wetland science & practice
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Vol. 35, No. 4 October 2018

FROM THE EDITOR'S DESK

Now that the storm has passed, we'll learn how much damage was caused by Hurricane Florence and the cost of cleanup. It is always tragic to witness loss of life and property damages from storms. It was especially disconcerting to see how much flooding occurred in communities along North Carolina rivers from the second so-called "500-year flood" in two years (Hurricane Matthews in 2016). We'll wait and see what effect this will have on government plans for the future, especially in North Carolina whose legislature voted to ignore science and climate change predictions in coastal planning back in 2012. Many of those flooded probably don't have flood insurance given their location above the 100-year floodplain. Yet for those covered by such insurance, how many times does one need to be flooded out to see that the solution is to relocate to higher ground? A November 4, 2017 article in the New York Times reported that "a house in Spring, Tex., has been repaired 19 times, for a total of $912,732 — even though it is worth only $42,024." Although federal flood insurance doesn't work for everyone inflicted with flood damages for a host of reasons, the frequency of this repair would not be done if it weren't for federal flood insurance. Floodplains are so named for an obvious reason yet people found them desirable places to build homes and commercial properties after levees and dams were built to reduce natural flooding. Now seemingly more frequent, extreme events overtop levees and cause millions of dollars of damage (https://www.climate.gov/news-features/blogs/beyond-data/2017-us-billion-dollar-weather-and-climate-disasters-historic-year). It will be interesting to see the response of various levels of government for minimizing flood damages in the future.

Ralph Tiner
WSP Editor

I hope you've noticed that we changed the publication schedule for *Wetland Science & Practice*. We decided to publish quarterly issues in January, April, July, and October (one month later than before). This allows us to devote the July issue to publishing abstracts from our annual meeting and focus on other meeting-related matters. We will also be publishing student research project reports funded by SWS research grants – the first of which is provided herein by Marisa Szubryt, Southern Illinois University Carbondale. All this plus other contributions will provide more information about ongoing wetland research, restoration projects, and other initiatives to readers. We continue to seek articles on your wetland activities or creative writing on the natural history of wetlands in your locale. Meanwhile thanks to all who have contributed to this issue: Royal Gardner and Erin Okuno for their indepth analysis of current U.S. wetland regulations, Evan Park and Martin Rabenhorst for introducing us to new technology for documenting reduction in anaerobic soils, Marisa Szubryt for her research project report, Max Finlayson for submitting the article he and SWS colleagues published in *The Conversation*, Mary Johnston for information on wetland activities in the Big Thicket, and Doug Wilcox for his *From the Bog* cartoon.

Happy Swamping! ■

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COVER PHOTO:
Spotted Turtle (*Clemmys guttata*)
Photo courtesy of Mal Gilbert

SOCIETY OF WETLAND SCIENTISTS
22 N Carroll St., Ste 300, Madison, WI 53703
608-310-7855
www.sws.org

Note to Readers: All State-of-the-Science reports are peer reviewed, with anonymity to reviewers.

PRESIDENT'S ADDRESS

As 2018 moves into its last quarter, those of us in the southern U.S. check the skies for hurricanes, academics and students return to the classroom, and researchers wrap up the last of their year's field work. For SWS, the last quarter brings new ways to promote internationalization.

Beth Middleton
U.S. Geological Survey,
Wetland and Aquatic
Research Center
SWS President

SWS has been invited to attend the Ramsar Conference of the Contracting Parties (COP3) in Dubai in October. SWS is honored to be a part of this major world gathering of wetland experts and policymakers. To support Ramsar planning efforts, SWS has proposed a meeting during the conference on Ramsar wetland management in changing future environments.

To support chapter activities and internationalization, Executive Board members attend many chapter meetings, both in the U.S. and elsewhere. I just returned from a very successful joint meeting of the China and Asia Chapters in Changchun China with nearly 400 attendees. We also have been moving forward with ideas to sponsor SWS section symposia in international wetland meetings.

SWS continues its efforts to communicate with members using new media approaches. Watch for announcements on the Twitter Symposium in upcoming weeks. Send your field photos to the SWS Instagram Page (www.instagram.com/societywetlandscientists). If you have videos of your projects, or phone apps that you have written to support field work, please send them to SWS (https://www.sws.org/About-SWS/new-media-initiative.html). Also, please consider writing an article for Wetland Science and Practice about your field trips and wetland activities.

The Baltimore Local Planning Committee is hard at work preparing the 2019 annual meeting (May 28-31). Symposia proposals relevant to the meetings theme, "The Role of Wetlands in Meeting Global Environmental Challenges: Linking Wetland Science, Policy, and Society" are being accepted until Monday, October 15, 2018. Please visit www.swsannualmeeting.org for more information.

As always, I look forward to hearing from you about your ideas and concerns for SWS. Please contact me: middletonb@usgs.gov. ■

wetland science & practice

Rural School District, Thicket of Diversity, and SWS Partner to Increase Understanding of Big Thicket and Other Local Wetlands

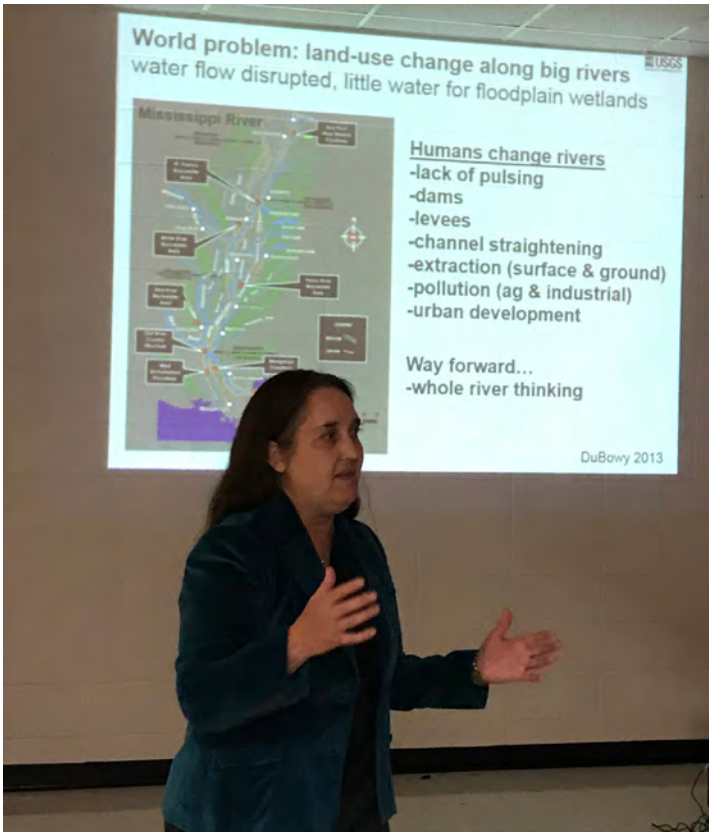
Contributed by Mary C. Johnston, Kountze High School; mjohnston@kountzeisd.org

The Thicket of Diversity, a project of the Big Thicket Association, promotes Big Thicket wetlands through research, educational outreach, and citizen science activities. In 2017-18 the non-profit organization organized activities throughout the school year with Kountze Intermediate School District as a partner. Researchers including Society of Wetland Scientists (SWS) President, Dr. Beth Middleton, presented at Kountze High School, while others guided field trips into the National Park Service's Big Thicket National Preserve.

Additional activities included planting of native trees, creation of a community garden, and student design of a *Flood and Drought* slideshow illustrating the effects of climate change on American bald cypress. Students at Kountze Intermediate School visited the preserve as part of the *Every Kid in a Park Program*, hosted a Science Fair, and created artwork for the SWS, earning two awards.

Kountze faculty and administration eagerly anticipate the 2018-19 school year and expansion of the partnership with the Thicket of Diversity and the Society for Wetland Scientists. Increased understanding of the significance of wetlands and suggested stewardship strategies is valued as the district is located in Hardin County, Texas and was heavily impacted by Hurricane Harvey. ■

SWS President Dr. Beth Middleton describing wetland functions to Kountze High School students.



Students viewing pitcher plants and sundews during field trip.

Another *Amicus Curiae* Brief in Support of Clean Water Rule is Filed on Behalf of the Society of Wetland Scientists

On July 24, 2018 an *amicus curiae* brief in support of Clean Water Rule was filed in the North Dakota Waters of the United States (WOTUS) Clean Water Rule case. The brief reiterates that the Clean Water Rule is scientifically sound and is based on state of the science studies, including those in the EPA's Connectivity Report. The Connectivity Report documents how wetlands and tributaries contribute to the chemical, physical and biological integrity of downstream waters. The July 24 brief supports Justice Anthony Kennedy's "significant nexus" opinion in *Rapanos v. United States* which has informed established law since 2006. SWS supports the Kennedy opinion due to the opinion's reliance on the relevant science. In 2006, SWS submitted an *amicus curiae* brief in the Rapanos Supreme Court case, providing an articulation of the underlying science to the Supreme Court justices.

SWS member Professor Royal Gardner (Director of the Institute for Biodiversity Law and Policy at Stetson Law), who won the 2018 SWS President's Service Award for his work on behalf of SWS with regard to the WOTUS Clean Water Rule, led the team of attorneys including Erin Okuno (Foreman Biodiversity Fellow at Stetson Law), Dr. Steph Tai (Associate Professor of Law at University of Wisconsin Law School), Kathleen Gardner, and Christopher Greer (Park Jensen Bennett LLP), who prepared the July 24, 2018 amicus curiae brief. The team filed this brief in the U.S. District Court for the District of North Dakota. This team also filed the May 7, 2018 *amicus curiae* brief on behalf of SWS in the U.S. District Court for the Southern District of New York. SWS *amicus curiae* briefs can be read at: https://sws.org/images/Doc-No-233-Brief-of-SWS-as-Amicus-Curiae.pdf. ■

Get Involved with Your Local Chapter

With more than 3,000 members around the world, SWS encourages you to participate in your local chapter to get the most out of your membership. These chapters provide a local resource for networking, education and other wetland-related events.

One chapter subscription is included with your membership. You are welcome to subscribe to as many chapters as you like for a small additional fee. More information about Chapters: http://www.sws.org/Membership/chapter-membership.html ■

Upcoming chapter meetings

- **Central Chapter**
  Stream Investigation, Stabilization & Design Workshop and Annual Meeting
  Lawrence, KS | Oct. 3-4, 2018
- **South Central Chapter**
  Fall Meeting
  North Little Rock, AR | Oct. 10-12, 2018
- **Pacific Northwest Chapter**
  Joint Regional Conference Restoring Resilient Communities in Changing Landscapes
  Spokane, WA | Oct. 15-18, 2018
  https://restoration2018.org/

SWS Twitter Symposium

SWS will be running a Twitter Symposium on **Thursday, October 18, 2018**, in the run-up to the Ramsar COP. Twitter conferences/symposia are becoming increasingly popular as a cost-free and low-carbon footprint alternative for researchers, policy makers, stakeholders and interested members of the general public to converse about research and share ideas. The SWS Twitter Symposium is a rewarding and fun way to share your research and meet other wetland scientists from the comfort of your own desk.

Taking part in **#SWSTwitterSymp2018** couldn't be easier. You can follow the symposium from anywhere around the world on your laptop, PC, smartphone or tablet via the Twitter website or Twitter app by using our symposium tag **#SWSTwitterSymp2018**! More info.

SWS Multicultural Mentoring Program (SWaMMP) Application Now Open!

SWaMMP is dedicated to increasing diversity in the field of wetland science by offering undergraduate students from underrepresented groups full travel awards to the SWS 2019 Annual Meeting, held May 28-31 in Baltimore, MD. Student winners will receive valuable career mentoring as well as exposure to professional networking forums. This program is supported by the National Science Foundation and several SWS Chapters.

PROGRAM BENEFITS

- Travel expenses (including airfare, hotel room, meals and conference fees) for the SWS Annual Meeting.
- Mentors to provide guidance and career advice.
- Special activities to introduce participants to postgraduate and career opportunities and meet professionals from diverse fields.
- The opportunity to present research posters.
- Access to a network of wetland science professionals.
- The opportunity to join a growing community of students who have already participated in our program.
- Membership in SWS for one year following the award.

APPLICANTS

- Participants must be citizens or permanent residents of the United States or its possessions and be undergraduate students enrolled in a degree program (part-time or full-time) leading to a baccalaureate or associate degree. Spring 2019 graduates are eligible; Fall 2018 graduates are not.
- For the purposes of these awards, applicants must belong to one or more of the following groups that have traditionally been underrepresented in wetland sciences: Black/African Americans, Hispanics/Latinos, Native Americans, Indigenous Alaskans, Native Pacific Islanders (Hawaiian/Polynesian/Micronesian).

Do you know someone who may be interested? Check out this promotional flyer, or visit the Multicultural Mentoring Program webpage to learn more. Please contact Dr. Vanessa Lougheed with any questions. Click here to apply to SWaMMP. Applications due November 2, 2018. ■

Take Full Advantage of Your Membership Through SWS' Monthly Webinar Series

Participate in outstanding educational opportunities without leaving your desk! SWS is pleased to provide its webinar series that addresses a variety of wetland topics. The convenience and flexibility of SWS webinars enables you to educate one or a large number of employees at once, reduce travel expenses, and maintain consistent levels of productivity by eliminating time out of the office.

If you're unable to participate in the live webinar, all webinars are recorded and archived for complimentary viewing by SWS members.

We are proud to announce that our webinars are pre-approved by the SWS Professional Certification Program. Webinar registration is a complimentary member benefit. Certificates of completion are available upon request and can be used towards PWS certification. A limited number of spots are available for each webinar.

Webinars are now viewable with subtitles on YouTube! The Webinar Committee is excited to announce that our free webinar recordings are now available on the SWS YouTube channel. SWS supporters around the world can watch the webinars with subtitles in their native language. ■

SWS New Media Initiative - Sharing Ideas Through Videos

The Society of Wetland Scientists' mission is to promote understanding, conservation, protection, restoration, science-based management and sustainability of wetlands. Currently, SWS achieves these goals by hosting webinars and meetings, publishing newsletters, moderating discussion forums and granting access to research journals, among other activities. Videos are a thriving communications medium, and are another effective way to share our mission.

The SWS New Media Team launched the SWS YouTube channel to share our mission with a wider audience. To help us with this initiative, we ask for members and non-members alike to share their work and experiences by submitting a video to be featured on our YouTube channel! Featured videos showcase various wetland topics that help to further our mission. Visit the SWS New Media Initiative webpage for more information and to submit a video: https://www.sws.org/About-SWS/new-media-initiative.html. ■

RECENTLY APPROVED VIDEOS:

Interreg's Green Danube Project
https://www.youtube.com/watch?v=1-BPUYMGUuU&list=PL8NOIq5cy6-f71smAnMB2EHi_v5wZLeCF&index=2

Freeing a Trapped River: Pocomoke Restoration
https://www.youtube.com/watch?v=PMBYlUzjlho

2019 SWS Annual Meeting Website Is Now Live

The Society of Wetland Scientists' 2019 Annual Meeting will be held in Baltimore, Maryland, May 28-31, 2019. The theme of the meeting is "The Role of Wetlands in Meeting Global Environmental Challenges: Linking Wetland Science, Policy, and Society." We are currently accepting proposals for symposia and workshops (please see below). Abstract submission will open in November, with registration launching in December. In the meantime, visit the meeting website at swsannualmeeting.org to stay up-to-date on all meeting developments. ■

SUPPORT THE SWS ANNUAL MEETING

Sponsor

A variety of sponsorship levels are available on a first-come, first-selected basis and are sure to provide international exposure among leaders in wetland science. For more information: https://www.swsannualmeeting.org/sponsor/. Not sure which sponsorship opportunity to choose? Construct your own sponsorship package to fit your unique needs and goals. To discuss sponsorship and reserve an opportunity for your company, please contact Amanda Safa (asafa@sws.org). ■

Exhibit

SWS meetings gather the highest level of wetland professionals to provide an unequalled opportunity for you to network and build countless connections. Simply complete and return the Exhibitor Agreement to reserve your booth today! For more information, visit the Exhibitors webpage (https://www.swsannualmeeting.org/exhibit/). To discuss exhibiting at the 2019 SWS Annual Meeting, contact Amanda Safa (asafa@sws.org). ■

Silent Auction

The SWS Mid-Atlantic Chapter will host a silent auction during the Poster Session reception on Thursday, May 30, 2019. All proceeds will go directly to the Chapter to support future initiatives including funding for students in wetland science. Donations may be related to the wetland profession, such as field equipment, or personal interests, such as books, movie passes, sports memorabilia, or gift cards. Silent auction items will be on display for all registrants to see and bid on. Visit the Silent Auction webpage (https://www.swsannualmeeting.org/silent-auction/) for more info. Thank you for investing in the future of wetland science! ■

