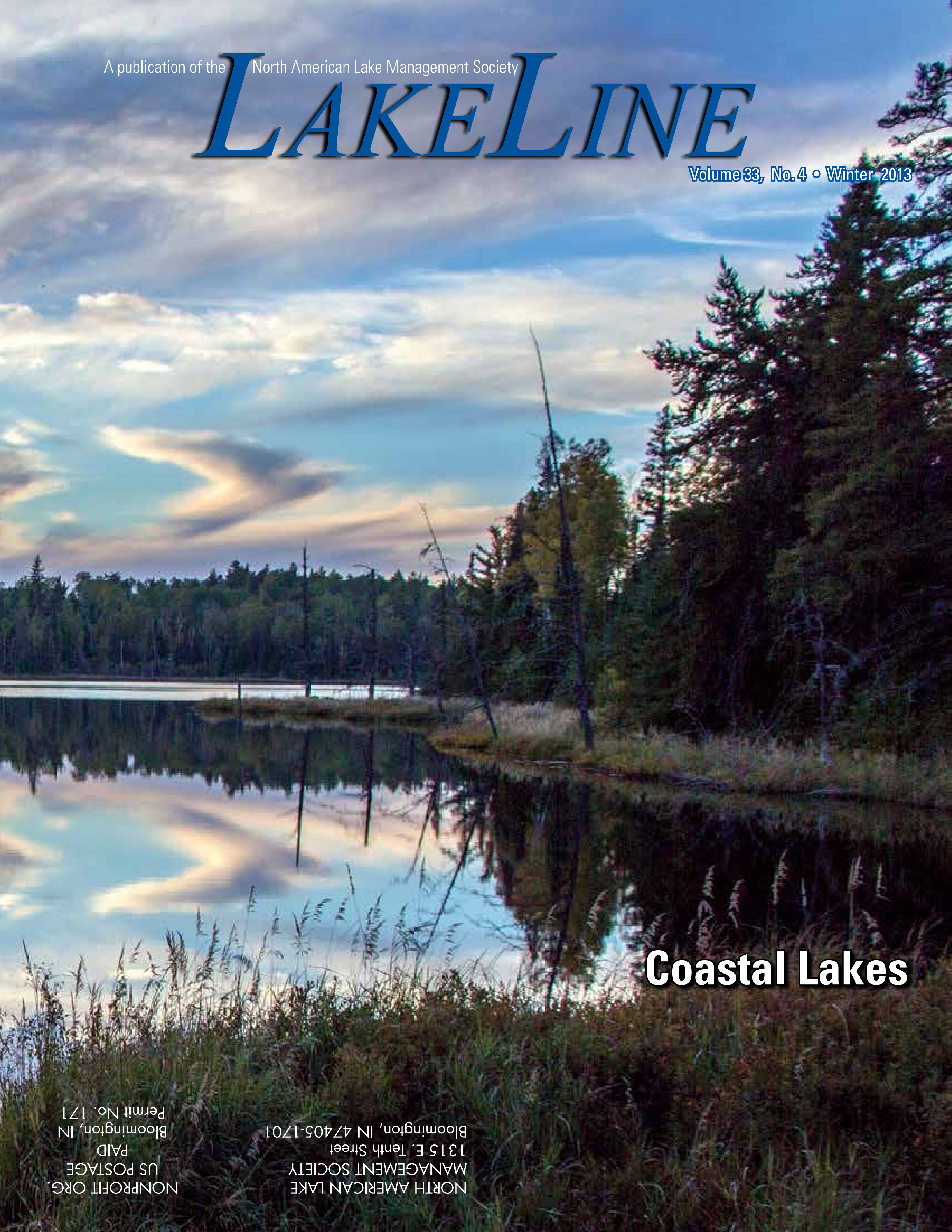
A publication of the North American Lake Management Society

LakeLine

Volume 33, No. 4 • Winter 2013



Coastal Lakes

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LakeLine

Contents

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On the cover:
"Swamper's Lake" by Jeff Spence, the first place Peoples' Choice award in the 2014 NALMS photo contest.

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4510 Regent Street
Suite 2A
Madison, WI 53705
(All changes of address should go here.)
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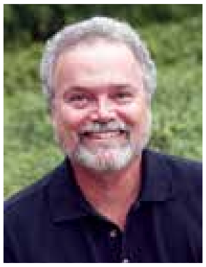
Address all editorial inquiries to:
William Jones
1305 East Richland Drive
Bloomington, IN 47408
Tel: 812/334-3485
joneswi@indiana.edu

Address all advertising inquiries to:
Philip Forsberg
NALMS
PO Box 5443
Madison, WI 53705-0443
Tel: 608/233-2836
Fax: 608/233-3186
forsberg@nalms.org

From Bill Jones the Editor

> *LakeLine* encourages letters to the editor. Do you have a lake-related question? Or, have you read something in *LakeLine* that stimulates your interest? We'd love to hear from you via e-mail, telephone, or postal letter.



We've had an unusually snowy and cold December thus far here in southern Indiana. As a Wisconsin native, I still look forward to winter each year. For those of you living where you are not favored with snow, let me offer several reasons for my joy: (1) shoveling snow is a much better and satisfying exercise than driving into town to the gym; (2) a pot of homemade savory soup tastes so much better on a cold winter's day; (3) the heat from the wood-burning stove feels fantastic; and (4) they don't call it a "winter wonderland" because it is ugly. I hope that you will find time to curl up in your favorite comfortable chair with this winter issue of *LakeLine* and forget about the weather outside, whatever it might be.

The annual NALMS elections were held in the fall. In his first *From the President* column, we learn something about new President **Terry McNabb** and his vision and goals for our Society.

We next include highlights from warm sunny, San Diego, the site of 33rd International NALMS Symposium. Some 400 attendees were treated to a great program, fine weather, and a chance to renew friendships and to make new ones. We met the newly elected NALMS Officers and recognized those who achieved noteworthy success with projects. We also learned the identity of this year's Secchi Disk Award winner. All of these highlights are included here.

The theme of this issue is "Coastal Lakes." Ever since I first read about coastal lakes in the winter 1999 *LakeLine* (Vol. 19, No. 3-4) I've been fascinated by these dynamic and unique systems. Coastal lakes were again mentioned in the winter 2010 *LakeLine* (Vol. 30, No. 4) issue on Northwestern Lakes but we've never featured them in an issue…until now.

Coastal lakes are often formed by ocean sand washed ashore that blocks a stream discharging into the sea. This sand plug creates a lake behind it that can last for many years, long enough for a freshwater, lacustrine system to establish. The plug is assailed from both sides – by runoff from intense rain storms or snow melt from the land side, and by storm surges from the sea. People have described coastal lakes as having a split personality; sometimes they are freshwater and sometimes they become brackish. This creates obvious stresses on the aquatic biota within coastal lakes and interesting management decisions.

We'll start our journey in this issue with a Cape Cod coastal pond, travel down the Atlantic Coast, and then jump across the continent to travel up the Pacific coast all the way to British Columbia. Along the way you'll be introduced to a variety of coastal lake types and some really interesting stories.

Cape Cod has more than 900 ponds within five miles of the coast. Recorded use of these ponds dates back to the Pilgrims. **Ed Eichner** describes one of them, Cedar Pond. Inadvertent and ill-advised management decisions have affected Cedar Pond for 175 years. In nearby Rhode Island, a dozen or so "salt ponds" dot a 20-mile-long stretch of that state's southern coast. Each is different from the other as **Elise Torello** and **Rhonda Smith** tell us in their article. No state is in the news more during hurricane season than Florida. The frequency of hurricanes wreaks havoc with Florida's coastal dune lakes. **Antonio Yaquian** and **James Jawitz** have studied the hydrology of several coastal lakes on Florida's panhandle and they report on one, Camp Creek Lake.

The coastal lakes of Oregon were formed some 6,000 years ago due to rising sea levels that pushed sand dunes inland impounding coastal streams. In addition to describing the history and limnology of Tenmile Lake, **Joe Eilers** also reports on the colorful challenges he faced while working on the lake. Limnologists often face similar challenges while in the field but I'll wager that few of us have ever encountered a dead human body bobbing in the water! I'm glad to welcome frequent contributor, **Doug Larson**, to these pages again and he doesn't disappoint. Drawing on his nearly 50 years of history with Cleawox Lake in Oregon, Doug assembled a detailed and well-documented story of this lake. Finally, we travel up to British Columbia where glacial activity 10 to 15 thousand years ago carved out deep basins with classic fjörd morphometries. **Rick Nordin** describes one of these, Nitinat Lake where the interplay between fresh and brackish waters causes disruption to the lake's biota and to humans living nearby as well.

In our *Student Corner*, **Victoria Chraïbi**, a doctoral student at the University of Nebraska, writes about her experiences travelling to Austria to study the resilience and adaptive management of stressed watersheds. We conclude this winter issue with *Literature Search*.

Enjoy!

From Terry McNabb the President

Now that I am two weeks into my term at the President of NALMS, my first duty is to communicate with the membership on this page. So here we go. . . .

First, a bit of an introduction. I was born in Madison, Wisconsin, to a graduate student at the UW in the 1950s. My dad received a Ph.D. in aquatic biology in that timeframe and was working with many of the pioneers in lake management. He went on to teach at UW Whitewater where he was working on the Kettle Lakes in southeast Wisconsin. As a child he took me everywhere with him and from my earliest days I was blessed to be exposed to the science of lake management. During the summers, he took our family to the UW Pigeon Lake Camp in Northern Wisconsin where he taught aquatic ecology and limnology and as kids we got to ride around on the water with the students and give them a hand. There was always a one-week camping trip where we packed 40 people with camping gear, lab equipment, and boats into an isolated bog-ringed lake and spent the week studying it. From there he went to St. Mary's College in Winona, MN and put together a hydro-biology lab and program on the Mississippi River. Those summers we spent doing things like pumping Rhodamine dye into the river at the outfall of treatment plants while they studied where things went and at what concentration, and keeping the grad students from using the electrofishing boat to catch dinner. In 1968, he moved on to Michigan State University – my freshman year in high school at a time where invasive aquatic plant were beginning to take over the region. Again we got to visit hundreds of lakes and study the impact of these species on these systems. He brought me and a number of his grad students to the Madison Lakes meeting in the late 1970s that eventually lead to the formation of NALMS. In my professional career, this head start from the time I was old enough to walk was a blessing and I have been lucky to make a career out of something I was taught to love from birth.

While my Dad passed about 11 years ago, one of the most remarkable things that happened was the outpouring of multi-page letters to my Mom from grad students both known and unknown to the family. They all had a common theme, he had made the same contribution to the lives of a huge number of people in our field. As I look around the NALMS membership and our recent meetings, it's clear that a significant number of our older members have done the same good work and touched many lives, including mine. It's also clear that the next generation is taking on that mission. It's impressive to see the current crop of professors and their students getting excited about this mission of contributing to the protection of North America's water resources.

So I am thankful for the opportunity to work for and with you for this coming year. A couple of thoughts on what I have seen and what we as a group want to accomplish in 2014.

My first year on the board as the President-Elect was very eye-opening. As a member you take a lot of things for granted about organizations like this, the magazine and journal come in the mail when they are supposed to, the annual meeting is always well run and informative, and you get good value for the dues you pay. Seeing first-hand the work that goes into making this happen was an enlightening experience. We have a very dedicated Board of Directors who donate their time, talent, and often their money into making sure these things happen. We also have an excellent staff that takes care of the key long-term and day-to-day functions of our organization.

As most of you know, we have just moved our corporate status from Maine to Wisconsin where our headquarters is located. The bylaws we were required to adopt to meet Wisconsin law spell out a number of committees that the Society has to maintain and we did this at our annual board and membership meetings a few weeks back in San Diego. We have also, through the hard work of board member Jason Yarbrough and his committee, just completed a Strategic Plan for our organization. We want to take this opportunity to really re-invigorate our committees and with the plan in place we have "to do" lists for all of these. Our standing committees are:

- Bylaws
- Executive
- Financial Advisory
- Grants, Marketing and Fundraising
- Nominating
- Outreach and Education
- Publications

Give this list a good look and think about what talents you have that might contribute a bit of time toward helping us move forward in these areas. This isn't a huge commitment of time, but like me I think you will find this very rewarding work and it is an excellent opportunity to meet some new people and make some new friends.

We are also launching or re-invigorating a number of programs we run to support our membership and our

(. . . continued on page 16)

NALMS 13

Symposium Highlights

~ Philip Forsberg

NALMS attendees flocked to San Diego, California, for our 33rd International Symposium, hosted by the California Lake Management Society (CALMS). NALMS and the local host committee welcomed approximately 380 attendees from 39 states and the District of Columbia, 5 Canadian provinces, Australia, Brazil, Germany, Japan, Mexico, Puerto Rico, South Korea, and the United Kingdom to the 2013 Symposium, held October 30 – November 1.

The Town and Country Resort & Conference Center was the site of the 2013 Symposium. Photo: Bill Jones

The week kicked off on Tuesday with five pre-symposium workshops on a variety of topics including, algal identification, internal phosphorus loading, and eutrophic assessment modelling, among others. Our traditional Tuesday evening welcome activities included a reception for new NALMS members and first-time NALMS symposium attendees followed by a Margarita Meander in Old Town San Diego, "the Birthplace of California."

The theme for this year's symposium was "Lake Management in an Era of Uncertainty," and was kicked off by plenary talks on Wednesday morning by Carly Jerla of the Bureau of Reclamation and Dr. Jeffrey Mount of the University of California, Davis. Ms. Jerla's talk focused on water supply and demand in the Colorado River Basin, while Dr. Mount discussed the water management challenges faced in California considering the state's ongoing drought and the use of the legal system to adjudicate water use disputes. On Thursday morning, Dr. Alex Horne presented a plenary talk focused on the uncertainties in lake management along with solutions to some lake management problems.

The symposium program included 39 concurrent sessions, with approximately 150 oral presentations and 25 poster presentations. Featured session topics included harmful algal blooms, dreissenids, and nutrient management, in addition to many other topics.

The annual Clean Lakes Classic 5K Run/Walk was held on a meandering route through the grounds of the Town & Country Resort complex and attracted approximately 40 participants. For the third straight year, Shoeless Paul Gantzer from Kirkland, Washington was the overall winner. He bested his time from last year by about 2 seconds with a time of 17 minutes, 23 seconds besting his nearest competitor by more than a minute. Fellow Washingtonian, Megan Skinner led the women with a time of 20:53. Next year, maybe we should handicap Paul by making him wear shoes to give someone else a fighting chance!

Runners vie for position at the start of the Clean Lakes Classic. Photo: Todd Tietjen

Wednesday evening's Exhibitors' Reception and Poster Session gave attendees an extended opportunity to visit the exhibit booths as well as take in the poster presentations and interact with the poster presenters. On Thursday, NALMS' Annual Awards and Recognition ceremony was included as part of that morning's plenary session and honored NALMS members and friends for their contributions to the society and to the field of lake management. NALMS' most prestigious award, the Secchi Disk Award, went to Mark Hoyer, the Director of the Florida Lakewatch Program and a past president of NALMS.

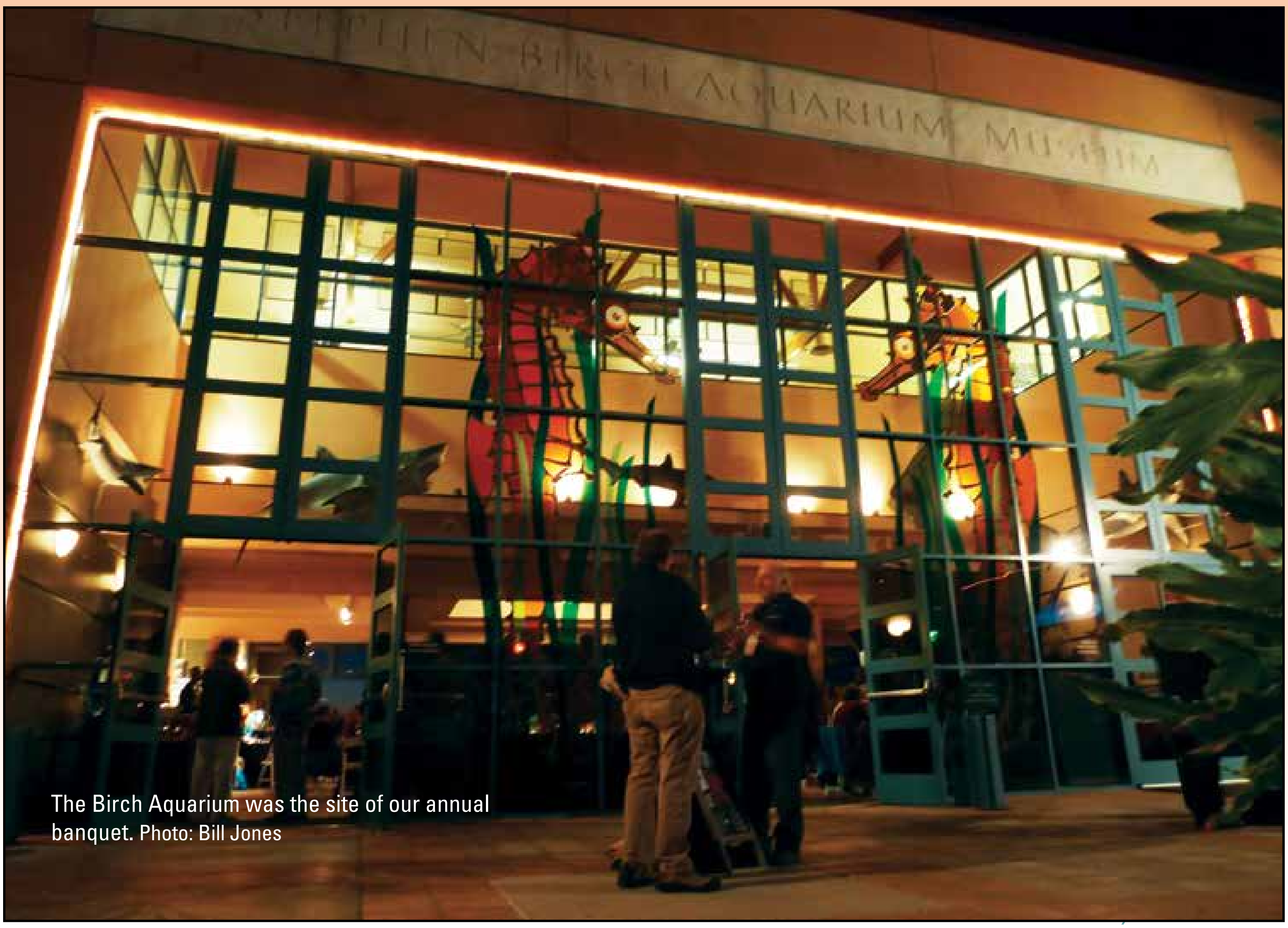
Our annual banquet was held this year at the Birch Aquarium at Scripps Institution of Oceanography in La Jolla, California. Attendees arrived just in time to take in a beautiful sunset over the Pacific Ocean. Once the sun went down, attendees enjoyed dinner, drinks, a chance to explore the Aquarium, and the company of fellow attendees on a beautiful autumn evening in Southern California.

NALMS and the host committee would like to thank all of the companies and organizations that offered sponsorship and support for this year's symposium. Without their generous support, as well as that of our exhibitors, we would not be able to provide the conference experience that our attendees expect.

