel reduced-risk herbicide technology under development for aquatic use and anticipated for US Environmental Protection Agency approval in 2017. PROCELLACOR (a.i., benzyl 4-amino-3-chloro-6-(4-chloro-2-fluoro-methoxyphenyl)-5-fluoropyridine-2-carboxylate) has unique, low-rate (50 ppb or less), short-exposure, systemic activity for selective control of major US submersed weeds including hydrilla (Hydrilla verticillata) and invasive watermilfoils. Relative to selectivity of control, PROCELLACOR has shown little to no effect on common US native submersed plants such as tapegrass (Vallisneria americana), common waterweed (Elodea canadensis), and pondweeds (Potamogeton spp.) as well as most common native emergent plants. In spring 2017, the response to multiple CET (concentration-exposure time) scenarios of PROCELLACOR was tested on four different HWM lineages from multiple northern US sites, 2 distinct EWM lineages, and native northern watermilfoil. These plants were established in late summer 2016 and allowed to overwinter before treatment in mid-April 2017. Plants were strongly established at time of treatment. Rates up to 12 ppb PROCELLACOR were evaluated with flowthrough-generated dissipation half-lives of 3 or 6 hours (simulating spot treatment) or 7 days (large partial treatment). These responses were compared to similar CET scenarios for common rates of 2,4-D or the combination of 2,4-D and endothall (dipotassium salt). Results showed that EWM lineages were highly sensitive to short, low-rate exposures of PROCELLACOR while the various HWM were less sensitive, but all were controlled at 12 ppb with short exposure. The 2,4-D alone or 2,4-D endothall combinations had good activity on...
EWM but greatly reduced activity on the various HWM lineages in the study. PROCCELLACOR appears to hold great promise for localized selective removal of HWM/EWM from infested aquatic sites.

Session J3: Lake Management
1:30 pm – 3:00 pm | Meadowbrook

Lake Management Adrift
Dick Osgood
Lake Advocates, Duluth, Minnesota

The profession and practice of managing lakes is adrift. There has been no net change in lake quality since the passage of the Clean Water Act, aquatic invasive species are overrunning our lakes, HABs are an increasing public health threat and water supplies are becoming undependable. Our (individuals, institutions & NALMS) response to and support for these threats has been half-hearted. We do stuff, but we neither expect nor demand tangible outcomes – with an obvious result. Fake science is increasingly prevalent and funding is waning. Are these concerns actionable, and if so, what should change? To make headway, we need a) compelling imperatives, b) cogent scientific underpinning and c) coherent institutional support. I will offer thoughts on tough choices, remedies and maybe coping.

Advanced Sediment Management – Adjustable and Continuous
Michael Detering and Thorsten Loechter
1DB Sediments GmbH, Duisburg, Germany; 2Uferstaal DB Sediments GmbH, Essen, Germany

Dams create a mass imbalance in the dynamic equilibrium of a river system. Upstream, the impounding structure causes lower current velocities and therefore profoundly more sedimentation in the storage basin. The dam itself is a barrier for sediment transport. Sedimentation impairs the usage of reservoirs (e.g., flood protection, power production) with economic and social consequences, among others, the loss of storage volume. In the river section downstream, the interrupted sediment transport leads to a sediment deficit. A sustainable sediment management strategy must address both imbalances while being economically attractive and environmentally sound. Conventional sediment management strategies often fail to deliver such solutions.

A concept replicating the previous natural sediment transport is needed. Continuous remobilization and transport of the sediment within the water body from the reservoir to the downstream river section is the strategy to aim for.

Recently, an economically favorable technique for continuous sediment transfer was successfully developed in cooperation with German Technical Universities. Sediments are transferred over (e.g., spillway) or through (e.g., the turbines of a hydropower plant) the impounding structure and released into the downstream river section. The equipment used is designed to operate unmanned and self-positioned in a reservoir 24/7, 365 days a year. The combination of scalable pump capacity, a controllable remobilization tool and monitoring devices, allows adjusting the sediment transfer to cope with environmental demands and possible limitations such as turbidity or solid concentration downstream.

First projects in Europe and Latin America indicated that “ConSedTrans” can be adapted to various projects’ demands.

Operation and Effects of an Intake Barrier Curtain in Iron Gate Reservoir on Downstream Water Quality in the Klamath River, California
Demian Ebert1, Mike Deas2, and Edwin Limanto2
1Pacific Power, Portland, Oregon; 2Watercourse Engineering Inc., Davis, California

Iron Gate reservoir, formed by Iron Gate dam, is the downstream-most hydroelectric reservoir on the mainstem Klamath River. The reservoir is subject to blooms of the cyanobacteria _Microcystis aeruginosa_ which produce the toxin microcystin. An impermeable curtain was installed in 2015 in Iron Gate reservoir upstream of the Iron Gate powerhouse intake to reduce releases of both _Microcystis_ and microcystin to the downstream Klamath River. The curtain was designed to be deployed at variable depths to segregate surface waters from deeper waters, reducing entrainment of cyanobacteria and associated toxins into the intake. Focused evaluations in 2015 and 2016 generated an array of data used to evaluate curtain function. Results from these two years indicated that the curtain was successful at segregating surface waters, and inducing withdrawal of deeper waters from Iron Gate reservoir. The curtain significantly reduced cyanobacteria and microcystin levels downstream of Iron Gate dam. These findings indicate that the curtain is a potential management tool that can be used to address issues pertaining to downstream cyanobacteria and associated toxins, and other water quality issues in the basin. Management challenges in the Klamath range from springtime water temperatures affecting juvenile salmon outmigrating and disease rates, to toxic cyanobacteria blooms causing public health concerns, to fall water temperatures affecting the migration and spawning of Chinook salmon. The curtain has demonstrated the ability to influence water quality downstream of Iron Gate dam and could be used to address some of these challenges.

Use of Aquatic Filter Barriers to Control Water Quality Impacts from Concentrated Nonpoint Sources
Andrew J. McCusker1, Melissa Hamlin1, Jaret Johnson2, and Chris Guelke3
1Mackworth-Enviro, Scarborough, Maine; 2Mackworth-Enviro, Chapel Hill, North Carolina; 3Mackworth-Enviro, Clinton, Connecticut

Aquatic filter barriers (AFBs) have been used to protect the water quality of lakes and reservoirs since the late 1990s. These full-depth, bottom-sealed underwater curtains have protected the drinking water supply of New York City from airport runoff, the drinking water supply of Boston from stormwater flows, Northeast and northern Midwest lakes from elevated nutrient loading, and a recreational lake in New Hampshire from toxic algae blooms. Each AFB application for lake protection has been a...
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relatively novel and new approach to water quality protection, and the technology is not yet widely known, especially among inland, managed western waters and fisheries.

Each application of the AFB for lake protection has been individually designed for the specific location and goals. Characteristics of the physical water body, its natural or managed elevations and flows, short- and long-term goals and many other factors all become part of an AFB's design basis. This site-specific adaptability has allowed for the AFB's use for a wide variety of environmental circumstances and for a breadth of knowledge to be gained about its capabilities.

The presentation will discuss AFB design considerations, successes and lessons learned, and applicability within managed reservoir environments to protect lake water quality for drinking water and other uses.
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Propose a session or topic! Call for papers will be available at nalms.org in January 2018

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