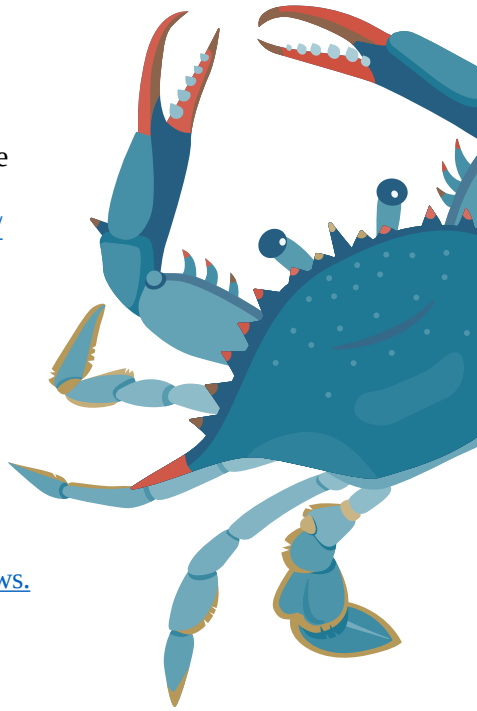
SYMPOSIUM AND WORKSHOP PROPOSALS DEADLINE: MONDAY, OCTOBER 15, 2018

Syposium Proposals

The SWS Program Committee is now accepting symposium proposals. Symposium proposals that focus on the meeting's theme, *The Role of Wetlands in Meeting Global Environmental Challenges: Linking Wetland Science, Policy, and Society* are particularly encouraged. Visit the Symposia webpage (https://www.swsannualmeeting.org/symposia/) on the meeting website for more information and to submit a proposal form (https://fs24.formsite.com/SWS2015/Call-for-Symposia/index.html). For any questions, please contact Emily Viles at eviles@sws.org. ■

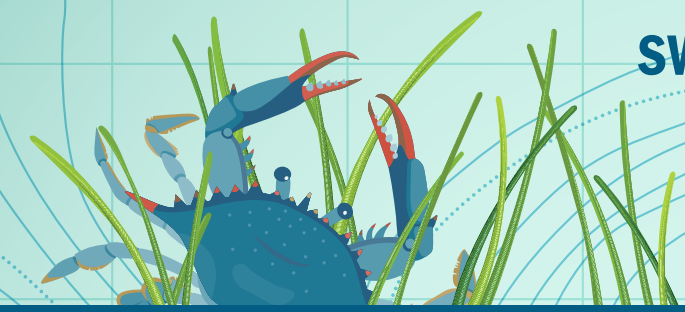
Workshop Proposals

Do you have an interest in leading a workshop? Visit the workshops webpage (https://www.swsannualmeeting.org/workshops/) for more information, and send your idea by submitting a workshop proposal form (https://fs24.formsite.com/SWS2015/Call-for-Workshops/index.html) for the Program Committee's consideration. Please contact Emily Viles at eviles@sws.org with any questions. ■



Planning Underway for 2020

Planning is underway for the joint Québec RE3 Conference, "*From Reclaiming to Restoring and Rewilding*," SWS is excited to join the Canadian Land Reclamation Association (CLRA) and the Society for Ecological Restoration (SER) in Quebec from June 7th to 11th, 2020. Check out the website, and follow the event on Twitter and Facebook. **#QuebecRE3**



SWS 2019 | Annual Meeting | May 28 - 31

The Role of Wetlands in Meeting Global Environmental Challenges: Linking Wetland Science, Policy, and Society

Baltimore, Maryland

Sponsorship Opportunities

A variety of sponsorship levels are available on a first-come, first-selected basis and are sure to provide international exposure among leaders in wetland science. Not sure which sponsorship opportunity to choose? Construct your own sponsorship package to fit your unique needs and goals.

CONTRIBUTING LEVEL — $500

Help make the SWS 2019 Annual Meeting a success by making a general contribution.

BRONZE LEVEL — $1,000

- **DAILY PLENARY SPEAKER.** The 2019 Annual Meeting will feature three renowned plenary speakers who will share research findings and new perspectives. Three opportunities available.
- **DAILY MORNING & AFTERNOON REFRESHMENTS.** Attendees will enjoy light snacks and beverages during daily morning and afternoon refreshments. Six opportunities available.

SILVER LEVEL — $2,500

- **POSTER SESSION & SILENT AUCTION.** The 2019 Poster Session Reception will showcase the latest wetland research and provide an opportunity to meet with experts to learn about their scientific studies. The Mid-Atlantic Chapter will also be hosting a silent auction to help fund Chapter activities.
- **STUDENT MIXER.** A great opportunity for student attendees to mingle, exchange ideas and learn about opportunities for involvement in SWS.
- **ATTENDEE PEN.** Attendees will receive a meeting-themed pen in their attendee bag which will feature the sponsor's logo.

GOLD LEVEL — $5,000

- **HOTEL ROOM KEY.** All guests will receive a custom hotel key card as they check in under the SWS hotel block which will feature the sponsor's logo.
- **ATTENDEE BAG.** Meeting-branded attendee bags will be distributed to all participants containing important meeting materials. The sponsor's logo will be featured on each bag.
- **LANYARDS.** Meeting-themed lanyards will be distributed to each attendee at registration which will feature the sponsor's logo.
- **WATER BOTTLE.** Attendees will receive a meeting-themed water bottle in their attendee bag which will feature the sponsor's logo.

PLATINUM LEVEL — $7,500

- **WELCOME RECEPTION.** The 2019 Annual Meeting will kick off with a special Welcome Reception providing attendees the chance to network with friends, old and new, over hors d'oeuvres and cocktails.
- **MOBILE APP.** Attendees will be able to access the daily programming, general meeting information and connect with fellow attendees via their smart phones and the web. The sponsor's logo will be featured on the homepage of the app.
- **WIFI.** Internet access will be available at the meeting venue. The sponsor's logo will be featured on the landing page with the option to customize the WIFI network and password.

BENEFITS OF SPONSORSHIP	$500	$1,000	$2,500	$5,000	$7,500
Logo + hyperlink featured on meeting website	★	★	★	★	★
Logo featured on onsite sponsor signage	★	★	★	★	★
Special recognition during sponsored event		★	★		★
One marketing item dropped in attendee bag			★	★	★
One complimentary registration to the SWS Annual Meeting				★	
Two complimentary registrations to the SWS Annual Meeting					★
One complimentary exhibit booth at the SWS Annual Meeting					★

**Prices in U.S. dollars.*

To discuss sponsorship opportunities for your company, contact Amanda Safa, asafa@sws.org, 608-310-7855.

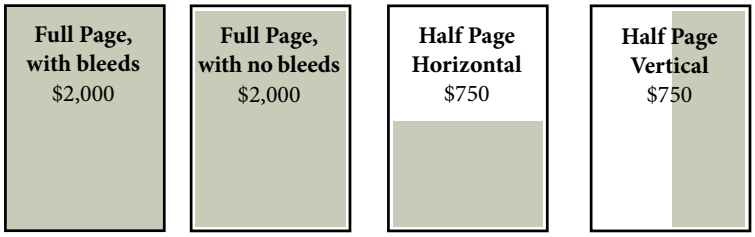
Conference Journal Advertising Opportunities

Increase your visibility at the SWS 2019 Annual Meeting by participating as an advertiser in the Conference Journal. Limited ad space available and insertion is on a first-come, first-served basis. Don't miss this special opportunity to showcase your brand to conference attendees.

SIZE OPTIONS (*prices in U.S. dollars)

Select	Size/Placement	Size	Rate
☐	Full Page (Inside Front or Back Cover), with bleeds	6.5"w x 11"h + .125" bleeds	$2,000
☐	Full Page (Inside Front or Back Cover), with no bleeds	6"w x 10.5"h	$2,000
☐	½-Page Horizontal *	6"w x 5.125"h	$750
☐	½-Page Vertical *	2.875"w x 10.5"h	$750

** Only eight ½-page ads will be sold.*



CONTACT AND BILLING INFO

Contact and billing information is the same:

Company name: _____

Contact name: _____

Street address: _____

City/State/Postal code: _____

Country _____

Phone: (incl. country + city code) _____

Email: _____

Fill in this section for billing, if different from main contact:

Company name: _____

Contact name: _____

Street address: _____

City/State/Postal code: _____

Country _____

Phone: (incl. country + city code) _____

Email: _____

☐ Advertisment attached/enclosed ☐ Advertisement arriving separately

IMPORTANT DATES

Advertising reservation deadline: March 29, 2019
Artwork submission deadline: April 5, 2019
Please send this reservation form, as well as print-ready art files, to asafa@sws.org.

SUBMISSION GUIDELINES

The advertising art file that you submit must follow these guidelines:

- .Pdf file type
- High-resolution, of at least 300 dpi
- CMYK color space
- Any bleeds need to be at least .125"

To discuss advertising opportunities for your company, contact Amanda Safa, asafa@sws.org, 608-310-7855.

OBITUARY

Roy R. "Robin" Lewis, III
1944 - 2018

Bill Mitsch, Past President of SWS, called on October 3 to let me know that his long-time friend and collaborator in wetlands Robin Lewis recently died in central Florida (see article in *The Gainesville Sun* - https://www.gainesville.com/news/20181005/noted-environmentalist-dies-at-home-in-salt-springs). Robin was a SWS member and a Professional Wetland Scientist Emeritus. He served on the Editorial Board of the Society's international journal – *Wetlands* from 1982-85 and on the Society's Professional Certification Board. He was founder and President of Lewis Environmental Services, Inc., Tampa, Florida and Coastal Resources Group, Inc., Salt Springs, Florida. He received his B.S. in Biology from the University of Florida and his Master's degree from the University of South Florida. Early in his career, he taught at Hillsborough Community College and in the 1970s, organized some of the earliest conferences on wetland restoration. Later he continued teaching through short courses on wetland restoration for the Corps of Engineers, Ohio State University, University of Wisconsin, Louisiana State University, Florida Gulf Coast University, and others. His expertise included the ecology, restoration, and creation of fresh and saltwater wetlands and aquatic habitats. He was particularly noted for his mangrove and sea-grass work, having designed more than 200 completed wetland restoration or creation projects in Florida, South Carolina, California, Puerto Rico, the U. S. Virgin Islands, Nigeria, Thailand, Hong Kong, Mexico, Brazil, Jamaica, Guyana and French Guiana. Among other contributions, Robin was a member of the National Research Council's Committee on the Role of Technology in Marine Habitat Protection and one of the original members of the Everglades Wetland Research Park advisory committee 2012-2018. He published more than 125 scientific papers on wetland and aquatic system restoration and creation. In the words of Bill Mitsch, Robin was "a wonderful man. I miss him enormously. Mother Nature has lost a great friend and ecosystem worker." Robin – thanks for sharing your knowledge and for your contributions in restoring and creating wetlands; may you rest in peace. ■

Photo courtesy of Bill Mitsch, Everglades Wetland Research Park

The Shifting Boundaries of Clean Water Act Jurisdiction

Royal C. Gardner[1] and Erin Okuno, Institute for Biodiversity Law and Policy, Stetson University College of Law, Gulfport, Florida

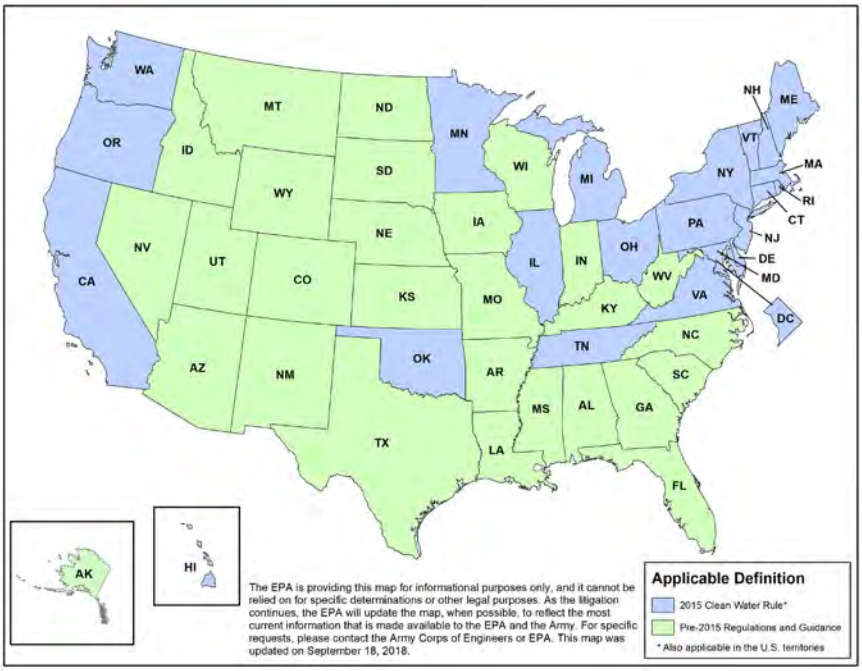
As a presidential candidate, Donald Trump promised to figuratively drain the ethical swamp of Washington. This has not come to pass. But as president, he has ordered regulatory changes that, if implemented, would result in the actual draining of swamps and other wetlands. These regulatory changes also may not come to pass—at least not right away.

The Clean Water Act (CWA) (33 U.S.C. §1251 et seq.) is the primary wetland protection law in the United States. If a wetland qualifies under the CWA as "waters of the United States"—often referred to as WOTUS—no one may discharge pollutants into that wetland without a federal permit. As of mid- September 2018, the precise authority of the federal government to regulate wetlands under the CWA exists in a muddled state.

In slightly less than half of the states, the 2015 Clean Water Rule, issued under the Obama administration, is in force. In the other half, the Clean Water Rule is enjoined by court orders, and pre-existing rules and guidance are used (see Figure 1). The Trump administration has tried to suspend the Clean Water Rule (unsuccessfully) and has formally proposed revoking it. The Trump administration has also stated that it intends to replace the Clean Water Rule with a new rule consistent with Justice Scalia's plurality opinion in *Rapanos v. United States*, a very restrictive view of the CWA's coverage. Meanwhile, litigation over the Clean Water Rule proceeds in various federal courts throughout the country. There is no clear path to definitively resolving the question of what constitutes a "water of the United States" under the CWA.

To understand how we got here, one must review the history of the federal government's protection of aquatic resources. As another president (Lincoln) noted: "Fellow citizens, we cannot escape history."

FIGURE 1. Current status of the Clean Water Rule across the country (as of September 18, 2018). Source: United States Environmental Protection Agency (2018).



THE RIVERS AND HARBORS ACT: A NINETEENTH CENTURY ANTECEDENT

Under the Rivers and Harbors Act of 1899, activities that impede "the navigable capacity of any of the waters of the United States" are prohibited unless authorized by the U.S. Army Corps of Engineers (Corps). In this context, "waters of the United States" are defined to be "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce" (33 C.F.R. § 329.4). Today, such waters are typically referred to as traditional navigable waters, or primary waters, or sometimes (a)(1) waters.[2]

1 Corresponding author: gardner@law.stetson.edu. Royal C. Gardner is a Professor of Law and the Director of the Institute for Biodiversity Law and Policy at Stetson University College of Law. Erin Okuno is a licensed attorney and the Institute's Foreman Biodiversity Fellow. The authors were part of a team of attorneys who prepared and filed two amicus curiae briefs on behalf of SWS in 2018.

2 The term "(a)(1) waters" refers to the specific subsection of the definition of "waters of the United States" (see 33 C.F.R. § 328.3(a)(1)).

THE CLEAN WATER ACT: EXPANDING THE CONCEPT OF WATERS OF THE UNITED STATES

After it became clear that states were not sufficiently protecting water quality (with the Cuyahoga River fire as the starkest example), Congress enacted the CWA in its present form in 1972. The CWA generally prohibits the discharge of pollutants into "navigable waters" without a permit. Under the CWA, the term "navigable waters" is defined as "the waters of the United States, including the territorial seas" (33 U.S.C. § 1362).

While the U.S. Environmental Protection Agency (EPA) received most of the regulatory authority under the CWA, the Corps was assigned responsibilities under Section 404. The discharge of dredged or fill material into "waters of the United States" requires a permit from the Corps (33 U.S.C. §1344). Initially, the Corps interpreted the CWA's "waters of the United States" to be the same as the Rivers and Harbors Act's "waters of the United States," i.e., traditional navigable waters (see Mulligan 2016). Environmental groups challenged this interpretation, and a U.S. District Court concluded that Congress wanted the CWA to apply to the fullest extent permitted by the Commerce Clause. Accordingly, the court instructed the Corps to revise its regulations to cover additional waters (*Natural Resources Defense Council, Inc. v. Callaway*).

To complicate matters, the EPA also has its own regulations defining "waters of the United States" (see, e.g., 40 C.F.R. §122.2, 40 C.F.R. §230.3). Because the EPA has the bulk of CWA responsibilities, it has the final call (as between the agencies) on questions of the CWA's geographic scope (Civiletti Memorandum 1979). Ultimately, through a series of public notice-and-comment rulemakings, the Corps' and EPA's definitions were aligned in their 1986 and 1988 regulatory definitions of waters of the United States, respectively.

The aligned 1986/1988 regulatory definition covered traditional navigable waters, as well as their tributaries and adjacent wetlands. It also covered "other waters" if their "use, degradation or destruction" could affect commerce (Final Rule 1986; Final Rule 1988). This regulatory definition was then challenged by the regulated community, with three cases reaching the U.S. Supreme Court.

WOTUS IN THE SUPREME COURT

In the initial case of the trilogy, in 1985, the Supreme Court in *United States v. Riverside Bayview Homes* unanimously held that it was reasonable for the Corps to define waters of the United States to include wetlands adjacent to a traditional navigable water. In doing so, the Court recognized that such wetlands form part of an aquatic ecosystem and play an important role regarding the water quality of the traditional navigable water. The Court also specifically rejected the notion that an adjacent wetland needs to have a continuous surface connection to traditional navigable waters to be covered by the CWA. The Court deferred to the agencies' technical expertise in determining which waters should be protected to achieve the CWA's goals.

In 2001, in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, the Supreme Court in a 5-4 decision ruled that the CWA did not cover certain so-called isolated waters. Here, the Corps attempted to demonstrate that seasonal ponds ("other waters" under the 1986/1988 regulations) had a connection to interstate commerce through the presence of migratory birds. The Court, concerned that the federal government might be straying into areas traditionally regulated by state governments, concluded that relying on migratory birds was an unreasonable interpretation of the CWA.