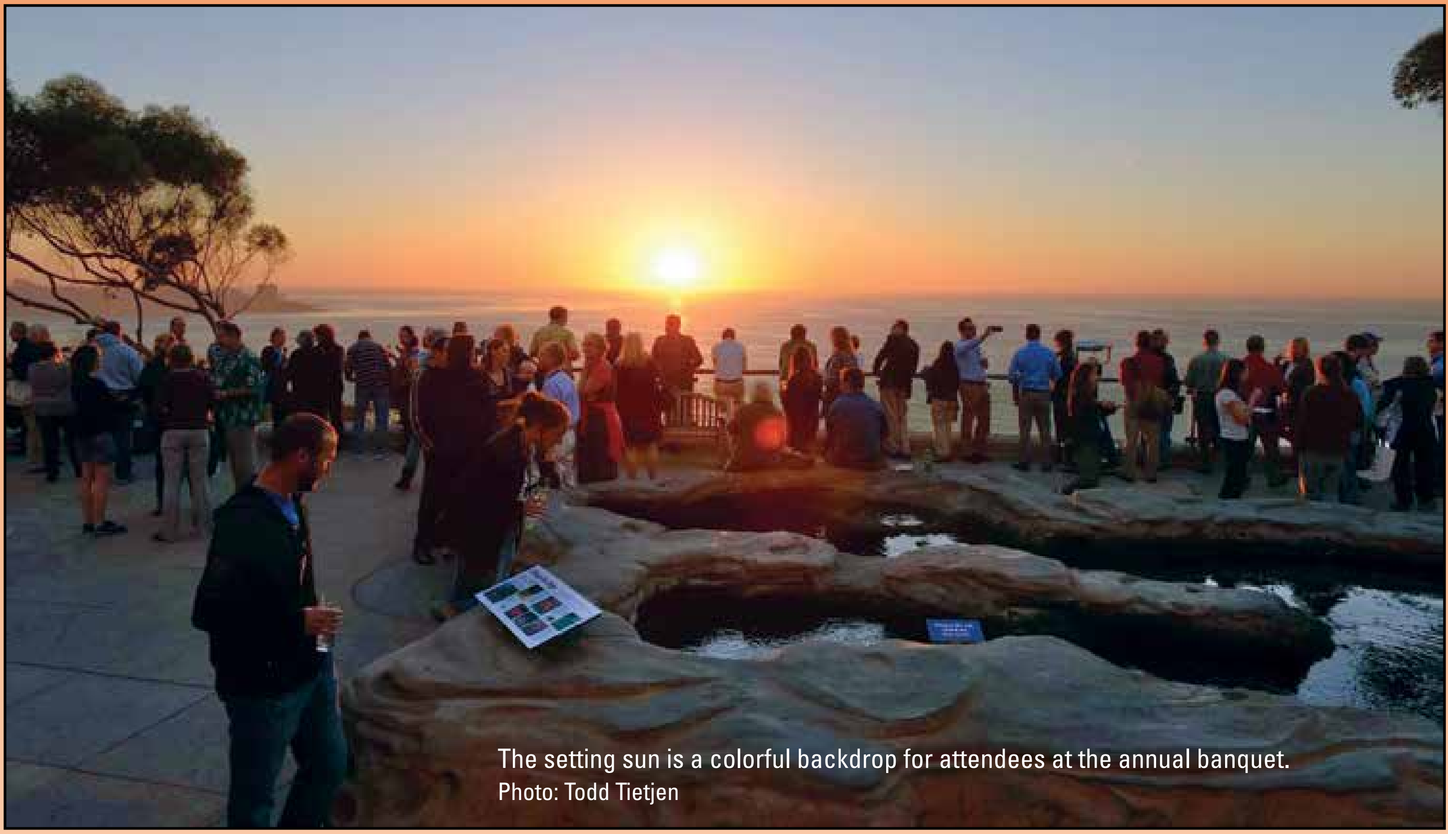
Thank you to all who attended this year's symposium! We look forward to seeing you next November in Tampa, Florida, for NALMS 2014!

Past-President Al Sosiak passes the gavel to incoming president, Terry McNabb at the annual business meeting. Photo: Bill Jones

The Exhibitor's Reception occurred on Halloween Eve. Photo: Bill Jones



The Birch Aquarium was the site of our annual banquet. Photo: Bill Jones



The setting sun is a colorful backdrop for attendees at the annual banquet. Photo: Todd Tietjen

The huge kelp forest tank was one of the more interesting exhibits at the Birch Aquarium. Photo: Bob Kirschner

Thank you to our symposium sponsors and supporters!

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Thank you to the 2013 symposium host committee!

Imad Hannoun, Chair
Todd Tietjen, Cochair
Bill Taylor, Program Committee Chair
Greg Arenz
Doug Ball
Philip Forsberg
Chris Holdren
Rich Losee
Jeff Pasek
Jeff Schloss

Members of the host committee: Rich Losee, Bill Taylor, Imad Hannoun, Todd Tietjen, Doug Ball, Jeff Pasek, and Chris Holdren. Photo: Todd Tietjen

NALMS San Diego 2013

Lake Management in an Era of Uncertainty
33rd International Symposium of the North American Lake Management Society
October 30 – November 1, 2013
San Diego, California

The 2013 NALMS Awards

~ Dick Osgood, NALMS Awards Committee Chair

A major highlight of this year's annual symposium in San Diego, California, was the recognition of individuals and organizations for their contributions to lake management and to the North American Lake Management Society.

Directors and Officers

The challenge and responsibility for keeping the NALMS ship afloat rests with NALMS officers and board members. We gratefully acknowledge the tremendous contribution each of these individuals has made or will make to NALMS. The following outgoing directors and officers were recognized this year:

- Past President – Al Sosiak
- Treasurer – Linda Green
- Region1 – Amy Smagula
- Region 3 – Nicki Bellezza
- Region 5 – Lyn Crighton
- Region 9 – Imad Hannoun

These incoming directors and officers were elected:

- President-Elect – Reed Green
- Treasurer – Mike Perry
- Region 1 – Wendy Gendron
- Region 5 – Melissa Clark
- Region 9 – Todd Tietjen

These directors were re-elected:

- Student At-Large – Lindsey Witthaus
- At-Large – Jason Yarbrough

Technical Merit Awards

Awards are given in these five categories.

- ***Successful Projects*** – for demonstrable success in achieving lasting improvements in water quality or recreational utility through lake and/or watershed management in a cost-effective manner. Projects are evaluated with respect to project success, cost-effectiveness, and benefit duration.
- ***Volunteer Actions*** – for individuals or groups involved in documented grass-roots efforts to manage a lake or watershed, with emphasis on local involvement, creative methods of funding and demonstrable success.
- ***Research Efforts*** – for individuals or groups performing research that contributes to the science of lake management. Selection criteria are relevance, approach and applicability (copies of journal papers should accompany Nominations).
- ***Public Education/Outreach*** – for individuals, groups or programs that have creatively and effectively contributed to the development and dissemination of watershed management and/or related educational programs, materials and/or assistance.
- ***Jim LaBounty Award*** – This award is given for the best paper published in *Lake and Reservoir Management* as determined by the editor and associate editors of the Society's technical journal.

This year's technical merit awards are:

Technical Merit Award for Successful Projects (2 Awards)

(1) Lake Shoreline Restoration at the Chicago Botanic Garden

Scenic water vistas and diverse aquatic habitat are defining landscape elements throughout the Chicago Botanic Garden's 60-acre system of interconnected lakes. Scientific studies in 1998 documented serious threats to these lakes, noting in particular the poor stability of shoreline soils and the near absence of native shoreline vegetation. Beginning in 1999, the Garden has engaged in a systematic rejuvenation of its lake shoreline using innovative bioengineering techniques. These approaches rely heavily on dense stands of native vegetation to control erosion of fragile lakeshore soils, establish ecologically diverse communities of native shoreline plants, enhance wildlife habitat, and demonstrate the importance of healthy lake ecosystems for visitors. To date, 4.5 miles (79 percent) of the Garden's lakeshore have been rejuvenated using a half-million native shoreline plants.

Aquatic habitat and wetland plantings along the Garden's lakeshores – previously measured in inches – now extend 50 feet or more. Innovative approaches for creating stable, shallow-water shelves along the lakeshore allow the new native plants to flourish and anchor shoreline soils. The project's planting palette, representing 210 species of native perennials and 34 species of native shrubs, focuses on resilient "workhorse" species that are carefully

Bob Kirschner of the Chicago Botanic Garden.

chosen for their ability to anchor shoreline soils and withstand environmental stresses inherent to urban waterways. By placing the plants in modest-sized drifts, the result has been ecologically functional lakeshore landscapes that offer a widely accepted aesthetic appeal. Creative uses of interplanted stones and boulders, as well as specialized plastic mesh and webbing materials, further help stabilize the shoreline edge and protect the newly installed aquatic plantings. Nutrient reduction strategies, including fertilizer management and nuisance waterfowl control, have lowered in-lake phosphorus concentrations by more than 50 percent.

Both private and public funds have been used to support the Garden's ambitious efforts including significant assistance from the U.S. and Illinois Environmental Protection Agencies, the U.S. Army Corps of Engineers, the Illinois Department of Natural Resources, and the Woman's Board of the Chicago Horticultural Society. The shoreline restoration efforts have received widespread recognition and commendation at the regional, state, and national levels.

The restored shorelines demonstrate to public and professional audiences innovative and effective approaches for restoring and protecting urban lake ecosystems – while serving as a living laboratory for Garden scientists and their colleagues studying urban water resource conservation. Through the School of the Chicago Botanic Garden, workshops and seminars help homeowners and landscape professionals learn from the Garden's experiences. Planting beds in restored habitats include identification labels so that the Garden's nearly one million visitors each year can learn more about the wide diversity of native plants used. Publications, brochures, interpretative signage, tours, and website information allow the public to expand their knowledge about urban lake ecosystems even more.

(2) Lake Reduction of Phosphorus, Pathogen, Sediment and Floatable Loading to Deal Lake

Encompassing 155 acres and with over 27 miles of shoreline, Deal Lake is the largest of New Jersey's coastal lakes. This highly eutrophic lake is on the State's List of Water Quality Limited Waters due to chronic violation of total phosphorus and fecal coliform standards. Additionally due to its 4,400 acre densely urbanized watershed, the lake receives large amounts of floatables during every storm. Nevertheless, Deal Lake is highly used by the community for fishing and boating.

As documented in the lake's Watershed Protection Plan, these impairments are directly attributable to inadequate stormwater management. In 2011, the Deal Lake Commission (DLC) implemented two projects to reduce pollutant loading and to demonstrate that it is possible to implement cost-effective stormwater management solutions, even though the lake's watershed is highly urbanized.

The first project involved the installation of a Suntree Baffle Box manufactured treatment device (MTD) to manage the runoff discharged from a 48-inch stormwater outfall. The device focused on the removal of floatables, sediments, and particulate pollutants.

The second project entailed the construction of three bioretention stormwater management basins. Each BMP was specifically designed to infiltrate runoff and reduce phosphorus, sediment, and bacteria loading. The combined cost of both projects was $225,000. The stormwater benefits associated with both projects were quantified; for the MTD post-installation water quality sampling was conducted whereas for the other BMPs improvements were predicted using the USEPA STEPL (4.1) Model.

On this basis, these pollution reductions occurred:

At the MTD: total phosphorus (53%), soluble reactive phosphorus (50%), *E. coli* (30%) and total suspended solids (67%)

At the other BMPs: 69% for total phosphorus, 56% for total nitrogen, and 89% for total suspended solids

Not only do these BMPs have a positive effect at their specific installation location, but the data show that use of similar BMPs elsewhere in the Deal Lake watershed would be valuable.

As part of this overall project the DLC also restored two badly eroded segments of shoreline. The DLC also

Steve Souza accepts the award for the Deal Lake Commission

implemented an extensive multi-media outreach program to promote the project's benefits to the community.

The DLC worked closely to implement these projects with NJDEP, Asbury Park, and Ocean Township. Technical assistance was provided by Princeton Hydro, LLC and Leon S. Avakian, Inc. The funding for these projects was provided through the NJDEP by means of a USEPA Section 319(h) grant.

TECHNICAL MERIT AWARD FOR PUBLIC EDUCATION/OUTREACH EFFORTS

Clear Choices Clean Water

Clear Choices Clean Water (CCCW) is a campaign to increase awareness and action about decisions homeowners make and the impact these decisions have on our lakes and streams. It is a combined effort of two Indiana watershed organizations. The campaign employs an online pledge system, interactive website at www.ClearChoicesCleanWater.org and an advertising initiative that includes the use of themed postcards, radio promotions, TV commercials, billboards, and social media outreach.

One of the unique aspects of the CCCW campaign is that it's focus and approaches are rooted in baseline data on social indicators. These data were used to target practices that people were not doing, but were willing to try. Thus, the CCCW has very focused messaging encouraging four practices: using phosphorus-free lawn fertilizer, landscaping with native plants, managing pet wastes, and properly maintaining septic systems. By educating individuals on these important actions and giving them the tools they need to make these essential changes on their own properties, the CCCW campaign empowers people to do their part for water quality.

One of the program's greatest strengths is the degree to which it engages participants. The online pledge – the central focus of the campaign – is supported by other tools that help the participant feel a part of something bigger and capable of *making a difference*. A watershed layer on the pledge map helps

Jill Hoffman and Lyn Crighton of Clear Choices Clean Water visitors identify their watershed and show how many people in their region have pledged. After pledging, participants learn how much pollution their action will eliminate from lakes and streams. A thank you email with this data is immediately sent to the participant. Four additional e-mails are sent within 60 days to provide positive feedback and other opportunities to help improve water quality.

The most meaningful measures of excellence are the program's impacts. The pledge campaign and website track the number and location of pledges, number of visitors, and an estimate of the amount of pollutant load reduction achieved. In the three years since the launch of the campaign, more than 17,000 people made over 24,630 total visits to the website. More than 2,160 pledges to make *Clear Choices* were made. Cumulatively, these pledges amount to the following reductions in pollution and improvements to water quality:

- 737,200 pounds of phosphorus runoff per year eliminated
- 363,000,000 pounds of algae each year prevented from growing
- 3.75 trillion fecal coliform bacteria (from 605 dogs) saved from local waters
- 715,200 pounds of sediment impeded

The *Clear Choices Clean Water* campaign is extremely relevant, targets many people who may not realize that they are part of the problem, and uses the latest social marketing techniques to best communicate with and target the audience. CCCW was featured in the summer 2013 issue of *LakeLine* and has won several awards, including the Indiana Governor's Award for Environmental Excellence. The Clear Choices Clean Water campaign deserves recognition by NALMS for its novel approach and measurable outcomes with a 2013 Public Education/Outreach Award.

LaBounty Best Paper Award

The James LaBounty Best Paper Award is presented annually to the paper deemed by the Editorial Board to be the "best" one published in *Lake and Reservoir Management* in the past year. This is always a difficult decision, and in reality, which paper is best really depends on the needs of the readers, which vary quite a lot. Just being nominated represents an honor, as this means that a very rigorous review by the Editorial Board finds each nominated paper to be worthy of special notice, usually because of its value to lake management. The nominees for the LaBounty Best Paper Award for 2013 were:

- Kurek, Lawlor, Cumming and Smol: 28 (3):177-188. Paleolimnology with chironomids and DO
- Debroux, Beutel, Thompson and Mulligan: 28 (3):245-254. Hypolimnetic oxygenation for WQ
- Frischer, Kelly and Nierzwicki-Bauer: 28 (4):265-276. Zebra mussel larvae detection
- Enache, Charles, Belton and Callinan: 28 (4):293-310. Paleolimnology with algae and TP
- Jones, Johnson and Newman: 28 (4):364-374. Herbicide impacts on native vegetation
- Cross and Jacobson: 29 (1):1-12. Land use vs. TP and fish
- Qin: 29 (1):33-46. Large scale biomanipulation experiment
- Eldridge, Wood, Echols and Topping: 29 (1):68-81. Algal toxin occurence in relation to algae

They are all winners, and it was again a very difficult decision, requiring multiple ballots, but only one paper can be awarded the prize. The recipient of the James LaBounty Best Paper Award for *Lake and Reservoir Management* for 2013 was **Timothy Cross** and **Peter Jacobson**. 2013. Landscape factors influencing lake phosphorus concentrations across Minnesota. *Lake & Reservoir Mgmt* 29 (1):1-12. All authors are to be congratulated on their nominations, but Tim Cross and Pete Jacobson are especially recognized for their excellent contribution to lake management.

Jody Connor Student Awards

Each year NALMS presents student awards to the best student presentation and best student poster at the annual NALMS symposium. The awards are sponsored by Water Quality Solutions. The NALMS Board renamed the student award as the Jody Connor Student Award in memory of Jody Connor, a long-time friend of NALMS who was active on the Education Committee and participated in the reviews of student presentations and posters.

The first place winner receives a check for $200 and a plaque. Honorable mention or second place winners receive a plaque. The Student Awards Committee is co-chaired by Alex Horne and Frank Browne. Members of the committee include Amy Smagula, Harry Gibbons, Holly Waterfield, Jennifer Graham, Ann St. Amand, and Alan Cibuzar. The awards are based on scientific merit, research design, visual aids, clarity, and presentation.

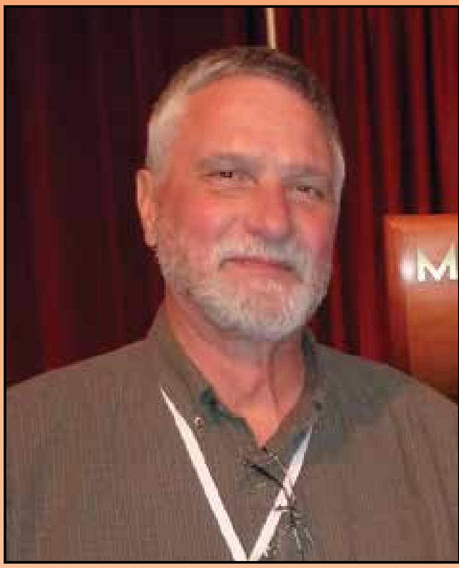
The 2013 first-place winner of the student presentation award was **Megan Skinner** from Washington State University for her paper "Feeding Ecology of a Mixed Cold- and Warm-Water Fish Community Following Hypolimnetic Oxygenation in Mesotrophic Twin Lakes, WA." The second place award went to **Ashlie Watters** from the University of Nevada, Las Vegas for her paper "Evaluating the Efficacy of Quaternary Ammonium Compounds for Wildland Firefighting Equipment Exposed to Dreissenid Adults and Veligers."

The 2013 first-place winner of the student poster session was **Jacob Shiba** from the University of California, Riverside for his poster "Sediment Properties Affecting Methane Storage and Ebullition in Southern California Lakes." Honorable mention for the poster session was **Megan Skinner** from Washington State University for her poster "Feeding Ecology of a Mixed Cold- and Warm-Water Fish Community Following Hypolimnetic Oxygenation in Mesotrophic Twin Lakes, WA."

Students are encouraged to present scientific papers at the NALMS symposium; it provides an excellent way to present research data and maybe win an award. We thank Water Quality Solutions for sponsoring the student awards.

2013 SECCHI DISK AWARD

"Presented to an individual member for depth of service and clarity of vision."



Mark Hoyer

Mark Hoyer is the perfect example of how an individual can contribute to while also enabling NALMS to achieve its goals. He has worked since the early 1980s as an active and effective volunteer to promote NALMS' goals both within NALMS and through his professional career. Both reflect his avocation of working toward better management of lakes and reservoir through science and public understanding.

Mark is the Assistant Director of Research and Program Services in the Program of Fisheries and Aquatic Sciences at the University of Florida and he is the Director of the Florida LAKEWATCH program, which Mark helped start. LAKEWATCH works with over 1,500 citizen scientists who monitor the water chemistry of 610 lakes, 130 near-shore coastal stations, and 125 river stations. Mark has researched the relationships among water chemistry, aquatic macrophyte communities, fish, and aquatic bird communities in Florida streams, lakes, and estuaries for over 30 years.

Mark has been a member of the NALMS for 30 years attending and presenting papers at all but about four of the annual conferences during that time. In the early 1990s when NALMS was facing tough financial times, Mark was instrumental in moving the NALMS office from Washington, DC, to Florida and then setting up and helping to manage the new NALMS office in Madison. During that time Mark was also the program chair for the 1994 NALMS conference. Mark has helped NALMS form partnerships with the Aquatic Plant Management Society and helped edit a jointly produced manual on aquatic plant management. Mark is a NALMS Certified Lake Manager (CLM) and an AFS Certified Fisheries Scientist (CFS). Mark has been especially active in NALMS serving as NALMS President-Elect in 2009, President in 2010 and Immediate Past President in 2011.

Mark has also been active in Florida Lake Management Society (FLMS) since its beginning in the early 1990s, receiving FLMS awards for Best Paper (1993), The President's Award (1996), and the Edward Deevy, Jr. Award (2008). Additionally, Mark serves on the Executive Board for the National Reservoir Fisheries Habitat Partnership, representing NALMS. He also serves on the Florida Water Resources Monitoring Council representing Volunteer Monitoring Programs and under that entity is actively working with both the Groundwater Salinity Network Working Group and Coastal Water Monitoring Network Working Group

Mark has consistently supported the NALMS journal, publishing 26 of his 80 refereed manuscripts in *Lake and Reservoir Management*, while also acting as a reviewer for dozens of manuscripts submitted to the journal. Mark has also been instrumental in bringing students into the organization and establishing student representation on the Board of Directors. Mark has brought both science and public outreach to NALMS as he has worked to consistently to promote NALMS and its goals.

(. . . from the President, *continued from page 5)*

mission. Our Professional Certification Program is one that I feel personally is very beneficial and potentially under-utilized by our membership. I think each of you that have not gone through the process should give it a look and consider if it would benefit you in your career. Our Student Programs and Student Award Program are also key and very important to the future of our Society. These are the people that will both sustain our Society into the future and do the good work to protect our lakes and reservoirs throughout their careers. We welcome member participation in this key mission was well and want to put some energy into this in 2014.

