WETLAND SCIENCE AND PRACTICE

VOL. 31, NO. 1
March, 2014

Uros (floating islands), boats and houses of the Aymara people on Lake Titicaca, Peru, are made of totora (*Schoenoplectus*) - Photo by Paul DuBowy

WETLAND SCIENCE AND PRACTICE
Vol. 301 No. 1
March, 2014

Contents

Aim and Scope of Wetland Science and Practice

The *WSP* is the formal voice of the Society of Wetland Scientists. It is a quarterly publication focusing on news of the *SWS*, at international, national and chapter levels, as well as important and relevant announcements for members. In addition, manuscripts are published on topics that are descriptive in nature, that focus on particular case studies, or analyze policies. All manuscripts should follow guidelines for authors as listed for Wetlands as closely as possible. All papers published in *WSP* will be reviewed by the editor for suitability. Letters to the editor are also encouraged but must be relevant to broad wetland-related topics. All material should be sent electronically to the current editor of *WSP*. Complaints about *SWS* policy or personnel should be sent directly to the elected officers of *SWS* and will not be considered for publication in *WSP*.

Wetland Science and Practice
2013-2014 CHAPTER PRESIDENTS

REGIONAL CHAPTERS - UNITED STATES

Alaska USA
President - Jeffrey Mason
Email: masonjeffreya@gmail.com

Central USA
President - Craig Gump
Email: craiggump@gmail.com

Mid Atlantic (US)
President - David Merkey
Email: dhmerkey@gmail.com

New England (US)
President - Chester Bigelow
Email: chet.bigelow@gmail.com

North Central (US)
President - Arnold Van der Valk
Email: valk@iastate.edu

Pacific Northwest (US)
President - Colin MacLaren
Email: colinmac.sws@gmail.com

Rocky Mountain (US)
President - Andy Herb
Email: andyherb@alpine-eco.com

South Atlantic (US)
President - Kelly Chinners Reiss
Email: kcr@ufl.edu

South Central (US)
President - Robert Kroger
Email: rkroger@cfr.msstate.edu

Western (US)
President - Michelle Stevens
Email: stevensm@csus.edu

REGIONAL CHAPTERS - INTERNATIONAL

Asia
President - Wei-Ta Fang
Email: wawaf@hotmail.com

Canadian
President - Patricia Chow-Fraser
Email: chowfras@mcmaster.ca

Europe
President - Jos Verhoeven
Email: j.t.a.verhoeven@uu.nl

International
President - Elijah Ohimain
Email: eohimain@yahoo.com

Oceania
President - Samantha Capon
Email: samantha.capon@gmail.com

South America
President - Elier Tabilo Valdivieso
Email: etabilo@centroneotropical.org

Editor's Message

EDITOR'S MESSAGE

Greetings from the New Editor of WSP and Request for Contributions

Hello and welcome "Spring" to our Northern Hemisphere readers! Last week our local maple syrup maker tapped our sugar maples – the first sign of Spring in our neighborhood, despite the snow covering the ground. It won't be long before I hear the wood frogs chorusing.

As the new editor of Wetland Science and Practice (WSP) I am excited about the opportunity to continue to move the publication forward. With this note I am reaching out to membership and readers to contribute articles for this journal. After all WSP is designed to be a medium for wetland practitioners to present information on their activities. Possible articles could be summaries of the results of on-the-ground projects such as monitoring wetland restoration projects (a synopsis of what you may already be providing to the project sponsor), botanical surveys of wetlands, characterizations of individual wetlands based on field investigations (vegetation, soils, and hydrology), problems you've encountered doing wetland delineations or restoration and recommended solutions, cooperative projects to improve wetland conservation, and outreach/educational programs with schools and other organizations. These are just examples that come to mind. As such WSP is a forum to profile some of your accomplishments and inform others on your activities. Members from federal and state regulatory agencies are encouraged to submit summaries/notices of any key issues addressing wetland regulation, litigation, delineation, restoration, inventory, and monitoring. We also would like to publish notices on the availability of wetland publications from your agencies, universities, organizations, or companies. Ideally such notices should include a brief summary of the content of the report.

I would also like to especially reach out to our universities – professors and students – and to federal research centers to use WSP as a means of communicating the types of research you're doing. These contributions would be summaries of projects and would inform readers on what type of research is going on across the country and who to contact for more information. Such contributions could follow one of two paths: 1) an abstract of the objectives and methods for ongoing projects or 2) a summary article (perhaps in a posterlike format like those we see at our annual meeting) briefly discussing the project and highlighting key findings (not to the detail that one would expect for a submission to Wetlands).

SWS chapter presidents please report on your activities and encourage your members to contribute to WSP. Also heads of various SWS committees, please submit summaries of ongoing activities and current issues.

I'm inviting all to contribute to WSP and make productive use of this journal to tell the rest of us what you are doing. We are currently accepting articles for the June issue and already have a couple in preparation. Draft articles need to be submitted before April 30 for consideration.

Outlined below are the latest format requirements (if questions, feel free to contact me):

Author Guidelines for Contributions to WSP

- In general, SWS style conforms to the Merriam Webster Collegiate Dictionary and The Associated Press Stylebook. Please have all content edited for style prior to design.
- Identify each author, position, place of employment and email address.
- Submit a title for your article.
- Break up lengthy text with subheads to separate the thoughts.
- Submit all text copy electronically in MS Word.
- If the manuscript contains any previously published material, including figures and tables, include copies of permission to reproduce.

Photos and Tables

- High resolution electronic files are preferred.
- Provide captions for all tables, photos and figures
- Whenever possible, graphs and tables should be submitted in their native format (in whatever software they were created in – i.e., PowerPoint, Excel, Word files).

Since the journal is published quarterly (March, June, September, and December), draft articles should be submitted by the end of February, April, July, and October, respectively.

I'm looking forward to reading about your programs, projects, and other accomplishments. Thanks for your cooperation and support.

Ralph Tiner (rtiner@eco.umass.edu)

Elections have consequences

While this headline originally referenced our national political scene, I can tell you from personal experience it is directly relevant to both me and SWS. The strength of SWS resides in our members and it should embody the thoughts and aspirations of our collective ideas on how to further our mission of promoting understanding and scientifically based management of wetlands worldwide. Having effective leaders who understand how to function as part of an executive team is critical to the success of an organization. As I have discussed in my previous messages, SWS faces some unique challenges as we have matured into the largest wetlands scientific society given that we are the owners, the customers, and the workforce of the organization. While we have a pool of active members who are willing to serve the Society on both the Board of Directors and the Executive Board, we need to constantly increase that pool in order to bring fresh energy and ideas to help lead SWS into the future. Now is a great time for you to bring your talents and capabilities to SWS and the best way to start is getting involved with a section, your local chapter, or with one of our many standing committees. Of course, one of the most important duties you have as a member is casting an informed vote for the next generation of SWS leaders. We are fortunate to have an excellent slate of candidates for President-Elect and Secretary-General. Please take the time to review their biographies and statements and, most importantly, vote!

As we draw closer to the Joint Aquatic Sciences Meeting (JASM) "Bridging Genes to Ecosystems: Aquatic Science at a Time of Rapid Change", in Portland, Oregon, May 18-23, 2014, I have been busy working with the Board and AMPED staff on a number of initiatives we will present to the membership at the meeting. Despite the epic snowstorm that shut-down the Washington D.C. area on Valentine's Day, we held our mid-year Board of Directors meeting followed by a delayed Executive Board meeting at AMPED headquarters in Madison, WI. We have been working on finalizing our leadership manual and updating our Bylaws and Standing Rules to more accurately reflect how we function as an organization and improve our operational efficiency. There will be several motions presented to the membership for a vote at the Business Meeting on Monday night. We will also be launching our new website that night as well. There were over 2,500 abstracts submitted to JASM and, as you can imagine, a lot of work organizing those into the various sessions across four societies. That has led to some delay in finalizing the schedule, but we anticipate the session schedule should be out soon (maybe by the time you are reading this) followed closely by the final presentation schedule. We have a full and

exciting scientific program that will have something for everyone. If you haven't planned to attend, I urge you to visit http://www.sgmeet.com/jasm2014/ and register and come join us! Portland is a fabulous venue and you will have a great time connecting with colleagues both old and new while learning about the latest in wetland and aquatic science and management!

Stephen Faulkner
SWS President

Society of Wetland Scientists www.sws.org

an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

2014 SWS Election of Officers President-Elect and secretary-general Candidate Profiles

Dear SWS Member,

Our organization continues to grow and remains vibrant thanks to you, our members, and the dedicated leadership of our Board of Directors, committee members, volunteers and staff. It is important to continue this leadership through the election of two individuals to serve as President-Elect and Secretary-General of SWS. The President-Elect serves a one-year term, followed by a one-year term as President, and then a final year as Past-President. The Secretary-General will serve a three year term. The elected officials will be introduced and take office during the 2014 Joint Aquatic Sciences Meeting in Portland, Oregon, USA.

Please take a moment to read the profiles and vote for one of the following two candidates for President-Elect:

- Kimberli Ponzio, PWS, St. Johns River Water Management District, Palatka, Florida, USA
- Neil Saintilan, PhD, New South Wales Government, Sydney, Australia

Please also review the profiles and vote for one of the following Secretary-General candidates:

- Loretta Battaglia, PhD, Southern Illinois University, Carbondale, Illinois, USA
- Robert "Robbie" Kroger, PhD, Mississippi State University, Mississippi, MS, USA

All individual members are entitled to one vote, which may be submitted with this paper ballot or using the electronic ballot circulated via email. All ballots must be received by 8pm EDT on Friday, April 18, 2014.

Thank you for your participation in choosing the leaders of your professional society – SWS.

Sincerely,

George Lukacs
SWS Past-President & Nominations Committee Chair

*The statements on the following pages were provided by the candidates for this office and are listed solely in alphabetical order by last name.

Society of Wetland Scientists www.sws.org
an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

Kimberli Ponzio, PWS
St. Johns River Water Management District
Palatka, Florida, USA

Professional Background:
Growing up in Florida, I was fortunate to have year-round access to a variety of outdoor activities that fostered my interest in the natural world - of which the fascinating and engaging world of wetlands was an important component. After earning a B.S. degree in Zoology at Florida Atlantic University in 1987, I worked for the South Florida Water Management District. I participated in research involving evaluation of cattail expansion, sawgrass growth dynamics, and water quality in the Everglades, and nutrient dynamics of marshes along the Kissimmee River. Shortly thereafter, I began work on my graduate degree while employed full-time at the St. Johns River Water Management District (SJRWMD). I received my graduate degree in Wetlands Ecology from the University of Florida in 1997 and my thesis was entitled "Characterization of Germination in Sawgrass with Implications for Wetland Restoration".