The 2006 case of *Rapanos v. United States*, a splintered 4-1-4 ruling, unleashed the chaos. In *Rapanos*, the Supreme Court considered whether the CWA covered wetlands adjacent to non-navigable tributaries of traditional navigable waters. There was no majority opinion. Four justices, led by Justice Scalia, argued that the only plausible interpretation of "waters of the United States" includes only those relatively permanent, standing, or continuously flowing bodies of water, such as oceans, rivers, and lakes. Accordingly, the CWA should cover only those wetlands with a continuous surface connection to bodies of water that are "waters of the United States" in their own right, making it difficult to determine where the "water" ends and the "wetland" begins. Four justices disagreed, contending that any hydrologic connection between a wetland and a traditional navigable water should suffice for CWA jurisdiction. Justice Kennedy, in the middle, advocated a third approach: a wetland is covered by the CWA if it has a "significant nexus" to a traditional navigable water.

Because the agencies had not made a specific finding with respect to the wetlands' "significant nexus," Justice Kennedy voted with Justice Scalia and his colleagues to remand the case for further consideration. There was, however, no majority or controlling opinion in *Rapanos* (see Mulligan 2016). Neither Justice Scalia's plurality opinion nor Justice Kennedy's concurrence in the judgment established a binding precedent.

In 2007, the EPA and the Corps responded with guidance, following Justice Kennedy's approach (Memorandum 2007). The agencies stated that they would assert CWA jurisdiction over certain waters such as traditional navigable waters, wetlands adjacent to these traditional navigable waters, non-navigable, relatively permanent tributaries of traditional navigable waters, and wetlands that directly abut

such tributaries. The agencies also identified a smaller class of waters that they would generally not assert jurisdiction over, including swales, gullies and small washes characterized by low volume, infrequent, or short duration flow, and certain ditches that do not carry a relatively permanent flow of water. For other waters (e.g., non-navigable tributaries that are not relatively permanent and adjacent wetlands thereto), the agencies indicated that a fact-specific analysis would be conducted to determine whether they have a significant nexus with a traditional navigable water. The guidance document then explained how to measure the extent to which a water contributes to the chemical, physical and biological integrity of downstream traditional navigable waters.

Although not required by the Administrative Procedure Act, the agencies sought public input on the significant nexus guidance. They received more than 66,000 comments and slightly revised the guidance document in December 2008 (see Memorandum 2008).

When deciding CWA jurisdictional cases post-*Rapanos*, lower courts typically applied Justice Kennedy's "significant nexus" standard, sometimes upholding CWA jurisdiction and sometimes not. Thus, up until 2015, the rules in place were the 1986/1988 regulations and the 2008 significant nexus guidance document.

THE 2015 CLEAN WATER RULE

In April 2014, the EPA and Corps issued for public input a proposed rule that sought to bring certainty to the scope of CWA jurisdiction. The comment period for the Clean Water Rule lasted nearly seven months, and the agencies received more than 1 million comments. In June 2015, the agencies formally promulgated the Clean Water Rule, which defined the term "waters of the United States" (Clean Water Rule 2015).

In conjunction with the rulemaking process, the EPA requested its Office of Research and Development to prepare a report to inform the rulemaking. The resulting document, sometimes referred to as the Connectivity Report, which reviewed and synthesized more than 1,200 peer-reviewed scientific publications, provides scientific support for the Clean Water Rule by establishing how streams and wetlands are connected to primary waters (United States Environmental Protection Agency 2015).

The Connectivity Report was one of the most thorough analyses, procedurally, ever conducted by the EPA. The Connectivity Report itself was subjected to multiple rounds of independent peer review, as well as public comment, and included only studies that were peer reviewed or otherwise verified for quality assurance.

Although the Clean Water Rule is a complex regulation, it has a straightforward organization. Certain waters are jurisdictional by rule, that is, they are categorically treated as waters of the United States and do not require any individual assessment. These categorical waters include traditional navigable waters, interstate waters, and the territorial seas, as well as tributaries of these waters and adjacent waters based on geographic proximity. Similarly, at the other end of the continuum, the Clean Water Rule excludes by rule certain waters from jurisdiction, based on their distance from traditional navigable waters. And, in between, other waters are subject to a significant nexus analysis (Clean Water Rule 2015).

Before we could see how the Clean Water Rule would play out on the ground, it was immediately challenged in numerous courts throughout the country on a multitude of procedural and substantive issues.

CLEAN WATER RULE LITIGATION: OPENING ROUND

Some challenges to EPA actions made pursuant to the CWA are initiated by filing a complaint in U.S. District Courts, while other challenges start with a petition to a U.S. Court of Appeals. One confounding aspect of the Clean Water Act litigation was that initially it was unclear which level of court had primary jurisdiction. Thus, complaints and petitions were both filed in District Courts and Courts of Appeals, respectively. While the District Court cases proceeded independent of each other, the litigation in the Courts of Appeals was consolidated before the Sixth Circuit (based in Cincinnati).

The Clean Water Rule litigation was moving on two tracks, and early results were not promising for the agencies. At the District Court level, in August 2015, the U.S. District Court for the District of North Dakota issued a preliminary injunction that covered 13 states (*North Dakota v. U.S. Environmental Protection Agency*). Meanwhile, in October 2015, the Sixth Circuit issued a nationwide stay of the Clean Water Rule (In re: *Environmental Protection Agency and Department of Defense Final Rule*).

The U.S. Supreme Court then stepped in to decide the (judicial) jurisdictional issue. That is when things became even more complicated.

CLEAN WATER RULE LITIGATION: THE META-JURISDICTIONAL QUESTION

On a positive note, in January 2018 in *National Association of Manufacturers v. Department of Defense*, the Supreme Court provided clarity about which court has jurisdiction to consider the challenges to agency rules on CWA jurisdiction. In a unanimous decision written by Justice Sotomayor, the Supreme Court held that a challenge to any WOTUS rule must begin in U.S. District Courts, not the Courts of Appeals. The Supreme Court based its ruling on the plain language of the CWA and rejected any policy-based arguments. Although vesting the Court of Appeals with primary

jurisdiction would promote national uniformity, the Court emphasized that Congress did not prioritize quick and orderly resolution of WOTUS rule challenges.

The immediate impact of the decision meant that since the Sixth Circuit lacked jurisdiction, it could not issue a stay. Thus, the nationwide stay preventing the implementation of the Clean Water Rule would be lifted—unless the Trump administration took some additional administrative action, which it did.

TRUMP ADMINISTRATION EFFORTS TO REPEAL AND REPLACE (AND SUSPEND) THE CLEAN WATER RULE

One month after taking office, President Trump issued an Executive Order calling on the EPA and Corps to rescind the Clean Water Rule and replace it with a rule consistent with Justice Scalia's plurality opinion in *Rapanos* (Presidential Executive Order 2017). Initially, the agencies contemplated a two-step process. First, they would formally rescind the Clean Water Rule and return to the *status quo ante* (the 1986/1988 regulations and previous guidance). Then they would propose a new, Scalia-based rule (see Proposed Rule 2017a).

A key point is that under the Administrative Procedure Act, repealing the Clean Water Rule is itself "rulemaking"—and thus requires the agencies to go through a notice-and-comment process before doing so. Accordingly, in July 2017, the EPA and the Corps announced their intention to rescind the Clean Water Rule (Proposed Rule 2017a). The agencies received more than 600,000 comments, including from the Society of Wetland Scientists, which strongly opposed the proposed repeal.

When issuing a final rule, agencies must explain how they considered the comments received during the notice-and-comment process. With so many substantive comments received, it was understandable that such the EPA and Corps' review would take time. Indeed, if the agencies engage in a cursory examination of and provide weak responses to the comments, any final rule could be vulnerable to a court challenge. But while the Sixth Circuit's national stay existed, there was no rush. The *status quo ante* that the repeal would effect was already in place.

Of course, the Supreme Court's decision—and the evaporation of the national stay—changed the calculus. Anticipating that decision, the Trump administration tried another administrative move. The EPA and Corps conducted a quick rulemaking with a three-week comment period to add an "applicability date" to the Clean Water Rule, essentially suspending implementation of the rule until February 2020 (see Proposed Rule 2017b). Again, SWS and Consortium of Aquatic Science Societies (CASS) commented, emphasizing that the agencies needed to consider the scientific basis of the Clean Water Rule before suspending it. The agencies contended they did not need to do so and quickly finalized this Suspension Rule, thereby preventing (briefly) the re-emergence of the Clean Water Rule (see Final Rule 2018).

CLEAN WATER RULE LITIGATION: CHALLENGING THE TRUMP ADMINISTRATION'S SUSPENSION RULE

Consistent with Newton's third law, the suspension of the Clean Water Rule brought a swift reaction from ten states and several environmental groups. Lawsuits were filed in U.S. District Courts in New York, South Carolina, and California, asserting that the Suspension Rule was procedurally invalid. The litigation in the Southern District of New York was brought by ten states and the District of Columbia, which asserted that the EPA and the Corps violated the Administrative Procedure Act by failing to consider and respond to comments raised during the truncated comment period (*New York v. Pruitt*).

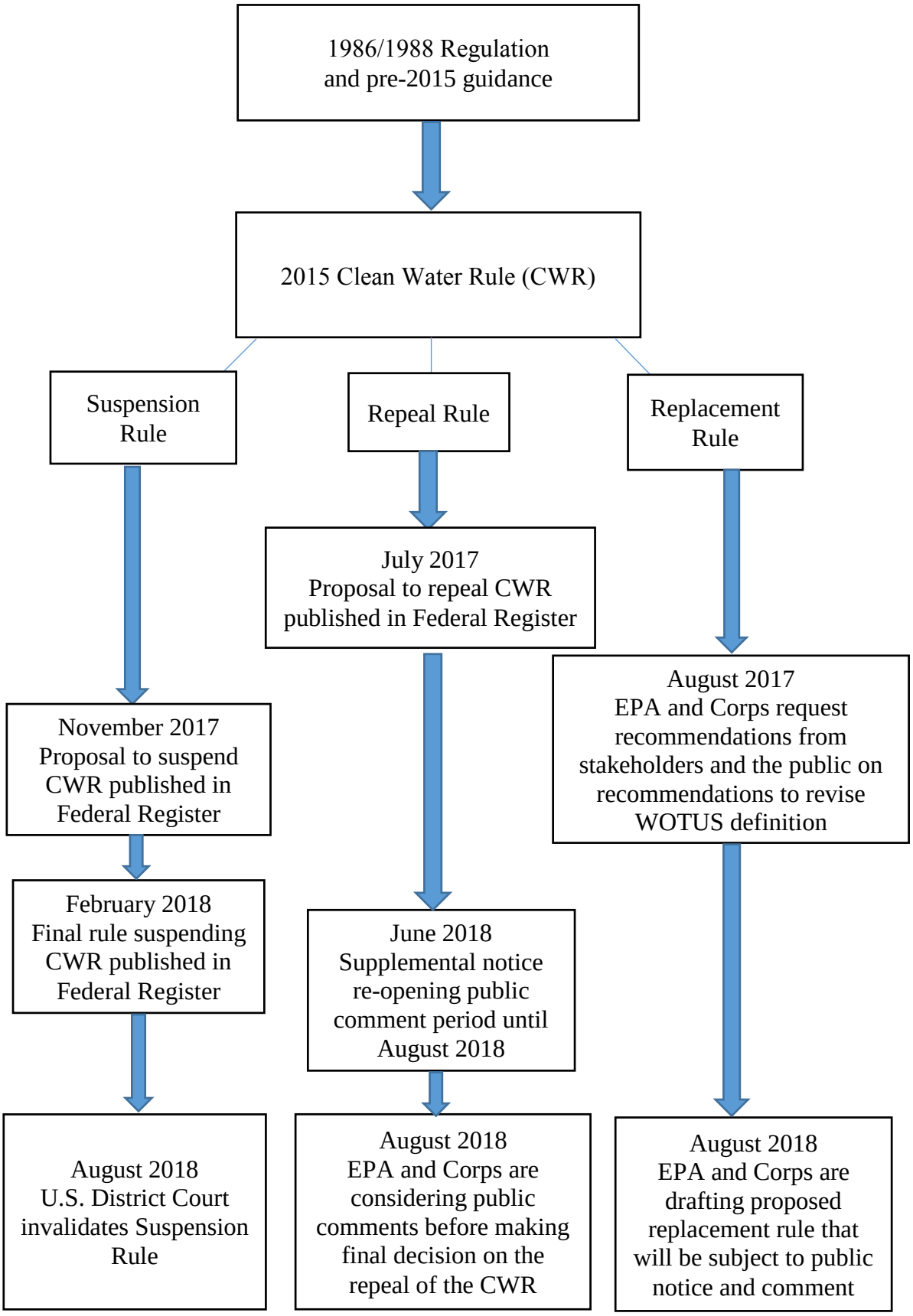
SWS filed an amicus brief in the Southern District of New York on behalf of the states to emphasize the importance of considering the scientific record. In summary, SWS stated:

> An agency must provide a reasoned explanation when promulgating or amending a rule. An agency's implausible explanation or its failure to consider relevant and significant aspects of a problem renders a rulemaking arbitrary and capricious. Because the EPA and Corps refused to consider the scientific basis of the Clean Water Rule, including the most current scientific understanding of how streams and wetlands contribute to the chemical, physical, and biological integrity of downstream waters, the Suspension Rule is arbitrary and capricious.
>
> More broadly, all major EPA policy decisions since the agency's inception have required the use of science. Science is critically important to furthering the goals of the CWA, and this Court should hold the EPA and Corps accountable for failing to consider science in their decisions. The agencies cannot so blithely disregard science related to the chemical, physical, and biological integrity of the Nation's aquatic resources.

(Brief of the Society of Wetland Scientists 2018a). The full amicus brief is available at http://stetso.nu/8J6ML.

While the Southern District of New York has yet to rule, the U.S. District Court for the District of South Carolina decided the matter quickly. On August 16, 2018, in *South Carolina Coastal Conservation League v. Pruitt*, the court invalidated the Suspension Rule. While the court acknowledged that agencies may change their views (and indeed it is expected when administrations change), agencies must nevertheless provide a reasoned analysis for the shift. The court stated:

Figure 2. Status of Trump administrative actions affecting the Clean Water Rule



> No such "reasoned analysis" was provided in the promulgation of the Suspension Rule. By refusing to allow public comment and consider the merits of the [Clean Water Rule] and the [1986/1988] regulation, the agencies did not allow a "meaningful opportunity" to comment. As such, the court finds that the agencies were arbitrary and capricious in promulgating the Suspension Rule. It vacates the Suspension Rule for this reason. To allow the type of administrative evasiveness that the agencies demonstrated in implementing the Suspension Rule would allow government to become a matter of the whim and caprice of the bureaucracy. Certainly, different administrations may implement different regulatory priorities, but the APA requires that the pivot from one administration's priorities to those of the next be accomplished with at least some fidelity to law and legal process. The agencies failed to promulgate the Suspension Rule with that required fidelity here. The court cannot countenance such a state of affairs.

(*South Carolina Coastal Conservation League v. Pruitt* [internal citations and quotations omitted]).

The U.S. District Court for the District of South Carolina's ruling applied nationwide. Thus, the effect of *South Carolina Coastal Conservation League v. Pruitt* is to resurrect the Clean Water Rule—except in those jurisdictions where a different U.S. District Court had enjoined it.

CLEAN WATER RULE LITIGATION: BACK TO THE MERITS

With the Suspension Rule no longer in force, and while we await more administrative moves, the legal battle shifts back to U.S. District Courts entertaining challenges to the Clean Water Rule. There are at least six such active cases at various stages. In *North Dakota v. U.S. Environmental Protection Agency*, for example, the U.S. District Court is considering making its preliminary injunction against the Clean Water Rule permanent. At this point, the Trump administration is not defending the substance of the Clean Water Rule in court. Instead, environmental groups such as the Sierra Club have intervened in support of the Obama-era rule.

In the North Dakota litigation (which involves 14 states), SWS has filed an amicus brief in support of the Clean Water Rule. The amicus brief explains why the Clean Water Rule is scientifically sound and how best available science supports the categorical treatment of tributaries and adjacent waters based on geographic proximity (Brief of the Society of Wetland Scientists 2018b). The amicus brief is available at http://stetso.nu/HbWZQ.

If a court strikes down the Clean Water Rule, the agencies will once again shift back to the 1986/1988 regulations and guidance, unless of course the EPA and Corps finalize any of their proposed or planned rulemakings. Even if the supporters of the Clean Water Rule prevail in court, the definition of "waters of the United States" can be modified administratively. But the agencies must follow the proper procedures, and any new rule will be subjected to legal attacks, both procedural (e.g., inconsistent with the Administrative Procedure Act) and substantive (e.g., inconsistent with the Clean Water Act).

RECAPPING THE ADMINISTRATIVE MORASS

Figure 2 illustrates the administrative state of play as of mid-September 2018. An attempt to suspend the Clean Water Rule for two years has been struck down. A proposal to permanently repeal or rescind the Clean Water Rule was issued for public comment. The comment period was reopened in July 2018 and extended until August 2018, and no final rule killing the Clean Water Rule has yet been published. The agencies are working on a proposed rule to replace the Clean Water Rule with a restrictive definition consistent with Justice Scalia's plurality opinion in *Rapanos*, but that proposed rule has yet to be published.