This issue of *LakeLine* focuses on Coastal Lakes. Growing up in the Midwest, moving to the West Coast of our country was eye-opening. There are a number of lakes along the Oregon Coast that are especially interesting in terms of being unique, a number of these vie for the title of "Shortest River in the World" at their outlet to the Pacific Ocean. A number of these systems have significant salmon runs moving through them and provide shelter and refugia for the little guys on their way out to sea. Invasive aquatic plants and introduced predator species are placing another undo burden on these systems and I'll be interested to learn more from the authors as they write about these unique water bodies.

Thanks for choking down my first message from the President, I'm looking forward to helping the Society to keep moving in the right direction.

Terry McNabb has been working in the field of lake and aquatic plant management for about 40 years and specializes in management of invasive aquatic species. He is a graduate of Michigan State University and works primarily in the Western United States. He lives in Bellingham, Washington, with his family.

2013 NALMS Photo Contest

The annual NALMS Photo Contest showcases not only many beautiful lakes from around North America but also the talents of our member photographers. Fourteen photographers submitted entries this year. This year's Photo Contest was sponsored by Water Resources Services, a consulting company located in Massachusetts. We awarded a $250 prize to each first place finisher in two categories:

1. **People's Choice** – as voted on by delegates attending the Annual NALMS Symposium.

2. **Editors' Choice** – chosen by *LakeLine* Editor-in-Chief Bill Jones and *LakeLine* Production Editor Cynthia Moorhead for the entry that would make the best cover for *LakeLine*. We considered composition, image and color quality, and general aesthetics.

We thank all the photographers who submitted this year and encourage all NALMS members to keep their cameras with them as they work, recreate, and travel.

This year's winners are pictured below.

People's Choice First Place –
"Swamper Lake" by Jeff Spence

People's Choice Third Place –
"Peek-a-Boo Frog" by Marisa Burghdoff

People's Choice Second Place –
"Leigh Lake – Grand Tetons" by Kevin Bierlein

Editors' Choice –
"Lake Everest Sunset" by Chris Mikolajczyk

NALMS San Diego 2013

Lake Management in an Era of Uncertainty
33rd International Symposium of the North American Lake Management Society
October 30 – November 1, 2013
San Diego, California

The 2013 NALMS Election Results

The annual election for officers and directors is an important way for NALMS members to provide input in the management of the Society. Our officers and directors are all volunteers who serve without pay. Thank you to all of the candidates for their dedication to NALMS and thank you to all NALMS members who participated in this year's election!

President-elect
Reed Green

Reed Green has been a member of NALMS since 1987. He has been with the USGS Arkansas Water Science Center since 1989 as Hydrologist (Limnologist) conducting a variety of reservoir and watershed studies. Prior to that, he worked with the USACE at Waterways Experiment Station (now ERDC) from 1986-1989 in their Aquatic Plant Control Research Program. He holds a B.S. and M.S. in Botany (1982 and 1985, respectively) and a Ph.D. in Biology (Limnology, 1998) from the University of Arkansas. Reed's project work with the USGS deals mostly with watershed hydrology and reservoir limnology and he has authored or co-authored over 35 USGS or USACE reports, journal papers, etc. When Reed is not on the softball field, coaching youth baseball or basketball, in the vegetable garden, teaching night classes at the local university, or leading a men's class on Sunday morning, you can find him on his fishing kayak.

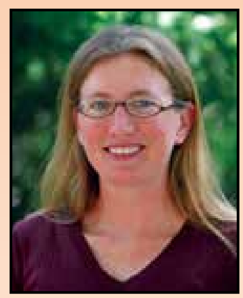
Treasurer
Michael Perry

Michael J. Perry has served on the Board of Directors of the Florida Lake Management Society since July 2001 and as Treasurer since June 2003. He was elected as the NALMS Region 4 Director in 2012. Mike serves as the Executive Director of the Lake County Water Authority. He has been in that position since July 2000, responsible for the surface and groundwater resources in Lake County and managing an annual budget in excess of $20 million. He has earned a B.S. in Marine Science and Biology from Jacksonville University in Jacksonville, Florida and a Masters of Science from the University of South Carolina. Prior to the Water Authority, Mike spent 12 years with the Southwest Florida Water Management District. Mike has over 27 years of extensive technical experience with managing the needs and implementation of restoration projects for large and complex estuarine, river and lake systems.

Region 1 Director
Wendy Gendron

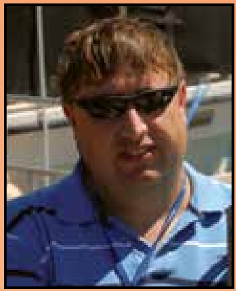
Ms. Gendron is a Certified Lake Manager with 17 years of experience in water resources management. She currently owns Aquatic Restoration Consulting, LLC, a small consulting firm specializing in lake, river, and watershed management. She also works as a Project Manager with the Army Corps of Engineers managing large aquatic restoration projects. Prior to 2009, she worked at AECOM as an environmental consultant. She's been a NALMS member since 1998 and has participated at annual symposia as presenter, session monitor and on the membership committee. She is active in the local chapter (NEC-NALMS) where she serves on the Leadership Committee and as Secretary.

Region 5 Director
Melissa Clark



Melissa, a Certified Lake Professional, is the Director of the Indiana Clean Lakes Program (CLP) and has been managing the Limnology Laboratory that administers the CLP through Indiana University's School of Public and Environmental Affairs (SPEA) since 2000. The CLP program also includes an expanding Volunteer Monitoring Program for 80 lakes with future efforts to include Aquatic Invasive Species early detection surveys. Melissa completed various Lake and River Enhancement projects for both lake and watershed diagnostic studies. She develops lake water quality monitoring programs for individual lake associations throughout Indiana. Melissa is a Senior Lecturer at SPEA. She teaches Limnology and Lake & Watershed Management.

Region 9 Director
Todd Tietjen



Todd Tietjen has been working in lake management and applied limnology for over two decades. He received a B.A. in Environmental Studies from Alfred University, a M.S. in Aquatic Biology from Southwest Texas State University, and a Ph.D. in Aquatic Ecology from the University of Alabama. For the past five years he has worked as the staff limnologist for the Southern Nevada Water Authority working on Lake Mead and the Lower Colorado River. Prior to this he was an Assistant Professor of Aquatic Resources at Mississippi State University. He was co-chair of the NALMS 2013 conference and an associate editor for *Lake and Reservoir Management*.

Student At-large Director
Lindsey Witthaus

Lindsey's love of lakes began at a young age with frequent family trips to local reservoirs and grew during her undergraduate career at the University of Pittsburgh, where she studied past climate using lake sediments from the Yukon Territory. In 2012, she completed her MS in Environmental Science utilizing in-lake nutrient empirical models. Currently, she is a doctoral student at the University of Kansas in the Environmental Science Program studying the implications of extreme climate events on water quality in Kansas reservoirs. Lindsey's first interaction with NALMS was at the fall 2010 meeting. Following the fall meeting, Lindsey worked with Dana Bigham and others in the NALMS student committee and in 2013 served on the NALMS Board as Student At-large Director.

At-large Director
Jason Yarbrough

Jason earned his B.S. in Fisheries Management from Auburn University (1997) and his M.S. in Fisheries Science from Mississippi State University (MSU, 1999). Jason is the manager of the Tennessee Valley Authority's (TVA) Aquatic Monitoring & Analysis workgroup, which is responsible for the biological monitoring of TVA's impact(s) on the Tennessee River watershed's aquatic resources. Jason has been a NALMS Certified Lake Professional since 2011. Due to the vacancy created by the election of the NALMS' At-Large Director to a regional directorship during NALMS' last election, Jason was appointed to and has been serving as the At-Large Director for the past year.

Fresh, Salt, or Brackish: Managing Water Quality in a Coastal Massachusetts Pond

Eduard Eichner

Introduction

Massachusetts is known as the Bay State, but what often goes unnoticed is that it is also blessed with thousands of lakes and ponds. Cape Cod, a peninsula that juts out into the Atlantic Ocean, is one of the regions in Massachusetts that has more than its fair share of ponds with over 900, all within five miles or so of the coast (Eichner et al. 2003). (Massachusetts lakes are legally "ponds." Ponds greater than ten acres are "Great Ponds" and are publicly owned. The terms "ponds" and "lakes" are typically used interchangeably.) Many of these ponds have been used and altered over the past few centuries in numerous ways, including supplying drinking water, irrigating cranberry bogs, and powering mills. However, one of the most profound and historically important uses has been the connections of many of these ponds to the nearby ocean.

Anadromous and catadromous fish runs have been a key to much of Massachusetts' history and the driving force for much of the alterations over the years. When the Pilgrims first arrived, local Wampanoag tribes helped the early colonists to understand the use of alewife, in particular, as a source of both food and fertilizer. Much of the region's lobster industry was based on the use of alewives as bait fish. As dams were installed in the 17th and 18th centuries to run various types of mills, a dynamic tension between needs for fish runs and power generation began to develop. Later years saw the installation of fish ladders and, in some cases, creation of new fish runs where none had existed. During the 19th century, unemployed Civil War veterans were hired in some cases to create connections to inland, kettle hole ponds on Cape Cod. But the power that the dams provided and the lack of legal requirements for sufficient fish ladders eventually saw the decline of the alewife fishery (Belding 1920).

Modifications of these types of management battles are now being fought pond-by-pond and state-by-state throughout the nation over eutrophication concerns and what constitutes appropriate "restoration" under the Clean Water Act. Massachusetts is no different in this sense, but the long history of the use of many of these ponds and their – often enhanced – connections to the coast, have created added dimensions of what restoration should be. A recent assessment of Cedar Pond in the Town of Orleans on Cape Cod helps to underscore these issues.

Cedar Pond, Orleans, Massachusetts

Cedar Pond is a 6.4-ha (15-acre) surface water body with a 48.4-ha watershed located within the Town of Orleans (Figure 1). The pond is approximately 3.5 m deep. The pond receives freshwater primarily through groundwater inflows around its margin, but is also connected to the Rock Harbor estuary through a surface water outlet.

Pond Management

The pond has been subject to a variety of inadvertent management actions over at least the past 175 years that have altered its salinity characteristics and associated water quality and aquatic habitats. Earliest records and recollections seem to indicate that Cedar Pond was fresh up until recently. An 1837 petition to the Massachusetts legislature asked for permission to deepen the small creek

Figure 1. Cedar Pond is located in the Town of Orleans, Massachusetts. The creek outlet from Cedar Pond flows under Route 6 and discharges into the Rock Harbor estuary. Rock Harbor straddles the town boundary between the Towns of Orleans and Eastham.

leaving the pond "sufficient to cause Alewives to pass in the stream where they can be taken" (Barnstable Patriot 1837). Aerial photos from 1947 show a dike along this creek protecting farm fields from tides and connection of the pond through another outlet to adjacent cranberry bogs. Long-term residents remember fishing for bluegill in Cedar Pond. All of these suggest that the pond was completely fresh at the time.

Over subsequent years a number of ad hoc management actions have altered the pond, including slowly transforming it from freshwater to brackish. These actions have included: (a) filling approximately 1.5 acres of the pond for the construction of a regional highway, (b) siting regional power lines over the northern portion of the pond, (c) allowing the control structure in the creek dike to collapse, and (d) removal of boards at the creek outlet control structure. Water quality monitoring in the early 2000s showed that the changes along the creek had allowed increased tidal interaction between the estuary and the pond and the pond had been converted to a brackish, slightly salty conditions (6.9 ppt surface salinity and 21.8 ppt bottom salinity). In 2007, the connection to the estuary tides were further enhanced and 2011-2013 monitoring shows that surface and bottom waters are both over 20 ppt salinity.

Water quality in the pond was definitely impaired, but it did provide some protection from watershed nutrient loads for the downstream estuary. Both before and after the 2007 enhancement, average dissolved oxygen concentrations failed to meet the minimum dissolved oxygen limits in Massachusetts surface water regulations (314 CMR 4) and the pond had semi-regular fish kills. However, intensive monitoring of the outlet creek before 2007 showed that the pond was removing 58 percent of the watershed nitrogen that would otherwise reach Rock Harbor (Howes et al. 2007). Comparison of nutrient concentrations showed that the nutrient management should involve both nitrogen and phosphorus.

Data Collection

In 2012, the Coastal Systems Program at the School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP-SMAST) was asked by the Town of Orleans to develop a management plan for Cedar Pond (Eichner et al. 2013). This effort included collection of a number of key, targeted datasets, including (a) sediment cores incubated to evaluate nutrient regeneration, (b) another set of flow and water quality data from the stream outlet (Cedar Pond Creek), (c) continuous dissolved oxygen, chlorophyll, temperature, and water level data within the pond, (d) in-pond water quality profiles and nutrient data, and (e) daily citizen counts of the cormorants roosting on the electrical wires crossing the pond. Management issues included (1) ecosystem and nutrient functions, (2) impacts on Rock Harbor, (3) protection of an adjacent Atlantic white cedar swamp, and (4) alewife habitat.

The collected data provided more specific detail on the impairments of Cedar Pond. Sediment core data confirmed extremely high sediment oxygen demand and showed how the pond sediments' role in nutrient regeneration varies through the summer. The sediments are generally a sink for phosphorus throughout the summer, but are a significant source of nitrogen during early summer and then a sink that accumulates nitrogen during late summer. Stream data confirmed the temporal variation in sediment nutrient flux, but also showed that both phosphorus and nitrogen are exported from the pond with increasing rates between June and August, before moderating somewhat in September (Figure 2). The mass of both nutrients in pond water column measurements also confirmed these interactions. The peak of late summer creek nutrient export and rise in pond nutrient mass correspond to large increases in the roosting cormorant population on the power lines above the pond. The collected data suggest the following summer nutrient transitions:

1. Nitrogen is released into the pond's water column by sediment regeneration in early summer raising the mass in the pond and increasing the export to Rock Harbor through the creek outlet;
2. when the cormorant population increases significantly in late July, the sediments become a sink for nitrogen and accumulate available nitrogen from the water column; and
3. nitrogen and phosphorus mass in the pond and export to Rock Harbor increase, however, due to cormorant defecation (creek export is greater than watershed inputs) and these levels are sustained through September.

This data collection provided CSP-SMAST and the Town with a better basis for management discussions. The findings were publicly presented and management goals were discussed with town boards. Presentations focused on the past freshwater history of the pond, pre-2007 brackish conditions, and the current high salinity conditions. It was stressed that effective management would require an initial decision about the salinity regime that was desired and that selection would determine a number of potential

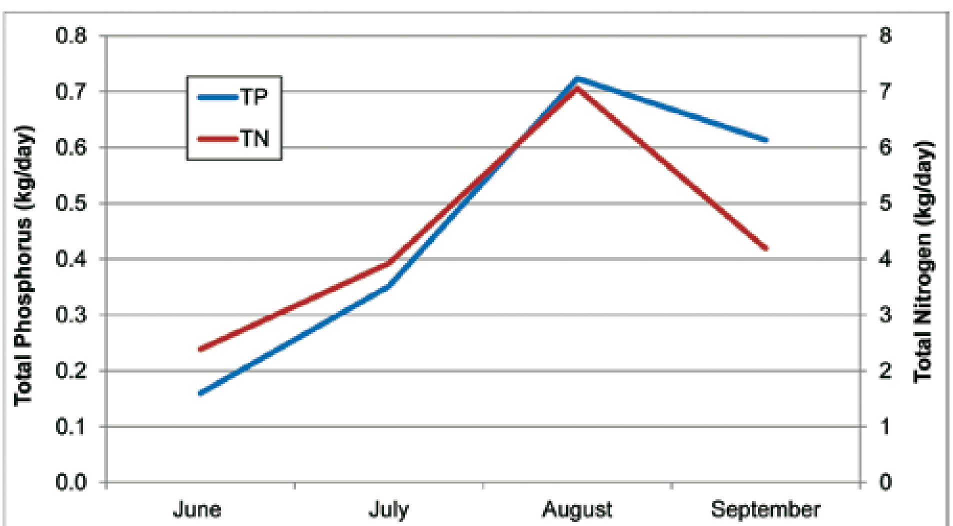


Figure 2. Cedar Pond Nutrient Exports: Summer 2013. Measurements of flow and nutrient concentrations in Cedar Pond Creek during the June, July, August, and September show a sharp increase to a peak in August. Export of TN during July to September is greater than watershed input.

management actions, while excluding others.

Management Goals and Plan Formulation

The Town committee asked CSP-SMAST staff for a recommended salinity target and steps to achieve the target. Project staff reviewed the characterization of the system, evaluated the pre– and post–2007 water quality conditions, evaluated the sustainability of the herring run and Atlantic white cedar swamp, and recommended that the system be returned to a fresh/brackish salinity regime with a salinity goal between 1 and 4 ppt.

The rationale for this recommendation included (1) restoration of the nitrogen attenuation capacity in Cedar Pond and protection of Rock Harbor, (2) restoration of the salinity range necessary to support herring spawning in the pond, and (3) protection of the adjacent Atlantic white cedar swamp. Alternative salinity regimes either do not attain the initial management goals or are structurally difficult to sustain.

A completely freshwater system was not recommended because extreme tides associated with storms/hurricanes appear to be able to enter the pond with the present dike configuration and the elevation of the creek. These types of periodic pulses would have negligible effect if the pond were brackish, but would cause major habitat degradation if the pond were completely fresh. The current high salinity condition, which appears to be close to its maximum salinity (between 21 and 23 ppt), is exporting nitrogen to Rock Harbor during the key summer period at loads in excess of the watershed loads and a recommended TMDL. These salinity concentrations are also incompatible with herring/alewife spawning and are threatening the Atlantic white cedar swamp. In addition, dissolved oxygen concentrations in current configuration still do not attain MassDEP regulatory goals.

CSP-SMAST staff recommended a series of sequential, adaptive management steps to attain the recommended salinity goal. It was recommended that each step in the process utilize ongoing monitoring and assessment of the impacts and that each subsequent step should be adjusted based on the monitoring. The first recommended steps were (a) restoring the boards in the Cedar Pond water control structure to a height that allows only highest tides to enter the pond and (b) pumping out the salt water in the deepest portion of the pond. Post–2007 tidal height data and an elevation survey around the outlet are available to help to define the initial height of the boards. Pumping was recommended based on the previous salinity regime characteristics, the estimated tidal exchange rate and the time needed to achieve the salinity goal, and the elevation difference between the bottom of the control structure and the bottom of the pond. Staff further recommended that pumping be done through the existing outlet and during low tide and only in the winter to minimize downstream impacts on Rock Harbor. It was also hoped that the pumping might help with subsequent management of sediment nutrient regeneration; monitoring will be reviewed with this in mind. Preliminary cost estimates of implementing these steps were presented to the town.

Two other key factors must also be addressed in order to restore water quality in Cedar Pond: reducing the cormorant population that roosts on the power lines during late summer and addressing sediment regeneration of nutrients. CSP-SMAST staff reviewed the options to control cormorants, including relocating the lines, and recommended the use of a handheld laser to discourage roosting. Potential issues with laser use are being discussed with the local electricity utility and the state Department of Transportation. Since sediment regeneration is likely to change following the implementation of the other key management components, CSP-SMAST staff recommended that selection of a nutrient regeneration control technique should await monitoring and reassessment of water quality conditions after the implementation of the salinity and bird control management steps.

Although Cedar Pond's management is somewhat out of the ordinary, its management discussions have components that are being discussed for coastal ponds in communities all along Massachusetts shorelines. Dam removal, removal of tidal restrictions, and enhanced fish runs, among other topics, are being brought into the usual discussions about nutrient thresholds and TMDLs. It is clear that many of these systems are impaired after centuries of significant manipulation and should be altered to make them more sustainable and resilient. It is also clear that we have the capabilities to avail ourselves of tools to understand these systems in ways not contemplated when grist mills were being built. The underlying question is do we have the commitment to bring all those tools together and do the monitoring and adjustments to attain the goals we set for these systems?

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Eduard Eichner is a Senior Water Scientist primarily affiliated with the Coastal System Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. Ed has worked to bridge gaps between science, policy, and regulatory issues related to water quality for over 20 years. Current work includes being the Watershed Land Use Technical Lead for the Massachusetts Estuaries Project and coordinating the Cape Cod Pond and Lake Stewardship Program.

The **Coastal Lagoons** of **Southern Rhode Island**

Elise Torello and Rhonda Smith

Adorning the beautiful southern coastline of Rhode Island like jewels are about a dozen special and surprisingly diverse water bodies known collectively as "the salt ponds." In truth, none of these water bodies are actually ponds; most are more accurately referred to as "coastal lagoons," and one is an estuary (Figure 1).