For the past 25 years, I have worked as an Environmental Scientist at SJRWMD. I have been involved in large-scale, ecological studies designed to better understand wetland ecosystem processes and serve as a basis for implementing science-based management strategies to restore and preserve wetlands. I coordinated wetland restoration of former agricultural lands and conducted research on the effects of wetland management activities on biotic communities. I am currently investigating evapotranspiration and CO2 dynamics in wetlands to help refine hydrologic criteria for preservation of marsh habitats. I received recognition from the US ACOE for my contribution to the Upper St. Johns River Basin project and a meritorious service award from the SJRWMD for work on the St. Johns River Water Supply Impact Study. My primary research interests are focused on wetland restoration, applied ecology, and botanical responses to wetland management activities.

Society of Wetland Scientists

www.sws.org

an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

Involvement And Interest In Sws And In Serving The Society:
I have been a member of SWS since 1989 and certified PWS since 1995. I am proud to have served as the Vice-Chair, Chair, and Past-Chair of the South Atlantic Chapter of SWS from 2003-2009. As an officer of the SAC-SWS, I focused my attention on increasing the visibility of the Chapter, establishing partnerships with like-minded organizations and other SWS Chapters, encouraging interest in membership, providing relevant wetland education and training to members, and supporting student involvement through the establishment of SWS student associations, funding for travel and research grants, and mentoring workshops. Since 2011, I have had the opportunity to serve as SWS Secretary-General. Through the teamwork of the SWS Board, staff, and engaged leaders / membership, we have met the challenges of navigating through significant changes in management, technology, and a difficult economic climate. In the past three years, the membership renewal process has been streamlined, positive membership trends have been realized, and engagement in Special Interest Sections has grown. Technologically, we evaluated our IT needs, migrated WSP to an electronic format, and initiated the redesign of the SWS webpage. Financially, we developed an investment policy and are now utilizing investment advisors to leverage our assets to provide enhanced membership benefits.

My goals are to continue these on-going initiatives and to:

1. Invigorate chapters by providing support needed for regional workshops, conferences, and activities that attract/retain members;
2. Enhance e-services that will enable all membership sectors to collaborate, educate, and provide feed-back when face-to-face participation becomes difficult; and
3. Foster communication among the wetland science community including interactions between SWS and other like-minded societies, SWS leadership and membership, and SWS chapters.

I enthusiastically welcome the opportunity to lead the team that continues to define SWS as the leader in wetland science.

SWS Society of Wetland Scientists www.sws.org

an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

Neil Saintilan, PhD
New South Wales Government
Sydney, Australia

Professional Background:

My work as a wetland scientist embraces research and management spheres. I worked for 15 years as a university-based scientist and professor, and in 2006 left academe for a senior government science appointment. I now lead the Water and Wetlands Theme in the New South Wales Government environment agency, where I am a Senior Principal Research Scientist, working in both freshwater and estuarine systems. Our work seeks to bring the best science to the conservation and restoration of rivers and wetlands in Australia's most populous state. I hold honorary Professorial appointments at several universities in Australia and China and continue to engage in training young scientists. I won the NSW Science and Engineering Prize in 2012 for my contributions to Public Sector Science and Engineering, particularly for the provision of hydrological and ecological response models supporting water planning in interior Australia. In 2014-2015 I will be working for three months in California on a Fulbright Fellowship, building bridges between Australian and US science, particularly around "blue carbon", the sequestration of carbon by coastal wetlands. This collaborative program is an outcome of my work on the CI-UNEP International Blue Carbon Scientific Working Group, and seeks to contribute to market-based mechanisms for the better protection of wetlands internationally.

Involvement And Interest In Sws And In Serving The Society:

I have been a member of SWS for 15 years and in that time have served for five years as Australian Chapter President and SWS board member (2001-2006). During my term as chapter president, we hosted the 2006 Annual Meeting of the SWS in Cairns, the first annual meeting outside of North America. I have since served as Chair of the Global Change Ecology Section (2009-2010) and as an editor of Wetlands (2009-2012). I accepted the Fellow Award at the 2011 meeting in Prague. As President my aim would be to maintain the strong US-based chapters while strategically advancing the society internationally. This is best achieved through an attractive meetings program, a strong and respected journal, and close co-operation between the board, secretariat and chapter committees internationally.

Loretta Battaglia, PhD
Southern Illinois University
Carbondale, Illinois, USA

Professional Background:

I am a community ecologist with over 25 years of experience working in wetlands. I received my B.S. in Zoology in 1988 and my M.S. in Biology in 1991 from the University of Louisiana at Monroe and my Ph.D. in Ecology from the University of Georgia in 1998. Following graduation, I entered a post-doctoral position at Louisiana State University. In 2003, I accepted a tenure-track Assistant Professor position in the Department of Plant Biology at Southern Illinois University (SIU) where I was promoted to Associate Professor in 2009. I am interested in the dynamics of wetland plant communities and the ecological processes that link them with the surrounding landscape. Specifically, research in my lab focuses on the effects of climate change and exotic species invasions on community structure and function, as well as development of restoration targets for coastal wetlands undergoing rapid climate change. My current projects include research on assisted migration and prescribed burning as management tools in coastal ecosystems threatened by climate change.

Involvement And Interest In Sws And In Serving The Society:

My first scientific meeting was the 1993 SWS meeting in Edmonton. It was a very positive experience for me; I was inspired to become a member and apply for funding to support my doctoral research through the Student Research Program. I have remained a member since graduate school and now I encourage my students to participate. Membership has been extremely rewarding personally and professionally, and I have witnessed firsthand the support of this Society at all career stages. Since 2009, I have had the honor of serving on the North Central Chapter's Executive Board (President-Elect, President, now Past-President). During this time, I helped to organize one chapter meeting and am currently organizing a fall 2014 meeting here at SIU. This period of service has given me the opportunity to interact with members of my chapter, officers from other chapters, and members of the International Executive Board. I have learned a great deal about SWS operations at the chapter and international levels of organization. I am well-prepared and eager to continue my service to the Society. As Secretary-General, I would lead the membership committee, providing the Executive Board with accurate membership reports and trends

SWS Society of Wetland Scientists www.sws.org
an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

and working on initiatives to grow the Society's membership. I would also coordinate with chapter and section leadership to organize reports and facilitate development of new chapters, particularly those organized by students, as they are a great source of energy and recruitment. As the point person for directing questions and addressing comments from the website, I would be eager to engage with our members to promote enhanced networking across the diversity of expertise within our Society. Finally, I am interested in working with the Executive Board to foster wetland research, education, and conservation by empowering our membership with enhanced access to the numerous benefits that SWS offers.

Society of Wetland Scientists
www.sws.org
an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

Robert "Robbie" Kroger, PhD
Mississippi State University
Mississippi, MS, USA

PROFESSIONAL BACKGROUND:
I am originally from Johannesburg, South Africa and have lived in Mississippi since 2003. My interest in wetlands started when I was 16 years old - when my grandfather, a staunch conservationist, took me to the Okavango Swamps - one of the most pristine wetland systems in the world. Seeing crystal clear waters, the incredible diversity of plants and animals, and being able to peer into the depths of the swamp and see hippo footprints on the floor (8 meters below the surface of the water) hooked me to wanting to spend the rest of my life working with wetlands. I got my B.S (Botany and Environmental Conservation Biology), B.S. with Honors (Botany), M.S. (Botany) from the University of Witwatersrand in South Africa under the supervision of Dr Kevin Rogers. I am trained as a theoretical wetland ecologist, but focused my interests on wetland function and aquatic biogeochemistry when I started my Ph.D. at the University of Mississippi, specifically understanding how wetlands or their characteristics can be integrated into agricultural landscapes to improve water quality. To that end, I have spent many days in drainage ditches utilizing these ubiquitous features to enhance water quality moving downstream and promoting synergies between wetlands and agriculture. I am an Associate Professor in the Department of Wildlife, Fisheries, and Aquaculture at Mississippi State University and am currently serving a year-long detail to the newly created RESTORE council (new federal entity tasked with managed the money associated with BP oil spill) as the science coordinator/advisor to that effort.

Involvement And Interest In Sws And In Serving The Society:

I started my career with SWS as a recipient of an SWS international student award when I first moved to the US in 2003. Since then I have been intimately involved with the South-Central Chapter in various capacities. I have attended multiple regional meetings, national, and international meetings over the last 10 years when finances were available. I have been involved with the chapter as a student member, served on the chapter board, served as chapter treasurer, and am currently serving as the South-Central Chapter president (thus serve on the full board of SWS). The full board has the responsibility of ensuring the growth of the organization. This growth has to encompass change that comes with time, budget concerns, as well as challenges that are facing all organizations. I am very interested in the Secretary-General position because it provides me the opportunity to give back to the society that has supported me over the last 10 years - paying it forward to the next generation of wetland scientists is mission critical. It is something that I feel is the key component to ensuring SWS's longevity and growth. Personally, I am committed to building for the future. In this particular office I can bring new ideas to the table that can help build the society for the future. I can work with chapters and help where possible to ensure growth and success. As we face new challenges we will have to adapt to ensure that we prosper. Having individuals on the board with their ears to the ground to hearing what we need to do to ensure success is essential.

Society of Wetland Scientists www.sws.org
an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

2014 SWS Board of Directors Election Ballot

All individual members are entitled to one vote, which may be submitted with this paper ballot or using the electronic ballot circulated via email. If you prefer to submit a paper ballot, please complete and return the following form to the address below. You may print mail, fax or email the ballot as an attachment by Friday, April 18, 2014. Post mail must also be postmarked by Friday, April 18, 2014.

Society of Wetland Scientists
22 North Carroll Street, Suite 300
Madison, Wisconsin 53703
USA

608.521.5941 Fax
bolson@sws.org

Duties of the President-Elect:

The President-Elect shall assume duties and responsibilities of the President at the conclusion of the President's term or if the office is vacated. In the absence of the President or in the event of inability or refusal to act, the President-Elect shall perform the duties of the President, and when so acting shall have all the powers of and be subject to all the restrictions of the Presidency. The term of office of the President-Elect shall be one year or until the next annual meeting and then the President-Elect shall automatically become President for the year following his or her term as President-Elect. If the President-Elect assumes the duties of President prior to the normal end of term, he or she shall complete the President's remaining term and then complete his or her term as President for which he or she had been previously elected. If the President-Elect is unable to fulfill the term of office of the President, the immediate Past-President shall assume the interim Presidency until an election can be held. The primary duties of the President-Elect shall be to assist the President in the execution of duties, and any other duties delegated by the Bylaws of the Society or designated by Board of Directors from time to time.