Meanwhile, as Figure 1 illustrates, the Clean Water Rule is being applied in 22 states, the District of Columbia, and U.S. territories, while the status quo ante (1986/1988 regulations and guidance) is being applied in the remainder.

CONCLUSION

In theory, Congress could step in at any time and amend the CWA's definition of "waters of the United States." Of course, such an intervention is not expected. Instead, it is more likely that the WOTUS battles will continue within the agencies and courts.

Whatever the next rulemaking steps the EPA and Corps might take—whether finalizing the Clean Water Rule's rescission or proposing and finalizing a Scalia-based rule—the agencies must provide a reasoned analysis for their decisions. Accordingly, the agencies must consider the scientific record, including the Connectivity Report, to justify their actions. Restricting the scope of waters protected under the CWA will be difficult to explain. ■

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Geographically isolated wetland in West Chicago, Illinois. (R. Tiner photo)

Assessing New Developments in IRIS Technology

C. Evan Park and Martin C. Rabenhorst[1], Department of Environmental Science and Technology, University of Maryland

ABSTRACT

Reducing soil conditions may impact more static properties like soil morphology, as well as more dynamic soil chemical properties and microbial ecology. Identifying reducing conditions is especially important when evaluating wetland soil systems. Indicator of Reduction in Soils (IRIS) tubes have been approved by the National Technical Committee for Hydric Soils (NTCHS) as a method to identify reducing soil conditions. Recently, a new development in IRIS technology utilizing flexible films has emerged. IRIS films are strips of vinyl sheeting painted with iron- or manganese-oxide paint. The films are intended to simplify field work and facilitate acquisition and computer analysis of IRIS images. This mesocosm study demonstrates that IRIS films perform comparably to IRIS tubes and accurately document reducing soil conditions.

INTRODUCTION

The Technical Standard for Hydric Soils (TSHS) was developed by the NTCHS to identify soils that satisfy the definition of a hydric soil, either where hydric soil field indicators are lacking, or in the development or evaluation of field indicators. The TSHS can be applied to numerous areas of study, including wetland delineation, wetland construction, and restoration projects. The TSHS requires proof that a soil is saturated and anaerobic. To this end, numerous methods have been developed to identify reducing conditions - the quantifiable evidence of anaerobic conditions. These include two basic methods: 1) the use of platinum electrodes (joined with a reference electrode) to directly measure the oxidation-reduction potential of a soil, which in conjunction with pH measurements can be used to confirm reducing conditions; 2) the application of alpha-alpha-dipyridyl dye to the soil - if the soil is reducing, the dye will react with Fe^{+2} and exhibit a bright pink color (National Technical Committee for Hydric Soils 2015). These methods have limitations because they require specialized equipment or expensive chemicals and they only provide data for the conditions at the moment of observation so the measurements must be made repeatedly for recording duration. In the early 2000s, a new method of identifying reducing conditions was introduced which addressed these limitations - Indicators of Reduction in Soils (IRIS) tubes. These were designed to be a simple, inexpensive field instrument (Castenson & Rabenhorst 2006; Jenkinson and Franzmeier 2006; Rabenhorst and Burch 2006; Rabenhorst 2008; Rabenhorst et al. 2008). The tubes are 60-cm long pieces of half inch schedule 40 PVC plastic (0.84" OD) painted with iron-oxide paint that are inserted into the soil. Under reducing conditions, the oxides in the paint become reduced and soluble and are removed from the tube, resulting in a pattern that can be quantified to identify reducing conditions. The TSHS requires a majority (3 out of 5) IRIS tubes to have at least 30% paint removal from any contiguous 15-cm zone in the upper 30 cm of the tube (National Technical Committee for Hydric Soils 2015). Estimation of paint removal by sight has proved unreliable (Rabenhorst 2010), so more trustworthy methods of quantifying paint removal have been developed. The simplest approach is to use 15x6.7-cm Mylar grids that can be wrapped around the zone of greatest paint removal on the IRIS tube which can be quantified after marking squares where substantial paint has been removed. Some image analysis approaches have also been applied to quantify paint removal, but the difficulty is in obtaining a 2-dimensional image from the 3-dimensional cylindrical tube in order to conduct the analysis.

TABLE 1. Properties of soils used in the study.

Property	Soil 1	Soil 2
Soil Series	Elkton	Downer
Sampling Location (coordinates)	39.007851, -76.847337	39.007929, -76.850181
Depth	0-15 cm	0-20 cm
Horizons sampled	A	A and AE
Texture	Silt Loam	Loamy Sand
% OC	8.4	1.4

1 Correspondence author for contact: mrabenho@umd.edu

Recently, a manganese oxide paint has also been developed for use on IRIS tubes (Rabenhorst and Persing 2016). Although IRIS devices painted with Mn oxide paint have not yet been approved for use by the NTCHS, they do appear promising with regard to their performance in helping to recognize reducing soil conditions (Persing and Rabenhorst 2016).

While IRIS tubes are attractive due to their conceptual simplicity, they do have some limitations. In addition to the previously mentioned problem of obtaining data from the 3-dimensional structure, the manufacturing of the tubes is time consuming because they must be painted one at a time on a special device that rotates the tube. There is also the issue of abrasion during insertion into the soil causing paint removal and thereby introducing error to the data collection. With these limitations in mind, the use of IRIS films is being explored in order to improve data collection and ease of use (Rabenhorst 2018). During the manufacture of films, large vinyl sheets can be painted and then cut into 3-inch wide strips, which reduces manufacturing effort. When films are inserted into the ground, they are enclosed in a protective polycarbonate sheath which mitigates abrasion. Then, when they are removed from the soil, they can be laid flat, simplifying image acquisition.

RESEARCH OBJECTIVES

The research objectives of this project were: 1) to assess the ability of IRIS films to document reducing conditions; 2) to compare paint removal from IRIS tubes and IRIS films under the same conditions; and 3) to generate preliminary laboratory data as background for projects assessing the efficacy of IRIS films in the field.

METHODS

This was a laboratory-based mesocosm study utilizing three replicate 20-L mesocosms of each of two contrasting soils that were saturated, and for which redox potential was documented using Pt electrodes and alpha-alpha-dipyridyl dye. Samples were collected from A-horizons of soils in the Elkton series and the Downer series. Approximately 80 L of each soil material was sieved moist through a ½" sieve and homogenized, and then stored refrigerated (6ºC) to minimize changes in organic carbon prior to initiation of the experiment. Mesocosms were made from 5-gallon (20 L) buckets that were perforated around the bottom.

Iron and manganese coated tubes and films were made using paint prepared following the procedures specified by Rabenhorst and Burch (2006) and Rabenhorst and Persing (2017). Into each mesocosm were installed 12 IRIS tubes (6 Fe and 6 Mn) and 12 films (6 Fe and 6 Mn). Also, into each mesocosm were installed 5 replicate Pt electrodes each, at depths of 5 cm and 15 cm from the surface, and a calomel reference was installed in each mesocosm using a salt bridge (Veneman and Pickering 1983). The mesocosms were placed within 10-gallon (38 L) containers and then were saturated from the bottom up to prevent air pockets by adding water to the outer container. The water table was equilibrated at the soil surface. Temperatures in the lab were monitored continuously at 1 hr intervals. One week, two weeks and four weeks after saturation, two replicates

FIGURE 1. Eh-pH stability diagram showing development of reducing conditions (means of 5-7 electrodes recorded daily over 28-day experiment). During the experiment the pH rose slightly (0.4 to 0.8 units). Redox potential (Eh) in both soils dropped below the ferrihydrite stability line and the NTCHS TS line within three days of saturation.

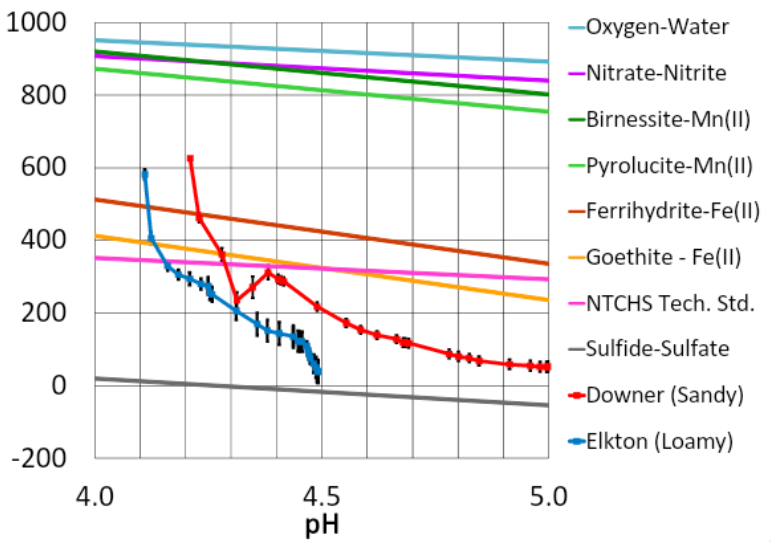
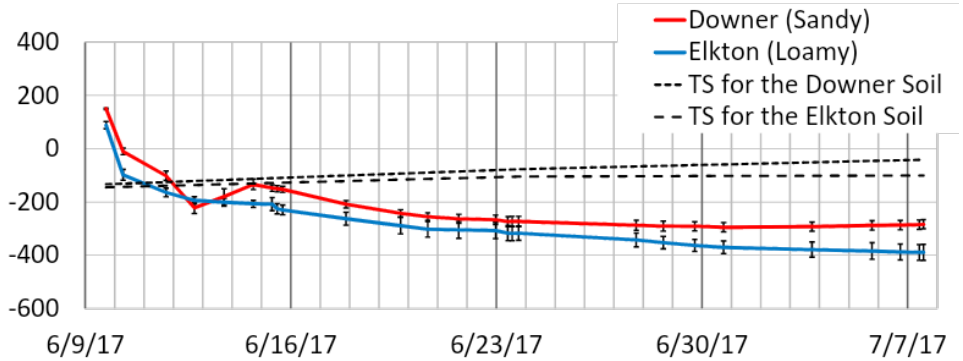


FIGURE 2. Mean Eh values (error bars show SEM) for the two sets of mesocosms relative to the ferrihydrite (Fh) stability line (0 on Y axis) and to the technical standard (TS) lines (based upon measured pH values). Both soils dropped below the Fh line within one day and they dropped below the TS line within 3 days.



of each IRIS device were removed from each mesocosm. After rinsing and drying, films were scanned using a flatbed scanner. Tubes were scanned using a specially modified flatbed scanner configured to roll the tubes keeping them directly above the scanning head as the image was collected. Tubes were scanned in two segments that were later recombined into a single image of the tube using Photoshop software. Digital scans of the devices were converted to binary images (painted areas white and stripped areas black). Paint removal from tubes and films was quantified using ImageJ software. Comparisons were made and the effects of device type, coating type and soil type were assessed by analysis of variance using JMP software (SAS Institute 2014).

FIGURE 3. Representative images of IRIS tubes and films from one of the Elkton and one of the Downer mesocosms.

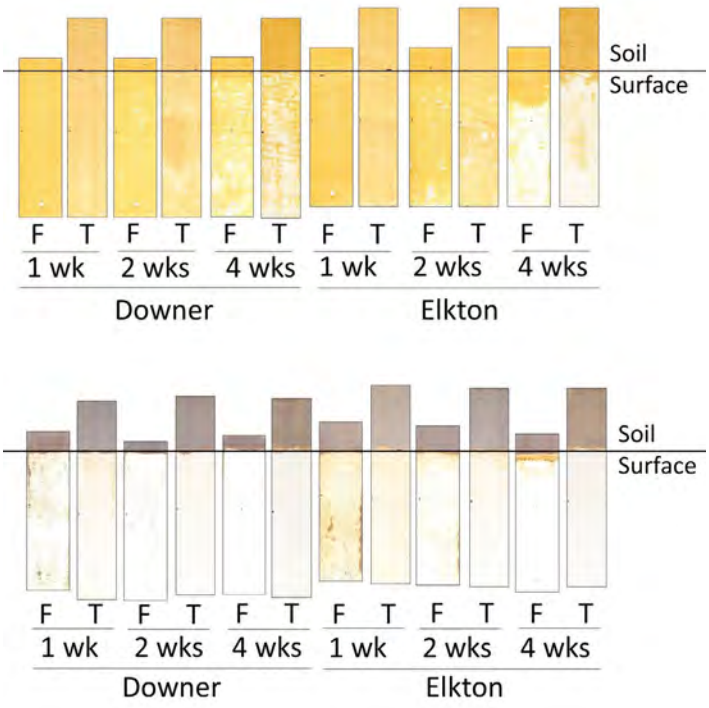
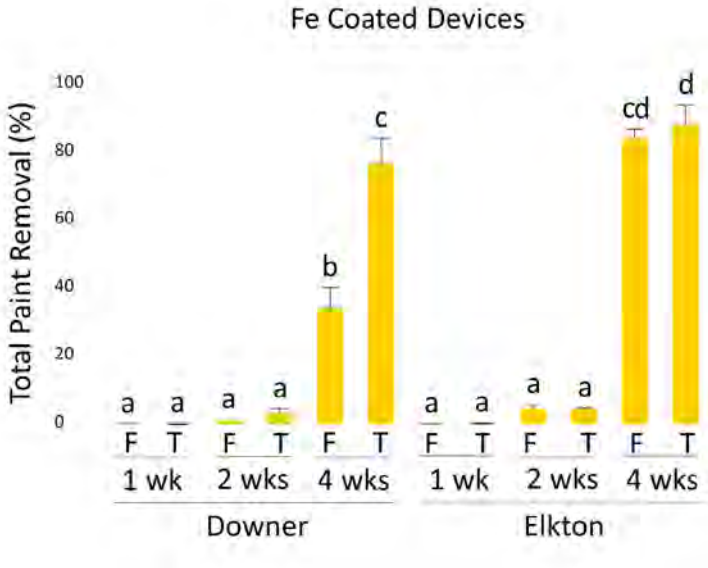


FIGURE 4. Portion of Fe oxide paint removed from IRIS devices after 1, 2 and 4 weeks from the two sets of mesocosms. Bars with the same letters are not significantly different at the 0.05 level.



RESULTS AND DISCUSSION

The redox potentials (Eh) and pH data are plotted on a stability diagram in Figure 1. The redox potentials of all mesocosms started out below the birnessite stability line and quickly dropped below the ferrihydrite stability line within one day and dropped below the technical standard line within three days (Figures 1 and 2). The speed with which the soils became reducing following saturation was probably related to both the relatively high organic carbon (OC) content of the soils (1.4 and 8.4% for the Downer and Elkton soils, respectively) and to the warm conditions of the laboratory which mostly ranged from 21.5°C to 23°C, averaging 22°C (data not shown). These temperatures were quite high relative to springtime soil temperatures and would have facilitated microbial activity.

Representative images of IRIS tubes and films from one of the Elkton and one of the Downer mesocosms are shown in Figure 3. A quick review shows that there was significantly more paint removed from Mn devices than from Fe devices at one, two, and four weeks. The percentage of Fe paint removal from the two soils is shown in Figure 4. Removal of the Fe paint from devices proceeded gradually. Over the first two weeks, there was negligible Fe paint removal (0- 5%) from devices in both the Elkton and Downer mesocosms. The amount of Fe paint removed from all devices and soils significantly increased between two and four weeks. At four weeks, more Fe paint was removed from devices in the Elkton mesocosms than from those in the Downer mesocosms (Figure 4), which may be the result of higher OC content and greater microbial activity.

Paint removal from the Mn devices was particularly rapid, where all devices (regardless of soil type) exhibited at least 80% removal after one week and approximately 99% after two weeks (Figures 3 and 5). After one week, slightly more Mn paint had been removed in the Elkton mesocosms than the Downer mesocosms, but this may not really be meaningful, and within two weeks there is no discernible effect of soil type (Figure 5).

When comparing performance of the two types of devices, mostly they performed the same but a few differences were observed. There were no effects observed with Fe coatings for the first two weeks. In week 4, there was significantly more Fe paint removed from tube than films

in the Downer soil, but no significant differences were observed in the Elkton soil (Figure 4). In the case of the Mn coatings, however, the only significant differences were observed in week 1, where there was slightly more (significant, but perhaps not meaningful) Mn paint removal from tubes than from films (Figures 3 and 5).

CONCLUSION

In this study, the most dramatic differences in IRIS paint removal were related to the coating type, with greater proportions of Mn oxide paint being removed relative to Fe oxide paint which reinforces previous research indicating the relative ease with which Fe and Mn oxides may be solubilized under reducing conditions. This study also shows that the properties of the soil can affect paint removal and may be related to the quantity of organic carbon present. Furthermore, the amount of paint removed from the devices is a function of how long they are deployed. Overall, coated PVC films performed comparably to coated PVC tubes and accurately documented reducing conditions, and this suggests that films could reasonably be used in lieu of tubes. The effort involved in obtaining scanned images of films is much less than in obtaining scanned images of tubes. Future studies should examine additional soil types in mesocosms and especially in field settings. ■

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FIGURE 5. Portion of Mn oxide paint removed from IRIS devices after 1, 2 and 4 weeks from the two sets of mesocosms. Bars with the same letters are not significantly different at the 0.05 level.