It is surprising that in a mere 20-mile stretch of coastline, from Watch Hill in the west to Point Judith in the east, each of these water bodies can be so unique. Furthest to the west among the largest ten of these lagoons are tiny Maschaug and Little Maschaug Ponds, usually separated from the ocean by their coastal barrier and highly impacted by surrounding development and golf courses. Next in line are Winnapaug, Quonochontaug, and Ninigret Ponds, all of which have permanent, hardened connections to the ocean (breachways) constructed in the middle of the 20th century. Next is Green Hill Pond, surrounded and impacted by development and without its own breachway. Green Hill Pond does have limited water exchange with neighboring Ninigret Pond via a narrow channel. Trustom Pond, to the east of Green Hill Pond, is a fascinating, ongoing case study in the dynamic nature of coastal lagoons. Usually separated from the ocean by the Moonstone Barrier, Trustom Pond was a freshwater system until it was breached during extra-tropical storm Sandy. Cards Pond, also very small and usually separated from the ocean, is periodically breached manually to control water levels. The last coastal lagoon to the east is Potter Pond, which unlike the other coastal lagoons that are oriented parallel to the coast, is oriented more perpendicular to the coast. The northern basin of Potter Pond is a deep "kettle hole" created as the last glacier retreated. Potter's only water exchange with Block Island Sound is via a channel into adjacent Point Judith Pond, which is actually the estuary of the Saugatucket River. Point Judith Pond is home to the Port of Galilee, which is one of the largest fishing ports on the east coast.

Figure 1. The coastal lagoons of southern Rhode Island.

The southern Rhode Island coastal lagoons were formed after the retreat of the Laurentide Ice Sheet at the end of the last glaciation. The Laurentide Ice Sheet extended south to Nantucket, MA, Block Island, RI, and Long Island, NY, about 25,000 to 30,000 years ago (CRMC 1999). At that time, with so much water locked up in ice sheets, the coastline was almost 100 miles further south than it is now and the sea level was about 120 meters lower. The thick glacial ice carried with it material ranging in size from small particles to rocks and boulders, collectively referred to as glacial till.

As the climate warmed, the ice retreated until the ice margin reached a position just north of the current RI coastline approximately 21,000 years ago. The ice margin fluctuated at this location a time, forming a hill of glacial material known as the Charlestown Moraine (Dr. J. Boothroyd, personal communication). Additional sand and gravel was deposited by meltwater rivers flowing underneath the melting ice sheet, around its edges, and through breakout channels along the length of the ice margin. These deposits, along with the direct deposition of till by the ice, created a series of headlands along the coast. Rapid climate warming starting about 14,000 years ago melted enough glacial ice to bring the sea level up to its approximate current height by about 4,000 years ago (CRMC 1999).

With wind, waves, and time, glacial deposits were eroded and carried along the shoreline by currents (Figure 2). This eroded material formed barrier spits between the higher headlands. Continuing erosion and deposition of sediments by waves and long-shore currents caused the spits to grow away from the headlands parallel to the shoreline. Eventually the spits almost completely connected the headlands, isolating the coastal lagoons behind them from the ocean except for narrow inlets through which ocean tides flowed (CRMC 1999). Unlike today, the inlets were not fixed in one place; rather, they periodically closed, changed location, and were re-opened by storm surges and waves.

Storm waves, storm surges, and rising sea level are continuing the process of eroding the glacial deposits. During big storms, storm surges and waves roll over low, narrow barrier spits (overwash). The overwash transports sand from the ocean and beach face across the barriers and sometimes all the way to the lagoons. In severe storms, temporary storm-surge channels might cut through the barriers, allowing additional sediment into the lagoon. Over time, these processes cause coastal barriers to move landward and upward.

With people living and building businesses around the ponds and on the coastal barriers, the natural processes driving the configuration and migration of these features no longer proceed unfettered. For many decades, overwashed sand that landed on roads or developed property has been moved back to the beach face, interfering with the natural landward migration of the coastal barriers. In addition, ongoing, decades-long studies of the advance and retreat of the southern RI shoreline show that long-term, most of the shoreline is eroding (CRMC 1999). Prevention of sand from reaching the back of the coastal barriers during and after storms, combined with erosion of beach faces, over time will cause the coastal barriers to narrow. This is a problem, since narrow, developed coastal barriers do not provide as much storm protection to landward structures as wider, more natural barriers. An accelerating rate of sea level rise in the northeastern U.S., plus the prospect of increasing storm frequency and severity due to climate change, is driving a major policy effort in RI to address shoreline change and sea level rise adaptation statewide (www.beachsamp.org).

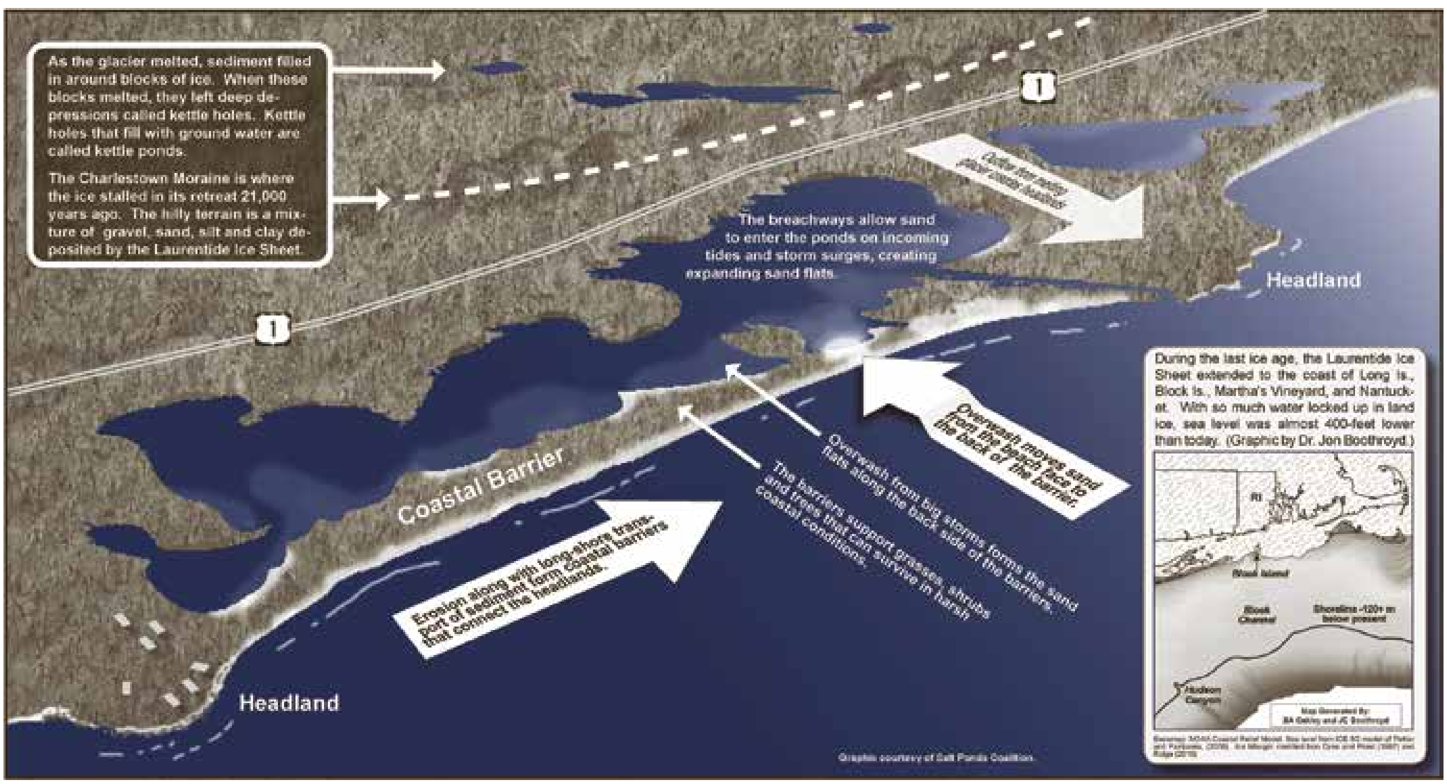

Figure 2. The geologic processes that formed southern Rhode Island's coastal lagoons.

Other Issues Facing the Coastal Lagoons

As is true for so many water bodies, the southern RI coastal lagoons are being impacted by the human activity taking place around them. Excess nutrients from septic systems, fertilizers, and animal waste are carried into the lagoons by surface runoff and groundwater. The excess nutrients fuel excess algal growth, which causes decreases in water clarity and dissolved oxygen concentrations. In addition, now that there are hardened, permanently fixed breachways into several of the lagoons, sand is transported through these inlets by incoming tides and then deposited within the lagoons as flood tidal deltas. This buries important eelgrass (seagrass) and shellfish habitat and decreases water circulation in the lagoons. Thus, the hardened breachways must be maintained through periodic dredging to maintain the exchange of pond waters with clean seawater and prevent shoaling within the ponds.

The coastal ponds of southern RI, and even different locations within a single pond, are affected by these stressors to varying degrees, depending upon how densely developed the shore is and how close to a breachway a location happens to be. Outreach efforts are ongoing to encourage people who live near the ponds to limit or eliminate their inorganic fertilizer use, properly maintain their septic systems, pick up after their pets, discourage Canada geese, and plant rain gardens and native plant shore-side buffers (Figure 3).

A wide array of uses and activities in and on the ponds results in user conflicts from time to time. Oyster aquaculture has been a booming industry in the ponds, which, thanks to the efforts of hard-working oyster farmers, produces a delicious and widely marketed product. However, other users of the ponds are sometimes resentful of the pond area used by aquaculture, currently capped at 5 percent of the area of each pond. Wild-harvest shellfishermen also work in the ponds, along with recreational clam diggers and fin-fishermen. The ponds are very popular with recreational sailors, boaters, and paddlers. In addition to RI's busiest fishing port, the Block Island ferry terminal and numerous marinas are located within Point Judith Pond. Managing all of these uses and users – the "social carrying capacity" of the ponds – is an ongoing challenge.

Trustom Pond: An Ongoing Case Study in Coastal Lagoon Dynamics

Trustom Pond is a 160-acre coastal pond completely within the boundaries of the U.S. Fish and Wildlife Service's (US F&WS) Trustom Pond National Wildlife Refuge (NWR) in South Kingstown, RI. Trustom Pond is unique in that it is Rhode Island's only coastal pond free of shoreline development. Moonstone Beach, which is the coastal barrier separating Trustom Pond from Block Island Sound, is managed by the Refuge for the benefit of migratory shorebirds and water birds, including the federally threatened piping plover.

From the 1600s to the 1900s, Trustom Pond was breached twice annually, usually by mechanical methods, to drain adjacent agricultural fields and encourage a healthy shellfish population in the pond. The Trustom Pond NWR was established in 1974 and from 1975-1996 the pond was breached about once per year, primarily to provide foraging habitat for piping plovers and other shorebirds. After 1996, a more natural breaching regime was allowed to take over and the pond was mechanically breached only once, in 2006. Mechanical breaching done by the Refuge typically resulted in the pond being open to the flow of seawater for a period of less than a day to as many as a few days.

Due to the lack of a recent breach, by 2012 Trustom Pond had become a freshwater ecosystem. In recent years, water quality monitoring in the Pond revealed some problems with nutrient enrichment. Each year, some nitrogen and phosphorus concentrations exceeded eutrophic, and occasionally hypereutrophic, levels. Concentrations of chlorophyll-a were also above the hypereutrophic level, and an algal bloom occurred during the summer of 2011. In addition, two species of exotic invasive freshwater aquatic plants, parrotfeather (*Myriophyllum aquaticum*) and Eurasian watermilfoil (*Myriophyllum spicatum*), had been discovered in the Pond between 2007 and 2009. A native aquatic plant, northern water-nymph (*Najas flexilis*), was over-abundant and growing in extremely dense mats.

Then, on October 28, 2012, Trustom Pond breached during extra-tropical storm Sandy. At the time of the breach, the water level in Trustom Pond was very high, which likely contributed to the breach being larger than it had been in previous years. While the breach was active, the water level in the Pond was at least four feet lower than pre-breach and the salinity averaged 29 ppt (seawater is about 35 ppt). These are the highest salinity measurements documented in Trustom Pond; previous breaching events resulted in salinity measurements ranging anywhere from 1.7 to 18 ppt. The breach stayed open for five months until closing naturally on March 24, 2013 (Figure 4). As of September 2013, thanks to the contributions of several freshwater tributaries and heavy spring rainfall, the salinity was down to about 9 ppt and the water level had risen by several feet.

The breach event had an immediate impact on the ecology of Trustom Pond. In past surveys, fish communities consisted of a variety of fresh- and brackish-water species, depending on how recently the pond had been breached. Immediately prior to the 2012 breach the fish community consisted mainly of common freshwater fish such as largemouth bass and pumpkinseed sunfish. Soon after the breach, many dead fish of these and other freshwater species were scattered on the mudflats around the pond, as they cannot survive in salt water. Summer 2013 surveys showed that the fish community in the pond consisted mainly of saltwater minnows like killifish, mummichogs, and sticklebacks. In addition, post-breach plant surveys have shown no evidence of the exotic invasive plants or water-nymph in the Pond, mainly replaced by a brackish-water plant called horned pondweed (*Zannichellia palustris*).

After observing the dramatic changes to Trustom Pond during the breach, many concerned members of the public wondered why the US F&WS had not manually closed the breach. The NWR staff had decided that the breaching event had the potential to both positively and negatively affect wildlife populations of various species. They also heard the opinions of several experts in coastal geology and morphology who (correctly) predicted that the breach would close on its own within a timeframe of weeks to months. Refuge staff collected data during 2013 on water quality, aquatic vegetation, rare plants, breeding and migrating

Figure 3. Steps pond-side residents can take to reduce their impact on water quality.

shorebirds, and fish communities. These data will provide important information on whether the US F&WS should employ a schedule of mechanical breaching as a pond management tool, or whether to allow natural events to dictate the breaching regime of Trustom Pond.

Summary

The coastal lagoons of southern RI are varied, beautiful, and ecologically, economically, and aesthetically valuable. They are also subject to stresses from a variety of sources. To know these ponds is to love them, and as we spread the word about these wonderful resources, we know that more residents of and visitors to their watersheds will become their active stewards and advocates.

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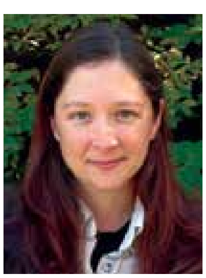
Elise Torello is Executive Director of the Salt Ponds Coalition (SPC), a non-profit conservation organization and the State of Rhode Island designated watershed council for the southern Rhode Island coastal lagoons. She previously served on SPC's Board of Directors for five years. Her background is in wildlife biology and computer science.



Rhonda Smith has worked as a Wildlife Biologist with the Rhode Island National Wildlife Refuge Complex (Refuge) for the past four years; prior to that she spent five years working in the biology field. While at the Refuge, she has coordinated projects such as a saltmarsh integrity assessment, shrubland bird monitoring, native habitat restoration and invasive plant control.

Figure 4. Before (top), during (middle), and after (bottom) photos of Trustom Pond's breach. Photo credits: before (RIGIS); during and after (U.S. Fish and Wildlife Service).

Climatic Influence on the Hydrology of Florida's Coastal Dune Lakes

Antonio Yaquian and James W. Jawitz

Introduction

In a short stretch of coast between Destin and Panama City Beach on Florida's panhandle there is a series of small and unique lakes. These lakes, known as coastal dune lakes, are shallow and fed by surface tannic waters from the surrounding forests. What separates these lakes from the more than 7,000 other lakes in Florida is their multiple interactions with the ocean. As their name suggests, they lie immediately behind coastal sand dunes, which constitute the only boundary between them and the Gulf of Mexico.

The most notable ocean/lake interactions occur during severe weather events. Marine waters directly enter the lakes as a consequence of tidal surges, or when the water level in the lakes builds up enough to breach the sand dune separating them from the ocean, discharging up to one-third of their contents into the ocean. The latter phenomenon, lake water discharge (LWD), occurs during heavy inland rain events, while sea water intrusion (SWI) events are driven by oceanic tides.

The LWD events tend to capture more public attention, due to the contrast between the relatively clear waters from the Gulf of Mexico and the tannic waters discharging from the lakes (Figure 1). Both LWD and SWI events are short-duration, lasting less than one day. However, ocean/lake interactions are more complex and periodic than is commonly recognized.

The Environmental Hydrology Lab at the University of Florida has studied the hydrology of several of Florida's coastal dune lakes since 2007. This article focuses on the ocean/lake hydrological interactions by closely examining 30 months of monitoring data at 24-ha Camp Creek Lake (CCL), in Walton County, FL. The lakeshed of CCL is mostly upland forests, with recent urban development encroachment. The population of Walton County almost doubled between 1990 and 2012. Figure 1 shows housing development around Big Redfish Lake; a similar situation occurs in CCL. Also evident in the figure is a meandering arm of the lake that is a permanent feature but is only periodically connected to the sea when the dune is breached; such outflow channels are characteristic features of these coastal dune lakes (including CCL).

Figure 1. A lake water discharge (LWD) event underway in Big Redfish Lake on 3 March 2004.

This article analyses ocean/lake interactions in CCL from June 2008 to December 2010. Electrical conductivity (µS), temperature, and water pressure were recorded at 60 minute intervals by a data logging transducer (In Situ Aqua TROLL 200). Atmospheric pressure, used to correct readings of absolute pressure from the transducer, as well as rain data observations were obtained from the Destin-Fort Walton weather station (Global Historical Climatology Network station USW00053853). Tide data were obtained from Panama City Beach (NOAA tide station 8729108) and are reported relative to the mean high water (MWH) datum.

Main Climatic Factors Influencing CCL

Climatic effects on the coastal dune lakes are especially complex since these lakes are subject to both inland and oceanic climate. Furthermore, the Gulf of Mexico basin is subject to hurricanes, tropical storms, and tropical depressios, which have a strong effect on rain and tides. Florida's precipitation is among the highest in the nation, and within the state, the panhandle area receives the most, 1600 mm (63 inch) on average, while the rest of Florida receives 1340 mm annually. Precipitation patterns in the state display strong changes with changes in latitude. Rain in South Florida follows a tropical pattern of intense summer storms, while precipitation in the Panhandle is highly influenced by continental weather and thus displays a defined bimodal rain pattern, with peaks during winter and summer.

Tropical cyclones (tropical storms, tropical depressions, and hurricanes) play a very important role in coastal lake dynamics as they have a strong influence on winds, rain, and tides. Tidal maxima increase during the rainy season due to higher storm activity in the Gulf of Mexico. Seasonal variability in evapotranspiration also affects lake water level. For example, winter storms are more likely to increase lake level since less water will be lost to the atmosphere.

Observed Data

The measured climatic variables that drive the dynamics of the hydrology of CCL are shown in Figure 2. The top two panels show wind, tides, and rain (all input drivers). The grey columns represent tropical cyclones, showing the relevance of hurricanes and their signature in all the recorded variables. Relative conductivity, shown in the bottom panel of Figure 2, is normalized to the mean value for the prior 24 hours, and is considered an indicator of ocean/lake interactions. Note that during the monitoring period, electrical conductivity in CCL ranged from 90 to 38,900 µS. Examining relative conductivity enables detection of interactions that would be difficult to determine by visual inspection of the un-normalized time series. For example, a change of 1,000 µS would not be noticed during the tumult of a hurricane, while if this occurred following a period of relative calm with low conductivity values, that same reading would be the signature of an extreme event.

A change in relative conductivity of more than 50 percent with respect to the previous 24-hour period would be registered as an anomaly, while a decrease in more than 10 percent with respect to the previous 24 hours in lake level would also be reported. This analysis allowed for the identification of several ocean/lake interactions that were not as evident as major events. A good example of this is the detection of the LWD during April 2009 (Figure 2), discussed in more detail in the following section.