Please vote for one of the following President-Elect candidates:

______ Kimberli Ponzio, PWS

______ Neil Saintilan, PhD

Society of Wetland Scientists www.sws.org

an international organization dedicated to the conservation, management and scientific understanding of the world's wetland resources

Duties Of The Secretary-General:

The term of office of the Secretary-General shall be three years. The terms of office for the Secretary-General and Treasurer shall be staggered so that their election does not normally coincide during the same year. The Secretary-General shall review the minutes of the meetings, give notices in accordance with the provisions of the Bylaws or as required by law. The Secretary-General shall also serve as the Chair of the Membership Committee and represent Sections on the Board of Directors. In collaboration with staff, the Secretary-General provides membership reports to the Board of Directors and to the membership at the annual meeting. The Secretary-General serves as back up signatory to the Treasurer on Society financial accounts. In the event the Secretary-General is not able to perform his or her duties, as defined by the President or Board of Directors, the position will be filled by appointment of the President with ratification at the next meeting of the Board of Directors.

Please vote for one of the following President-Elect candidates:

______ Loretta Battaglia, PhD

______ Robert "Robbie" Kroger, PhD

Please provide the following information:

NAME: ____

SWS MEMBER ID: ______________________________________

Variations in shoreline vegetation and turbidity of shallow lakes.

Ryan D. Sullivan[1], La Toya Kissoon [2], Donna Jacob[1], Mark Hanson[3], Emily K Fischbach[1], and Marinus Otte[1]

[1] Wet Ecosystem Research Group, Department of Biological Sciences, North Dakota State University, Fargo, ND.
[2] Wet Ecosystem Research Group, Department of Biological Sciences, North Dakota State University, Fargo, ND. Corresponding Author: latoya.kissoon@gmail.com Phone: 701-231-8999.
[3] Wetland Wildlife Population and Research Group, Minnesota Department of Natural Resources, Bemidji, MN.

Abstract
Shoreline vegetation provides vital ecological services and can impact water quality of shallow lakes. We determined the area and composition of shoreline vegetation for 20 shallow lakes of varying turbidities in the Prairie Parkland Province of Minnesota. We examined differences in shoreline vegetation between clear and turbid lakes and identified relationships between shoreline vegetation and several lake environmental variables (lake depth, submerged vegetation cover, turbidity, chlorophyll-a, total phosphorus, Ca+Mg, conductivity, and pH). In contrast to turbid lakes, the clear lakes had greater emergent and submerged vegetation cover. *Typha* spp. dominated the shorelines of clear lakes, while woody vegetation dominated the shorelines of the turbid lakes. Redundancy analysis (RDA) showed depth and chlorophyll-a concentrations were related to emergent vegetation composition. The percent shoreline of *Typha* spp. was negatively associated with chlorophyll-a concentrations and the percent shoreline of woody vegetation was positively associated with water depth.

Key words:
chlorophyll-a; emergent; shallow lakes; *Typha* spp.; turbidity.

Introduction
Aquatic plants play a crucial role in the function of shallow lakes that includes preventing the suspension of sediments and subsequent release of nutrients, uptake of nutrients that would otherwise be available for algal growth, and provision of food and habitat for fish, invertebrates, and water birds (Dieter 1990; Blindow 1992; Weisner et al. 1994; Scheffer 1999, 2004; Horppila and Nurminen 2001, 2005). Lake shorelines can be colonized by a variety of emergent plant species, which provide various ecological services for lakes

such as diminished runoff, nutrient sequestration (Tyler et al. 2012), wave attenuation, shoreline stability, and provision of food and habitat for fish, invertebrates, water birds and other wildlife (Cronk and Fennessey 2001; Scheffer 2004).

The plant communities associated with shallow lakes can vary as these lakes shift from a clear, plant-dominated regime to a turbid, phytoplankton-dominated regime and back again (Blindow et al. 1998; Scheffer and Jeppesen 1998; Bayley et al. 2007; Zimmer et al. 2009). Clear lakes generally have low phytoplankton biomass and abundant submerged vegetation (Bayley et al. 2003). Submerged plants help maintain a clear-water environment by reducing sediment resuspension, releasing allelopathic compounds that inhibit phytoplankton growth, providing habitat for algae grazing zooplankton, and sequestering nutrients making them unavailable to phytoplankton (Blindow 1992; Weisner et al. 1994).

Algal blooms form when environmental conditions favor excessive phytoplankton growth (Assmy and Smetacek 2009) and can occur naturally or as a result of nutrient loading from surface runoff of agricultural or nutrient-rich uplands (Welch et al. 1979; Nilsson and Håkanson 1992; Carstensen et al. 2007). Freshwater algal blooms 1) decrease the aesthetic and recreational value of water bodies by coating the water surface with a green scum and producing foul smells, 2) release toxins such as microcystins, anatoxins, and nodularins, and 3) dramatically alter photic zone depths, levels and distribution of available nutrients, and dissolved oxygen concentrations (Ridge et al. 1995; Anderson 2007; Lopez et al. 2008). Management of algal blooms in shallow lakes is becoming a high priority because of their increasing occurrence and negative effects (Arbuckle and Downing 2001; Fraterrigo and Downing 2008).

Preemptive methods of controlling algal blooms often focus on constructed wetlands to remove excess nutrients and contaminants in wastewater and agricultural runoff (Salt et al. 1995; Goulet and Pick 2001; Hoagland et al. 2001; O'Sullivan et al. 2004). Abundant emergent vegetation in constructed wetlands often decreases nutrient availability for phytoplankton by uptake and accumulation of nutrients, and by stabilizing sediment, thus decreasing resuspension of sediment-bound nutrients (Chen and Barko 1988; Hoagland et al. 2001; Horppila and Nurminen 2005). Emergent plants can also be a source of organic matter, which can bind nutrients and thus make them available for phytoplankton growth (Barnes 1980; Davies 1994; Jackson 1998; Goulet and Pick 2001). Organic matter accumulation enhances reducing conditions of wetland sediments and subsequently influences nutrient mobility (Golterman 1995; Jacob and Otte 2004a, 2004b). A variety of chemical and biological methods have been used to treat lakes where algal blooms are problematic (Lembi 2002). For example, the application of barley straw (*Hordeum vulgare*), is reported to produce algae-static effects upon decomposition, inhibiting the reproduction of various algal species (Ridge et al. 1995; Everall and Lees 1996, 1997; Ball et al. 2001; Ferrier et al. 2005). Some submerged plants such as e*ratophyllum demersum, Chara* spp., and *Stratiotes obliquus* may exert allelopathic effects on algal growth (Wium-Andersen et al. 1983; Mjelde and Faafeng 1997; Mulderij et al. 2005). Della Greca (1990) reported that *Typha latifolia* produced allelopathic compounds that inhibited the growth of blue-green algae in cultures, but field studies have yet to confirm these findings. Here, we compared shallow lakes of varying turbidities to identify relationships between shoreline vegetation and the environmental variables at these sites. We considered the shoreline vegetation as the fringe or marginal emergent vegetation occurring from water depths of approximately 1 m to waterlogged soil on the shore (where water was not standing) (Sculthorpe 1967; Cronk and Fennessy 2001). We hypothesized that lakes with more shoreline vegetation, especially areas with dense *Typha* stands, would often be characterized by clear-water conditions in response to large litter inputs.

Methods

Vegetation assessment

Our study was carried out on 20 shallow lakes in southwestern Minnesota in the Prairie Parkland Ecological Province (Omernik 1987) during August 8-18, 2011 (Figure 1). More than 80% of the land in these watersheds is agricultural (Minnesota Geospatial Information Office Staff 1999). For each lake, the percent shoreline vegetation was determined at 10 locations around the lake. Each of the 10 sampling locations was located more or less equidistant of one another and at least 4 m from shoreline. At each location, we identified the plant species present and the percent cover of each species over an approximately 50 m transect that was parallel to the shoreline. Species were identified on site or collected for identification in the laboratory. Vegetation was grouped into the following 7 categories: *Typha* spp. (hereafter *Typha*), *Scirpus* spp. (hereafter *Scirpus*), *Phalaris arundinacea* (hereafter *Phalaris*), *Polygonum amphibium*, *Sparganium* spp., *Asclepias incarnata* and woody (including all mature trees). *Polygonum amphibium*, *Sparganium* spp., and *Asclepias incarnata* occurred in less than 15% of the lakes and so were not included in the analysis. Total emergent vegetation area (EVA) and basin area (BSN) for each lake were estimated using aerial photographs (details described by Hanson et al. 2012; Table 1). Woody shoreline (trees, shrubs) vegetation was not included in this delineation because it was not classified as emergent vegetation. The percent cover of submerged aquatic vegetation (SAV) was also determined at each of the 10 locations using an acrylic glass bottom cylinder (Kissoon et al. 2013).

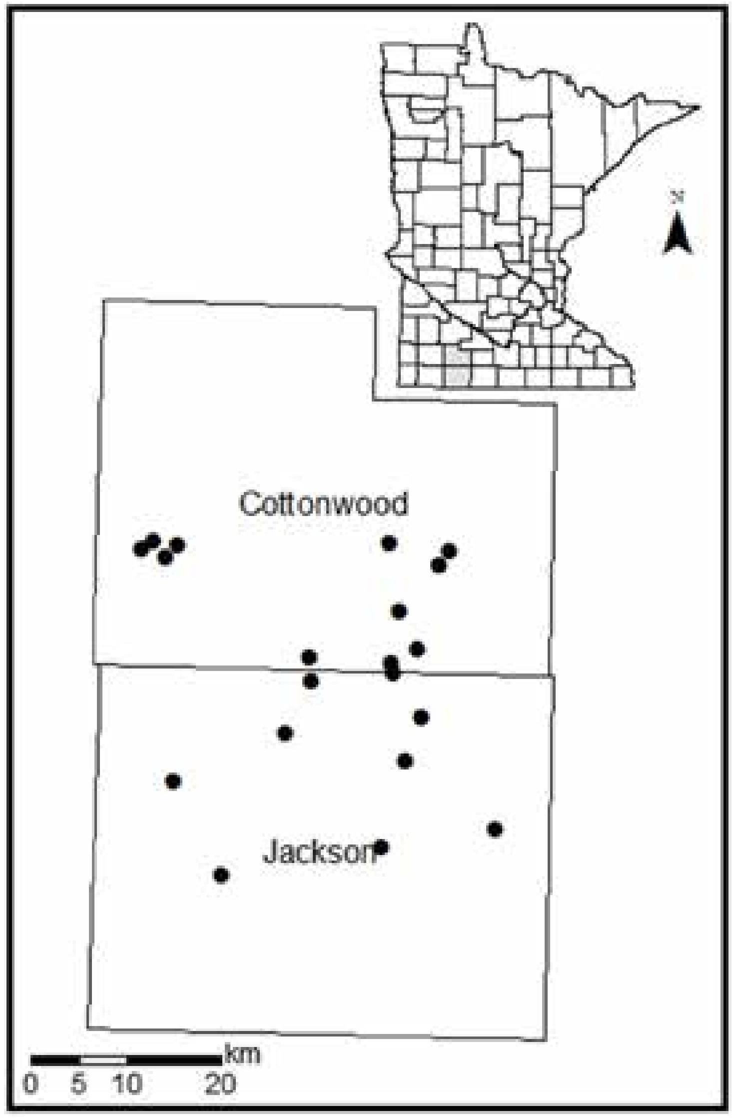

Figure 1: Map of study area showing the locations of the 20 shallow lakes in southwestern Minnesota that were used in this study.