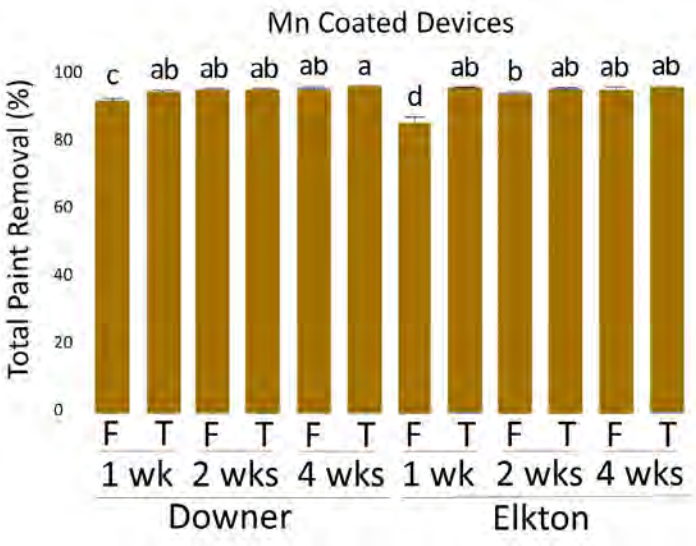
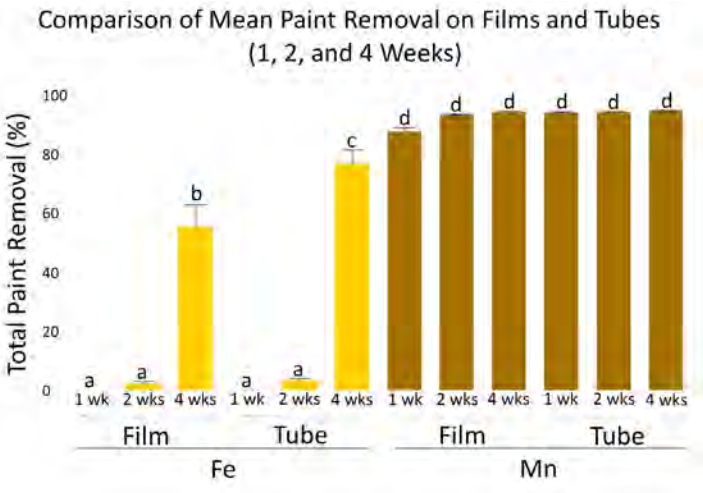


FIGURE 6. This graph reiterates the difference between Fe and Mn paint removal and the time effect for Fe devices. It also indicates that at four weeks, there is significantly more removal from Fe tubes than Fe films (statistical groups "b" and "c"). Note this figure groups devices from the two soils together.



Wetland Plant Evolutionary History Influences Soil and Endophyte Microbial Community Composition

SWS Research Grant – Final Report

Marisa Szubryt[1], Plant Biology Department, Southern Illinois University Carbondale, IL

BACKGROUND

Gaseous methane absorbs approximately twenty-seven times more heat than carbon-dioxide over hundred-year intervals (Boucher et al. 2009; Christensen et al. 2003), making it a potent and important greenhouse gas which contributes to climate change (Cao et al. 1998). Wetland ecosystems are responsible for 20-39% of global methane emissions (IPCC 2007). Methane emission rates differ among wetlands (Barlett et al. 1989), and this variability can be partially explained by differences in plant composition (Grünfeld and Brix 1999) and activity (Wang and Han 2005). While plants influence methane emissions, they do not directly produce methane in wetlands. Microbes known as methanogens, which grow in highly reduced, submerged soils, primarily produce methane (Grünfeld and Brix 1999; Laanbroek 2010). Methanogens only persist in anoxic conditions where organic matter is available for decomposition (Zeikus 1977). By reducing labile carbon compounds, chiefly acetate, methanogens can produce energy in environments where other microbes cannot survive (Jetten et al. 1992; Karakashev et al. 2006).

Plants contribute to methane production and emissions (Grunfeld and Brix 1999, Chanton et al. 1989) by providing substrates for microbial decomposition and an accelerated medium for gas diffusion between the atmosphere and soils (Denier van der Gon and Neue 1995; Kludze et al. 1993). Senesced shoot tissues differ chemically and structurally between plant species (Davis and van der Valk 1977), which likely influence microbial communities, including methane-utilizing microbes. Root exudates additionally differ between species (Bais et al. 2010) and influence soil microbial communities (Bridgham et al. 2013; Gagnon et al. 2007). These provide additional substrates which wetland microbes can metabolically utilize, and the products from microbial activity become increasingly reduced as oxygen availability decreases (Laanbroek 2010). Organic matter and low molecular-weight carbon compounds in the most reduced soil layers are metabolized to methane, which largely accumulates in flooded, stagnant soils (Tokida et al. 2005).

Flooded wetland soils which accumulate methane are typically anoxic and restrict gas flow (Cao et al. 1996; Laanbroek 2010), so ebullition in unvegetated soils presents the most effective means of gas diffusion from wetland soils (Fechner-Levy and Hemond 1996). In vegetated soils however, specialized porous plant tissues known as aerenchyma provide an alternative medium which allows for faster diffusion of gases such as methane and oxygen (Brix et al. 1992). The diffusion of oxygen into rhizosphere soils immediately adjacent to plant roots alters the soil's redox state (Colmer 2003) and allows different microbes to compete in otherwise anoxic conditions (Laanbroek 2010). By providing oxygen to adjacent soils, wetland plants can support microbes, such as nitrifying and methane-consuming, or methanotrophic, bacteria (Bodelier and Frenzel 1999; Ibekwe et al. 2003), in soils where they typically could not survive. Plant species differ in gas flow rates through aerenchyma (Brix et al. 1992, Konnerup et al. 2010); higher oxygen flow and subsequent oxygen availability will likely alter plant-associated wetland microbial communities since they are partitioned according to redox status.

The combination of substrate provision and soil oxidation influences wetland microbial communities and subsequently methane emissions (Bridgham et al. 2013; Laanbroek 2010). Plants in upland systems contain different microbes in their tissues and adjacent soil (Winston et al. 2014; Zarraonaindia et al. 2015), and different plants associate with different microbial communities (Kourtev et al. 2002; Westover et al. 1997). Closely related plant species may have more similar biochemistry (Giannasi 1978) and gas flow rates through aerenchyma in certain instances (Brix et al. 1992), so more closely related plant species may have more similar microbial communities and potentially methane emissions.

Do more closely related plants share more similar microbial communities overall and, more specifically, quantities of methanogens and methanotrophs? I anticipated that, owing to probable similarities in biochemistry and gas flow rates between related plants, microbial communities will differ according to plant species, with more similar microbial communities associating together with more closely related plants. I further hypothesized that both methanogen and methanotroph population sizes of each plant species will be more similar according to the relatedness of plant species.

1. Corresponding author: marisaszubryt@gmail.com. Note that the report has been reformatted along with minor edits for publication in this journal; Final Grant Report for 2017 SWS Student Research Grant; advised by Dr. Pamela Weisenhorn, Argonne National Laboratory, Lemont, IL.

MATERIALS AND METHODS

Five large, rhizomatous, monoculture-forming wetland plants in the order Poales were selected for study. Two hydrologically connected wetland sites housed these five species. Two grasses, (*Phalaris arundinacea* and *Phragmites australis*), one sedge, (*Bolboschoenus fluviatilis*), one cattail (*Typha x glauca*), and one bur-reed (*Sparganium eurycarpym*) were selected: the grasses belong to the family Poaceae and are related to *Bolboschoenus* in the sedge family Cyperaceae while the cattail and bur-reed reside within a more distantly related family, Typhaceae. *Bolboschoenus*, *Phragmites*, and *Typha* dominated various regions of wetland one (Figure 1); *Phalaris* and *Sparganium* occupied wetland two (Figure 2).

Unvegetated soils were selected from each wetland site, over one meter away from any discernable plant shoots. Three soil samples between within fifty centimeters from a plant shoot were taken for each plant species, and three rhizosphere soil samples were gathered by placing soil attached directly to roots in polypropylene tubes. Three root and leaf tissues per plant species were thoroughly rinsed under tap water to remove soil before chopping into small pieces and inserting in tubes for surface sterilization. A series of three solutions (70% ethanol, 10% bleach, and 90% ethanol) were used to surface sterilize tissues so that only endophyte DNA remained.

The soils and surface sterilized tissue samples were extracted using a Qiagen PowerSoil DNA Kit according to the protocol included. Polymerase chain reactions (PCR) of the prokaryotic ribosomal 16S region using the 515F/806R primers and PNA clamps, to avoid amplification of eukaryotic mitochondria and plastid DNA in root and leaf samples, produced viable amplified DNA for sequencing (Caporaso et al. 2011; Caporaso et al. 2012; Lundberg et al. 2013). Sequencing was performed on the Illumina Mi-Seq platform.

To quantify the abundance of methanotrophs and methanogens in these samples, we ran qPCR on triplicate subsamples for their respective genes: *pmoA* (Bourne and McDonald 2001) and *mcrA* (Steinberg and Regen 2009). Averages and standard deviations amongst sample types and plant species were calculated, and statistical tests evaluated the data for significance.

Differences in microbial community composition were evaluated by Anosim and permanova analyses and visualized using non-metric multidimensional scaling (NMDS) plots using the vegan package in R (Team 2013). A maximum parsimony phylogeny of the host plants was developed using internal transcribed spacer sequences from GenBank, and branch lengths between each taxon were recorded. Mantel tests were used to compare differences in microbial community composition with plant phylogenetic distance.

FIGURE 1. Wetland One in late July, after samples were collected. *Bolboschoenus fluviatilis* in the foreground, *Phragmites australis* further back, and *Typha x glauca* in the distance. *Lemna* were present at this site, which appears to have once contained trees which rotted and died many years before. A prairie of *Agrimonia, Asclepias, Euthamia* (*E. graminifolia, E. gymnospermoides*), and *Solidago* grew to the northeast while *Phalaris arundinacea* occupied the southwestern and drier border.

FIGURE 2. Dr. Pamela Weisenhorn (advisor) measuring water pH, voltage, and temperature in a *Sparganium eurycarpum* stand at Wetland Two.

FIGURE 3. NMDS ordination plots of all microbial samples. All samples colored to denote sample type and plant species respectively. Adonis tests indicated that type accounted for 52% of the variation, species for 18%, and site for 7% (all significant, p=0.001).

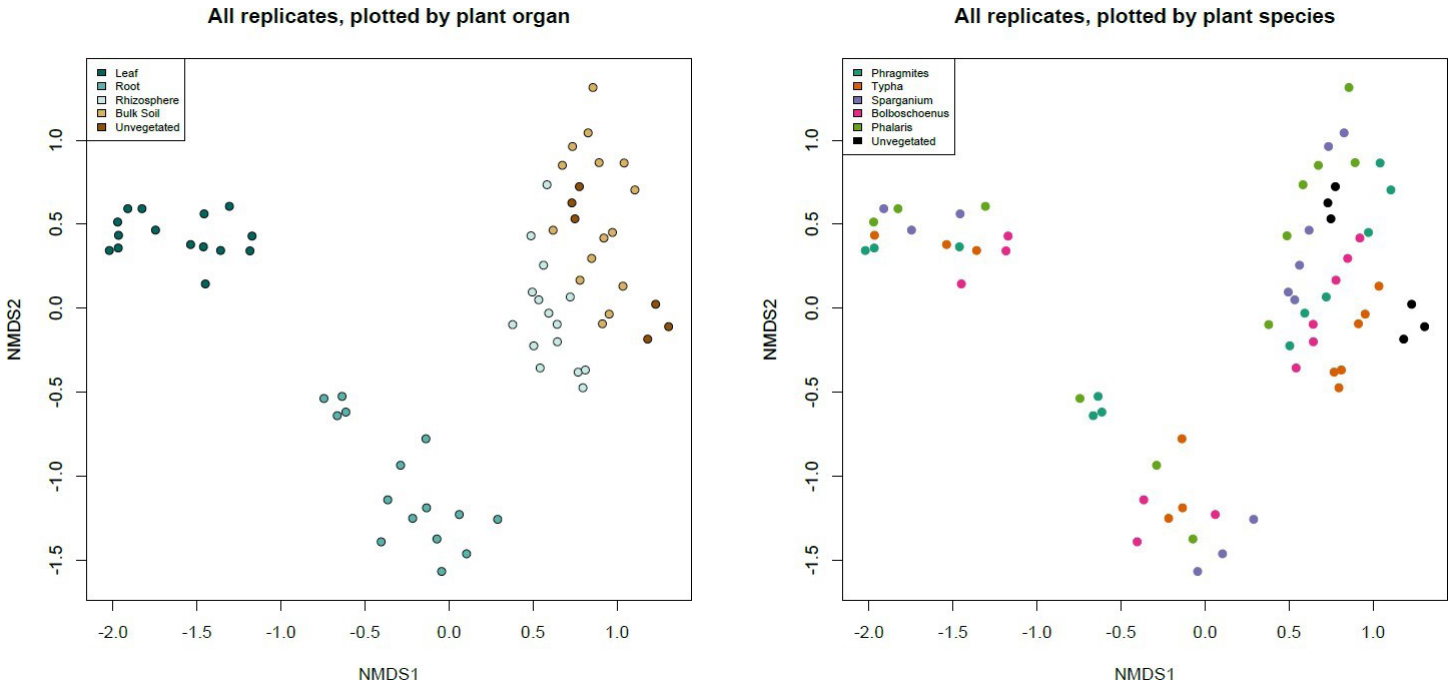


FIGURE 4. NMDS ordination plots of bulk soil samples, colored to denote wetland site and plant species respectively. Site and species accounted for 37% and 76% of the variation observed, respectively (both significant, p=0.001)

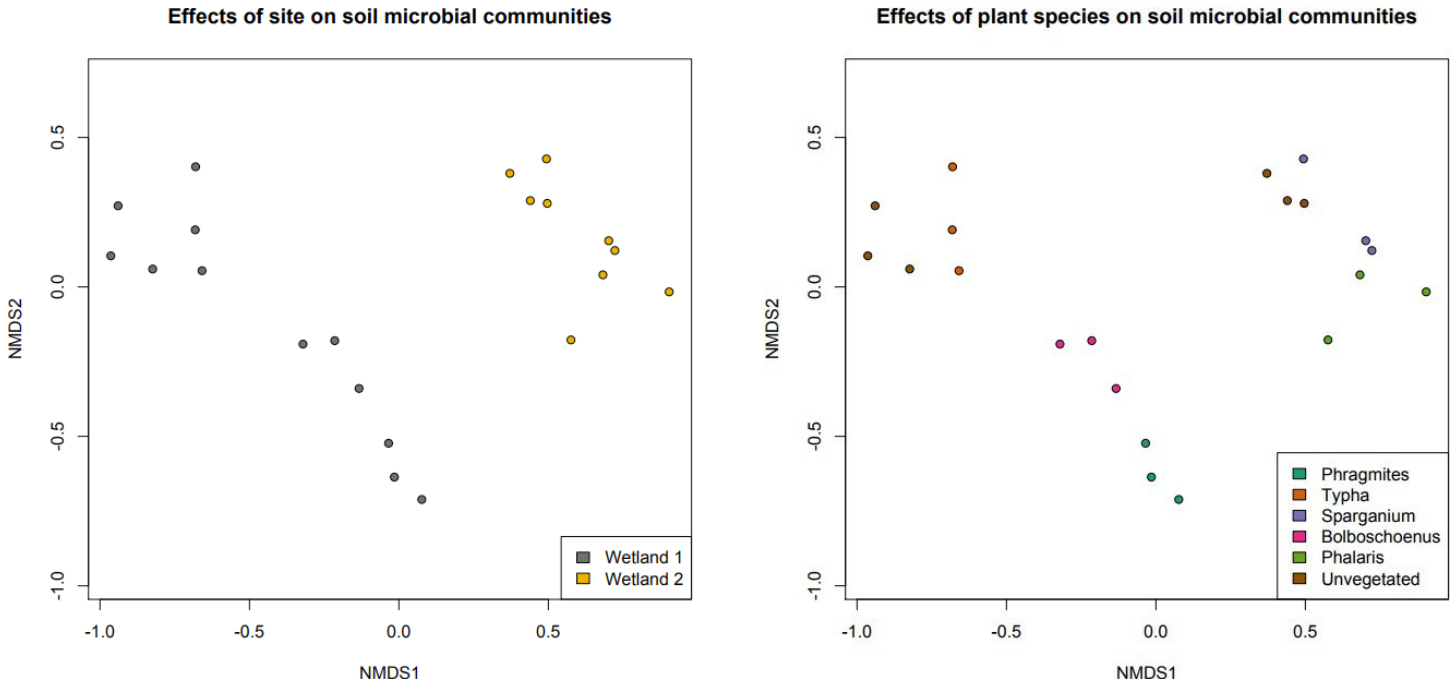


TABLE 1. Anosim and permanova tests evaluated if significant differences between sample types existed. Mantel tests take evolutionary distance between plant hosts (Figure 5) into account.

	Anosim p	Anosim R	Permanova p	Permanova r^2	Mantel p	Mantel r^2
Bulk	0.001	0.8919	0.001	0.722	0.001	0.4034
Rhizosphere	0.001	0.8222	0.001	0.624	0.002	0.4034
Root	0.002	0.6459	0.001	0.542	0.001	0.5345
Leaf	0.001	0.4296	0.001	0.518	0.007	0.2022

RESULTS

Taxa were assigned based on similarity to sequences provided in the microbial database

GreenGenes. Entire communities from each sample were compared to evaluate wholistic differences and determine which factors primarily influenced community compositions. Sample type (soils or plant tissues) influenced community differences more than plant species or wetland site (Figure 3); plant species explained most of the variation observed within each sample type, particularly soils (Figure 4). Each sample type differed significantly from one another according to Anosim and permanova tests, and phylogenetic distance of plant hosts correlated with phylogenetic distance of the plant hosts according to Mantel tests (Table 1; Figure 5). Rhizosphere samples were the most diverse, followed by bulk soil samples; endophytic communities were less diverse, with leaves displaying the lowest diversity of any sample type. The ten most abundant microbial orders are displayed in Figure 6 to help visualize across sample differences.