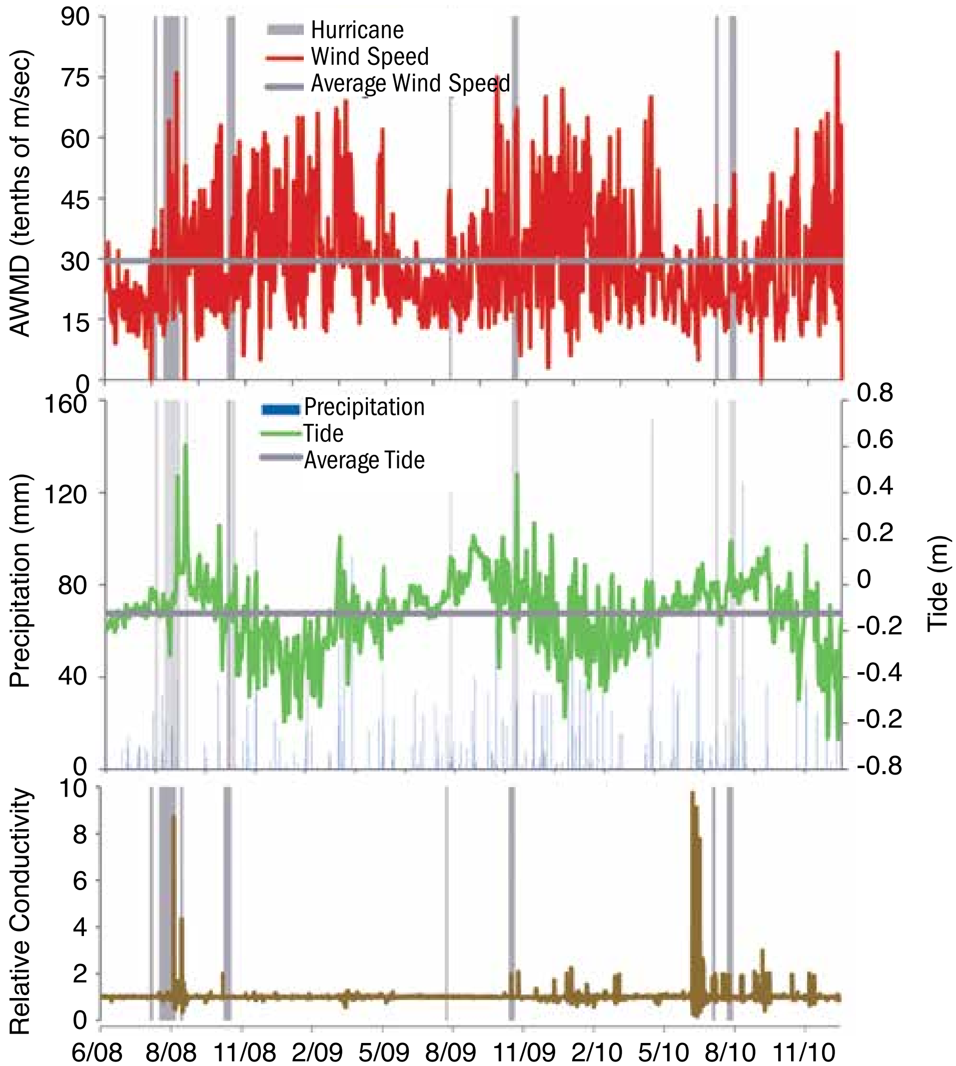


Figure 2. Record of the system inputs (hurricanes, wind, precipitation, and tides) during the monitoring period in CCL and Relative Conductivity as output.

Lake Water Discharge

Two LWD events were recorded during the monitoring period: April 2009 and July 2010. Neither event was produced by a hurricane; both were caused by seasonal rains. Only the event in 2010 is shown (Figure 3) as both developed under similar circumstances. Heavy rains in late March 2009 led to an increase in the CCL water level from 1.68 m to 2.02 m in less than 24 hours on 1 April (data not shown). Shortly after that peak, the lake level decreased until it reached 1.34m on 6 April, 90 hours after the maximum height. Relative conductivity did not increase for more than three months after this LWD event. In the LWD event of late June and early July of 2010, the CCL water level rose to a maximum of 2 m, as a consequence of 140 mm of rain in the previous four days (Figure 3). Shortly after reaching the maximum height, the water level started to decrease rapidly and CCL lost one meter of water in less than 36 hours. Relative conductivity (Figure 3) did not present major changes for several days as the tides were low when the LWD occurred. In both events, shortly after the lake level reached 2 m there was an abrupt exfiltration of lake water into the sea; this was due to a LWD breach of the sand dune.

Unlike the event on April 2009, it is believed that the elevation of the

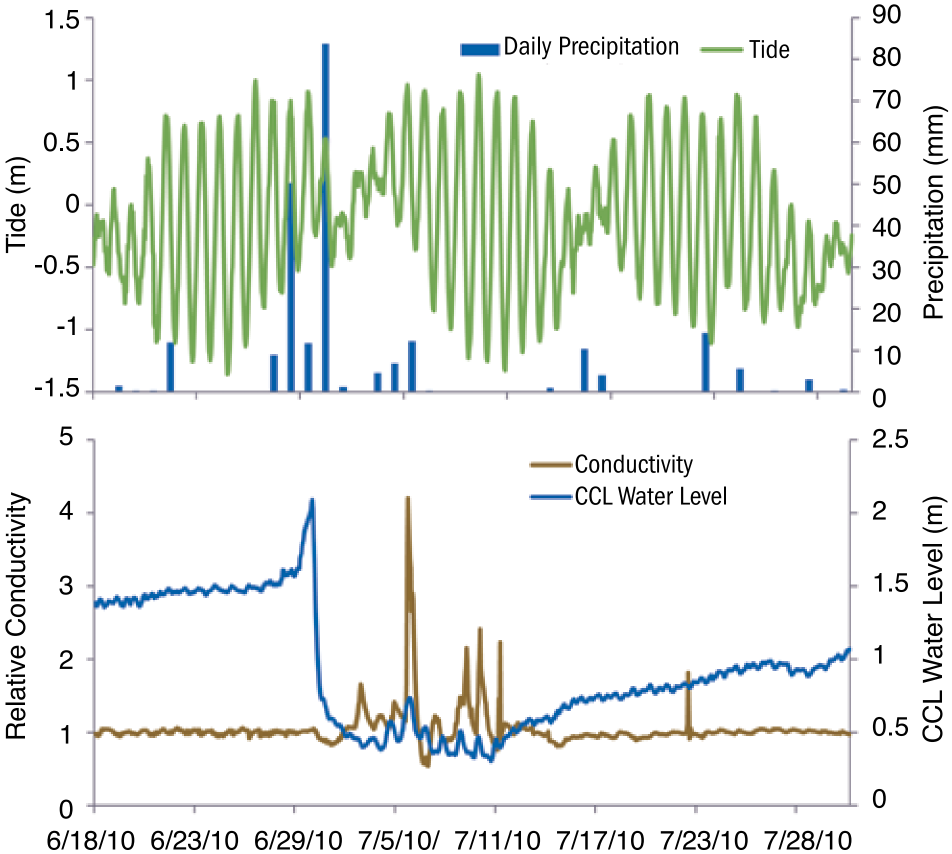


Figure 3. LWD event during late June and early July 2010.

outflow channel with respect to the ocean decreased after the July 2010 event, allowing brief incursions of sea water into the lake, increasing relative conductivity, during the high tides of the following several days. The lake outflow channel level then filled due to sand deposition, again separating the lake and the sea, allowing the lake level to begin increasing again on July 12.

Sea Water Intrusion

Four SWI events occurred during the rainy seasons of the monitoring period. All of these events were related to hurricanes, two of these events are analyzed below.

In late August and early September 2008, hurricanes Gustav and Ike crossed the Gulf of Mexico. Rain in the CCL area increased considerably as a consequence of Gustav, which made landfall on 1 September just west of New Orleans, LA. Ike crossed the Gulf farther south, making landfall in Galveston, TX on 14 September. The closer proximity of Gustav to the study area resulted in a more distinct rainfall signal from that storm. However, both of these hurricanes did have an effect on the local tides, and their storm surges reached land on 31 August and 9 September (Figure 4).

The rains from Gustav began 30 August and lasted until 1 September. The corresponding rapid increase in CCL level is due to the coupled effect of rain and SWI. On 31 August the lake level rose 0.6 meters when Gustav's tide surge reached the coast. A similar event occurred on 9 September when Ike's tide surge reached the coast. This event is even clearer as this more distant hurricane did not produce significant local rainfall, yet the lake level increased from 1.2 to 1.4 m in several hours. Notice that while the tide surge in September was higher than in August, the lake level was up from the previous event, which may explain the weaker signal from the second hurricane's storm surge.

Another series of blow-in episodes occurred in November and December of 2009 (Figure 5). The first occurred as a consequence of Ida2009, as rainfall on 5 and 6 November 2009 increased under its influence. Ida2009 was a category 2 hurricane while traversing the Yucatan Peninsula, but made landfall in CCL's vicinity as a tropical depression. When

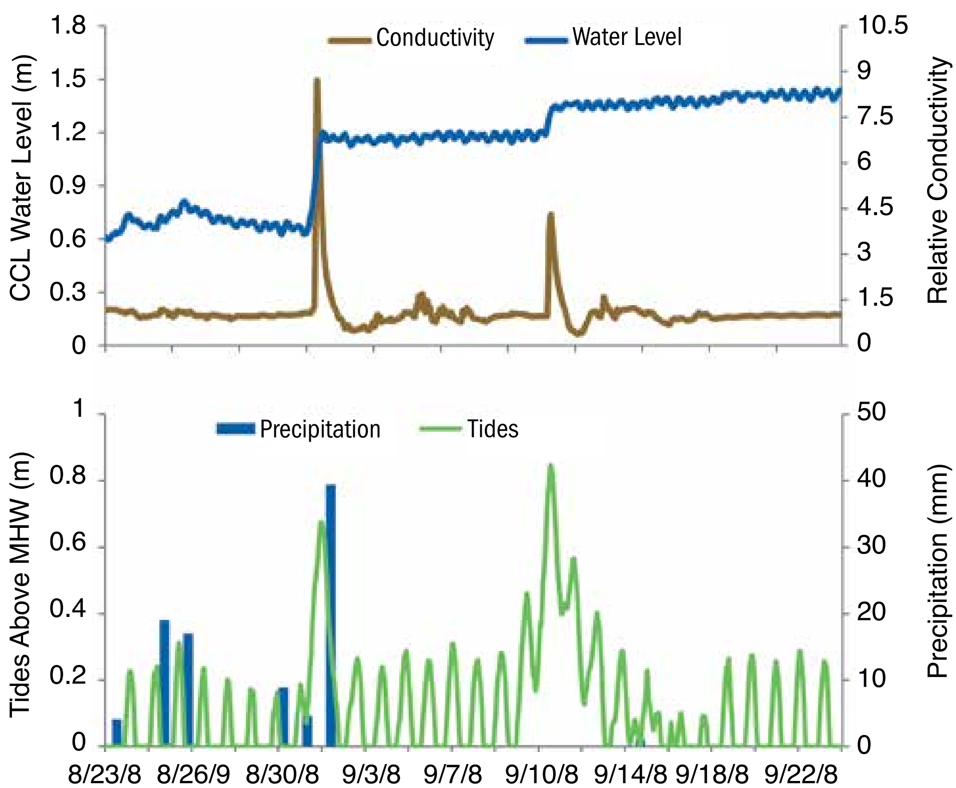


Figure 4. Sea Water Intrusion (SWI) in August and September 2008. Hurricanes Gustav and Ike had a strong signal in tides.

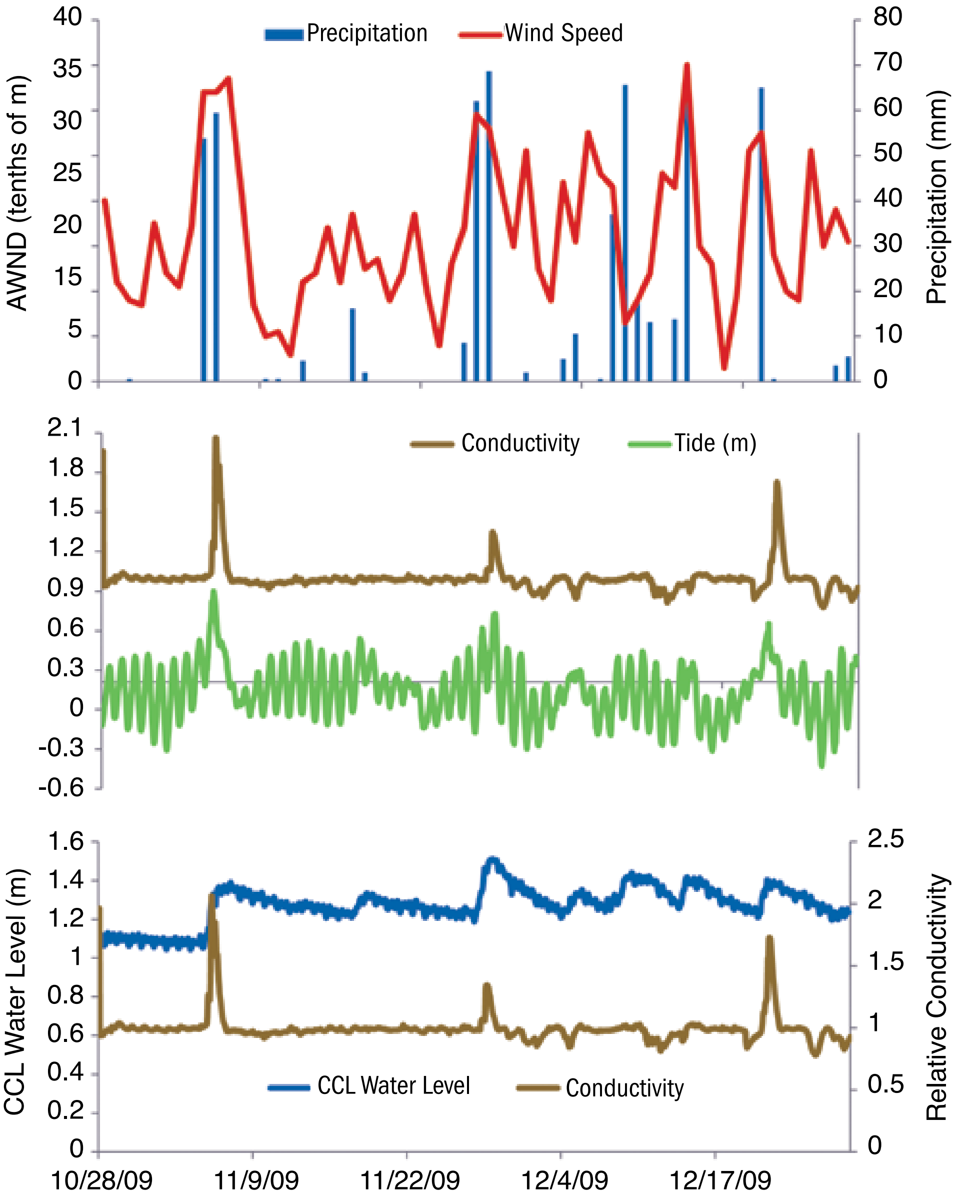


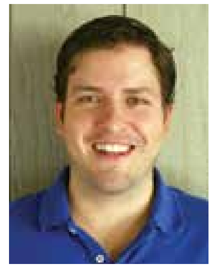
Figure 5. SWI episodes during late 2009, Ida2009 had a strong signal on early November.

Ida's surge hit the coast, CCL level rose 0.4 m in less than one day. Electrical conductivity (not shown) rose from 800 to 2500 µS in the same time span. During these two months there were at least two more events in which sea water entered the lake (1 and 26 of December, Figure 5).

Similar situations also were caused by Paloma in November 2008, which was a tropical depression by the time it reached the coast, and tropical depression Five2010 in August 2010.

Conclusions

A deep understanding of inland and oceanic climatic variables is necessary to comprehend dune lakes behavior and dynamics. Multiple ocean/lake interactions were observed at Camp Creek Lake, FL, during the monitoring period of June 2008 to January 2010. Some of these interactions were extreme and obvious, while others were more subtle and may have escaped notice without further time series analysis. In this case tropical cyclones were the main force behind sea water intrusions in the lake, while lake water discharge events were transient and products of heavy rain in the lake vicinity.



Antonio Yaquian is a doctoral student in the Soil and Water Science Department at the University of Florida. His main academic interests are to enhance his understanding of regional hydrological processes and how to relate those findings to the general public. His dissertation research is related to quantifying the relative effects of human and climatic influences on water resource availability.

Dr. James Jawitz is a professor in the Soil and Water Science Department at the University of Florida. He directs the Environmental Hydrology Laboratory and works to minimize human impacts on natural hydrologic ecosystems, including lakes, watersheds, wetlands, and aquifers.

Tenmile Lake:
Life and Limnology on the Oregon Coast

Joe Eilers

Many of my lake projects have been pretty routine. You sign the contract, conduct the work, deliver your report, and say goodbye to the client. Sometimes there would be follow-up work and, if fortunate, you make some friends along the way. But a few projects become very personal either because of the intense nature of the work, dangerous events, remarkable beauty of the site, or fascinating people that you encounter. For Tenmile Lake, it was all of the above. But, first a description of the lake and its origins.

Tenmile Lake is officially two lakes, Tenmile Lake on the south and North Tenmile Lake to the north, both connected by a canal. However, the features of the lakes are so similar (Figure 1, Table 1), that for convenience, I'll just to refer to them collectively as Tenmile Lake. Most Oregon coastal lakes, such as Tenmile (formerly called Johnson Lake), bear relatively predictable names assigned by settlers, whereas others to the north of Tenmile still bear reminders of the original inhabitants with mellifluous names such as Tahkenitch, Woahink, and Siltcoos.

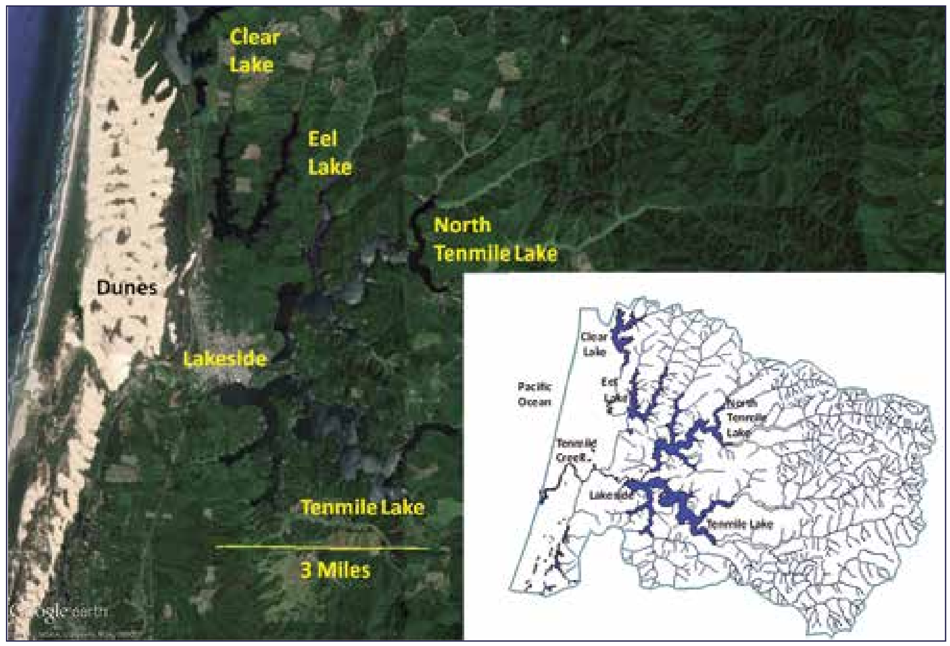


Figure 1. A satellite image of Tenmile Lake (north and south) converging on the town of Lakeside. Clear Lake and Eel Lake are located to the north and both lakes discharge into Tenmile Creek, the outlet from Tenmile Lake. The inset shows the watershed boundaries and dense stream network.

Table 1. Tenmile Lake Morphometry.

	North Tenmile	*Tenmile*	*Combined*
Lake Area (ac)	829	1130	1958
Lake Perimeter (mi)	19.8	23.2	43
Depth (max- ft)	26.8	27	
Depth (mean- ft)	14.8	16.3	

The Past

Tenmile Lake, as with most Oregon coastal lakes, is a transient feature of the landscape. The dune formation process that was responsible for creation of lakes such as Tenmile began about 18,000 ybp (years before present) and were largely completed about 6,000 ybp (Cooper 1958). The rising seas pushed dunes inland and impounded coastal streams to form these highly dendritic lakes, superficially similar to human-built impoundments. Other coastal lakes were formed between rows of dunes. These lakes have remained fairly stable during the Holocene, occasionally impacted by tsunamis that breach the dunes. As the dunes ebbed and waned, the outlets to the ocean could be temporarily blocked and driven under the sand.

The Tenmile Lake was attractive to settlers for the timber and the grazing land. There are only two angles in the watershed – flat valleys and 30-degree slopes on the uplands. The demarcations are abrupt. The valleys are typically used for livestock and the tree-covered slopes provide timber. There is not much in between except for the houses and cabins clinging to the lakeshore. Timber harvest has been a source of income for generations of local families. In the early days, logs would be skidded down to the lake and rafted to the mill at Lakeside.