Water sampling and analysis

Water samples were collected at approximately the same 10 locations at depths of 25 cm and a portion of the water sample was used to measure turbidity using a Hach® Portable Turbidimeter (Model 2100P) and pH using a VWR Symphony SP90M5 Handheld Multi-meter. The remaining water was filtered (0.45-µm pressure filter, Pall Corporation Supor® -450), acidified with 0.1 ml $HNO_{3,}$ and later analyzed for Ca and Mg with a Spectro Genesis Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The sum of the mmol l^{-1} f Ca and Mg (Ca+Mg) was used as an indicator of alkalinity (Kissoon et al. 2013). Conductivity, chlorophyll-*a* (chl-a), and total phosphorus concentrations (TP) were measured in water samples collected from two different locations in each lake during July of the same year. Chl-a was determined using fluorometry following acetone extraction and TP was measured according to methods of APHA (1994).

Regime	Lake ID	Emergent Vegetation Area (EVA)	Basin Area	EVA/Basin Area
		hectares	*hectares*	*ratio*
Turbid	03	0.23	40.61	0.01
	04	0.00	42.31	0.00
	06	2.27	6.14	0.37
	07	19.94	38.33	0.52
	08	0.33	6.52	0.05
	09	0.15	26.24	0.01
	11	0.97	12.45	0.08
	12	1.19	4025	0.03
	16	2.50	37.48	0.07
	19	0.36	13.93	0.03
	20	2.00	31.75	0.06
Clear	01	15.87	40.41	0.39
	05	2.05	26.75	0.08
	10	10.20	13.49	0.76
	13	8.65	11.54	0.75
	14	23.47	31.58	0.74
	15	2.27	58.66	0.04
	17	0.66	3.49	0.19
	18	1.09	3.81	0.29
	21	1.54	3.59	0.43

Table 1: Emergent vegetation area and emergent vegetation area relative to basin area for 20 shallow lakes in Minnesota (*Lake 04 had a predominant woody shoreline, which was not included in the delineation of emergent vegetation).

Statistical analysis
Prior to performing statistical analyses, turbidity, chl-a, Ca+Mg, and macrophyte data were log transformed to increase homogeneity of variance. K-means cluster analysis (Lattin et al. 2003) was carried out in Minitab to classify lakes into two groups based on, turbidity, chl-a concentrations, and submerged vegetation cover. The two resulting groups consisted of lakes in clear (macrophyte-dominated) and turbid regimes. A General Linear Model was then used to test for significant differences between the clear and turbid lakes (One-Way ANOVA, $p<0.05$) using Minitab® Minitab® 15 © 2006 Minitab Inc.). Pearson correlations and p-values were calculated in Minitab to explore the relationships between the percent shoreline for the different vegetation categories, emergent vegetation area relative to basin size, and turbidity. Relationships between environmental variables (depth, SAV cover, turbidity, chl-a, pH, Ca+Mg, conductivity, and total phosphorus) and percent shoreline vegetation were assessed using redundancy analysis (RDA)

in CANOCO (© 2005 CANOCO Version 4.5). Preliminary Detrended Correspondence Analysis (DCA) indicated that linear gradient analysis (RDA) was appropriate because the gradient lengths were < 4.0 standard deviations (ter Braak and Šmilauer 2002). Prior to performing the RDA the shoreline vegetation data were relativized by maxima to reduce the influence of highly abundant species (McCune and Grace 2002) and the environmental variables were log transformed to increase homogeneity of variance. Forward selection with Monte Carlo permutation tests (999 permutations) was used to identify environmental variables associated with variation in shoreline vegetation for inclusion in the final model ($p<0.05$).

Results

Clear lakes had larger areas of emergent vegetation and higher ratios of emergent vegetation: basin area (Table 2). *Typha* was the most abundant shoreline vegetation in clear lakes while woody vegetation was more abundant in the margins of turbid lakes (Figure 2). The percent shoreline extent of *Phalaris* and *Scirpus* did not differ between the turbid and clear lakes. Depth, turbidity, and chl-a concentrations were greater in turbid lakes, while submerged vegetation was more abundant in the clear lakes (Table 2). Total phosphorus, conductivity, Ca+Mg concentrations, and pH did not differ between turbid and clear lakes.

The extent (percent) of shoreline for the different vegetation categories correlated with several environmental variables. For example, *Phalaris* was positively correlated with chl-a and total phosphorus, while *Typha* was negatively correlated with depth, turbidity, and chl-a and positively correlated with SAV cover. Woody vegetation was positively correlated with depth, turbidity, and chl-a and negatively correlated with SAV cover. Emergent vegetation area was negatively correlated with depth, turbidity, and pH, but positively correlated with SAV cover and Ca+Mg. The ratio of emergent vegetation area: basin area was negatively correlated with depth, turbidity, chl-a, and pH and positively correlated with SAV cover and Ca+Mg. Results of the RDA indicated that water depth and chl-a were associated with 45% of the variance in percent of shoreline vegetation. Percent shoreline of *Typha* was negatively associated with chl-a while woody vegetation and *Scirpus* were positively associated with water depth (Figure 3).

Discussion

Our study found that the shorelines of clear shallow lakes in Minnesota's prairie parkland region had more extensive emergent vegetation compared to turbid lakes, and that these stands of vegetation tend to be dominated by *Typha*. Previous studies indicated that emergent vegetation accumulates elements in the rhizosphere and plant tissues (Kissoon et al. 2010, 2011) and sequesters nutrients (Tyler et al. 2012), demonstrating their potential to decrease nutrient availability and perhaps turbidity in shallow lakes. Dense stands of *Typha* may

Variables	Clear (n=9)	Turbid (n=11)
Emergent vegetation area (hectares)	7.3±7.6*	2.7±5.6
Emergent vegetation area/basin area (ratio)	0.4±0.3*	0.1±0.2
Environmental variables		
Depth (m)	0.9±0.4	1.5±0.7*
Turbidity (NTU)	8±8	45±25*
chlorophyll-a ($\mu g\ l^{-1}$)	35±46	105±97*
SAV cover (%)	88±29*	14±33
pH	8.9±0.7	9.0±0.3
Ca+Mg (mmol l^{-1})	2.5±0.6	2.2±0.4
Conductivity (µS)	351±75	381±49
Total phosphorus ($\mu g\ l^{-1}$)	147±146	195±98

Table 2: Mean emergent vegetation area and environmental variables (*indicates the significantly higher value between lakes for a particular variable; p≤0.01).

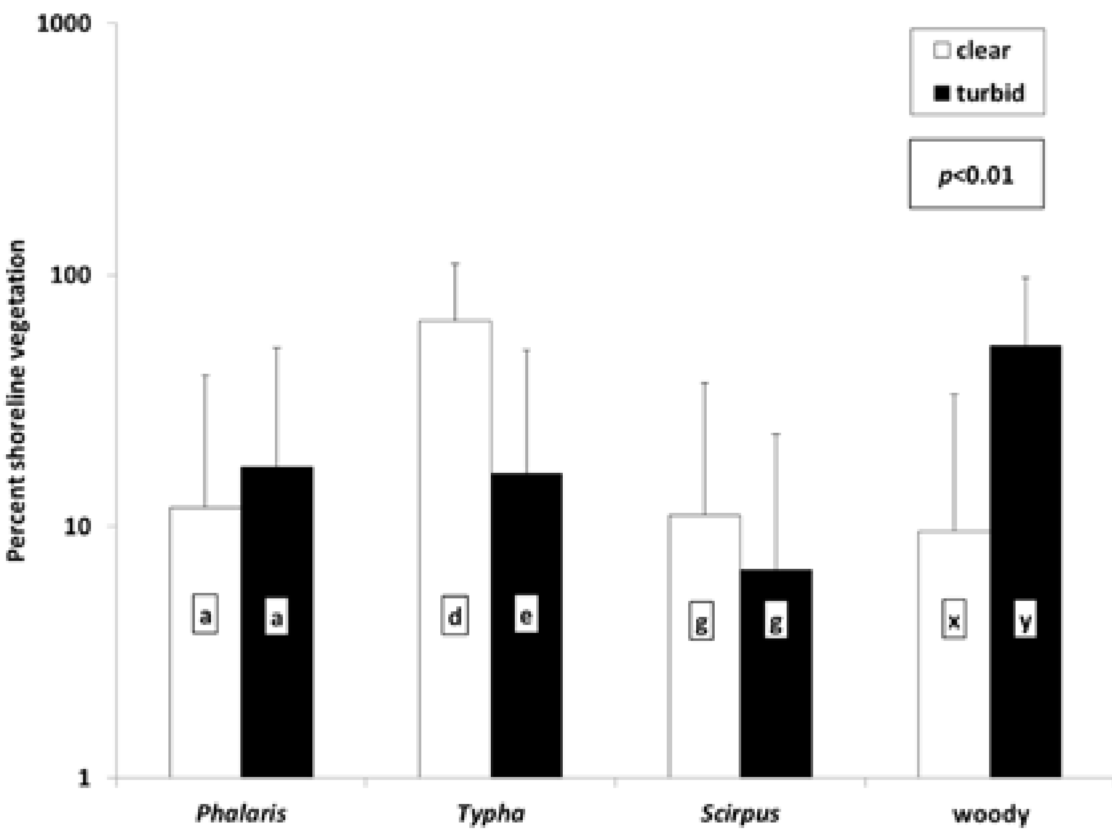

Figure 2: Mean percent of shoreline vegetation for the four different vegetation categories (*Phalaris* spp., *Typha* spp., *Scirpus* spp., woody) for clear and turbid lakes (different letters within each vegetation category indicate significant differences between turbid (n=8) and clear (n=12) lakes, p<0.01)

