wetland science & practice
published by the Society of Wetland Scientists
Vol. 32, No. 4 Dec 2015

FROM THE EDITOR'S DESK

Greetings to all. At this point I, like most New Englanders, am preparing for winter – splitting, stacking wood, and bringing loads indoor for heat. Since I'm retired I decided that splitting wood would be a productive form of exercise to replace, at least in part, lunchtime trips to the local gym - it is. Being newly retired, I initially spent my enormous "free time" catching up on movies I hadn't seen. I started to take care of plants I put in the ground years ago – up to now I was a Darwinian gardener – give the plant some ground and let nature take its course (i.e., survival of the fittest). Upon retirement I was scheduled to update my *Wetland Indicators* book that was published back in 1999. I was having some difficulty getting motivated to do this, but the onset of cooler weather gave me the boost I needed. I am now going full bore, working from dawn to well past dusk on most days. It feels good to be back in the groove.

Ralph Tiner
WSP Editor

In this issue of *Wetland Science & Practice*, you'll find, in addition to some SWS news, articles on the use of wetlands to remediate boron, a rapid assessment technique for amphibian habitat, and an overview of research supporting wetland and ordinary high water mark delineation plus a request for information comparing NWI maps to field delineations and summaries of student grant projects. I was also informed that Dr. Daniel Sarr passed on unexpectedly this summer. Daniel was a contributor to WSP – please read his article on the wetlands of Ireland's Burren National Park in the March 2015 issue. To notify SWS membership of the passing of a fellow wetlander, an obituary box has been created in the SWS News section. This box will contain a short bio and will link to one or more websites with more detailed information about the person. In this issue, you'll notice that "Notes from the Field" is changed to "From the Field." This will put the focus on simply displaying photos of wetlands which should take less time than recording observations. You are invited to submit photos of wetlands, plants, animals, even soils for posting to share with members. Just send me the image with a brief caption (what it is, location) and we'll post the image depending on photo quality and allowable space.

Chapter leaders are encouraged to contribute submissions about chapter activities. Readers would appreciate hearing what is going on beyond their area so please consider preparing a short summary of ongoing or planned activities for WSP. Finally, we are always in search of contributions about your projects and topics of interest, so please get a pen and paper, or turn on your computer and start the process. With WSP going public (issues available free to the world via the internet after one year), your work will be widely available. If you have questions about the suitability of an article before you write it let me know.

May your Marshes be Merry and Wet – Enjoy the Holidays! ■

CONTENTS

Vol. 32, No. 4 December 2015

Cover photo:
Distichia muscoides cushion fen
(Apolobamba, Peru; 4,400 m elevation)
Photo by David Cooper

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

Attention:
For additional remarks about last issue's State-of-the-Science report on fracking, please see page 8.

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

PRESIDENT'S MESSAGE

Can you believe that the year is already coming to an end? Field seasons are likely winding down for those in colder climes and soon we will be taking a little time off to spend with our family and friends for the holidays. Well, SWS has the perfect gift to help you bring wetlands to those that you love - yourself included! Keep reading to find out more….

Kimberli Ponzio, PWS
SWS President

COMMUNICATION & EDUCATION

With over 130 wetland images, our Wetland Promotions Sub-committee had a tough time narrowing it down to just a handful of winners in order to make our very first *International SWS Wetlands Calendar!* Please visit the SWS website to see photo submissions and to learn more about how to place your order before the holidays.

Our new SWS Webinar Series, which started in September, has been getting rave reviews. SWS members are pleased with this new e-benefit that allows them to get scientific education from afar. And the best part is that even if you miss a webinar, you can login to the SWS website and watch them "On-Demand" on the "Past Webinars" webpage. Thanks go out to Ariana Sutton-Grier, Scott Neubauer and Beth Middleton for presenting in the first quarter of the series. Make sure to join us on December 17, 10am U.S. Eastern Time for Jan Kvet's presentation on "Wetlands and Agriculture".

PARTNERSHIPS

After envisioning a collaborative partnership since the year 2000, SWS signed a 5-year agreement with the Association of State Wetland Managers (ASWM). Since SWS and ASWM share the common goals of encouraging sound science in wetland research, management, restoration, policy, and conservation, a collaboration like our new Memorandum of Cooperation just makes sense. This collaboration allows us to leverage the strengths of both organizations (and their various partners) in meeting those goals. SWS looks forward to building more partnerships like this with other national and international groups that focus on wetland science and implementing that science in practice and policy.