Aggressive timber harvest practices on the steep slopes with erosive soils, combined with channelization of the valley streams, allowed for transport of large amounts of sediment into the lake (Figure 2). Timber is now moved via logging roads that snake through the coastal hills to more distant mills; the mill that operated at Lakeside has been leveled. Dairy farming was attractive because of the flat lowlands that extended up the arms of the lake. However, to make the land usable for livestock, the natural meandering streams had to be re-routed. That was accomplished by channelizing both sides of the valleys and transforming these elongated wetlands into pasture (Figure 3). These channelized streams with long straight reaches are far more prone to erosion (Figure 4). The rains ensured ample growth of the grass and minimized the need for hay production. Roads are scarce in the recesses of the watershed and milk was moved to the dairies by boat. In fact, most everything moved by boat – kids going to school, rafting logs to the mill, and delivering mail. Much of the lake is still a boat-based economy.

Tenmile Lake, like many Oregon coastal lakes, gradually accumulated shoreline cabins as those with disposable income sought solace along the miles of shoreline. The growth of shoreline dwellings was initially imperceptible. Access to the lake was difficult without a coastal highway or rail line. A spur line was finally brought into Lakeside and trains disgorged carloads of eager fishermen awaiting the chance to fish the waters of Tenmile Lake (Figure 5). My father recounted stories of trips to the lake from his Portland home in the 1930s.

Figure 2. Early days of logging on the shoreline of Tenmile Lake. Current practices are far more regulated.

Arriving at the lake they would have their choice of coho, steelhead, or sea-run cutthroat trout, depending on the season and flows. The challenge among his buddies was to land the largest fish with the lightest fly rod tackle. The salmon population in the lake was so abundant that commercial fishing boats would be launched into the lake to take advantage of the bounty during the salmons' sprint from the ocean to the tributaries. The first non-native fish species to arrive were yellow perch and brown bullhead in 1930s. These were followed by bluegill in the 1960s. The bluegill over-populated the lake and the Oregon Department of Fish & Wildlife (ODFW) sought to eradicate these invasives with a rotenone treatment in 1968. That treatment was not successful and ODFW sought to remedy the problem by introducing largemouth bass to prey on the bluegill. The largemouth bass found the salmonid young more to their liking than the bluegill and delivered a major blow to the once-great coho fishery (Abrams et al. 1991). Fingerling and juvenile salmonids entering the lake after their parents had spawned in the tributaries were ambushed by the bass. Although coho escapement has increased somewhat over the last decade, probably because of more favorable ocean conditions, the population remains only a small fraction of its historic levels.

Figure 3. Comparison of an ungrazed lowland site in the Tenmile Lake watershed (left) with a grazed valley floor (right).

Figure 4. Example of a channelized stream reach with pasture on the right and the uplands beginning on the left.

Figure 5. A successful day of trout fishing on Tenmile Lake.

The Present

High-powered bass boats now ply the waters on weekend tournaments, some participants likely oblivious to what the lake used to be. The lake waters that used to run relatively clear in the summer months now are sometimes an electric green as cyanobacteria blooms cause the lake to be posted for contact. Invasive aquatic plants choke portions of the waters. The local watershed council continues to make progress in replacing culverts that block anadromous fish passage and encouraging landowners to fence the livestock from the streams and upgrade their septic systems. These all help, but progress is slow.

There are about 500 homes and seasonal cabins bordering the lake. Sewering these shores would be extremely expensive and even maintenance of standard septic systems is a challenge. What is viewed by sanitarians as a functioning septic system, namely no surface upwelling of discharge, hides transport of septic wastes into the lake. It's a problem that is difficult to quantify and even more difficult to correct. Modeling analyses suggested that the load of septic wastes to the lake represented only 10 to 22 percent on an annual basis, but approached the majority of the total phosphorus load in the summer load when it would be most likely to have an impact on the lake.

My years working on Tenmile Lake were long, and wet…really, really wet. The annual precipitation at Lakeside, the small town adjoining the lake, is only about 58 inches, but it can double that in the upper parts of the watershed. There were days when the transitions between the lake, ground, and air were just technicalities. And no amount of raingear kept you dry. But it's the rain that also made everything green – the trunks of trees, the dense undergrowth, sides of buildings – and highly attractive to the native salmonids.

Besides the incessant rain from November through May, it was the people that left the biggest impression of Tenmile Lake. One sharp retired fellow kept a houseful of high-end computers and compiled GIS layers of the area for fun and profit. A former mayor and nearly perpetual councilman dropped out of a Ph.D. program at Cornell and was lured by the political sirens to work for the Kennedy administration. What a story-teller. Jim seemed to know where most of the skeletons were buried. An heiress, we'll call her Suzie, travelled in an old beat-up rig, wore faded jeans and flannel shirts and didn't care what folks thought about her. She purchased a farmstead tucked in the back part of the watershed, removed the cattle from her property, and let it return to the wild. She graciously let us use the stream through this reclaimed river of grass as a reference site for monitoring what likely represented pre-development water quality (Figure 6). When I returned to the monitoring station a year or two afterthe end of the field work to retrieve equipment from the enclosure we had constructed to house equipment, it had become home to

Figure 6. A restored sub-watershed with the stream meandering through the grass. These rivers of grass carried only one percent of the sediment load compared to the channelized streams. Amazingly, salmon would find their way through these obscure channels to spawning sites in the uplands.

wood rats that sprang out when I pried open the door. I initially felt badly about leaving the structure on Suzie's property, but between the vines, blackberries, and alders, it appeared to be re-adsorbed into the landscape. Besides, I hate rats.

The only individual that gave me grief on the lake was a local law enforcement official. He threatened to give me a ticket for piloting my boat too fast through the canal joining the lakes. I was less than sufficiently contrite after being scolded for going 4.8 mph versus the posted 3 mph. Wow, what a danger to society. The next encounter was a little more serious. When launching our boat early on a rainy winter morning, my co-worker called me over to take a look behind the boat prior to shoving off. What initially looked like an old rubber tire nailed to the dock was actually a dead body with a black jacket bobbing in the water. I respectfully floated the individual to shore and called the authorities. I expected to be congratulated for doing my civic duty, or at a minimum dismissed quickly, but the encounter rapidly spiraled into some intense questioning. After all, why in the heck would anyone in their right mind be out at dawn on a miserable morning – without a fishing pole – unless one was up to no good? After that, I vowed never to find any more bodies, or at least not report them. My assistant, Gus, took my side when it came to law enforcement (Figure 7).

Figure 7. My trusty assistant, Gus, at Tenmile Lake keeping a lookout for cops. He didn't care for authority figures.

The Future?

Tenmile Lake and the local population have witnessed massive changes in the last century associated with various types of development. However, changes in the 21st century may dwarf those of the 20th century. The transient nature of Tenmile Lake and other coastal lakes could be realized once again as global warming and its consequent rise in sea level begin to reclaim the shoreline. Tenmile Lake ranges from about 9 to 13 feet above current sea level, below most predicted rises in sea level (Pfeffer et al. 2008). But even a rise in sea level of a few feet will cause havoc among these coastal lakes because of increased susceptibility to storm surges, combined with accelerated coastal erosion. Susceptibility to tsunamis also will increase. If the sea level changes are true, these areas will change radically. My children may not witness the event, but it's possible that the subsequent generation will see lakes such as Tenmile transition to an estuary. Bass and other warm-water species will disappear with the influx of saltwater, and salmon, steelhead, and cutthroat trout may once again thrive in these waters. Seals will chase the salmon up the inlets and orcas will follow the seals. It could be quite a show.

Acknowledgments

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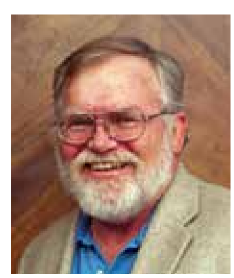

Joe Eilers has worked as a limnologist in Oregon for the last 25 years. He received his formal training and early job experience in Wisconsin. He is a Certified Lake Manager, a registered professional hydrologist, and a certified fisheries biologist.

Cleawox Lake, Oregon:
The Coastal Sands of Cultural Omission

Douglas W. Larson

Nearly 50 years have passed since I first plied the crystal clear waters of Oregon's Cleawox Lake, collecting water samples while marveling at the towering, steep-faced sand dune rising majestically along the lake's south shoreline (Figure 1). The dune, referred to as one of the largest single dunes in the world, is part of the vast Coos Bay dunal sheet that extends for about 80 kilometers along Oregon's central Pacific Coast. Winding along this coastal region is a chain of maritime lakes, most of which are sand-barrage lakes including Cleawox (Figure 2). As their designation implies, these lakes were originally coastal streams impounded by ocean sand dunes advancing inland. Cleawox Lake owes its existence largely to its imposing south-shore dune that blocked the lake's drainage to the ocean (Figure 3).

During a recent visit to the Oregon coast to photograph lakes, I stopped at Cleawox Lake to once again observe the lake's condition and shoot the dune, so to speak, as I had done many times in years past. What my camera captured was a forlorn remnant of a scenic wonder (Figure 4), its former grandeur lost forever and a large portion of its luminous sand lying submerged in the lake. Although wind and other natural processes contributed significantly to the dune's in-lake encroachment, humans bear much of the responsibility for the irreversible impact to dune and lake. The main damage appears to have taken less than 50 years, the result of (1) human failure to recognize the dune's vulnerability and its fragile structure, (2) failure of individual dune-users to perceive how their self-serving actions affected the common good, and (3) failed stewardship on the part of federal and state resource agencies to protect and preserve a natural treasure.

Figure 1. Cleawox Lake and south-shore dune, July 1968. Visitors are seen climbing a trail that cuts diagonally across the dune's slip face. Photo by the author.

Hydrology

Despite its dunal impoundment, Cleawox Lake continues to drain through a small, intermittent creek that flows northward before more or less disappearing into a complex of dunal sands, riparian vegetation, and wetlands somewhere between the lake and the Siuslaw River (Figure 2). The extent of drainage into the Siuslaw River is uncertain. Creek outflow has steadily diminished over the years due to various obstacles in the channel, principally beaver dams and proliferating vegetation planted to stabilize dunes. Efforts to clear the waterway and improve drainage have largely failed. This restricted outflow likely explains why lake surface elevation rose an estimated 1.1 meters between 1937 and 2008 (Witter et al. 2008).

Inflowing drainage is derived from a relatively small area covering about four square kilometers (Johnson et al. 1985). Surface inflows include Buck Creek, which enters near the upper end of the lake's two-kilometer-long northerly arm (Figure 2), and several intermittent unnamed rivulets.

Water also enters the lake from direct precipitation and subsurface seepage. Rainfall, normally heaviest during winter and measured at the U.S. Weather Bureau's Canary station located about five kilometers east of the lake, averaged 213.1 centimeters annually during the period 1948-1970 (NOAA). Due to the permeability of dunal sand,

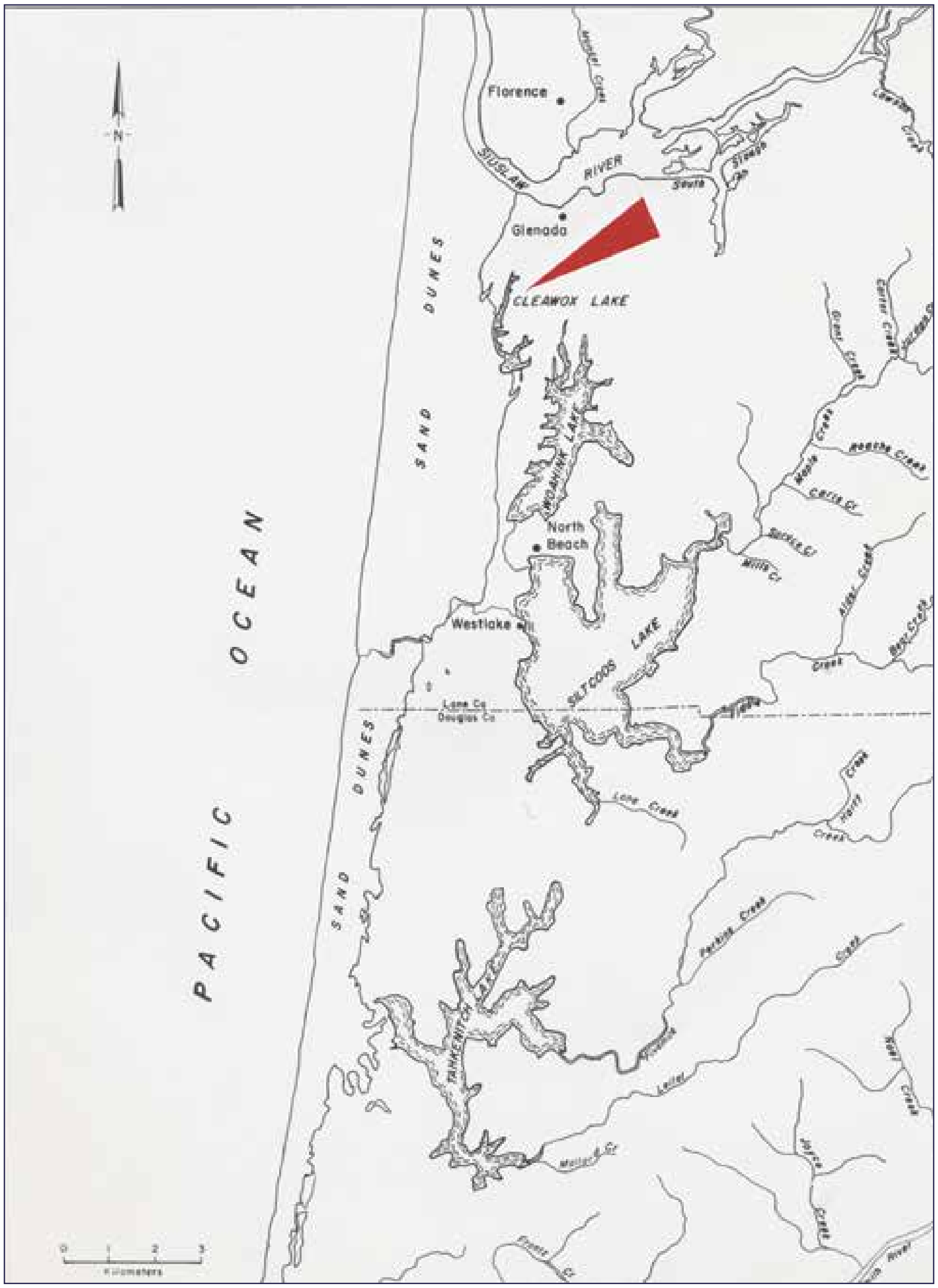

Figure 2. Map showing Cleawox Lake and other sand-dunal lakes.

only a small percentage of total rainfall is discharged as surface runoff while the balance infiltrates into the sand to recharge the ground-water supply. In a study of dunal sands a few miles north of Cleawox, Hampton (1963) estimated that about 85 percent of precipitation enters ground-water storage through infiltration. Assuming that this high infiltration rate also occurs in the dunal sands around Cleawox, approximately 6,000 acre-feet of water per year recharges the ground-water supply for the Cleawox drainage area. Much of this ground water probably flows into the lake's relatively small basin (lake volume equaled 1,391 acre-feet in 1960), resulting in a short hydraulic water residence time of about four months (Johnson et al. 1985) and thus considerable basin flushing.

Limnology

The limnology of Cleawox Lake and other sand-dunal lakes on the Oregon Coast was described in earlier reports (Daggett et al. 1996; Larson 1970, 1974, 1999; McHugh 1972). Cleawox Lake is generally oligotrophic, as exhibited by its water chemistry, relatively high water-transparency, and microbiota (Table 1).

The lake's current morphometry is largely unknown. The lake has steadily filled with sand since the lake's complete bathymetry was last mapped 54 years ago, in March 1960 (Figure 5). Back then, the few morphometric variables reported included the lake's surface elevation (23 meters above mean sea level), surface area (33 hectares), volume (1,391 acre-feet), and maximum depth (15 meters). Shoreline length was approximately eight kilometers.

More recently, in January 2008, Witter and others (2008) obtained depth soundings along five transects extending across the western one-third of the main lake and along three transects across the lake's northerly arm. A maximum depth of about 12 meters was recorded along the transect positioned about 140 meters from shore. Closer to shore, however, shallower waters indicated substantial shoaling due to sand-dune encroachment. Shoaling was also evident in the arm, with depths being somewhat less than they had been in 1960. Then, the distance across the arm at its juncture with the main body of the lake was about 120 meters and the depth at that point was 3-6 meters (Figure 5). But by 1980, the arm was essentially isolated from the main body by an advancing tongue of dunal sand. Dredging during the mid-1980s removed the sand, presumably for the purpose of allowing boats to enter the arm (Witter et al. 2008). Still, aerial photos taken in 1989 indicated renewed shoaling of the arm at its juncture with the main body and at a second point about 100 meters upstream (Figure 6).

As a warm monomictic lake, Cleawox is thermally stratified during much of the summer, with the thermocline located around ten meters. By late summer, the lake begins to turn over and undergo vertical mixing. During winter, the lake is completely mixed at temperatures of 8-9ºC throughout the water column (Saltzman 1961; Larson 1974).

When thermally stratified, the lake's dissolved-oxygen (DO) tends to diminish at depths below ten meters. In late September 1992, for example, Whereat

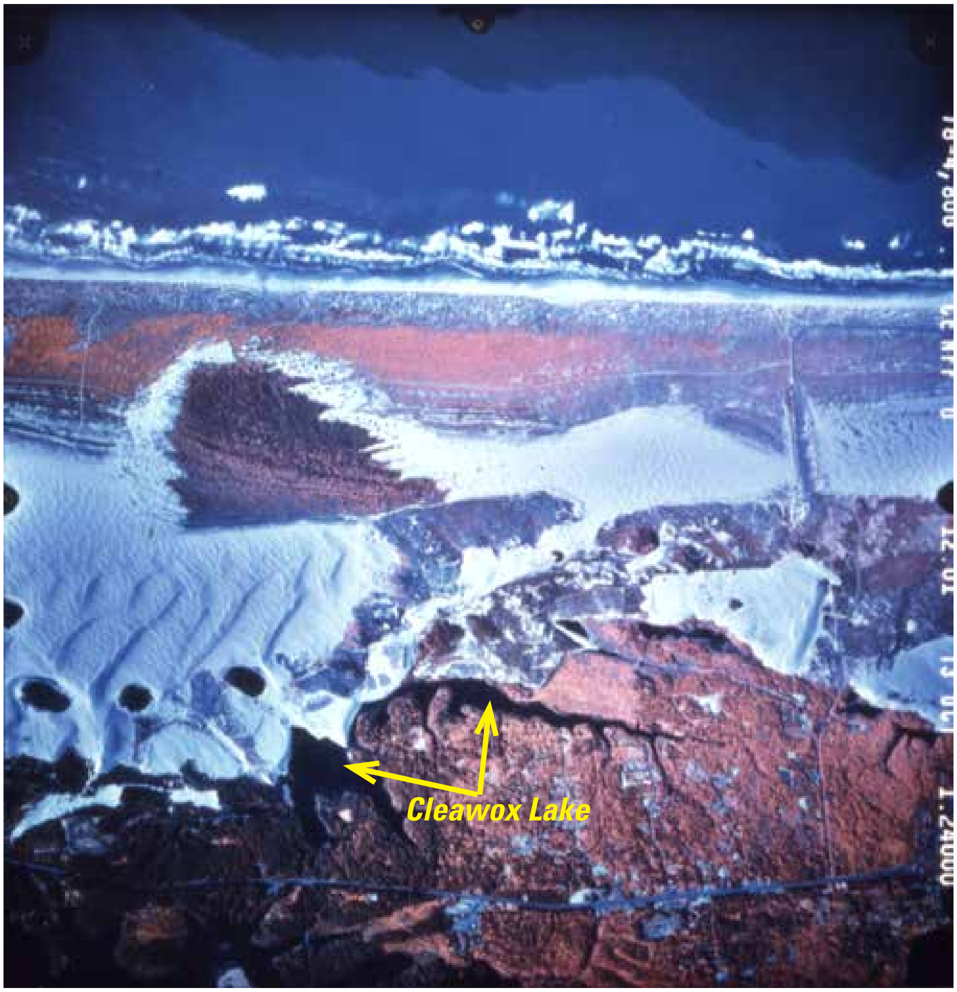

Figure 3. Vertical aerial photo of Cleawox Lake and adjoining dunes, color infrared, October 13, 1978, 1200 hours. Scale=1:24,000. Source: U.S. Army Corps of Engineers.

Figure 4. South-shore dune, August 16, 2013. Photo by the author.

and Merritt (1993) obtained a DO reading of 0.5 milligrams per liter at eight meters, indicating that the hypolimnion was anoxic, possibly due to sediment oxygen demand. Conversely, when vertically mixed during winter, the lake is oxygen-saturated throughout the water column (Saltzman 1961; Larson 1974).

Although the lake is considered oligotrophic, macrophytes are prolific nevertheless in shallow-water zones where dunal sand and more fertile soils have accumulated. Macrophytes include a water lily (*Nuphar polysepalum*), a buttercup (*Ranunculus* sp.), and a pondweed (*Zannichellia* sp.). *Utricularia gibba*, a bladderwort discovered in 1991, has been listed by the Oregon Natural Heritage program, as endangered or threatened in Oregon (Whereat and Merritt 1993).