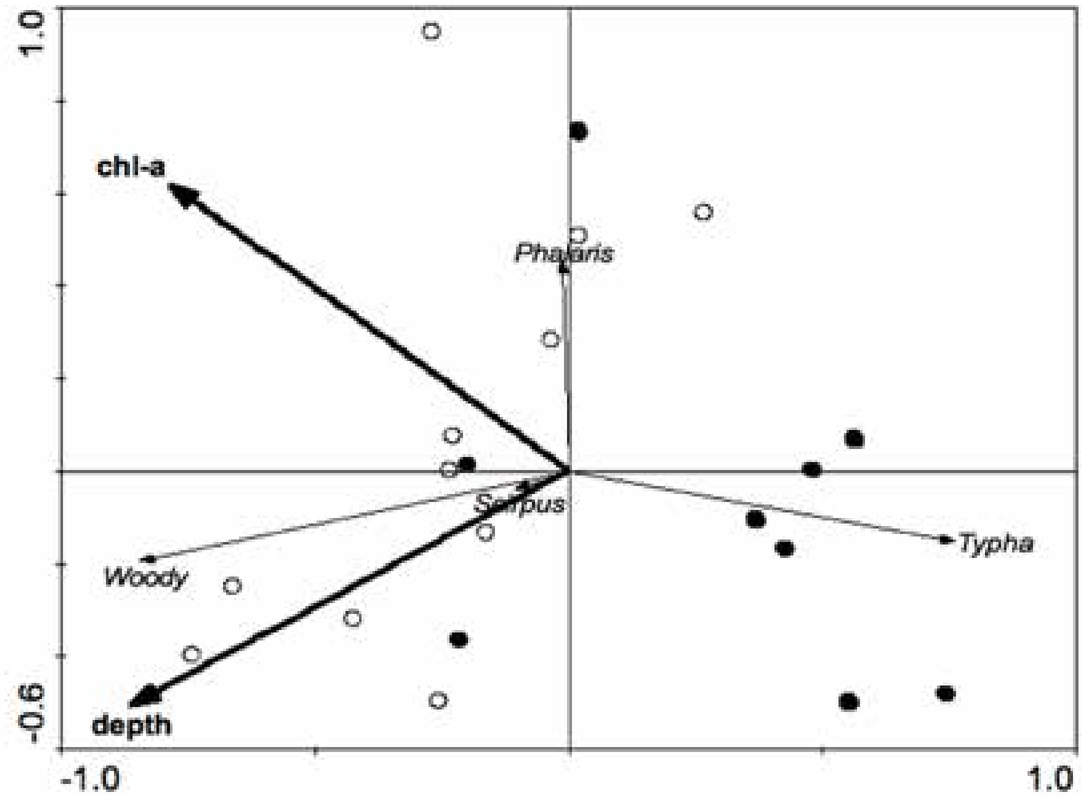

Figure 3: RDA ordination plot of percent shoreline vegetation constrained by environmental variables (environmental variables (in bold): depth and chlorophyll-*a* concentrations (chl-a); vegetation categories (occurred in >14% of lakes): *Typha* spp., *Scirpus* spp., *Phalaris* arundinacea and woody vegetation; Lake regimes: turbid (O), clear (•)).

decrease and block nutrient access to algae due to *Typha's* affinity for nitrogen and phosphorus (Koottatep and Polprasert 1997; Chiang et al. 2000; Maddison et al. 2009). Dubbe et al. (1988) reported that nutrient utilization by *Typha* peaks during June to August, potentially taking up these nutrients when phytoplankton populations are most dependent on them. The greater emergent vegetation area in the clear lakes also allow sediment to stabilize (Dieter 1990) and may serve to filter nutrient runoff, perhaps limiting nutrient inputs to open-water areas in shallow lakes (Horppila and Nurminen 2001; Tyler et al. 2012).

Emergent vegetation area may also contribute to clear water conditions by providing habitat for aquatic invertebrates that feed on algae (Voigts 1976; Campeau et al. 1994; Oertli and Lachavanne 1995; Lembi 2003). Emergent plants and resulting litter may also protect invertebrate populations by providing them with cover from predators (Campeau et al. 1994). Low oxygen levels in *Typha* stands also discourage fish and invertebrates that may prey on zooplankton, thus favoring higher zooplankton densities which, in turn, contribute to lower phytoplankton biomass and clear-water conditions (Timms and Moss 1984; Murkin et al. 1992; Scheffer 2004). The clear lakes were also dominated by SAV that could also be contributing to the clear conditions by stabilizing sediment, blocking nutrient access to algae, and providing suitable habitat to algal grazers (Scheffer and Jeppesen 1998; Scheffer 2004).

	Phalaris	*Thypha*	woody	EVA	EVA: Basin area
Depth		-0.482	0.755	-0.505	-0.618
Turbidity		-0.433	0.359	-0.341	-0.478
Chl-a	0.411	-0.493	0.624		-0.545
Sav cover		0.532	-0.492	0.346	0.583
Ca+Mg				0.361	0.386
pH				-0.328	-0.358
Total Phosphorus	0.477				

Table 3: Pearson correlations for shoreline vegetation and environmental variables (only significant correlations where $r \geq 0.316$ and $p < 0.01$ are shown).

Allelopathic substances released by submerged vegetation may also decrease phytoplankton growth and contribute to the clear-water conditions (Wium-Andersen et al. 1983; Mjelde and Faafeng 1997). Della Greca et al. (1990) isolated an allelopathic compound from *Typha latifolia*, which inhibited blue-green algae in cultures. This allelopathic compound may be released from *Typha* stands and might favor clear-water conditions in lakes with *Typha*-dominated shorelines. Ridge et al. (1995, 1999) reported algae-static properties associated with brown-rotting wood and with the breakdown of tannins in oak leaf litter. However, in our study, the lake shorelines dominated by woody vegetation tended to be turbid and supported high phytoplankton biomass.

The results of the RDA indicated that water depth and chl-a were important variables associated with the extent of shoreline emergent vegetation. Water levels play a key role in the distribution of emergent vegetation (Squires and van der Valk 1992; Grosshans and Kenkel 1997) and may explain the variation in the composition and abundance of emergent vegetation in our shallow lakes. Negative correlations between emergent vegetation area and water depth also indicated that water levels play a critical role in the abundance of emergent plants along the margins of shallow lakes. Negative relationships between turbidity and chl-a with emergent vegetation area and extent of *Typha* may indicate the role of emergent vegetation in maintaining clear-water conditions by stabilizing sediments and subsequently contributing to decreased nutrient availability and phytoplankton growth (Dieter 1990).

Initially we suspected litter inputs from decomposing emergent vegetation in our shallow lakes inhibited the reproduction of phytoplankton, similar to responses observed following additions of barley straw. The lignin content of emergent vegetation such as *Typha* is about 15% and similar to that seen in barely straw (Ridge et al. 1995; Jaques and Pinto 1997). Barley straw has been reported to have algae-static effects which result from the decomposition of its ligneous fraction (Ridge et al. 1995, 1999; Everall and Lees 1996, 1997; Ball et al. 2001; Ferrier et al. 2005). In fact, we found that the extent of emergent vegetation area and presence of a *Typha*-dominated shoreline were positively associated with clear lakes. Water depth appeared to play a role in the emergent vegetation composition and possibly contributed to water clarity. Other factors such as submerged vegetation cover and nutrient availability may also explain clear or turbid conditions in these lakes. Future studies are needed to determine whether *Typha* and other emergent vegetation inhibit phytoplankton growth, and if so, in what ways. We hypothesize that *Typha* litter inputs may reduce phytoplankton growth rates in shallow lakes similar to additions of barley straw and, if so, addition of a *Typha* litter or extract to lakes may warrant evaluation as a management option for future control of phytoplankton in shallow or eutrophic lakes.

Conclusion

Shallow lakes with a greater area of emergent vegetation and a Typha-dominated shoreline tend to be clear. Depth and water clarity appear to be related to the emergent vegetation composition. There may be several benefits of the extent of the emergent vegetation area and a Typha-dominated shoreline that contribute to low lake turbidity. Some of these include the capacity of emergent plants to take up nutrients otherwise available for algae, provide refugia for algae grazing invertebrates, and contribute organic matter that bind nutrients. Future studies are needed to determine if algae-static compounds are released from emergent vegetation litter in field conditions.

Acknowledgements

This publication was made possible by ND ESPCoR and NSF (grant #EPS-0814442), the Minnesota Department of Natural Resources (The Legislative-Citizen's Commission on Minnesota Resources), The Wetland Foundation, Sigma Xi Grants-in-Aid of Research, and by NIH grant number P20 RR016471 from the INBRE program of the National Institute of General Medical Sciences. We would also like to thank Dr. Wei Lin of North Dakota State University for the use of his turbidimeter. Thanks to Alex Yellick for constructing a map of the study area.

References

Anderson DM (2007) The ecology and oceanography of harmful algal blooms: multidisciplinary approaches to research and management. IOC Technical Series 74, UNESCO 2007. http://unesdoc.unesco.org/images/0016/001631/163114e.pdf Accessed 25 February 2013

APHA (1994) Standards methods for the examination of water and wastewater. American Public Health Association, Washington D.C.

Arbuckle KE, Downing JA (2001) The influence of watershed land use on lake N:P in a predominantly agricultural landscape. Limnol Oceanogr 46:970-975.

Assmy P, Smetacek V (2009) Algal Blooms. In: Schaechter M (ed) Encyclopedia of microbiology, 3rd edn. Elsevier, Oxford, pp 27-41.

Ball AS, Williams M, Vincent D, Robinson J (2001) Algal growth control by a barley straw extract. Bioresour Technol 77:177-181.

Barnes RSK (1980) The Unity and diversity of aquatic ecosystems. In: Barnes RSK, Mann KH (eds) The Fundamentals of Aquatic Ecosystems. Blackwell Scientific Publications, Oxford. pp. 5-23.

Campeau S, Murkin HR, Titman RD (1994) Relative importance of algae and emergent plant litter to freshwater marsh invertebrates. Can J Fish Aquat Sci 51:681-692.

Carstensen J, Henriksen P, Heiskanen A-S (2007) Summer algal blooms in shallow estuaries: definition, mechanisms, and link to eutrophication. Limnol Oceanogr 52:370-384.

Chen RL, Barko JW (1988) Effects of freshwater macrophytes on sediment chemistry. J Freshw Ecol 4:279-289.

Chiang C, Cract CB, Rogers DW, Richardson CJ (2000) Effects of 4 years of nitrogen and phosphorus additions on Everglades plant communities. Aquat Bot 68:61-78.

Cronk JK, Fennessy MS (2001) Wetland plants: biology and ecology. Lewis Publishers, Boca Raton, FL.

Davies BE (1994) Soil chemistry and bioavailability with special reference to trace elements. In: Farago M (ed) Plants and the chemical elements: biochemistry, uptake, tolerance and toxicity. VCH Verlagsgesellschaft, Weinheim, Germany, pp. 2-30.

Della Greca M, Mangoni L, Molinaro A, Monaco P, Previtera L (1990) (20S)-4α-Methyl-24-Methylenecholest-7en-3β-ol, an allelopathic sterol from *Typha latifolia*. Phytochem 29:1797-1798.