Long-time SWS member, Royal Gardner, was reappointed to chair of the Scientific and Technical Review Panel (STRP) of the Ramsar Convention on Wetlands for 2016-2018. Other SWS members serving on the STRP or as an Observing Organization Representative include Nick Davidson, Robert McInnes, Siobhan Fennessy, Max Finlayson, and Dulce Infante.

Since 2008, the Asia Chapter, lead by Wei-Ta Fang, has been working with a number of entities to bring SWS Presidents to Taiwan to foster collaboration among our groups and to exchange wetland information. The audiences range from academics, NGO's, governmental organizations, and practitioners. As a part of that effort, Gillian

continued on page 6

wetland science & practice

SOCIETY of WETLAND SCIENTISTS

Join us at next year's Annual Meeting

SWS2016

Corpus Christi — May 31 - June 4

Protecting wetland ecosystem services.
Promoting stronger economies.

Field Trips and Workshops Promise Exploration, Deep Learning

SWS is pleased to present an amazing array of field trip and workshop options as part of the SWS 2016 Annual Meeting in Corpus Christi, Texas. Dig deeper into your research interests by participating in one of these hands-on activities. Get full descriptions of each opportunity at www.swsannualmeeting.org. Additional registration fees are required. ■

Call for abstracts

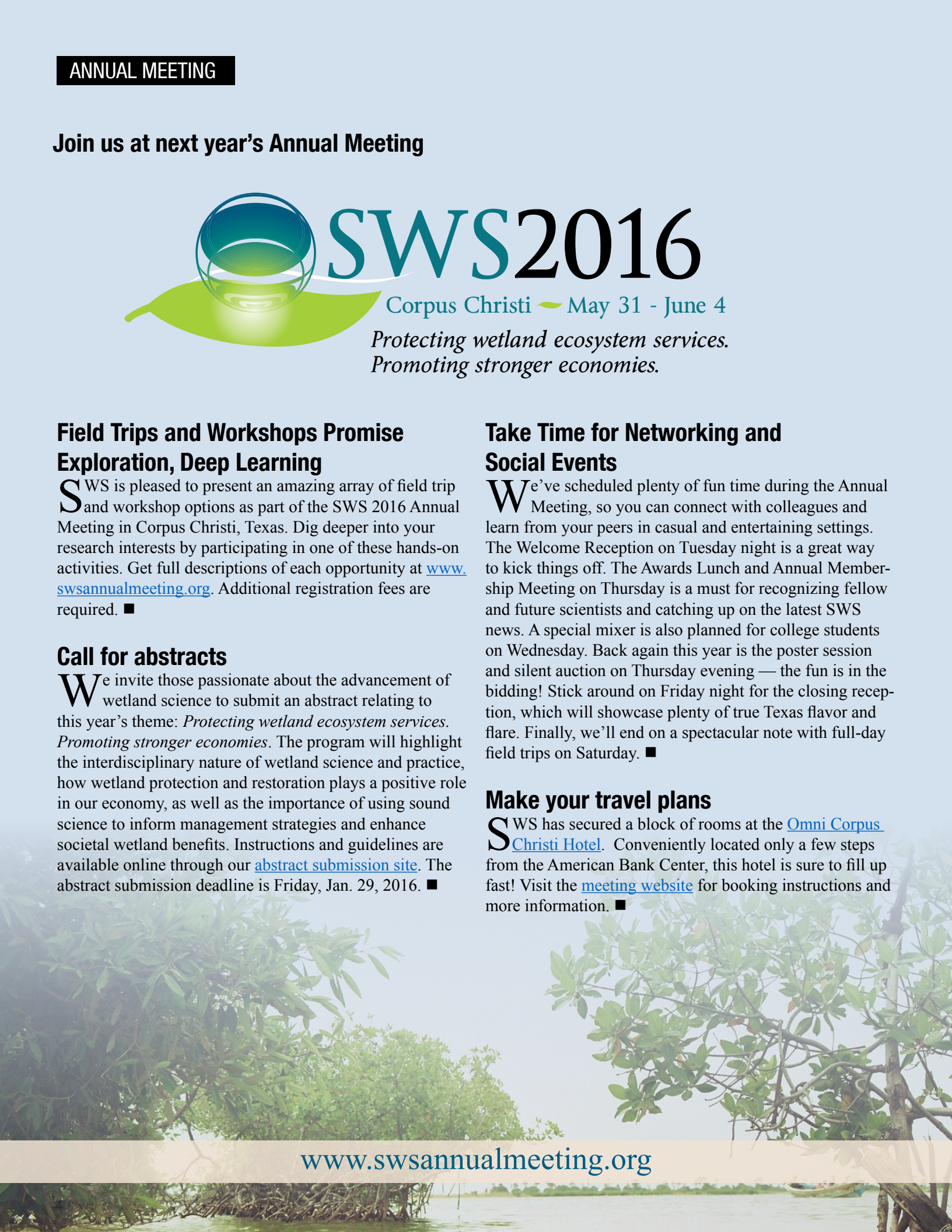
We invite those passionate about the advancement of wetland science to submit an abstract relating to this year's theme: *Protecting wetland ecosystem services. Promoting stronger economies*. The program will highlight the interdisciplinary nature of wetland science and practice, how wetland protection and restoration plays a positive role in our economy, as well as the importance of using sound science to inform management strategies and enhance societal wetland benefits. Instructions and guidelines are available online through our abstract submission site. The abstract submission deadline is Friday, Jan. 29, 2016. ■