Little is known about the lake's benthic macroinvertebrates: Only two known benthic surveys have been conducted, in October 1960 (Saltzman 1961) and again in October 1992 (Whereat and Merritt 1993). The 1960 survey collected 45 Ekman dredge samples, yielding a total of 111 organisms, 90 percent of which were mayflies, snails, and midges. Results of the 1992 survey were similar, both in total abundance and species diversity.

Fish production is limited, largely due to the scarcity of zooplankton and macroinvertebrates. In 1951, the Oregon Game Commission (OGC) launched a "put and take" sport fishery by stocking the lake with 56 large rainbow trout. After a seven-year hiatus, OGC resumed stocking in 1958, introducing around 6,000 trout (roughly 70 percent rainbows, 30 percent cutthroat) that year followed by a similar batch in 1959 and 1,500 rainbows in 1960. Since then, both rainbows and cutthroat have been restocked annually (Saltzman 1961; Whereat and Merritt 1993). With over 18,000 rainbows introduced in 2012, the lake has acquired the reputation as the second most heavily planted lake on the Oregon coast.

Various "warm-water" species are also present, most if not all of which were introduced unofficially and perhaps illegally by anglers and other lake visitors. These species include yellow perch, largemouth bass, black crappies,

Table 1. Limnological Data, Cleawox Lake, Oregon.

Water Chemistry	*8/6/68*[1]	*8/27/73*[2]	*8/16/82*[3]	*9/29/92*[4]
number of samples/variable	6	2	1	1
pH	6.3-6.9	6.7, 6.8	6.8	7.2
specific conductance, µmos/cm	112-119	109,110	94	102.3
total alkalinity, mg/liter as CaCO3	8.9-9.0	7.0, 8.0	7.0	3.03(?)
total hardness, mg/liter as CaCO3	12.2-12.6	12.0, 12.8		
sodium, mg/liter		13.0	11.4	12.0
potassium, mg/liter		0.5, 0.6	1.2	0.87
magnesium, mg/liter			1.9	1.96
chloride, mg/liter			14.8, 15.6	29.1
sulfate, mg/liter			3.9, 4.4	4.6
nitrate-nitrogen, µg/liter				<100, <100
nitrate-nitrite nitrogen, µg/liter				000.0
ammonia-nitrogen, µg/liter				100,100
soluble reactive phosphorus, µg/liter		<100, 200	1.0	
total phosphorus, µg/liter			500	10

Transparency	*8/6/68*[1]	*8/27/73*[2]	*8/16/82*[3]	*9/29/92*[4]
number	1	3	1	1
Secchi depth, meters	4.0	4.3-5.0	5.0	3.9

Phytoplankton (no data for '68 and '74)	*8/16/82*[3]	*9/29/92*[4]
chlorophyll a, µg/liter	0.9 (n=1)	1.62 (n=1)
predominant species	Dinobryon sertularia	Aphanocapsa elachista
		Aphanocapsa delicatissima
		Dinobryon sertularia
		Dinobryon bavaricum
		Chlorella vulgaris
		Oocystis solitaria
		Crucigenia tetrapedia
		Dictyosphaerium pulchellum
		Merismopedia tenuissima
		Ophiocytium capitatum

Zooplankton (no data for '68,' 74, or '82)	*9/29/92*[4]	
rotifers	*copepods*	*clodocerans*
Polyarthra dolichoptera	Diaptomus franciscanus	Diaphanosoma leuchtenbergianum
Conochilus unicornis		Bosmina longirostris
Keratella cochlearis		Daphnia longiremis
Ploesoma truncatum		

[1]D.W. Larson, unpub.; [2]Larson 1974; [3]Johnson et al. 1985; [4]Whereat and Merritt 1993.

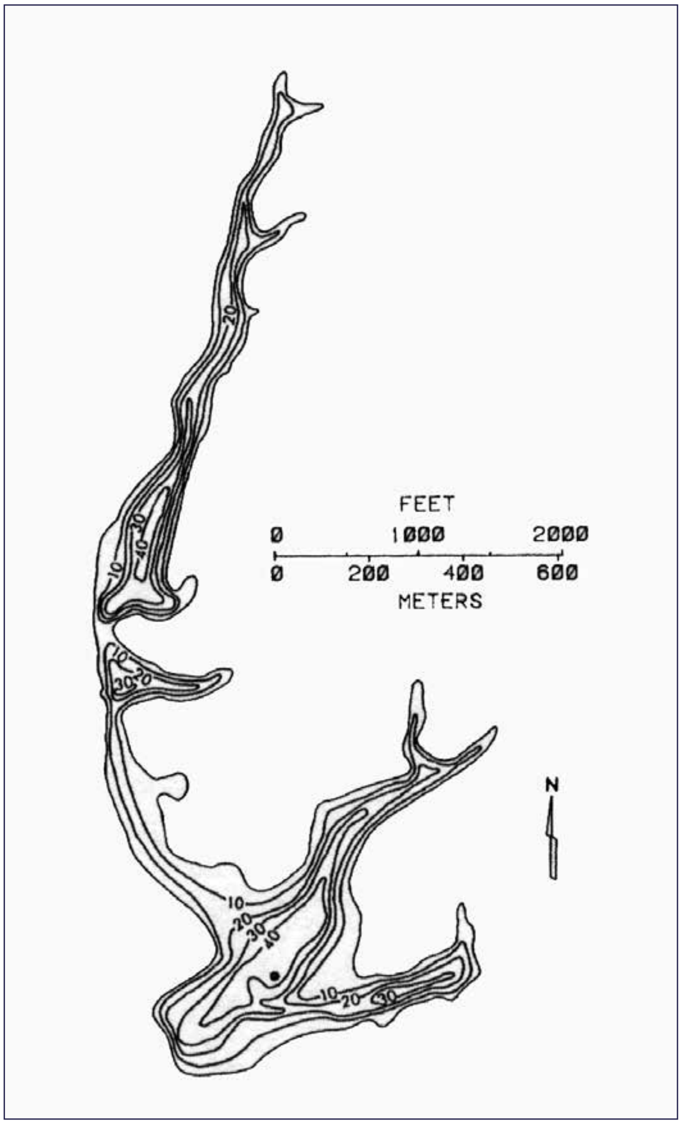

Figure 5. Bathymetric map of Cleawox Lake. Maximum recorded depth (15 meters) is indicated by a dot near lake center. The map is based on depth soundings by the Oregon Game Commission in March 1960. Source: Saltzman 1961.

Figure 6. Sand has nearly blocked the lake's northerly arm where the arm meets the lake's main body and at a second point about 100 meters upstream, as indicated by arrows, September 1989. Photo by the author.

brown bullheads, bluegills, sculpins, and golden shiners (Whereat and Merritt 1993). Other species (northern pikeminnows, coarse scaled suckers, sticklebacks) were found in nearby Lily Lake, a small pond connected to Cleawox Lake by a short channel. In 1960, aware that these species had access to Cleawox where they could threaten planted trout, OGC treated the pond with fish-killing rotenone. This might have been unnecessary, however, since extensive gillnetting in Cleawox during 1957, 1958, and 1959 captured only one pikeminnow (Saltzman 1961).

Stewardship of Lake and Dune

Cleawox Lake is surrounded almost entirely by public lands administered by both the federal government and the State of Oregon. Much of the lake lies within the Oregon Dunes National Recreation Area (NRA), managed by the U.S. Forest Service. Land south and east of the lake is the Jessie M. Honeyman Memorial State Park, administered by the Oregon Parks and Recreation Department (Figure 7).

The Oregon Dunes NRA was established by the U.S. Congress in March 1972 (Public Law 92-260) for the "conservation of scenic, scientific, historic and other values contributing to public enjoyment." Congress then directed the U.S. Forest Service to "manage and protect this *rare and beautiful gem*…." (author's italics). The Forest Service accepted this assignment with considerable zeal, proclaiming in the agency's 1972 NRA Resource Inventory that "the dunal area is fragile and easily altered. Its ecology is complex and can be turned, reversed, or even destroyed within one man's lifetime" (Pinto et al. 1972). Renowned for its sand dunes that exist nowhere else in the Northern Hemisphere, the Oregon Dunes NRA covers about 110 square kilometers and extends for about 65 kilometers between the coastal cities of Florence and Coos Bay. Between one and two million people visit this reserve

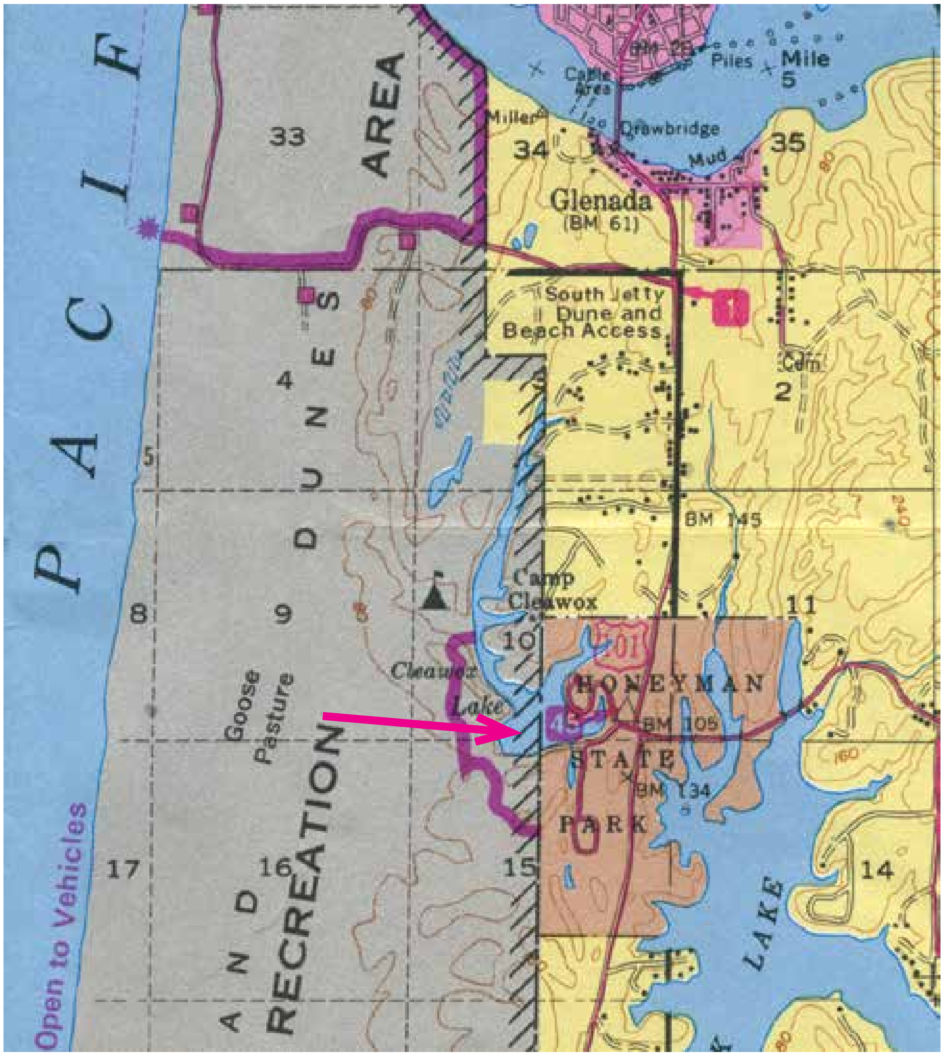

Figure 7. Map, dated 1981, showing location of Cleawox Lake relative to Honeyman State Park and the Oregon Dunes National Recreation Area. Purple boundary along west shore of the lake indicates lake closure to off-road vehicles. Source: Oregon Dunes NRA, Siuslaw National Forest, U.S. Forest Service.

annually. More than 400 bird species are also present, a few of which are threatened, notably the snowy plover. The Jessie M. Honeyman Memorial State Park was constructed between 1935 and 1940 by the Civilian Conservation Corps. The park, covering about two square kilometers (Figure 7), offers visitors a variety of recreational opportunities, including overnight camping (200 campsites), swimming, fishing, boating, hiking, bird-watching, ATV access, dune-buggy rides, and sandboarding. Other shoreline facilities include a Girl Scout camp (Camp Cleawox), a stone-and-log concession building built in 1938 as the Cleawox Lake Bathhouse, and the park office building constructed in 1936-37 as the park caretaker's house and garage. The park is heavily used, logging nearly 20 million visitors between 1989 and 2013, including 4.3 million visitors to the sand-dune area during the same period (source: Honeyman State Park). As stewards, park officials assure the public that the agency's mission is "to provide and protect outstanding natural, scenic, cultural, historic and recreational sites for the enjoyment and education of present and future generations."

Dune Migration and Lake Filling: The Legacy of Cultural Omission

There's a bit of irony in the history and fate of Cleawox Lake: Created by sand dunes, it is conceivable that the lake will someday cease to exist as migrating dunes finally overwhelm the entire basin. Since 1939, the south-shore dune has migrated northeastward for a total distance of about 150 meters at the average rate of about 2.3 meters annually (Figure 8). The rate of migration was highest between 1972 and 1979, averaging between 3.9 and 4.8 meters per year. Dune migration has since diminished somewhat, averaging around 1.5 meters or less per year between 1984 and 2005 (Witter et al. 2008). Nevertheless, the process continues as human intervention in this rare and fragile environment prevails.

I have tracked this process over the past 40 years, photographing the lake and its encroaching dune from both the ground and the air (Figures 9-13 showing stages of dune migration between 1973 and 1990). During that period, hundreds of thousands if not a million or more park visitors have scrambled up the face of the dune to its summit before sliding, striding, or galloping back down toward the lake, pushing sand ahead of them as they descended, with many repeating their descents (Figure 14). In recent years, dune users have introduced the sandboard, a surfboard-like device that further "bulldozes" sand toward the lake. Sandboarding has become a major attraction, advertised in travel brochures and in other media. The boards are readily accessible, sold or rented by vendors outside the park.

Adding to the turmoil are scores of dune buggies, all-terrain vehicles, jeeps, and motorcycles barreling across the surrounding dunes year-round, uprooting vegetation, plowing over dunes and scattering resting birds. Vehicular impacts to dunes and dunal vegetation have contributed sizably to accelerated sand-dune encroachment and, consequently, the in-filling of Cleawox and other dunal lakes. Oregon Wild, a Portland-based environmental organization, reported that off-road vehicles have "established more than 100 miles of unauthorized trails through vegetated areas" throughout the Oregon Dunes NRA. These sensitive areas, replete with rare plants and vegetation planted for dune stabilization have been partly denuded and scarified, the end result of a 15-year delay by the U.S. Forest Service, the NRA's custodian, to begin implementing zoning rules for off-roader usage (Oregon Wild 2012).

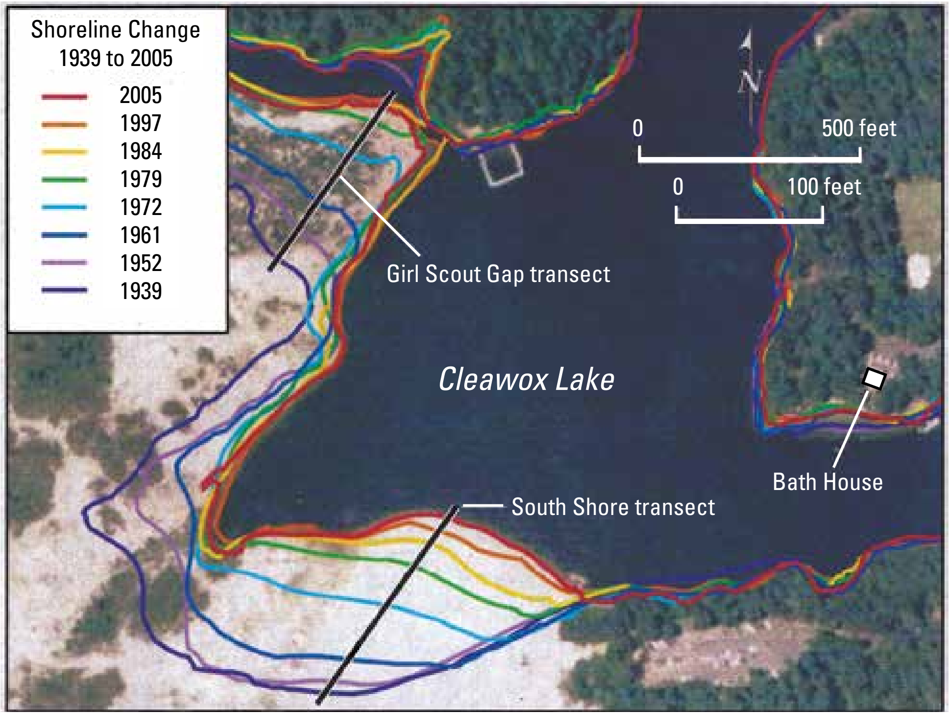

Figure 8. Illustration showing northeast migration of south-shore dune between 1939 and 2005. Illustration printed with permission from R.C. Witter, U.S. Geological Survey and lead author of 2008 publication by R.C. Witter, G.H. Grondin and J.C. Allan.

Dr. Joseph Miller Jr., the Portland physician who single-handedly halted illegal and destructive industrial logging in Oregon's Bull Run Watershed, the City of Portland's primary source of municipal drinking water, often said that battles to protect and preserve environmental treasures were won by educating the public. At Cleawox Lake, unfortunately, the public was not educated about how their footprints, actually and metaphorically, trampled the dune to a near-level profile (Figures 15 and 16), partially filling the lake and causing irreparable ecological harm.

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Figure 9. Aerial photo of Cleawox Lake, September 1973. Arrow indicates south-shore dune. Photo by the author.

Figure 10. Aerial photo of Cleawox Lake, November 1978. South-shore dune visible in photo's upper right-hand corner. Note the dune's arching oblique ridge that has developed. Photo by the author.

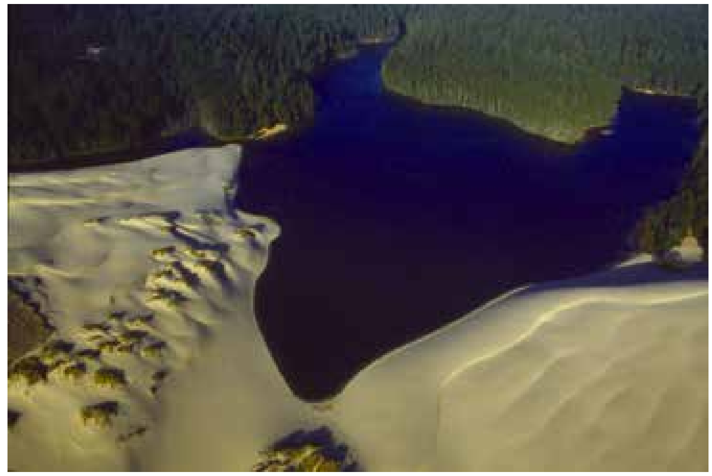

Figure 11. Aerial photo of Cleawox Lake, October 1980. Photo by the author.

Figure 12. Aerial photo of Cleawox Lake, September 1989. Photo by the author.

Figure 13. Aerial photo of Cleawox Lake, August 1990. Photo by the author.

Figure 14. Visitors wade out into shallow waters from the dune's leading edge, July 2000. Photo by the author.

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Douglas W. Larson, Ph.D., is a limnologist and writer in Portland, Oregon.

Figure 15. Side profile of south-shore dune looking east, August 1990. Photo by the author.

Figure 16. Side profile of south-shore dune looking east, July 2000. Photo by the author.

Nitinat Lake – A British Columbia Tidal Lake

Rick Nordin

The Pacific Coast of British Columbia has a large number of unusual lakes. One group of lakes is notable in that they have major marine influences. Ten to 15 thousand years ago, during the last glaciation, most of British Columbia was covered by a vast ice sheet, thousands of meters thick. As the climate warmed and the ice sheet melted, the present mountainous landscape emerged, shaped by ice movement with many narrow valleys sloping to the pacific coast. Many of these glacial trenches became marine inlets – many with the classic fjörd morphometry with a shallow sill at the mouth of the fjörd. As the ice melted and the weight of the ice was removed, the land area began to rise in elevation – a process called isostatic rebound. Consequently, the outlets of many of the ocean inlets rose above sea level and the coastal fjörds were cut off from the sea and gradually the seawater was replaced with inflowing fresh water and the coastal inlets evolved into lakes. Many coastal lakes at low elevations have had complete replacement by fresh water (e.g., Kennedy presently at 12 meters above sea level, Hobiton at 5 meters ASL, but with their deepest depths well below sea level). Other lakes such as Sakinaw and Powell are completely cut off from the sea with the lake surface above sea level but are strongly stratified meromictic lakes with a surface layer of fresh water and the depths of the lake occupied by 10,000-year-old sea water that has been slowly replaced by fresh water (Williams et al. 1961; Northcote and Johnson 1964).