Dieter CD (1990) The importance of emergent vegetation in reducing sediment resuspension in wetlands. J Freshw Ecol 5:467-473.

Dubbe DR, Garver EG, Pratt DC (1988) Production of cattail (*Typha* spp.) biomass in Minnesota, USA. Biomass 17:79-104.

Everall NC, Lees DR (1996) The use of barley straw to control general and blue-green algal growth in a Derbyshire reservoir. Water Res 30:269-276.

Everall NC, Lees DR (1997) The identification and significance of chemicals released from decomposing barley straw during reservoir algal control. Water Res 31:614-620.

Ferrier MD, Butler BR Sr, Terlizzi DE, Lacouture RV (2005) The effects of barley straw (Hordeum vulgare) on the growth of freshwater algae. Bioresource Technol 96:1788-1795.

Fraterrigo JM, Downing JA (2008) The influence of land use on lake nutrients varies with watershed capacity. Ecosystems 11: 1021-1034.

Golterman HL (1995) The labyrinth of nutrient cycles and buffers in wetlands: results based on research in the Camargue (southern France). Hydrobiol 315:39-58.

Goulet RR, Pick FR (2001) The effects of cattails (*Typha latifolia* L.) on concentrations and partitioning of metals in surficial sediments of surface-flow constructed wetlands. Water Air Soil Pollut 132:275-291.

Grosshans RE, Kenkel NC (1997) Dynamics of emergent vegetation along natural gradients of water depth and salinity in a prairie marsh: delayed influences of competition. UFS (Delta Marsh) Annual Report 32: 83-93.

Hanson MA, Herwig BR, Zimmer KD, Fieberg J, Vaughn SR, Wright RG, Younk JA (2012) Comparing effects of lake-and watershed-scale influences on communities of aquatic invertebrates in shallow lakes. PLOS ONE 7: e44644.

Hoagland CR, Gentry LE, David MB (2001) Plant nutrient uptake and biomass accumulation in a constructed wetland. J Freshw Ecol 16:527-540.

Horppila J, Nurminen L (2001) The effect of an emergent macrophyte (T*ypha angustifolia*) on sediment resuspension in a shallow north temperate lake. Freshw Biol 46:1447-1455.

Horppila J, Nurminen L (2005) Effects of different macrophyte growth forms on sediment and P resuspension in a shallow lake. Hydrobiol 545:167-175.

Jackson LJ (1998) Paradigms of metal accumulation in rooted aquatic vascular plants. Sci Total Environ 219:223-231.

Jacob DL, Otte ML (2004a) Long-term effects of submergence on metals in a 90-year old abandoned Pb-Zn tailings pond. Environ Pollut 130: 337-345.

Jacob DL, Otte ML (2004b) Influence of *Typha latifolia* and fertilization on metal mobility in two different Pb-Zn mine tailings types. Sci Total Environ 333: 9-24.

Jaques N, Pinto P (1997) Seasonal differences in the decomposition of *Typha angustifolia* leaves in a Mediterranean river. Limnetica 13:19-23.

Kissoon LT, Jacob DL, Otte ML (2010) Multi-Element accumulation near Rumex crispus roots under wetland and dryland conditions. Environ Pollut 158: 1834-1841.

Kissoon LT, Jacob DL, Otte ML (2011) Multiple elements in *Typha angustifolia* rhizosphere and plants: Wetland versus dryland. Environ Exp Bot 72: 232-241.

Kissoon LT, Jacob DL, Hanson MA, Herwig BR, Bowe SE, Otte ML (2013) Macrophytes in shallow lakes: relationships with water, sediment and watershed characteristics. Aquatic Botany, 109, 39-48.

Koottatep T, Polprasert C (1997) Role of plant uptake on nitrogen removal in constructed wetlands located in the tropics. Water Sci Technol 36:1-8.

Lembi CA (2002) Aquatic Plant Management: Barley straw for algae control. Purdue University, West Lafayette, IN. http://www.btny.purdue.edu/pubs/APM/APM-1-W.pdf Accessed 25 February 2013.

Lembi CA (2003) Control of nuisance algae. In: Wehr JD, Sheath RG (eds) Freshwater algae of North America: ecology and classification. Academic Press, Boston, pp 805-834

Lopez CB, Jewett EB, Dortch Q, Walton BT, Hudnell HK (2008) Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC. http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/FreshwaterReport_final_2008.pdf Accessed 25 February 2013.

Maddison M, Soosaar K, Mauring T, Mander U (2009) The biomass and nutrient and heavy metal content of cattails and reeds in wastewater treatment wetlands for the production of construction material in Estonia. Desalination 246:120-128.

McCune B, Grace JB (2002) Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, OR.

Minnesota Geospatial Information Office Staff (1999) Minnesota Land Use and Cover: 1990s Census of the Land. Minnesota Geospatial Information Office, St. Paul, MN. http://www.mngeo.state.mn.us/landuse/ Accessed 25 February 2013.

Mjelde M, Faafeng BA (1997) *Ceratophyllum demersum* hampers phytoplankton development in small Norwegian lakes over a wide range of phosphorus concentrations and geographical latitude. Freshw Biol 37: 355-365.

Mulderij G, Mooij WM, van Donk E (2005) Allelopathic growth inhibition and colony formation of the green alga *Scenedesmus obliquus* by the aquatic macrophyte Stratiotes aloides. Aquat Ecol 39: 11-21.

Murkin EJ, Murkin HR, Titman RD (1992) Nektonic invertebrate abundance and distribution at the emergent vegetation-open water interface in the delta-marsh, Manitoba, Canada. Wetlands 12: 45-52.

Nilsson A, Håkanson L (1992) Relationships between drainage area characteristics and lake water quality. Environ Geol Water Sci 19: 75-81.

O'Sullivan AD, Moran BM, Otte ML (2004) Accumulation and fate of contaminants (Zn, Pb, Fe and S) in substrates of wetlands constructed for treating mine wastewater. Water Air Soil Pollut 157: 345-364.

Oertli B, Lachavanne JB (1995) The effects of shoot age on colonization of an emergent macrophyte (Typha latifolia) by macroinvertebrates. Freshw Biol 34: 421-431.

Omernik JM (1987) Ecoregions of the conterminous United States. Ann Assoc Am Geogr 77: 118-125.

Ridge I, Pillinger J, Walters J (1995) Alleviating the problems of excessive algal growth. In: Harper DM, Ferguson ADJ (eds) The Ecological Basis for River Management. Wiley, England, pp 211-218.

Ridge I, Walters J, Street M (1999) Algal growth control by terrestrial leaf litter: a realistic tool? Hydrobiol 395/396:173-180.

Salt DE, Blaylock M, Kumar NPBA, Dushenkov V, Ensley BD, Chet I (1995) Phytoremediation: A novel strategy for the removal of toxic metals from the environment using plants. Biotechnology 13: 468-474.

Scheffer M (1999) The effect of aquatic vegetation on turbidity; how important are the filter feeders? Hydrobiologia 408/409: 307-316.

Scheffer M (2004) Ecology of Shallow Lakes. In: Usher MB, DeAngelis DL, Manly BFJ (eds), Population and Community Biology Series 202. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Sculthorpe CD (1967) The biology of aquatic vascular plants. Edward Arnold Publishers Ltd., London.

Squires L, van der Valk AG (1992) Water-depth tolerances of the dominant emergent macrophytes of the Delta Marsh, Manitoba. Can J Bot 70: 1860-1867.

ter Braak CJF, Šmilauer P (2002) Canoco Reference Manual and CanoDraw for Windows User's Guide. Biometris, Wageningen University and Research Center, Wageningen, The Netherlands.

Timms RM, Moss B (1984) Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing, in the presence of zooplanktivorous fish, in a shallow wetland ecosystem. Limnol Oceanogr 19:472-486.

Tyler HL, Moore MT, Locke MA (2012) Potential for phosphate mitigation from agricultural runoff by three aquatic macrophytes. Water Air Soil Pollut 223: 4557-4564.

Voigts D (1976) Aquatic invertebrate abundance in relation to changing marsh vegetation. Am Midl Nat 95:313-322.

Welch EB, Perkins MA, Lynch D, Hufschimdt P (1979) Internal phosphorus related to rooted macrophytes in a shallow lake. In: Breck JE, Prentki RT, Loucks OL (eds) Aquatic plants, lake management, and ecosystem consequences of lake harvesting. Proceedings of Conference at Madison, Wisconsin, pp. 81-99.

Wium-Andersen S, Anthon U, Christophersen C, Houen G (1983) Allelopathic effects on phytoplankton by substances isolated from aquatic macrophytes (Charales). Oikos 39: 187-190.

Restoring the Garden of Eden: Negative Impacts

WSP
March, 2014
SECTION 1

RESEARCH

Ali Abdul Zahra Douabul[1] and Sama Sameer AlMaarofi[2]

[1]Qarmatt Ali, University Campus, Basra, Iraq. e-mail: adouabul@mscbasra.org, adouabul@live.com, cell phone: +9647802368341, +9647716197889, corresponding author.
[2]Biology Department, University of Waterloo, 200 University Avenue West, Waterloo-Ontario, Canada. E-mail: sdouabul@yahoo.com, cell phone: +9647808030529.

Abstract:
Widely known as the "Garden of Eden", the extensive Mesopotamian Marshes in Iraq once teemed with life. The marshes were the source of the Shatt Al Arab River and provided fresh water and aquatic resources to many communities downstream. Almost half a century of poor management and intentional drainage by military campaigns, government diversion and irrigation usage have resulted in a substantial deterioration of water quality and subsequent loss of wildlife and habitat. With good intentions, inundation efforts were implemented and additional measures are planned by the Iraqi government to regulate water flow; however decisions have not been based on sufficient scientific data and the complex marshland interactions have not been fully understood. A common misconception is that salinity increases have resulted from Arabian Gulf salt intrusions. Field studies conducted through the Marine Science Centre at the University of Basrah (Iraq) investigated various environmental parameters pertaining to hydrology, water quality, ecology and sedimentology between 2004 and 2013 within the Shatt Al-Arab. The data highlights the integral role of the marshes in maintaining water quality in the Shatt Al-Arab and that the marshes are the main source of salt upstream of the Shatt Al-Arab.

Key words:
Mesopotamian marshlands, restoration impact, Shatt Al-Arab River, salinization, re-flooding

Introduction

Historically, the Mesopotamian marshlands are the most extensive wetlands in Iraq and one of the most important aquatic systems in the Middle East (Kubba, 2011) These marshes previously sustained several important habitats that provided resources for local communities and maintained significant populations of wildlife including endemic and endangered aquatic and semi-aquatic species (Scott, 1995). Unfortunate practices over many years, including intentional drainage and misguided diversions of waterways resulted in a substantial loss of marshland and extensive desiccation. Decades later, potential inundation of the dried marshlands brought hope for restoring the valuable and unique "Garden of Eden". Although parts of these marshes were successfully inundated (Douabul, et al., 2012; Al Maarofi et al., 2013), the chaotic re-flooding processes still threaten the entire marsh system (Richardson et al., 2005; AlMaarofi et al., 2012).