Take Time for Networking and Social Events

We've scheduled plenty of fun time during the Annual Meeting, so you can connect with colleagues and learn from your peers in casual and entertaining settings. The Welcome Reception on Tuesday night is a great way to kick things off. The Awards Lunch and Annual Membership Meeting on Thursday is a must for recognizing fellow and future scientists and catching up on the latest SWS news. A special mixer is also planned for college students on Wednesday. Back again this year is the poster session and silent auction on Thursday evening — the fun is in the bidding! Stick around on Friday night for the closing reception, which will showcase plenty of true Texas flavor and flare. Finally, we'll end on a spectacular note with full-day field trips on Saturday. ■

Make your travel plans

SWS has secured a block of rooms at the Omni Corpus Christi Hotel. Conveniently located only a few steps from the American Bank Center, this hotel is sure to fill up fast! Visit the meeting website for booking instructions and more information. ■



www.swsannualmeeting.org

SWS2016

Corpus Christi — May 31 - June 4

Protecting wetland ecosystem services.
Promoting stronger economies.

Sponsorship Opportunities

A variety of sponsorship levels are available on a first-come, first-selected basis and are sure to provide international exposure to supporting organizations. 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 2016 Annual Meeting a success by making a general contribution. Sponsor's logo will be featured on the meeting website with a link to their corporate page, on signage at registration and in the meeting mobile app.

BRONZE LEVEL — $1,000

- **DAILY PLENARY SPEAKER.** The SWS 2016 Annual Meeting will feature three highly renowned plenary speakers who will present the latest wetland research. 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

- **STUDENT MIXER.** This special reception will provide students the opportunity to exchange ideas and network with expert wetland professionals. All attendees welcome.
- **AWARDS LUNCH & ANNUAL MEMBERSHIP MEETING.** Meeting registrants will be invited to attend this special event to honor SWS award winners and catch up on the latest SWS initiatives.
- **POSTER SESSION & SILENT AUCTION RECEPTION.** The 2016 poster session will showcase the latest wetland research and will provide an opportunity for all meeting attendees to network. The South Central Chapter will also be holding a special silent auction to help fund Chapter activities.

GOLD LEVEL — $5,000

- **REGISTRATION BAG.** Meeting branded registration bags will be distributed to all participants containing relevant meeting materials. The sponsor's logo will be featured on each registration bag.
- **LANYARDS.** Meeting themed lanyards will be distributed to each attendee at registration. The sponsor's logo will be featured on each lanyard.
- **WATER BOTTLE.** Attendees will receive a meeting themed water bottle at registration which will feature the sponsor's logo.

PLATINUM LEVEL — $7,500

- **MOBILE APP.** Attendees will be able to access the meeting program, general meeting information and session details via their smart phones and the web. The sponsor's logo will be featured on the homepage of the app.
- **WELCOME RECEPTION.** The SWS 2016 Annual Meeting will kick off with a special Welcome Reception.

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 registration 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 are quoted in US dollars.*

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

President's Message continued from page 3

Davies (SWS President-elect) and I will travel to Taiwan this December to present wetland research, develop a 2016-2021 Memorandum of Understanding with the federal agency involved in wetland issues, and potentially to start the conversation about a student exchange program.