Nitinat Lake is a long, narrow, and strongly salt-stratified fjörd-lake located on the west coast of Vancouver Island, British Columbia (see Figures 1 and 2). It is at sea level, connected to the ocean by a 3-km long natural channel,

Figure 1. Nitinat Lake showing the lake outlet and the Pacific ocean at the bottom of the photo.

Figure 2. Nitinat Lake aerial view down the lake

only 2.5m deep at low normal tides that limits exchange between the 205m-deep lake and the Pacific Ocean. It has inputs of saltwater at high tidal elevations at its narrow southern ocean outlet and freshwater inputs from its terrestrial watershed at the north end of the lake. This unusual situation results in very unusual physical stratification as well as resulting unconventional chemical and biological features. The unusual stratification with a thin freshwater surface layer over a mostly seawater volume was first reported by Northcote et al. 1964 and a number of studies of this unusual lake have followed. Its location on the west coast of Vancouver Island is subject to high rainfall – 3000-4000 mm per year (Lamont 2005) and the area is geographically a temperate rainforest and heavily forested (Figure 3).

Nitinat Lake and the surrounding region are an important part of the Vancouver Island economy. Tourism is important to the region, with the close proximity of Pacific Rim National Park and Carmanah Valley, while the lake itself is an internationally known destination for windsurfing and kite-boarding due to the strong and regular wind that blows from down the valley along the lake axis, as well as being well known for recreational fishermen (Figure 4). Furthermore, a number of important salmon runs access spawning grounds through Nitinat Lake, and the Canadian Department of Fisheries and Oceans operates the largest hatchery for pacific salmon in the country on the Nitinat River, which is the major tributary to the lake (Lamont et al. 2004).

Nitinat Lake is important as a major producer of salmon – primarily of chum salmon (*Onchorynchus keta*). Prior to about 1925 returns of fish were about 350,000 per year but numbers declined up to the 1980s due to overfishing and habitat damage (Fedorenko et al. 1979). Recent salmon returns have improved as a result of better management. The lake contains several other large salmon runs and at the head of the lake is the largest salmon hatchery in Canada, rearing over 40 million fry annually.

Physical Characteristics

Nitinat lake is 23 km long, 1.2 km wide with a surface area of 27.6 km^2 The tidal influence is minor with a tidal

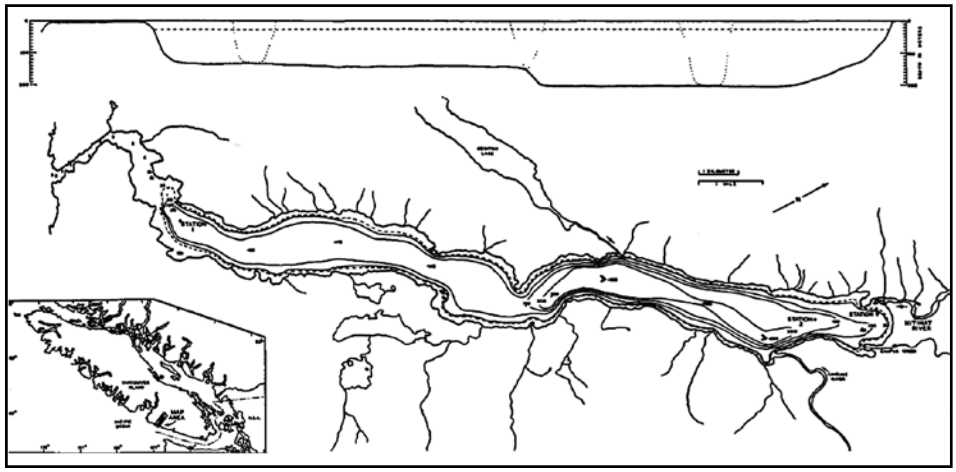

Figure 3. Location map/bathymetric/side profile of Nitinat Lake, Vancouver Island, British Columbia. Longitudinal profile and depth contours in meters. Source: Northcote et al., Figure 1.

range of 8 to 45 cm. The depths below 20-30 meters are permanently anoxic and contain high concentrations of hydrogen sulfide. The thermocline and halocline (a strong, vertical salinity gradient) occur in the upper 10 meters (typically between 5-10 meters depending on the time of year) with a strongly stratified brackish surface layer and the deeper waters maintaining temperature and salinity fairly constant at 10°C and 31 ppt salinity (Fedorenko et al. 1979). The watershed receives relatively heavy precipitation, typically between 250 and 350 cm per year. Almost all of the rainfall is in the October through March period typical of BC coastal lakes. Snow is rare and the relatively mild maritime-influenced climate precludes any ice cover on the lakes in this area (Nordin et al. 2004).

Upwelling events where the thin fresh and brackish surface water layer is disturbed have been observed on the lake by both the Ditidaht First Nation of the area and the Nitinat Fish Hatchery employees, and have resulted in

Figure 4. Wind surfing on Nitinat Lake.

significant fish kills in the lake. Upwelling events are usually localized and are often detected by smell ("rotten egg") or by sight (surface waters turn a "brown color") (Shortreed et al. 1987). The record of events is incomplete as there has never been continuous monitoring of the lake, but does provide a starting point for examining conditions that lead to upwelling events (Lamont et al. 2004).

Due to the remote location, it is likely that many upwelling events were not documented, but several dates have been recorded: July and October 1970, October 1972, November 1987, March 2002 and March 2003. The upwelling events in the 1970s resulted in the evacuation of the village of Malachan for several days due to the strong sulfide smell and the 2002 and 2003 events were significant enough to have been reported in newspaper stories. These upwelling events are particularly significant for fisheries as they result in the mortality of hundreds of thousands of salmon.

Strong winds blowing parallel to the long axis of the lake are thought to be a primary factor leading to upwelling events (Ozretich 1975). These winds impart a shear stress onto the lake surface that "pushes" the surface layer toward one end of the lake. If sufficient sustained winds are present during times of weak stratification, it is possible that upwelling of anoxic water will occur at the upwind end of the lake. On Nitinat Lake, an upwelling event due to wind shear is most likely to occur in the late fall after a dry summer. The upwelling event of October 1972 was probably caused by this combination of weak stratification and strong NE winds (Ozretich 1975).

There are several motivating factors for further study of wind-induced upwelling on Nitinat Lake. First, the density stratification is weakest in the late fall, which coincides with the time that spawning fish are returning to the lake (Ozretich 1975). Second, upwelling is most likely to occur at the northern end of the lake, since anoxic water is shallower at the north end of the lake than the south (Broenkow, 1969). This is unfortunate due to the fact fish pens used by the Nitinat River Hatchery are located at the north end of the lake (Lamont et al. 2004).

Water Chemistry Patterns

The initial survey by Richards et al. (1965) reported accumulations of ammonia, carbonates, phosphate silicates, and sulfides in the deep water of the lake that they attributed both oxidation and fermentation processes in the decomposition of planktonic organisms. Methane in the deeper waters indicates anaerobic fermentation. The chemical processes in the lake are of interest to contemporary researchers (Pawlowicz et al. 2007) to provide insight into the basic physical and microbiological / biochemical processes in the water column that maintain stable anoxia for most of the time except during turnover. Understanding of the complex chemistry in *meromictic lakes* (lakes where the deepest water does not mix with surface water) is still being examined (Perry and Petersen 1993). Environments such as Nitinat Lake are stable natural models for the emerging use of man-made pit lakes receiving mine wastewater where the aim is to precipitate metals by sulfate reduction cheaply and over long periods of time (Boehrer and Schultze 2006).

Aquatic Biology

Northcote et al. (1964) sampled the phytoplankton and reported that the species were all brackish and marine species. The zooplankton observed were also almost entirely brackish or marine but a few freshwater taxa were reported from the east end of the lake near the Nitinat River inflow. The benthic plant community was marine to brackish, the two dominant species being the seaweeds *Fucus* and *Pylaiella*. Animal benthos was also marine or estuarine in nature. The fish community sampled included marine species (herring, seaperch, flounder, and sculpins) as well as salmonids (coho, chinook, chum, and sockeye salmon, steelhead, and cutthroat trout).

Summary

Of major concern from an economic and ecological perspective is the instability of the stratification of the lake. In times of low freshwater input, the wind energy input can be sufficient to destratify the lake and bring the anoxic deeper water to the surface with its high concentration of hydrogen sulfide.

Upwelling events of anoxic water are potentially catastrophic for fish hatchery operations such as fish harvesting and juvenile releases, highlighting the need to better understand the physical mechanisms that lead to upwelling (Lamont et al. 2004).

Scientific interest in the lake is focused on the complex water chemistry of the deeper waters as well as the physics of the density stratification as well as the microbial community that exists in these unusual environments (Pawlowicz et al. 2007).

Nitinat Lake has a dual personality. For windsurfers and fisherman, it is a wilderness lake in a pacific coast rainforest with extraordinary aesthetic potential. For scientists it represents a lake of unusual and interesting physical, chemical, and biological characteristics as a rare hybrid of a lake and a fjörd – perhaps thought of as the confused child of the Pacific Ocean and the coastal rainforest.

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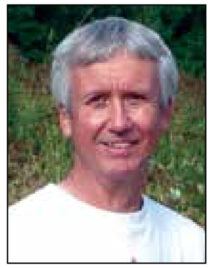

Rick Nordin is a mostly retired limnologist who has worked for more than 40 years on a variety of lakes in British Columbia as a government scientist and researcher and teacher at the University of Victoria. He is a former NALMS board member and was the local committee chair for the 2004 NALMS conference in Victoria, BC (where attendees were surprised to find an umbrella in their registration kits – but soon discovered why).

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Victoria Chraïbi

Student Corner

Saline Systems in Austria

We drove along a small dirt road, hedged in by reeds on one side and grapevines on the other. In a fallow field, small biplanes refueled and took off, flying precariously low to the vineyards. Every few seconds, we heard the *Pop! Pop! Pop!* of gunshots. "Don't worry, those aren't real guns," Lucas, the park intern, reassured us, "it is an automated sound machine to scare away the birds." *The birds* refer to the 340+ species that migrate through this small region in western Austria every year on their way to Africa. Unfortunately, the bird migration corresponds with the grape harvest, so a miniature war of sound and wind replays itself every autumn. After all, the birds and the grapes are both here for the same reasons: salt and water.

I am currently abroad in Austria with members of the NSF-IGERT group from the University of Nebraska-Lincoln to study the resilience and adaptive management of stressed watersheds. I am leading a small discussion group focusing on the resilience and management of saline systems. Several of us study saline systems in Nebraska. Because these unique systems exist both in Nebraska and Austria, we are excited for the opportunity to visit and research how these two countries' systems compare. We recently began our study by visiting Austria's saline systems, and would like to share what we have learned so far. For our discussion, we focus on Williams' (2002) prediction of two different threats related to salt and aquatic systems in the coming decades: the loss of naturally saline lakes, and the anthropogenic salinization of freshwater lakes. We visited examples of both situations in Austria: Neusiedler See and Hallstättersee.

Neusiedler See: A Threatened Saline Lake

First, we visited the National Park of Neusiedler See-Seewinkel to learn about imperiled saline water bodies. Neusiedler See hosts one large (315 km^2), very shallow (1.8 m max. depth) alkaline lake, the namesake of the region. Fed only by precipitation and continually mixed by wind, the lake hosts one of the largest reed belts in Europe (Figure 1). This feature has earned the area designations as a UNESCO Cultural Heritage Site as well as a Bird Heritage Site, and its management must serve a delicate balance between these two.

We met with Alois Lang, who has worked at the park since its inception in 1983, and has encyclopedic knowledge of the physical and natural characteristics of the area and the intricacies of its conservation. He explained that the strong winds mixing the lake also push sand out of the lake onto the eastern shore, providing the sandy soil that the vineyards covet. This soil gradates into a more saline soil in the Seewinkel region, which is also dotted by transient, groundwater-fed saline ponds, and finally into black soil suitable for other types of agriculture. Until 70 years ago, the land was mainly used for pasturing cattle, haying, and harvesting reed for house thatching. The vineyards arrived in the 1960s and '70s, changing the landscape.

Next, we met with Prof. Alois Herzig, the former director of the park and biological station, and Harry, who is in charge of park education. They animatedly discussed the park's

Figure 1. The second-largest reed belt in Europe fringes Neusiedler See.

management successes and challenges. Rather than owning land, the park annually rents the land and the right to manage it from the local landowners. In this way, the park is composed of 10,000 hectares of little islands of land surrounded by agriculture and linked together by plots that have gone fallow as part of a government-subsidized program.

The management of the land depends entirely upon the decisions of the 28 national park staff; they are not given goals by government entities such as bird population numbers or hectares conserved. If they notice something that works, they continue to do it. For example, they noticed that cattle-grazed land provided more bird habitat than mowed land or unmanaged land, so they paid to borrow traditional grey cattle from southern Austria and Hungary. In this way, they reintroduced a traditional land use practice in the region that also serves an ecological function.

The national park has enjoyed other successes in addition to recovering grasslands. The lake was once used as an eel fishery, introducing an exotic species that decimated the local fish population. In order to become a national park, the government required this industry be stopped, helping to recover the lake's natural species assemblage.

They also count successes within the community of Neusiedler See. The national park serves as a role model for sustainable land use, and through the years they have witnessed a change in the way local residents value and use their land. Much of the land is now rented to the park or allowed to go fallow because it is of economic value to the whole community for the ecotourism it brings, which supports stable jobs so young people can afford to stay in the community.

The national park faces challenges ahead. The first is money. The current budget is based on a contract between the regional and national governments, each paying 50 percent of a budget upon which the governments decide every year. The budget for 2014 is uncertain as both governments consider defunding both the national park and the fallow land subsidy. Should the park be unable to pay its rent to landowners – which already requires 60 percent of the budget – the landowners may choose to redevelop the land. The budget restrictions also leave only 3 percent for monitoring and 2.5 percent for education. The park does not receive revenue from tourism, so its land management, tourism advertising, and monitoring data rely solely on personal agreements it has made with local landowners, industries, and university researchers in Vienna.

Ecologically, the main challenge is now water retention. Water management in the area focuses on maintaining stable lake levels and avoiding floods. Water is also free and unlimited, so sloppy water use is common. This inefficient consumption lowers the water table so much that the smaller Seewinkel saline ponds, which naturally tend to dry up in the summer, are drying up permanently because the groundwater that feeds them is now too deep. The park has lost 60 ponds in this way, and now focuses on educating the public on the importance of saving the remaining 40 ponds in its area.

Hallstättersee: A Threatened Freshwater Lake

Second, we visited the Salzkammergut region in the western Alps of Austria to learn about freshwater lakes exposed to saline influences. The Salzkammergut, or "salt kingdom," is where salt has been mined for thousands of years, providing the region with economic stability and a vital natural resource. The region is also characterized by several freshwater lakes; we visited the lake Hallstättersee (area = 8.6 km^2; mean depth = 12.5 m) and its small associated town of Hallstatt. The town has about 1,000 permanent inhabitants. Every morning, two fishermen cruise the lake with nets and return with the catch of the day for the locals and restaurants to prepare for dinner. Swans were introduced to the lake to please Empress Elisabeth when she would vacation here; today they cruise the lake looking for handouts from the peasant tourists.

We ascended the nearby mountain to visit the local salt mine (Figure 2). Hallstatt is thought to be the oldest salt mine in the world, established about 7,000 years ago. Neolithic people mined the salt to preserve meat; this area became one of the first known human settlements, and its archaeological importance is recognized by an era of time named after it (Hallstatt Era 800-400 BC).

The mine has functioned continuously through the millennia. The mining techniques adapted with technology, and today the salt is mined by being dissolved into water under pressure. The salt is then transported as brine through pipes 40 km to the town of Ebensee, where it is placed in evaporative

Figure 2. The view of Lake Halstättersee from the salt mine mountain.

pools to extract the salt. The system is so efficient that the mine only employs 28 workers total. Because of the loss of jobs in the mining industry, young people have left town for opportunities elsewhere; the population has shrunk by half, and many of the houses have become rental properties for tourists.

Hallstättersee receives wastewater discharges from the mine through one of its tributaries. On two occasions in the last few decades, the brine pipes burst, releasing large amounts of brine into the lake. News reports suggested that the brine sank to the bottom immediately and therefore had no impact on the lake; we were interested in the effects of sudden intense additions salt on the benthic ecosystem. Ficker and others (2011) found that the brine spills caused *ectogenic meromixis* (the lake stops mixing during turnover periods) and *hypoxia* (low or no oxygen) in the deeper regions of the lake that showed temporary die-off of benthic fauna. Even though one brine spill was much larger than the other, the lake took the same amount of time to recover from the shock by flushing the salt out of its basin (three years, or six times its water residence time). As far as we can tell culturally and economically, though the lake is beautiful, here salt is king. The lake is lucky that it has the natural ability to respond rather quickly to the occasional "oops" of large brine spills, because the salt isn't going anywhere soon.

Many of our group members were struck by how similar the Neusiedler See region was to the Nebraska Sandhills in appearance and ecological function, and how the Salzkammergut compared to some of our other study sites. We look forward to returning home to Nebraska and to continue our ongoing study on how saline systems in Austria and Nebraska compare in their ecological and social resilience and management.

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Victoria Chraïbi is a Ph.D. student at the University of Nebraska-Lincoln in earth and atmospheric science, with emphases in paleolimnology and science education. She is a member of the NSF-IGERT program on the resilience and adaptive management of stressed watersheds. She holds an M.S. in water resources science from the University of Minnesota Duluth and a B.A. in biology from Hanover College.

Bill Jones

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William (Bill) Jones is *LakeLine*'s editor and a former NALMS president, and clinical professor (retired) from Indiana University's School of Public and Environmental Affairs. He can be reached at: 1305 East Richland Drive, Bloomington, IN 47408; e-mail: joneswi@indiana.edu.

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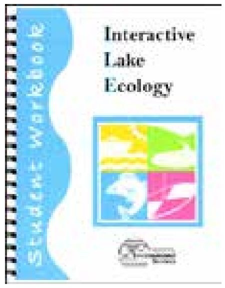

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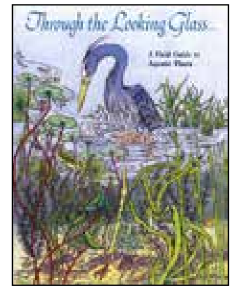

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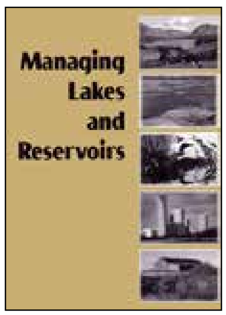

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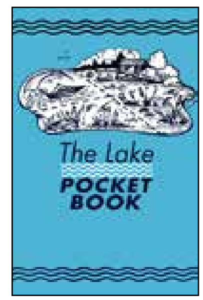

The Lake Pocket Book is a 176-page guide that provides explanations of aquatic chemistry; lake ecology and biology; collecting lake information and how to use it; developing lake management plans and organizing a lake association– all presented in plain English. This easy-to-understand style combined with its in-depth information has made The Lake Pocket Book an extremely popular publication among citizen lake lovers.

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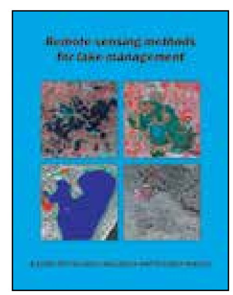

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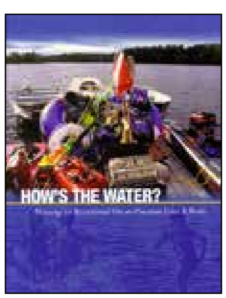

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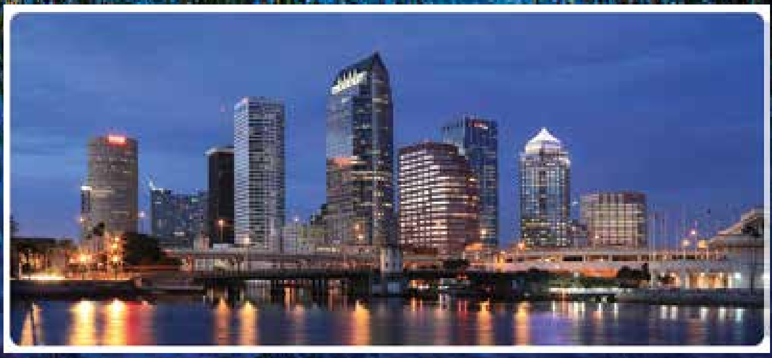

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