Amplification of the *pmoA* gene via qPCR and subsequent statistical analyses calculated that methanotroph population sizes did not differ substantially between plant species when considering all sample types together. Plant species and sample type had an interactive effect ($p=0.0016$, $F=4.3$) on population sizes, estimated by the *pmoA* gene. Methanotrophs were the most abundant in root samples and least abundant in leaf tissues across each plant species tested (Figure 7). *Typha* and *Sparganium* respectively contained fifteen and nine times more methanotrophs in their roots than unvegetated soils while *Bolboschoenus, Phalaris,* and *Phragmites* contained three times more than unvegetated soils.

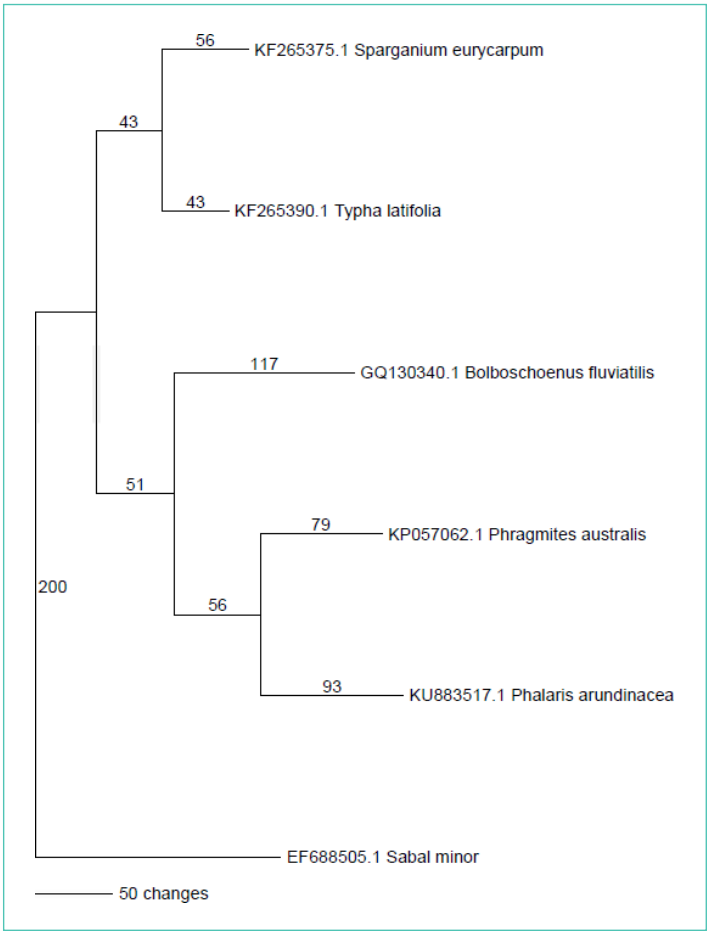
Unlike methanotroph population sizes, methanogen populations were almost always smaller than the average unvegetated soil populations from both localities based on amplification of the *mcrA.* Plant species and plant part had a significant interactive effect on methanogen population sizes ($p=0.02$, $F=2.3$). Methanogens were the most abundant in rhizosphere samples and least abundant in root and leaf tissues across each plant species tested (Figure 7). *Typha* bulk soil, *Bolboschoenus* rhizosphere soil, and *Sparganium* rhizospheres soil were the only samples to contain more methanogens than unvegetated soils.

DISCUSSION

Sample type was the single largest influence on microbial communities as noted in the NMDS ordination plots, Anosim, and permanova tests. Plants species influenced bulk soil communities, although the influence of plants upon their microbial communities at the order level overall decreased from bulk to rhizosphere to root to leaf samples. Microbial alpha diversity was higher in soils than plant tissues, with rhizosphere soils and leaf tissues representing the most and least diverse habitats respectively.

Organic matter accumulates in anoxic, wetland bulk soils and may become thermodynamically difficult to degrade (Tanner and Sukias 1995), requiring particular syntrophic microbes to decompose (McInnery et al. 2009). While specific, cooperative microbial interactions exist which extract energy from organic matter, the anoxic conditions within bulk soil limit total microbial diversity. The wide array of organic matter at various states of decomposition within bulk soils allow many anaerobic microbes to survive, but bulk soils are likely less diverse than rhizosphere soils since the latter contain greater redox heterogeneity. Microbes in rhizosphere soils are additionally exposed to root exudates rather than organic matter derived from senesced shoots in bulk soil. The presence of low molecular-weight, labile chemicals deposited to the substrate likely provide more easily metabolized com-

FIGURE 5. Evolutionary relationships between the five plants sampled, all within the order Poales with Sabal minor (Arecales) as an outgroup. Most parsimonious tree found from 10,000 trees of the internal transcribed spacer (ITS) region from GenBank.



pounds for generalist microbes to utilize, likely increasing microbial community diversity.

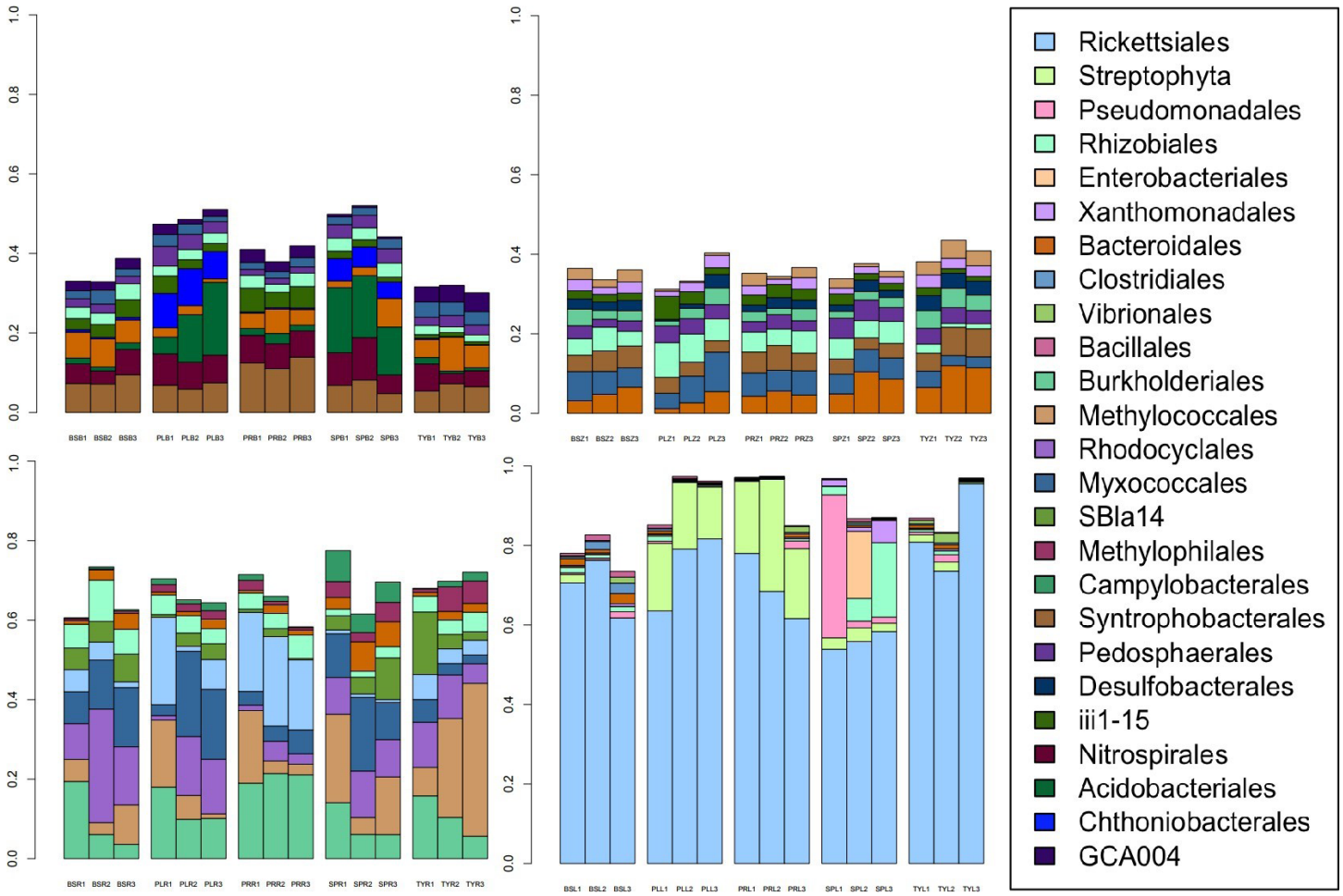
Endophytes have immediate access to additional substrates, but they must also avoid destruction by their host's immune system. Subsequently, less diversity would be expected, and were found in these data, within plant tissues. Endophytes also likely differ from soil-associated microbes since root and leaf tissues contain high oxygen concentrations even though root endophytes are surrounded by anoxic soils in wetlands. The large disparity in redox states between rhizosphere soils and root tissues indicates that the microbes may not be able to survive in both environments. Leaf tissues present additional light, heat, redox, and water stresses in addition to host defenses. Fewer microbes, including members of the orders Rickettsiales, would be able to tolerate these environments, hence showing decreased diversity but increased abundance. Furthermore, particular microbes appeared to specialize in certain plant parts and species. A cyanobacterial order was prominently found within grass (*Phalaris* and *Phragmites*) roots and particularly leaves, the latter cases being the only instances of a non-Rickettsiales order being consistently above 15% abundance in leaf tissues and may represent a shared evolutionary symbiosis within Poaceae.

Methanogen population sizes, as measured by the *mcrA* gene, were largest across most species in redox-heterogeneous rhizosphere soils or, in the case of *Typha*, bulk soils. Methanogen population sizes were the smallest in plant tissues. This indicates that anaerobic pockets in rhizosphere soils exist for methanogens to survive. (Hackstein 2010). Conversely, the oxidized state of plant tissues likely prevents methanogens from surviving, explaining why they were almost exclusively confined to soils.

Higher abundances in rhizospheres may indicate that methanogens grow most successfully in proximity to root exudates. Additionally, these microbes' metabolic product, methane, is quickly removed from their immediate environments, making methanogenesis more energetically favorable.

Methanotroph population sizes, as measured by the *pmoA* gene, were largest across all species in roots where oxygen is readily available and smallest in bulk soils and leaf tissues. Each plant species contained more methano-

FIGURE 6. The top ten most abundant microbial orders found amongst samples.



trophs in their roots than in any soils samples, indicating that the plants allow these microbes to grow as endophytes. The endophytes, in return, likely turn methane into carbon dioxide, which the plants can then use for photosynthesis. This would explain the exceptionally high carbon dioxide concentrations found within *Typha* leaves at night, (Constable et al. 1992) and may improve *Typha*'s photosynthetic efficiency and its subsequent ability to compete with other plants. The variation amongst methanotrophs within roots were far higher than initially expected, especially given the static nature of methanogen populations in the data presented. Methanotroph population sizes were particularly large for both members of Typhaceae (*Sparganium* and *Typha*).

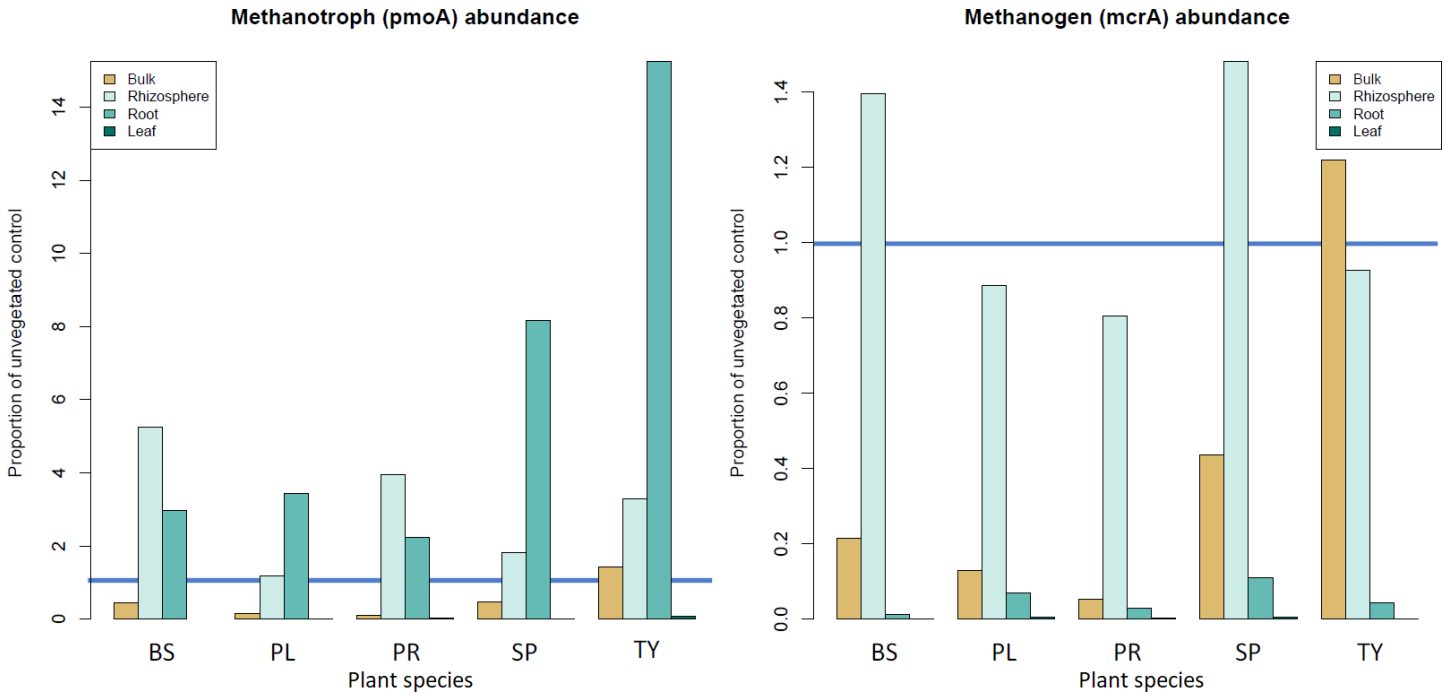
CONCLUSION

The data here corroborate past findings that sample type (leaf tissue, root tissue, rhizosphere soil, bulk soil) had the largest effect on microbial communities according to Anosim and permanova tests. Plant species had the second strongest influence on microbial communities overall. Mantel tests determined that differences between microbial communities correlated with differences in evolutionary history. Methanogen population sizes were the largest in rhizosphere samples while methanotrophs were most abundant in root samples overall. The high number of methanotrophs in Typhaceae, especially *Typha*, roots may partially explain the high carbon dioxide concentrations found in *Typha* leaves overnight from previous research (Constable et al. 1992). This would additionally indicate that *Sparganium* and *Typha* species likely emit less methane than other dominant wetland plants, such as *Bolboschoenus* or *Phragmites.*

FUTURE DIRECTIONS

The current sampling provides a limited perspective on the co-evolution between wetland plants and their microbial symbionts; an expanded sampling may help determine the influence specific soils and plant hosts have upon microbial communities. While *Typha*, and *Sparganium* to a lesser degree, in this study harbored vast numbers of methanotrophs within their root tissues, the extent of this trend in other Typhaceae species and wetland habitats remains unknown. Given the prevalent, nearly cosmopolitan nature of each species investigated, their influence upon microbial communities and subsequently global methane emissions may be substantial. *Typha* species are potentially more effective at reducing greenhouse emissions than their competitors, although additional work in additional habitats and with other species will be necessary to confirm this notion. If such is true, *Typha x glauca* and other cattail species may be a preferable wetland macrophyte rather than *Phragmites australis* or other competitors. These data are currently being synthesized into a publication for the journal *Phytobiomes*. ■

FIGURE 7. Results from qPCR of methanotroph pmoA gene (left) and methanogen mcrA gene (right). Blue bar indicates the average amount of methanotrophs or methanogens found in the unvegetated soils.



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What the World Needs Now to Fight Climate Change: More Swamps

William Moomaw, Professor Emeritus of International Environmental Policy, Tufts University; Gillian Davies, Visiting Scholar, Global Development and Environment Institute, Tufts University; Max Finlayson, Director, Institute for Land, Water and Society, Charles Sturt University

This article first appeared in *The Conversation (*https://theconversation.com/what-the-world-needs-now-to-fight-climate-change-more-swamps-99198*)*.

Drain the swamp has long meant getting rid of something distasteful. Actually, the world needs more swamps (https://www.epa.gov/wetlands/classification-and-types-wetlands#swamps)– and bogs (https://www.epa.gov/wetlands/classification-and-types-wetlands#bogs), fens (https://www.epa.gov/wetlands/classification-and-types-wetlands#fens), marshes (https://www.epa.gov/wetlands/classification-and-types-wetlands#marshes) and other types of wetlands (https://link.springer.com/referenceworkentry/10.1007%2F978-94-007-4001-3_186).

These are some of the most diverse and productive ecosystems on Earth. They also are underrated but irreplaceable tools for slowing the pace of climate change and protecting our communities from storms and flooding.

Scientists widely recognize (https://www.millenniumassessment.org/en/index.html) that wetlands are extremely efficient at pulling carbon dioxide out of the atmosphere and converting it into living plants and carbon-rich soil. As part of a transdisciplinary team of nine wetland and climate scientists, we published a paper earlier this year that documents the multiple climate benefits provided by all types of wetlands, and their need for protection (https://link.springer.com/article/10.1007/s13157-018-1023-8).