FINANCES

The financial status of SWS is strong and we have all the resources needed to be a vibrant, relevant society that continues to be the world leader in wetland science. Knowing that, the Board of Directors just approved the SWS 2016 Budget and we are excited about the new *Chapter Grant Funding* and *Chapter Outreach* initiatives. Both are designed to help boost membership and expand programs of smaller chapters or international chapters. In fact, the first call for Chapter Grant Funding proposals will roll out in January 2016 and we are hoping to award our very first grants at the annual meeting in May 2016.

ANNUAL MEETING

We hope you are gearing up to participate in the Annual Meeting in Corpus Christi, TX on May 31 – June 4, 2016. The meeting theme of "Protecting wetland ecosystem services. Promoting stronger economies." promises to offer some interesting topics for an engaging meeting. Now is the time to get your abstract ready for submission in December.

WETLAND ISSUES

It is likely that you've heard all the excitement concerning the U.S. Clean Water Rule in the past several months. As of October 9, 2015, the Sixth Circuit U.S. Court issued an order staying the new Clean Water Rule nationwide. This means that the prior 1986 regulations are in effect for making jurisdictional determinations or taking other actions based on the definition of "waters of the United States".

SWS, along with our partners at CASS (Consortium of Aquatic Scientific Societies), sent a letter to the U.S. Senate to address the Senate Joint Resolution 22 (S.J. RES. 22) that aimed to use the Congressional Review Act to overturn the current Clean Water Rule and prevent any future rulemaking. Since the goal of CASS is to promote scientific study, education, and outreach about aquatic and wetland ecosystems, we urged the legislature to make wise decisions about aquatic and wetland resources that are based on the best scientific information available. Unfortunately, the Senate voted and passed the Resolution to overturn the current CWA ruling. The legislation will now move onto the House and ultimately to President Obama.

SWS has also been active in making the case for using sound science to guide wetland protection and restoration in Europe. Together with Europe Chapter President, Jos Verhoeven, SWS issued letters to authorities in Macedonia regarding our concern about the recent plans for the Studenchishta Wetland area on the shores of an ancient lake, Lake Ohrid. SWS wanted to make authorities aware of the current services and benefits provided by the wetland to the people of the region and the potential impacts any change to the management/protection of this area might incur. SWS members and collaborators plan to draft a "State of the Resource" report with an extensive review of the scientific literature on the ecosystem services of Studentchishta wetland by May 2016.

MEMBERSHIP

Our membership numbers continue to climb and we now have the greatest number of members since 2010 (> 3,200). Thanks to all the members who participated in our recent membership survey. We had over 400 respondents and expect to summarize the results of the survey in the coming months. We are committed to enhancing the value of your membership in YOUR Society – the Society of Wetland Scientists.

Finally, I wish you a blessed 2015 holiday season and I leave you with a quote from a great 20th century scientist: "Most people say that is it is the intellect which makes a great scientist. They are wrong; it is character."
-Albert Einstein ■

Society of Wetland Scientists Multicultural Mentoring Program (SWAMMP): Undergraduate Mentoring at the Annual Meeting

Vanessa Lougheed, Frank Day, and Chris Solek

The Society of Wetland Scientists (SWS) Multicultural Mentoring Program (SWAMMP) for Undergraduates celebrated its 12th anniversary at its last annual meeting in Providence, RI. With a recent commitment from the National Science Foundation (NSF) for an additional 5 years of funding through 2020, the program is poised to continue its great work in helping students from underrepresented groups in their career decisions and informing our membership at-large about the values and needs of promoting diversity in the sciences.

In fall 2014, we completed an online survey of previous program participants to measure the success of our efforts. Below are just a few examples that highlight the success of our program:

- Of those former participants who had graduated with a Bachelor's degree, 52% are currently pursuing graduate degrees, with an additional 39% planning to attend graduate school. The majority of these were in biology or environmental science programs.
- 70% of those former participants who were employed were employed in either research or education.

Just a few other success stories:

- A previous participant returned as a mentor at the 2012 Orlando INTECOL meeting after completing an environmental law degree and being employed by the National Parks and Conservation Association.
- In three of the twelve years of meetings to date, two participants in our program have won the best student poster award, with one honorable mention, in a predominantly graduate student-level competition.
- Two recent participants have been awarded prestigious graduate school fellowships, including an NSF Graduate Research Fellowship Program (GRFP) fellowship.