Salinization of the marshes and downstream in the Shatt Al-Arab is now evident mainly due to thoughtless desiccation methods (i.e., as a result of economic sanctions and military activities; AlMaarofi et al., 2012). The Mesopotamian marshlands also suffered as a result of other anthropogenic activities including a reduction in water supply due to dam construction which disrupted the annual hydrological cycle and deteriorated water quality (Partow, 2001; IMET, 2006). These impacts affected the function of the marshes and changed their role from being a sink for salts and pollutants to becoming a source (Mahamed, 2008; Douabul et al., 2012; Al Maarofi et al., 2013). Unintentionally disorganized and unsystematic efforts have been undertaken to understand and investigate the restoration potential of the Mesopotamian marshlands, however, the ecological and hydrological limitations need to be considered more carefully (Richardson et al., 2005).

Field studies conducted through the Marine Science Centre at the University of Basrah (Iraq) investigated various environmental parameters pertaining to hydrology, water quality, ecology and sedimentology between 2004 and 2013 within the Shatt Al-Arab. These data identify critical interactions within the marshes and the Shatt Al-Arab.

The Mesopotamian marshlands discharge water to the Shatt Al-Arab River, which is the sole fresh water supply to the City of Basra. The Shatt Al- Arab River extends southeast approximately 200 km from the confluence of the Tigris and Euphrates rivers at the City of Al-Qurna, through the City of Basra and continues along the Iranian-Iraqi border before draining into the Arabian Gulf. Although, the Shatt Al-Arab is an estuary, the salt wedge prior to 1980 extended less than 30 km upstream (Rzoska, 1980). Before draining the marshlands (1993-200), the Shatt Al-Arab River at the City of Al-Qurna received more than 500 m3/sec of fresh water with a concentration of less than 0.5 g/L dissolved salt (Rzoska, 1980). In 1996 fresh water discharges into the Shatt Al-Arab River were dramatically reduced to less than 100 m3/sec with dissolved salt concentrations exceeding 1.5g/L (Al-Yamani et al., 2006). Currently, the Shatt Al-Arab River receives less than 50 m3/sec with an average dissolved salt concentration of more than 2 g/L (Isaev & Mikhailova, 2009). Figure 2 illustrates the situation in the Hammer and Central Marshes. The increasing salt concentration and decreasing water volume has adversely impacted the local population and their livelihoods, regional agriculture and industries and has destroyed habitat for flora and fauna (Nielsen et al., 2003).

Figure 1: Iraq Map indicating Mesopotamian marshlands (HZ= Al-Hawizeh, CM= Central, HM= Al-Hammar), Marshlands outlets into Shatt Al-Arab, Al-Hartha, Shatt Al-Arab upstream and downstream and the Arabian Gulf; (source: Data SIO, NOAA, U.S. Navy, NGA, GEBCO 2013Google Image Landsat U.S. Department of State Geographer)

Believing that the main source of elevated salt concentrations in the Shatt Al-Arab River was a result of salt water intrusion from the Arabian Gulf (Al Maarofi et al., 2012), the Iraqi government is considering constructing a regulator (dam) within the river. However, based on several extensive surveys and monthly monitoring programs between 2004 and 2012, the main source of salinity within the north section of the Shatt Al-Arab River is actually the re-flooded marshes (Al Maarofi et al., 2012). Mapping of the Shatt Al-Arab River salt content (Figure 3) clearly shows maximum salt concentrations at Hartha village during August and November 2008. This is further supported by the salt budget of the marshes for May 2006 to March 2007 illustrated (Figure 4). Although the salt budget of Mesopotamian Marshes is for the year 2006-2007, the salinization problem has been magnified. Thus, salinity of > 12 g/l was recorded at the exit of the marshes during 2012-2013.

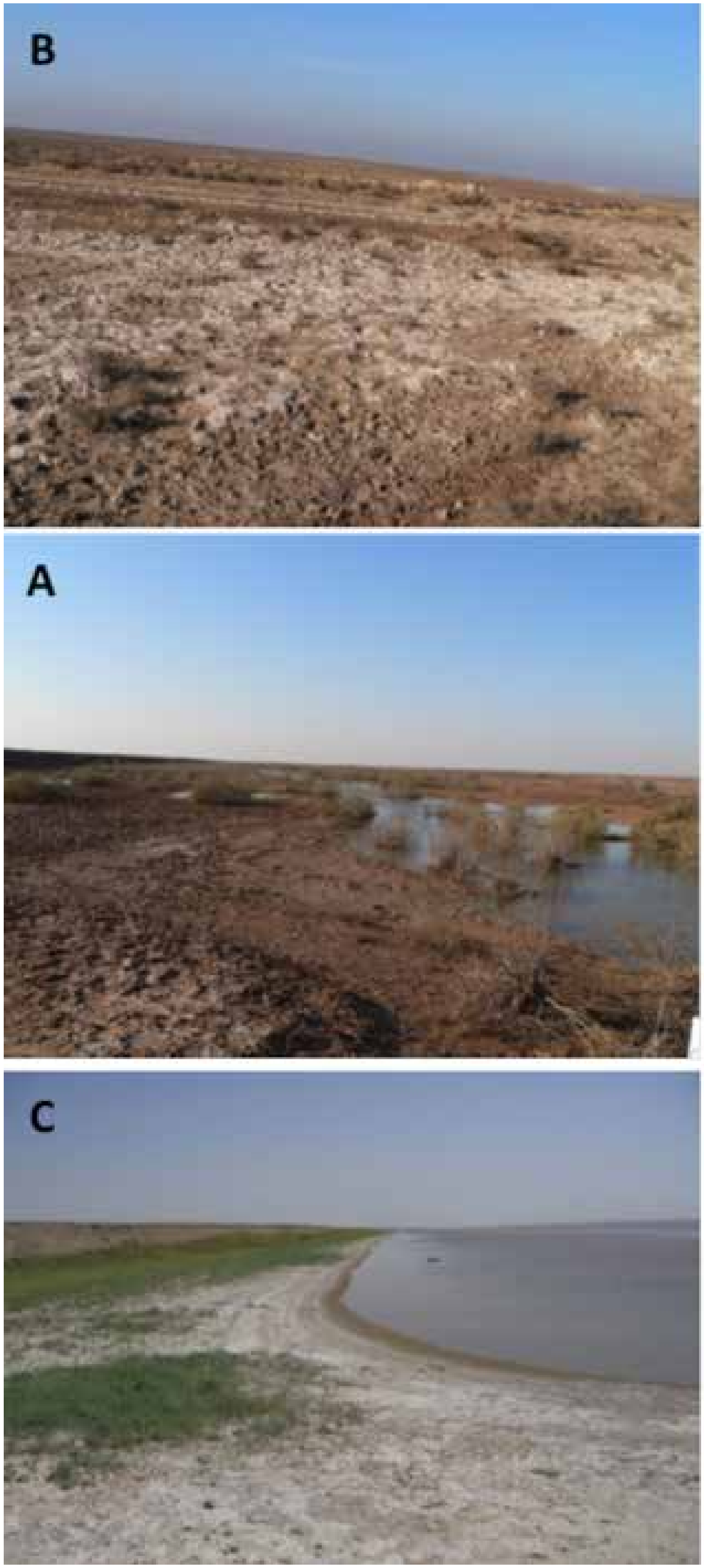

Figure 2: Salt accumulations on dried marshes sediment; (A) Saroot marsh 32”20’52°N 46 47 56° E in Hammar marshes, January 2007, (B) Al-Seiniya marsh 31”55’10°N 46”45’50°E and (C) Al-Rayan marsh 31”34’42°N 47”2’0°E in the Central marshes, January 2007.

These data indicate that the historical role of the Mesopotamian Marshes in regulating the concentration of salts become limited. Consequently, the impacts on the marshes have caused them to be a source of dissolved salts in the surface waters, especially Shatt Al-Arab River. We suggest that the main source of salt upstream of the Shatt Al-Arab is the drained marshes. Based on the findings of this study, we recommend that future decisions taken by the Iraqi government regarding the Shatt Al-Arab waterway should consider all factors related to the provenance of increasing dissolved salt concentrations.

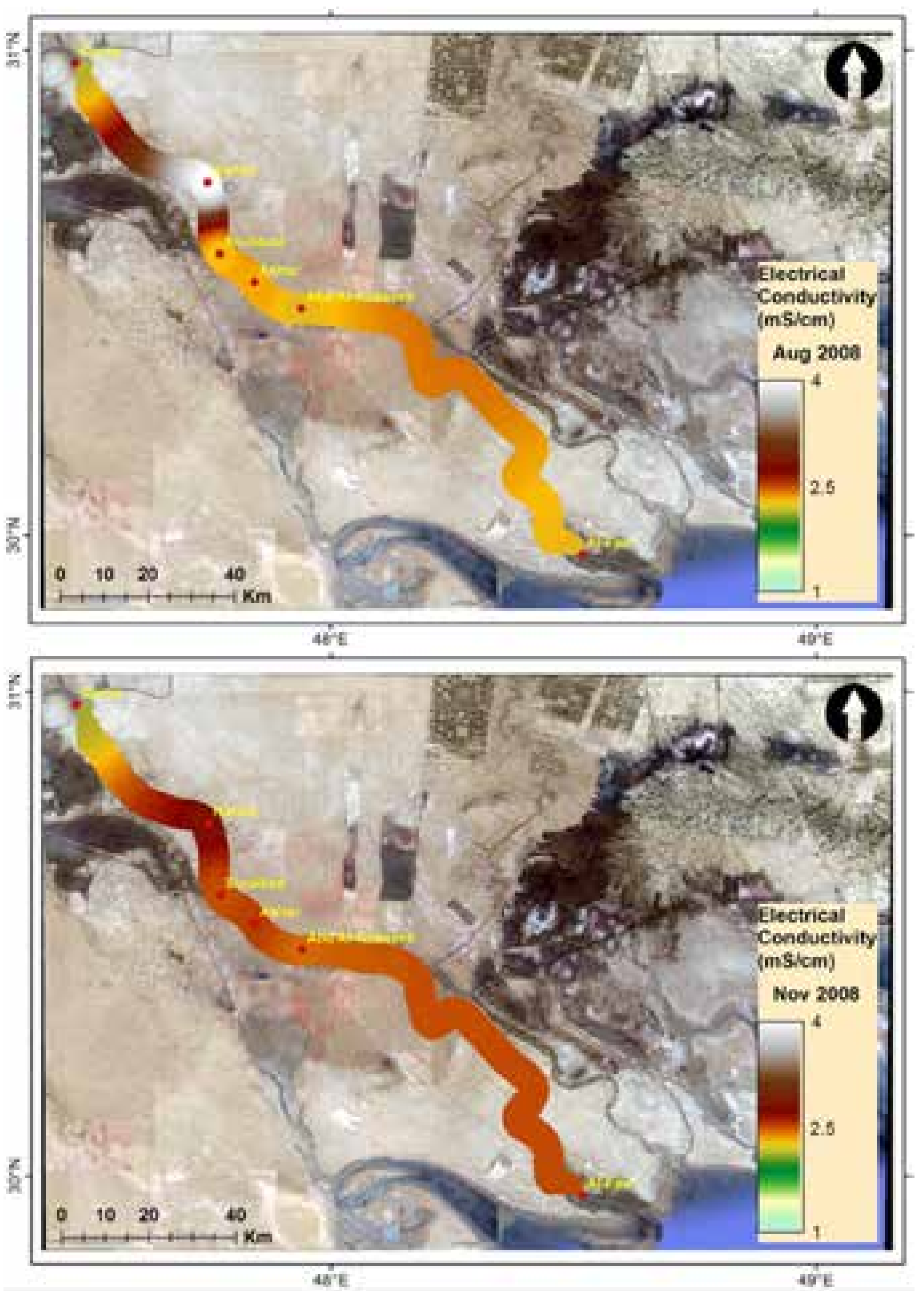

Figure 3: Shatt Al-Arab electrical conductivity concentration mapping. Maps were generated using Arc-GIS 10 software.