Saltwater wetland, Waquoit Bay Estuarine Research Reserve, Mass.
Ariana Sutton-Grier, CC BY-ND

A VANISHING RESOURCE

For centuries human societies have viewed wetlands as wastelands to be "reclaimed" for higher uses. China began large-scale alteration of rivers and wetlands (https://www.chinahighlights.com/travelguide/culture/grand-canal.htm) in 486 B.C. when it started constructing the Grand Canal, still the longest canal in the world. The Dutch drained wetlands (https://www.jstor.org/stable/pdf/4313944.pdf?seq=1#page_scan_tab_contents) on a large scale beginning about 1,000 years ago, but more recently have restored many of them. As a surveyor and land developer, George Washington led failed efforts to drain the Great Dismal Swamp (https://www.mountvernon.org/library/digitalhistory/digital-encyclopedia/article/dismal-swamp-company/) on the border between Virginia and North Carolina.

Today many modern cities around the world are built on filled wetlands. Large-scale drainage continues, particularly in parts of Asia (https://www.weforum.org/agenda/2017/01/southeast-asias-ecosystem-is-under-threat-the-problem-is-worse-than-you-think). Based on available data, total cumulative loss of natural wetlands (http://www.publish.csiro.au/mf/MF14173) is estimated to be 54 to 57 percent – an astounding transformation of our natural endowment.

Vast stores of carbon have accumulated in wetlands, in some cases over thousands of years. This has reduced atmospheric levels of carbon dioxide and methane – two key greenhouse gases that are changing Earth's climate. If ecosystems, particularly forests and wetlands, did not remove atmospheric carbon, concentrations of carbon dioxide from human activities would increase by 28 percent more each year (https://www.earth-syst-sci-data.net/10/405/2018/).

FROM CARBON SINKS TO CARBON SOURCES

Wetlands continuously remove and store atmospheric carbon. Plants take it out of the atmosphere and convert it into plant tissue, and ultimately into soil when they die and decompose. At the same time, microbes in wetland soils release greenhouse gases into the atmosphere as they consume organic matter.

Natural wetlands typically absorb more carbon than they release. But as the climate warms wetland soils, microbial metabolism increases, releasing additional greenhouse gases. In addition, draining or disturbing wetlands can release soil carbon very rapidly.

For these reasons, it is essential to protect natural, undisturbed wetlands. Wetland soil carbon, accumulated over millennia and now being released to the atmosphere at an accelerating pace, cannot be regained within the next few decades, which are a critical window for addressing climate change. In some types of wetlands, it can take decades to millennia (https://link.springer.com/article/10.1007%2Fs10980-014-0067-2) to develop soil conditions that support net carbon accumulation. Other types, such as new saltwater wetlands, can rapidly start accumulating carbon.

Wetland soil core taken from Todd Gulch Fen at 10,000 feet in the Colorado Rockies. The dark, carbon-rich core is about 3 feet long. Living plants at its top provide thermal insulation, keeping the soil cold enough that decomposition by microbes is very slow. William Moomaw, Tufts University, CC BY-ND

Kuujjuarapik is a region underlain by permafrost in Northern Canada. Nigel Roulet, McGill University., CC BY-ND

Arctic permafrost, which is wetland soil that remains frozen for two consecutive years, stores nearly twice as much carbon as the current amount in the atmosphere. Because it is frozen, microbes cannot consume it. But today, permafrost is thawing rapidly, and Arctic regions that removed large amounts of carbon from the atmosphere as recently as 40 years ago are now releasing significant quantities of greenhouse gases (http://www.pnas.org/content/114/21/5361). If current trends continue, thawing permafrost will release as much carbon by 2100 as all U.S. sources, including power plants, industry and transportation (https://whrc.org/project/arctic-permafrost/).

CLIMATE SERVICES FROM WETLANDS

In addition to capturing greenhouse gases, wetlands make ecosystems and human communities more resilient in the face of climate change. For example, they store flood waters from increasingly intense rainstorms. Freshwater wetlands provide water during droughts and help cool surrounding areas when temperatures are elevated.

Salt marshes (https://theconversation.com/as-communities-rebuild-after-hurricanes-study-shows-wetlands-can-significantly-reduce-property-damage-83935) and mangrove forests (https://theconversation.com/mangroves-protect-coastlines-store-carbon-and-are-expanding-with-climate-change-81445) protect coasts from hurricanes and storms. Coastal wetlands can even grow in height (https://www.researchgate.net/publication/225304301_A_blueprint_for_blue_carbon_Toward_an_improved_understanding_of_the_role_of_vegetated_coastal_habitats_in_sequestering_CO2) as sea level rises, protecting communities further inland.

But wetlands have received little attention from climate scientists and policymakers. Moreover, climate considerations are often not integrated into wetland management. This is a critical omission, as we pointed out in a recent paper (https://link.springer.com/article/10.1007%2Fs13157-018-1064-z) with 6 colleagues that places wetlands within the context of the Scientists' Second Warning to Humanity (http://scientistswarning.forestry.oregonstate.edu/), a statement endorsed by an unprecedented 20,000 scientists.

The most important international treaty for the protection of wetlands is the Ramsar Convention (https://www.ramsar.org/), which does not include provisions to conserve wetlands as a climate change strategy (http://www.publish.csiro.au/mf/MF16244). While some national and

subnational governments effectively protect wetlands, few do this within the context of climate change.

Forests rate their own section (Article 5) in the Paris climate agreement (https://unfccc.int/process/conferences/pastconferences/paris-climate-change-conference-november-2015/paris-agreement) that calls for protecting and restoring tropical forests in developing countries. A United Nations process called Reducing Emissions from Deforestation and Degraded Forests, or REDD+ (http://www.un-redd.org/) promises funding for developing countries to protect existing forests, avoid deforestation and restore degraded forests (https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1526-100X.2011.00822.x). While this covers forested wetlands and mangroves, it was not until 2016 that a voluntary provision (https://www.ipcc-nggip.iges.or.jp/public/wetlands/) for reporting emissions from wetlands was introduced into the U.N. climate accounting system, and only a small number of governments have taken advantage of it.

MODELS FOR WETLAND PROTECTION

Although global climate agreements have been slow to protect wetland carbon, promising steps are starting to occur at lower levels.

Ontario, Canada has passed legislation (https://www.ontario.ca/laws/statute/10f18) that is among the most protective of undeveloped lands by any government. Some of the province's most northern peatlands, which contain minerals and potential hydroelectric resources, are underlain by permafrost that could release greenhouse gases if disturbed. The Ontario Far North Act specifically states that more than 50 percent of the land north of 51 degrees latitude is to be protected from development, and the remainder can only be developed if the cultural, ecological (diversity and carbon sequestration) and social values are not degraded.

Also in Canada, a recent study reports large increases in carbon storage from a project that restored tidal flooding to a saltmarsh near Aulac, New Brunswick, on Canada's Bay of Fundy. The marsh had been drained by a dike for 300 years, causing loss of soil and carbon. But just six years after the dike was breached, rates of carbon accumulation in the restored marsh averaged more than five times (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0193930) the rate reported for a nearby mature marsh.

In our view, instead of draining swamps and weakening protections (https://theconversation.com/does-scott-pruitt-have-a-solid-case-for-repealing-the-clean-water-rule-80240), governments at all levels should take action immediately to conserve and restore wetlands as a climate strategy. Protecting the climate and avoiding climate-associated damage from storms, flooding and drought (https://www.nature.com/articles/s41598-017-09269-z) is a much higher use for wetlands than altering them for short-term economic gains. ■

Saltwater mangrove forest along the coast of the Biosphere Reserve in Sian Ka'an, Mexico. Ariana Sutton-Grier, CC BY-ND

Ten feet (3 meters) of carbon-rich soil accumulation along Dipper Harbour, Bay of Fundy, New Brunswick, Canada, has been radiocarbon dated to have accumulated over 3,000 years. Gail Chmura, McGill University, CC BY-ND

Big Thicket Nematode (Worm) Research Discovers Species Possibly New to Science

Submitted by Mary Catherine Johnston (mathicket@aol.com), Thicket of Diversity Chair, Big Thicket Association, Beaumont, TX (www.thicketofdiversity.org)

From 2012-2016 Dr. Thomas Powers of University of Nebraska-Lincoln and his team made six collection trips to the Big Thicket wetlands of Southeast Texas to inventory soil-dwelling nematodes. The project was conducted in two phases and received generous support, time and constructive advice from the Big Thicket Association's Thicket of Diversity and the National Park Service staff at the Big Thicket National Preserve. This research encompassed completely new territory for the Powers Nematology Laboratory and yielded remarkably high levels of soil diversity and new species discoveries. As of 2018, 1026 nematodes have been identified of which a smaller group of 614 nematodes have digital images, morphometric measurements and DNA template vouchers. Of note is that nine species are considered as candidates for new species to science! Dr. Power's research is described in further detail in various publications including *Nematology* and the *Journal of Nematology*. The project was performed with penalty monies from a Texas Commission on Environmental Quality enforcement action. ■

Extracting soil samples for inventorying nematodes in the Big Thicket.

WETLANDS IN THE NEWS

Listed below are some links to some random news articles that may be of interest. Members are encouraged to send links to articles about wetlands in their local area. Please send the links to WSP Editor at ralphtiner83@gmail.com and reference "Wetlands in the News" in the subject box. Thanks for your cooperation. ■

Wetland damage from roseau cane plague visible in satellite images
https://articles.nola.com/environment/index.ssf/2018/09/wetland_plague_damage_in_missi.amp

Wetlands disappearing 3 times faster than forests threatening fresh water supplies: Report
https://timesofindia.indiatimes.com/india/wetlands-disappearing-3-times-faster-than-forests-threatening-fresh-water-supplies-report/articleshow/65974012.cms

Why we must save the Endangered Species Act
https://e360.yale.edu/features/why-we-must-save-the-endangered-species-act-from-the-trump-administration-babbitt

Beavers are redefining the landscape at Smith and Bybee Lake Wetlands Natural Area
https://katu.com/news/local/beavers-are-redefining-the-landscape-at-smith-and-bybee-lake-wetlands-natural-area

What the world needs now to fight climate change: More swamps
http://theconversation.com/what-the-world-needs-now-to-fight-climate-change-more-swamps-99198

Proposal for wetland buffers doesn't hold water in Lewes
https://www.capegazette.com/article/proposal-wetland-buffers-doesn%E2%80%99t-hold-water-lewes/165372

Future of tidal wetlands depends on coastal management
https://www.nature.com/articles/d41586-018-06190-x

Moving a floating wetland from a beach in Minnesota
https://www.atlasobscura.com/articles/what-happened-to-the-minnesota-bog

Stop using "Swamp" as a negative term (e.g., "drain the swamp")
https://www.nytimes.com/2018/05/05/opinion/sunday/stop-calling-washington-a-swamp-its-offensive-to-swamps.html

Upcoming ASWM webinar on compensatory mitigation registration
https://attendee.gotowebinar.com/register/7485952740901587715

Restoring wetlands for desert pupfish
https://www.ecowatch.com/desert-fish-endangered-2569323966.html

North Carolina wetland regulations
https://portcitydaily.com/local-news/2018/05/11/3-days-vs-3-months-regulatory-structure-makes-it-tougher-protect-wetlands/

Massachusetts wetland enforcement
https://www.ecori.org/government/2018/5/3/appeals-court-upholds-decision-to-restore-damaged-wetlands

Wetlands for downtown Durham, NC
http://www.heraldsun.com/news/local/counties/durham-county/article209713499.html

Wetland conservation in Texas
http://kfdm.com/news/local/additional-wetlands-protection-provides-defense-against-flooding

Wetland banking in Minnesota
http://www.startribune.com/bank-gives-landowners-committed-to-restoring-minnesota-wetlands-a-financial-incentive/480463381/

Columbian wetlands
http://www.columbian.com/news/2018/apr/18/shoring-up-a-key-wetland-in-camas/

Wetland restoration in Milwaukee
https://www.jsonline.com/story/news/local/milwaukee/2018/04/17/restoration-one-last-wetlands-milwaukees-harbor-estuary-provide-more-public-recreation-ato-restored/522547002/

Kansas wetland park
http://www.kansas.com/news/politics-government/article208500834.html

Walden Pond revisited
https://www.smithsonianmag.com/smart-news/new-study-details-man-made-damage-done-walden-pond-180968700/

Wisconsin Frac mining permit
https://www.wpr.org/dnr-staff-felt-pressure-approve-wetland-fill-frac-sand-mining-project

Minnesota wetland conservation
http://www.startribune.com/federal-project-leader-scott-glup-sees-work-as-the-front-lines-of-protection-for-wetlands-and-waterfowl/479060743/

Hong Kong wetlands
https://www.hongkongfp.com/2018/04/08/trouble-paradise-suspicious-fires-land-battles-afflict-hong-kongs-nam-sang-wai-wetlands/

Spokane County wetland restoration
http://www.spokesman.com/stories/2018/apr/03/spokane-county-central-valley-district-make-saltes/#/0

Florida wetland regulation
https://www.tcpalm.com/story/news/local/indian-river-lagoon/health/2018/03/19/wetland-protection-poised-shift-corps-engineers-florida-dep/417298002/

Sea-level rise threatens local tribe in Louisiana
https://e360.yale.edu/features/on-louisiana-coast-a-native-community-sinks-slowly-into-the-sea-isle-de-jean-charles

Turtles in crisis
http://therevelator.org/turtle-extinction-crisis/

Pantanal wetlands
https://www.worldwildlife.org/stories/5-interesting-facts-about-the-pantanal-the-world-s-largest-tropical-wetland

http://www.worldwaterforum8.org/en/news/brazil-bolivia-and-paraguay-signed-declaration-conservation-pantanal

Penguins seen from space
https://gizmodo.com/poo-stains-seen-from-space-lead-to-discovery-of-massive-1823457294

Wisconsin wetland regulations
http://www.gazettextra.com/news/government/county-officials-say-isolated-wetlands-bill-could-have-adverse-effects/article_7f98b9ef-48eb-55cc-b4b6-f851f1213d3d.html

http://host.madison.com/wsj/news/local/govt-and-politics/politicized-wisconsin-dnr-erasing-rare-wetlands-retirees-say/article_881666fc-f9c0-5cf7-ac2a-272e9c1d4094.html

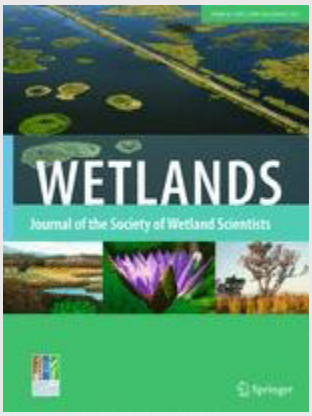
Ballona wetlands historic images
http://www.businessinsider.com/history-of-los-angeles-ballona-creek-wetlands-watershed-2018-2

Mining impacts proposed for Minnesota
https://search.app.goo.gl/EUQb6

What's New in the SWS Journal - *Wetlands*?

The following articles appear in Volume 38, Issue 4 of *Wetlands*:

- Using Macroinvertebrates and Birds to Assess the Environmental Status of Wetlands across Different Climatic Zones in Southwestern Ethiopia
- Landscape-Scale Effects of Supra-Seasonal Drought on Semi-Aquatic Snake Assemblages
- Influence of Sieve Mesh Size on Relationships between Macroinvertebrate Assemblage and Environmental Variables in Wetlands
- Sea Level Rise Impacts to Coastal Marshes may be Ameliorated by Natural Sedimentation Events
- Responses of Wetland Ecosystems to Drought-Induced Fish Eliminations
- Effects of Different Land Types on Soil Enzyme Activity in the Qinghai Lake Region
- Emission Characteristics of Greenhouse Gases and Their Correlation with Water Quality at an Estuarine Mangrove Ecosystem – the Application of an In-situ On-site NDIR Monitoring Technique
- Seasonal Variability of the Carbon and Nitrogen Isotopic Signature in a *Zostera noltei* Meadow at the NW Iberian Peninsula
- Effects of Hydroclimatic Change and Rehabilitation Activities on Salinity and Mangroves in the Ciénaga Grande de Santa Marta, Colombia
- Short-term exposure to Oil Sand Process-Affected Water does not reduce microbial potential activity in three contrasting peatland types
- Diverse Sediment Permeability and Implications for Groundwater Exchange in Closed Lake-Wetland Catchments (West Polesie, East Poland)
- Genetic Structure and Morphometric Variation among Fragmented Michigan Wild Rice Populations
- Patterns of Vegetation Dynamics across Mild Disturbance Gradient in a Freshwater Wetland System in Southern India
- Evaluation of Vegetation-Fire Dynamics in the Okefenokee National Wildlife Refuge, Georgia, USA, with Bayesian Belief Networks
- Short-Term Study on Variations of Carbon Dioxide and Methane Emissions from Intertidal Zone of the Yellow River Estuary during Autumn and Winter
- Effects of Sediment Application on *Nyssa aquatica* and *Taxodium distichum* Saplings



DO YOU WANT TO PUBLISH YOUR ARTICLE IN THIS JOURNAL?

Please visit the homepage of *Wetlands* for full details on aims and scope, editorial policy and article submission.

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New Book on Wetland Assessment Available

Elsevier's Academic Press just published *Wetland & Stream Rapid Assessments: Development, Validation, and Application* edited by John Dorney, Rick Savage, Ralph Tiner, and Paul Adamus. The book is a primer for developing assessment techniques for wetlands and streams at both the landscape and onsite levels, complete with a summary of the history of wetland assessment. The majority of the book is dedicated to presenting numerous applications of a variety of techniques used across the U.S. and Canada as well as from places beyond North America - France, the Caribbean, New Zealand, the Himalayans, and Southern Africa.