In addition, collaboration with the ESA Strategies for Ecology Education, Diversity and Sustainability (SEEDS) Program has been highly successful. We have received excellent feedback from the students as well as the SEEDS organizers from the participation of our students in their annual Leadership Meeting.

In 2016, the SWS Human Diversity Program committee members look forward to working with student participants in the SWAMMP program and assisting them with networking, relationship building, and future career decisions to guarantee their long-term success in the wetland science field. ■

Notices on the Passing of SWS Colleagues

This section will post notices on the passing of SWS colleagues. The notices will be short with a link to any tributes posted elsewhere. Since our last issue, we've lost the following members.

DANIEL SARR

Dr. Daniel Sarr, ecologist, family man, and friend, passed away unexpectedly last August 2015, while hiking to the Colorado River over rugged country in Grand Canyon National Park. Daniel, most recently a research ecologist with the USGS Grand Canyon Monitoring and Research Center in Flagstaff, Arizona, passed on route to join his USGS colleagues studying riparian vegetation along the Colorado River. Daniel was well known as the former program manager for the National Park Service's Klamath Network Inventory and Monitoring Program. Daniel was a friend to many wetland and aquatic scientists across the American West, and his absence will be felt by many within SWS and beyond. Read the full notice at the SWS-PNW Chapter website (http://www.sws.org/pacific-northwest-chapter) ■

Authors' Clarification: State-of-the-Science Report on Fracking in September's WSP

We regret that our article contained a statement that implied that the use of natural gas does not emit CO2. To clarify, we should have noted that although CO2 is a product of natural gas combustion, the use of natural gas as a source of energy releases considerably less CO2 than the combustion of coal or oil. Please remember that we were requested to prepare a State of the Science (SOTS) overview with the major focus on the direct impact of natural gas extraction activities from shale deposits on wetland ecosystems (Perry pers. comm.). As such, we did not try to explicitly address the influence of climate change on wetlands.

Although the issues are certainly linked, unfortunately, a discussion of the role of natural gas extraction in mitigating or accelerating climate change was well beyond the scope of our task. There are large uncertainties about the role of "fugitive" methane emissions from natural gas extraction (Allen et al. 2013; Brandt et al. 2014; Howarth et al. 2014), which largely influence whether natural gas from hydraulic fracturing can be viewed as a 'bridge' to a more sustainable energy economy or a source of greenhouse gases on par with other fossil fuels. Further research on the full life cycle of natural gas and the role of hydraulic fracturing on ecosystems, including wetlands, is required. Hopefully others will be able to address this much larger issue in future SOTS. ■

REFERENCES

Allen, D.T., V.M. Torres, J. Thomas, D.W. Sullivan, M. Harrison, A. Hendler, S.C. Herndon, C.E. Kolb, M.P. Fraser, A.D. Hill, B.K. Lamb, J. Miskimins, R.F. Sawyer, and J.H. Seinfeld. 2013. Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences 110(44):17768-17773.

Brandt, A.R., G.A. Heath, E.A. Kort, F. O'Sullivan, G. Petron, S.M. Jordaan, P. Tans, J. Wilcox, A.M. Gopstein, D. Arent, N.J. Brown, R. Bradley, G.D. Stucky, D. Eardley, R. Harriss. 2014. Science 343:733-735.

Howarth, R.W. 2014. A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas. Energy Science and Engineering (Open Access) 1-14.

Perry, James E III. June 2014. Personal Communications. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point VA 23062.

Evaluating a Rapid Assessment Method Using Salamander Community Metrics

Elizabeth A. Summers[1], Jacob F. Berkowitz[1], Chris V. Noble[1], and Frank Spilker[2]*

Headwater ecosystems in Appalachia have been subjected to human alterations including mountain-top mining activities, road construction, forest harvesting, conversion to pastureland, and housing development (Hagen et al. 2006; Palmer et al. 2010). These activities degrade or eliminate habitat for stream and riparian dwelling organisms including amphibians, which have exhibited widespread declines due to habitat degradation (Stuart et al. 2004).