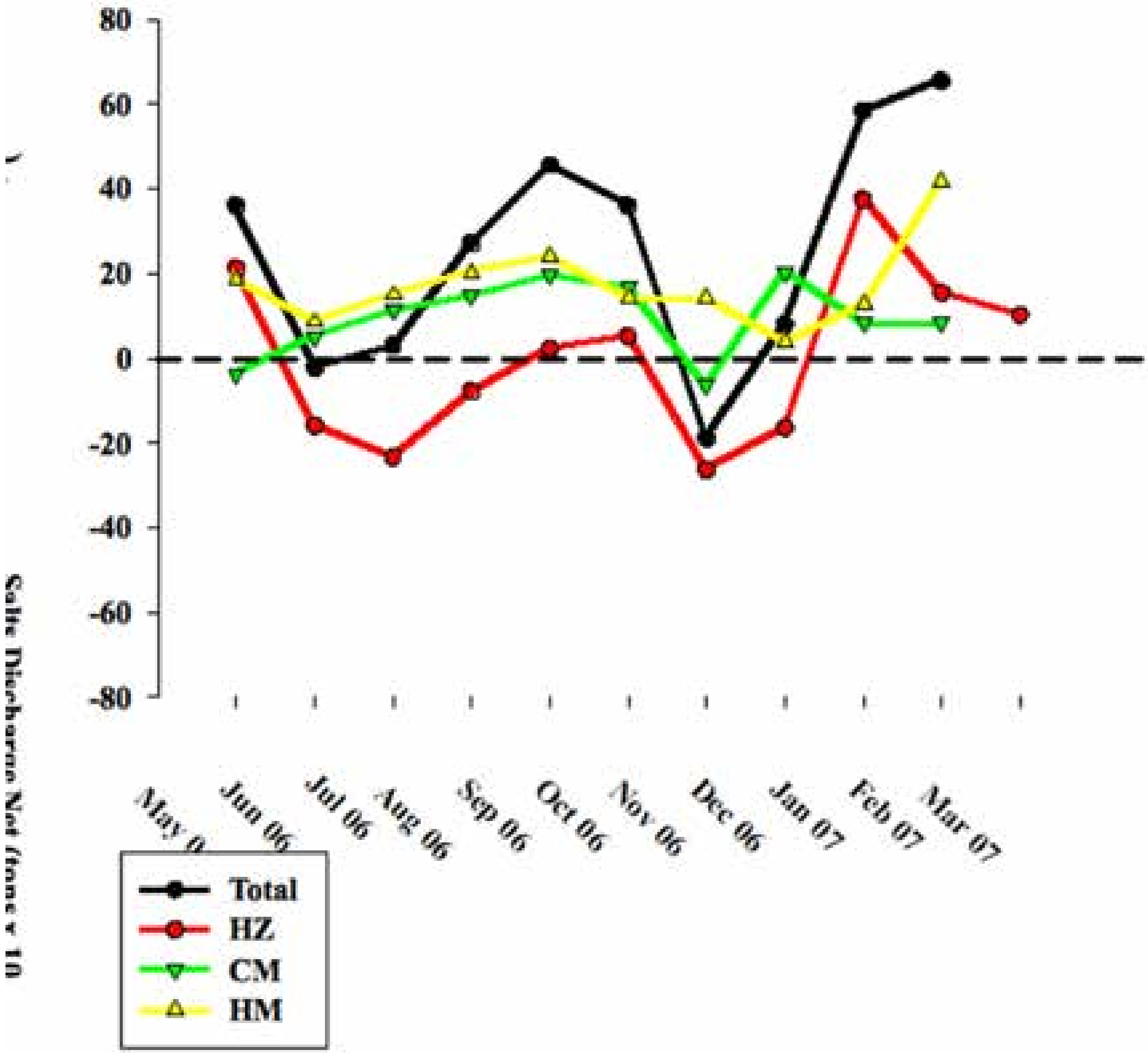

Figure 4: Mesopotamian Marshes salt budget (HZ= Hawizeh marsh, CM= Central marshes and HM= Hammar marsh, see Fig. 1 for locations).

Acknowledgments

Authors would like to acknowledge the United Nations Environment Programme, the United States Agency for International Development, the Canadian International Development Agency and the Italian Ministry of Environment and Territories for their fund. The Marine Science Centre at the University of Basra implemented the research under the supervision of the University of Waterloo (Canada) and the University of Victoria (Canada).

References

Al Maarofi, S. S. et al., 2013. Desiccation versus Re-flooding: I-Heavy Metals Mobilization. Journal of Environmental Protection, August.Volume 4.

AlMaarofi, S. S., Douabul, A. A. & Al-Saad, H. T., 2012. Mesopotamian Marshlands: Salinization Problem. Journal of Environmental Protection, Volume 3, pp. 1295-1301.

Al-Yamani, F. et al., 2006. Primary Production off Kuwait, an Arid Zone Environment, Arabian Gulf. International Journal of Oceans and Oceanography, Volume 1, pp. 67-85.

Douabul, A. A. et al., 2012. Restoration versus Re-flooding: Mesopotamian Marshlands. Hydrology: Current Research, 3(5).

IMET, 2006. Master Plan for Integrated Water Resources Management in the Marshland Area. Phase 2, Italy: Italian Ministry of Environmnet and Territories.

Isaev, V. A. & Mikhailova, M. V., 2009. The Hydrography, Evolution, and Hydrological Regime. Water Resources, 36(4), p. 380–395.

Kubba, S., 2011. The Iraqi Marshlands and the Marsh Arabs: The Ma'dan, Their Culture and the Environment. UK: Ithaca Press.

Mahamed, S. S., 2008. Phosphorus and Nitrogen in Al-Hawizeh marshes, southern Iraq. Waterloo(ON): University of Waterloo.

Nielsen, D. L., Brock, M. A., Rees, G. N. & Baldwin, D. S., 2003. Effect on Increasing Salinity on Fresh Ecosystem in Australia. Australian Journal of Botany, Volume 51, pp. 655-665.

Partow, H., 2001. The Mesopotamian Marshlands: Demise of an Ecosystem, Nairobi: United Nations Environment Programme (UNEP).

Richardson, C. J. et al., 2005. The Restoration Potaintial of the Mesopotamian marshes of Iraq. Science, Volume 307, pp. 1307-1310.

Rzoska, J., 1980. Euphrates and Tigris, The Mesopotamian Ecology and Destiny. Boston and London: W. Junk, the Hague.

Scott, D. A., 1995. A Directory of Wetlands in the Middle East. U.K.(Slimbridge): IUCN, Gland, Switzerland and IWRB.

Seeking Interested Wetland Specialists to Recording Phenology in and around Wetlands

Some of you may be familiar with the National Phenology Network (NPN) that is collecting information on seasonal changes in plants and animals across the country (https://www.usanpn.org/), while others may already be participating in the NPN, Bird Conservation Network or local frog and amphibian surveys. Since many SWS members are actively engaged in field work throughout the year, I thought it would be a good opportunity for wetland specialists as a group or individually to contribute information to the NPN. Given that observations of bud break, leaf-out, and flower emergence in the spring are important indicators for wetland delineation, keeping a record of such activities would be a meaningful effort to assist in developing some regional benchmarks as well as for their possible use in tracking the effects of climate change in the long run. Observations of the onset of fall foliage, leaf drop, and plant senescence might also be worth recording. For members with a special interest observing wildlife such as the return of certain birds to our locales or the beginning of the chorusing of breeding frogs or the departure of birds in the fall, documenting these occurrences would also be of interest. Today (March 25), our local red-winged blackbird returned to the cattail marsh next at our office and came pecking at our window – a sign of spring despite the temperatures in the teens/twenties. As an incoming editor of WSP, I thought it might be worthwhile to devote a section of the journal to recording nature observations through the seasons and across the country. So if you would like to participate in recording your observations of nature, please let me know by email (rtiner@eco.umass.edu). In your email, please put "WSP Nature Observations" in the subject box and in your response please indicate your geographic area and specific interest. Thanks for your cooperation!

Ralph Tiner

Figure: A few signs of spring from southern New Jersey: Swamp Pink (Helonias bullata) in bloom and the emergence of leaves of Skunk Cabbage (Symplocarpus foetidus) and fiddleheads of Cinnamon Fern (Osmunda cinnamomea). Swamp Pink is a federally threatened plant with 225 occurrences reported, half of which are in New Jersey. (U.S. Fish and Wildlife Service photo by Gene Nieminen)

Editor's Choice

Wishful thinking.

Editor's Note: Checking out

Well, I tried to do this a few years ago but was convinced to stay on. This time I'm finally passing along the editorship of Wetland Science and Practice to the very capable hands of Ralph Tiner. I've been here for 13 years and March 2014 marks my 52nd issue, some print and some digital. I want to thank all of the members of SWS for putting up with me over the last few years, and especially for tolerating my predilection for Doug Wilcox's cartoons. I hope they continue! Where WSP goes next is up to Ralph, the executive board of SWS, and you, the members of SWS. However, I'm sure it will continue to grow and get better…and not have quite so many images of central Pennsylvania on the cover.

Thanks – and I look forward to seeing all of you in print in the WSP!

Andy Cole

WETLAND SCIENCE AND PRACTICE

www.sws.org