For the latest news on wetlands and related topics, readers are referred to the Association of State Wetland Managers website. Their "Wetland Breaking News" section include links to newspaper articles that should be of interest: https://www.aswm.org/news/wetland-breaking-news. Their blog – the Complete Wetlander – may also be of interest: https://www.aswm.org/wordpress/. Additional resources are listed below. Please help us add new books and reports to this listing. If your agency, organization, or institution has published new publications on wetlands, please send the information to Editor of Wetland Science & Practice at ralphtiner83@gmail.com. Your cooperation is appreciated. ■

BOOKS

- Wetland & Stream Rapid Assessments: Development, Validation, and Application https://www.elsevier.com/books/wetland-and-stream-rapid-assessments/dorney/978-0-12-805091-0
- Eager: The Surprising Secret Life of Beavers and Why They Matter https://www.chelseagreen.com/product/eager/
- Wetland Indicators – A Guide to Wetland Formation, Identification, Delineation, Classification, and Mapping https://www.crcpress.com/Wetland-Indicators-A-Guide-to-Wetland-Identification-Delineation-Classification/Tiner/p/book/9781439853696
- Wetland Soils: Genesis, Hydrology, Landscapes, and Classification https://www.crcpress.com/Wetland-Soils-Genesis-Hydrology-Landscapes-and-Classification/Vepraskas-Richardson-Vepraskas-Craft/9781566704847
- Creating and Restoring Wetlands: From Theory to Practice http://store.elsevier.com/Creating-and-Restoring-Wetlands/Christopher-Craft/isbn-9780124072329/
- Salt Marsh Secrets. Who uncovered them and how? http://trnerr.org/SaltMarshSecrets/
- Remote Sensing of Wetlands: Applications and Advances. https://www.crcpress.com/product/isbn/9781482237351
- Wetlands (5th Edition). http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118676823.html
- Black Swan Lake – Life of a Wetland http://press.uchicago.edu/ucp/books/book/distributed/B/bo15564698.html
- Coastal Wetlands of the World: Geology, Ecology, Distribution and Applications http://www.cambridge.org/us/academic/subjects/earth-and-environmental-science/environmental-science/coastal-wetlands-world-geology-ecology-distribution-and-applications
- Florida's Wetlands https://www.amazon.com/Floridas-Wetlands-Natural-Ecosystems-Species/dp/1561646873/ref=sr_1_4?ie=UTF8&qid=1518650552&sr=8-4&keywords=wetland+books
- Mid-Atlantic Freshwater Wetlands: Science, Management, Policy, and Practice http://www.springer.com/environment/aquatic+sciences/book/978-1-4614-5595-0
- The Atchafalaya River Basin: History and Ecology of an American Wetland http://www.tamupress.com/product/Atchafalaya-River-Basin,7733.aspx
- Tidal Wetlands Primer: An Introduction to their Ecology, Natural History, Status and Conservation https://www.umass.edu/umpress/title/tidal-wetlands-primer
- Wetland Landscape Characterization: Practical Tools, Methods, and Approaches for Landscape Ecology http://www.crcpress.com/product/isbn/9781466503762
- Wetland Techniques (3 volumes) http://www.springer.com/life+sciences/ecology/book/978-94-007-6859-8
- Wildflowers and Other Plants of Iowa Wetlands https://www.uipress.uiowa.edu/books/2015-spring/wildflowers-and-other-plants-iowa-wetlands.htm
- Wetland Restoration: A Handbook for New Zealand Freshwater Systems https://www.landcareresearch.co.nz/publications/books/wetlands-handbook
- Wetland Ecosystems https://www.wiley.com/en-us/Wetland+Ecosystems-p-9780470286302
- Constructed Wetlands and Sustainable Development https://www.routledge.com/Constructed-Wetlands-and-Sustainable-Development/Austin-Yu/p/book/9781138908994

ONLINE PUBLICATIONS

U.S. ARMY CORPS OF ENGINEERS

- Regional Guidebook for the Functional Assessment of Organic Flats, Slopes, and Depressional Wetlands in the Northcentral and Northeast Region http://acwc.sdp.sirsi.net/client/en_US/search/asset/1047786
- Wetland-related publications:
  -http://acwc.sdp.sirsi.net/client/en_US/default/search/results?te=&lm=WRP
  -http://acwc.sdp.sirsi.net/client/en_US/default/search/results?te=&lm=WRP
- National Wetland Plant List publications: http://rsgisias.crrel.usace.army.mil/NWPL/
- National Technical Committee for Wetland Vegetation: http://rsgisias.crrel.usace.army.mil/nwpl_static/ntcwv.html
- U.S. Environmental Protection Agency wetland reports and searches: http://water.epa.gov/type/wetlands/wetpubs.cfm
- A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in Alluvial Valleys of the Coastal Plain of the Southeastern United States ERDC/EL TR-13-1
- Hydrogeomorphic (HGM) Approach to Assessing Wetland Functions: Guidelines for Developing Guidebooks (Version 2) ERDC/EL TR-13-11
- Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing the Functions of Flat and Seasonally Inundated Depression Wetlands on the Highland Rim ERDC/EL TR-13-12
- Wetland Plants and Plant Communities of Minnesota and Wisconsin (online publication) http://www.mvp.usace.army.mil/Missions/Regulatory/?Page=12

U.S. FISH AND WILDLIFE SERVICE, NATIONAL WETLANDS INVENTORY

- Wetland Characterization and Landscape-level Functional Assessment for Long Island, New York http://www.fws.gov/northeast/ecologicalservices/pdf/wetlands/Characterization_Report_February_2015.pdf or http://www.aswm.org/wetlandsonestop/wetland_characterization_long_island_ny_021715.pdf
- Also wetland characterization/landscape-level functional assessment reports for over 12 small watersheds in New York at: http://www.aswm.org/wetland-science/134-wetlands-one-stop/5044-nwi-reports
- Preliminary Inventory of Potential Wetland Restoration Sites for Long Island, New York http://www.aswm.org/wetlandsonestop/restoration_inventory_long_island_ny_021715.pdf
- Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors. Version 3.0. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA. https://www.fws.gov/northeast/EcologicalServices/pdf/wetlands/Dichotomous_Keys_and_Mapping_Codes_for_Wetland_Landscape_Position_Landform_Water_Flow_Path_and_Waterbody_Type_Version_3.pdf
- Connecticut Wetlands Reports:
- Changes in Connecticut Wetlands: 1990 to 2010
- Potential Wetland Restoration Sites for Connecticut: Results of a Preliminary Statewide Survey
- Wetlands and Waters of Connecticut: Status 2010
- Connecticut Wetlands: Characterization and Landscape-level Functional Assessment
- Rhode Island Wetlands: Status, Characterization, and Landscape-level Functional Assessment http://www.aswm.org/wetlandsonestop/rhode_island_wetlands_llww.pdf
- Status and Trends of Prairie Wetlands in the United States: 1997 to 2009 http://www.fws.gov/wetlands/Documents/Status-and-Trends-of-Prairie-Wetlands-in-the-United-States-1997-to-2009.pdf
- Status and Trends of Wetlands in the Coastal Watersheds of the Conterminous United States 2004 to 2009. http://www.fws.gov/wetlands/Documents/Status-and-Trends-of-Wetlands-In-the-Coastal-Watersheds-of-the-Conterminous-US-2004-to-2009.pdf
- The NWI+ Web Mapper – Expanded Data for Wetland Conservation http://www.aswm.org/wetlandsonestop/nwiplus_web_mapper_nwn_2013.pdf
- Wetlands One-Stop Mapping: Providing Easy Online Access to Geospatial Data on Wetlands and Soils and Related Information http://www.aswm.org/wetlandsonestop/wetlands_one_stop_mapping_in_wetland_science_and_practice.pdf
- Wetlands of Pennsylvania's Lake Erie Watershed: Status, Characterization, Landscape-level Functional Assessment, and Potential Wetland Restoration Sites http://www.aswm.org/wetlandsonestop/lake_erie_watershed_report_0514.pdf

U.S. FOREST SERVICE

- Historical Range of Variation Assessment for Wetland and Riparian Ecosystems, U.S. Forest Service Rocky Mountain Region. http://www.fs.fed.us/rm/pubs/rmrs_gtr286.pdf
- Inventory of Fens in a Large Landscape of West-Central Colorado http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5363703.pdf

U.S. GEOLOGICAL SURVEY, NATIONAL WETLANDS RESEARCH CENTER

- Link to publications: http://www.nwrc.usgs.gov/pblctns.htm (recent publications are noted)
- A Regional Classification of the Effectiveness of Depressional Wetlands at Mitigating Nitrogen Transport to Surface Waters in the Northern Atlantic Coastal Plain http://pubs.usgs.gov/sir/2012/5266/pdf/sir2012-5266.pdf
- Tidal Wetlands of the Yaquina and Alsea River Estuaries, Oregon: Geographic Information Systems Layer Development and Recommendations for National Wetlands Inventory Revisions http://pubs.usgs.gov/of/2012/1038/pdf/ofr2012-1038.pdf

U.S.D.A. NATURAL RESOURCES CONSERVATION SERVICE

- Link to information on hydric soils:http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/use/hydric/
- Field Indicators of Hydric Soils of the United States, Version 8.1 (online publication) https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053171.pdf

PUBLICATIONS BY OTHER ORGANIZATIONS

- The Nature Conservancy has posted several reports on wetland and riparian restoration for the Gunnison Basin, Colorado at: http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/Colorado/science/climate/gunnison/Pages/Reports.aspx (Note: Other TNC reports are also available via this website by looking under different regions.)
- Book: Ecology and Conservation of Waterfowl in the Northern Hemisphere, Proceedings of the 6th North American Duck Symposium and Workshop (Memphis, TN; January 27-31, 2013). Wildfowl Special Issue No. 4. Wildfowl & Wetlands Trust, Slimbridge, Gloucestershire, UK.
- Report on State Definitions, Jurisdiction and Mitigation Requirements in State Programs for Ephemeral, Intermittent and Perennial Streams in the United States (Association of State Wetland Managers) http://aswm.org/stream_mitigation/streams_in_the_us.pdf
- Wetlands and People (International Water Management Institute) http://www.iwmi.cgiar.org/Publications/Books/PDF/wetlands-and-people.pdf
- Waubesa Wetlands: New Look at an Old Gem (online publication) http://www.town.dunn.wi.us/land-use/historic-documents/

ARTICLES OF INTEREST FROM VARIED SOURCES

- Comparative phylogeography of the wild-rice genus Zizania (Poaceae) in eastern Asia and North America; American Journal of Botany 102:239-247. http://www.amjbot.org/content/102/2/239.abstract

LINKS TO WETLAND-RELATED JOURNALS AND NEWSLETTERS

JOURNALS

- Aquatic Botany http://www.journals.elsevier.com/aquatic-botany/
- Aquatic Conservation: Marine and Freshwater Ecosystems http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291099-0755
- Aquatic Sciences http://www.springer.com/life+sciences/ecology/journal/27
- Ecological Engineering http://www.journals.elsevier.com/ecological-engineering/
- Estuaries and Coasts http://www.springer.com/environment/journal/12237
- Estuarine, Coastal and Shelf Science http://www.journals.elsevier.com/estuarine-coastal-and-shelf-science/
- Hydrobiologia http://link.springer.com/journal/10750
- Hydrological Sciences Journal http://www.tandfonline.com/toc/thsj20/current
- Journal of Hydrology http://www.journals.elsevier.com/journal-of-hydrology/
- Wetlands http://link.springer.com/journal/13157
- Wetlands Ecology and Management https://link.springer.com/journal/11273

NEWSLETTERS

Two of the following newsletters have been terminated yet maintain archives of past issues. The only active newsletter is "Wetland Breaking News" from the Association of State Wetland Managers.

- Biological Conservation Newsletter contained some articles that addressed wetland issues; the final newsletter was the January 2017 issue; all issues now accessed through the "Archives") http://botany.si.edu/pubs/bcn/issue/latest.htm#biblio
- For news about conservation research from the Smithsonian Institution, please visit these websites:
  -Smithsonian Newsdesk http://newsdesk.si.edu/
  -Smithsonian Insider http://insider.si.edu/
  -The Plant Press http://nmnh.typepad.com/the_plant_press/
  -SCBI Conservation News http://nationalzoo.si.edu/conservation
  -STRI News http://www.stri.si.edu/english/about_stri/headline_news/news
- Wetland Breaking News (Association of State Wetland Managers) http://aswm.org/news/wetland-breaking-news
- National Wetlands Newsletter (Environmental Law Institute) – access to archived issues as the newsletter was suspended in mid-2016 due to the changing climate for printed publications. https://www.wetlandsnewsletter.org/

About *Wetland Science & Practice (WSP)*

Wetland Science and Practice (WSP) is the SWS quarterly publication aimed at providing information on select SWS activities (technical committee summaries, chapter workshop overview/abstracts, and SWS-funded student activities), brief summary articles on ongoing or recently completed wetland research, restoration, or management projects or on the general ecology and natural history of wetlands, and highlights of current events. *WSP* also includes sections listing new publications and research at various institutions, and links to major wetland research facilities, federal agencies, wetland restoration/monitoring sites and wetland mapping sites. The publication also serves as an outlet for commentaries, perspectives and opinions on important developments in wetland science, theory, management and policy.

Both invited and unsolicited manuscripts are reviewed by the *WSP* editor for suitability for publication. Student papers are welcomed. Please see publication guidelines at the end of this issue.

Electronic access to Wetland Science and Practice is included in your SWS membership. All issues published, except the the current issue, are available via the internet to the general public. At the San Juan meeting, the SWS Board of Directors voted to approve release of past issues of WSP when a new issue is available to SWS members only. This means that a WSP issue will be available to the public four months after it has been read by SWS members (e.g., the June 2017 issue will be an open access issue in September 2017). Such availability will hopefully stimulate more interest in contributing to the journal. And, we are excited about this opportunity to promote the good work done by our members.

HOW YOU CAN HELP

If you read something you like in WSP, or that you think someone else would find interesting, be sure to share. Share links to your Facebook, Twitter, Instagram and LinkedIn accounts.

Make sure that all your SWS colleagues are checking out our recent issues, and help spread the word about SWS to non-members!

Questions? Contact editor Ralph Tiner, PWS Emeritus (ralphtiner83@gmail.com). ■

WSP Manuscript – General Guidelines

LENGTH:

Approximately 5,000 words; can be longer if necessary.

STYLE:

See existing articles from 2014 to more recent years available online at:
http://www.sws.org/category/wetland-science-practice.html

TEXT:

Word document, 12 font, Times New Roman, single-spaced; keep tables and figures separate, although captions can be included in text. For reference citations in text use this format: (Smith 2016; Jones and Whithead 2014; Peterson et al. 2010).

FIGURES:

Please include color images and photos of subject wetland(s) as WSP is a full-color e-publication.
Image size should be less than 1MB – 500KB may work best for this e-publication.

REFERENCE CITATION EXAMPLES:

- Claus, S., S. Imgraben, K. Brennan, A. Carthey, B. Daly, R. Blakey, E. Turak, and N. Saintilan. 2011. Assessing the extent and condition of wetlands in NSW: Supporting report A – Conceptual framework, Monitoring, evaluation and reporting program, Technical report series, Office of Environment and Heritage, Sydney, Australia. OEH 2011/0727.
- Clements, F.E. 1916. *Plant Succession: An Analysis of the Development of Vegetation*. Carnegie Institution of Washington. Washington D.C. Publication 242.
- Clewell, A.F., C. Raymond, C.L. Coultas, W.M. Dennis, and J.P. Kelly. 2009. Spatially narrow wet prairies. *Castanea* 74: 146-159.
- Colburn, E.A. 2004. *Vernal Pools: Natural History and Conservation*. McDonald & Woodward Publishing Company, Blacksburg, VA.
- Cole, C.A. and R.P. Brooks. 2000. Patterns of wetland hydrology in the Ridge and Valley Province, Pennsylvania, USA. *Wetlands* 20: 438-447.
- Cook, E.R., R. Seager, M.A. Cane, and D.W. Stahle. 2007. North American drought: reconstructions, causes, and consequences. *Earth-Science Reviews* 81: 93-134.
- Cooper, D.J. and D.M. Merritt. 2012. Assessing the water needs of riparian and wetland vegetation in the western United States. U.S.D.A., Forest Service, Rocky Mountain Research Station, Ft. Collins, CO. Gen. Tech. Rep. RMRS-GTR-282.

WEB TIP

Resources at your fingertips!

For your convenience, SWS has compiled a hefty list of wetland science websites, books, newsletters, government agencies, research centers and more, and saved them to sws.org.

Find them on the Related Links page [sws.org](sws.org).

From the Bog

Writing an invited ecohydrology manuscript.

by Doug Wilcox

wetland science & practice

WSP is the formal voice of the Society of Wetland Scientists. It is a quarterly publication focusing on the news of the SWS and providing important announcements for members and opportunities for wetland scientists, managers, and graduate students to publish brief summaries of their works and conservation initiatives. Topics for articles may include descriptions of threatened wetlands around the globe or the establishment of wetland conservation areas, and summary findings from research or restoration projects. All manuscripts should follow guidelines for authors listed above. All papers published in WSP will be reviewed by the editor for suitability and may be subject to peer review as necessary. Most articles will be published within 3 months of receipt. 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. ■