Salamander communities are an important component of headwater ecosystems and represent a useful indicator of headwater ecological function due to their susceptibility to environmental stressors (Welsh and Ollivier 1998). Salamanders are major contributors to energy flow and nutrient cycling in eastern forests, often acting as the dominant predators in headwater ecosystems (Spight 1967; Burton and Likens 1975; Ohio EPA 2001). Headwater systems provide critical habitat for salamanders due to the absence of predation by fish (Barr and Babbit 2002; Schneider 2010). Population studies demonstrate significantly lower salamander abundances in watersheds affected by alterations such as clearcutting and residential developments (Pough et al. 1987; Petranka et al. 1993; Hyde and Simons 2001; Knapp et al. 2003; Willson and Dorcas 2003; Maigret et al. 2014). Many salamander species have highly permeable skin, unshelled eggs, limited dispersal capability, and biphasic life histories that require both aquatic and terrestrial habitats, resulting in sensitivity to habitat degradation (EPA 2002). Salamander communities recover slowly from above-ground disturbance, with recolonization after clearcutting requiring as much as 50 years (Petranka et al. 1993, Ford et al. 2002).

Habitat rapid assessment methods have been developed to estimate ecosystem characteristics at site-specific scales as an alternative to direct measurements of biotic communities, including salamander population studies (Brinson 1993; Whigham 1999; Kentula 2007; Wardrop et al. 2007). Recently, rapid assessment techniques have been developed for headwater ecosystems because most traditional evaluation methods (i.e. benthic macroinvertebrate and water chemistry studies) are constrained to the narrow windows of time when water is present in the channel, making them impractical for year-round application in areas with ephemeral hydrology (Mack et al. 2000; Berkowitz et al. 2011). Habitat rapid assessment approaches employ easily attainable measurements, which are combined using simple multimetric equations to produce a single habitat assessment score ranging from zero to 1.0 (Brinson 1993, 1995; Rowe et al. 2009; Noble et al. 2010) with a score of zero indicates the absence of habitat function, and a score of 1.0 indicates that ecosystem characteristics are comparable to highly functional habitats within the region (Smith et al. 1995). Available literature sources often form the basis for selecting the features and characteristics incorporated into a rapid assessment approach. The current study 1) evaluates the ability of a habitat rapid assessment approach to differentiate between catchment alteration categories impacting salamander habitat, 2) measures salamander communities exposed to a range of catchment alterations, and 3) identifies ecosystem characteristics related to salamander community metrics.

SEAL SALAMANDER
(*Desmognathus monticola*)

*Corresponding author. Jacob F. Berkowitz. 601-634-5218. Jacob.F.Berkowitz@usace.army.mil
[1] US Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS
[2] Independent biologist, Charleston, WV 25302.

MATERIAL AND METHODS

Ten high-gradient headwater systems in western West Virginia were selected for this study. Study sites included both the stream channel and a 7.62 m (50 ft) wide riparian buffer zone. Study sites exhibited the range of conditions commonly observed within the region (Berkowitz et al. 2011; 2013) (Table 1).

FIGURE 1.
Configuration of the habitat rapid assessment equation.

$$\text{Habitat Assessment Score} = \left\{ \left[\frac{CCANOPY + \min(EMBED, SUBSTRATE)}{2} \right] \times \left[\frac{\left(\frac{LWD + DETRITUS}{2} \right) + \left(\frac{\left(\frac{SNAG + TDBH + SRICH}{3} \right) + WLUSE}{2} \right)}{2} \right] \right\}^{1/2}$$

TABLE 1.
Headwater catchment condition, characteristics, and habitat rapid assessment score.

Catchment condition	Catchment area (ha)	Elevation (m)	Time since last alteration (yr)	Habitat rapid assessment score
Forested	6.53	239	82	0.95
Forested	4.13	248	94	0.94
Forested	12.90	228	109	0.95
Forested	1.28	726	103	0.87
Forest harvesting	8.90	780	95	0.72
Forest harvesting	1.03	265	77	0.71
Pasture	4.37	251	67	0.50
Mining	9.13	247	13	0.46
Mining	1.39	372	17	0.25
Mining	3.12	274	12	0.21

SLIMY SALAMANDER
(*Plethodon glutinonsus*)

Riparian salamander community sampling utilized eight plywood cover boards placed at each site as described in Willson and Gibbons (2009). Cover boards were overturned once per month from August – November 2011 and March – June 2012, and the species and abundance of all salamanders detected were recorded. Identification of any ambiguous or larval specimens was verified by Dr. Thomas Pauley, Marshall University. Salamander sampling within the stream channel utilized basket samplers (Talley and Crisman 2007). Each basket sampler was filled with 4.5 kg of purchased cobble (average diameter 2.8-cm, average mass 38.5 g) and leaves collected onsite. Basket samplers remained in place for approximately one month allowing colonization by salamanders and sampled April 2011, October 2011, January 2012 and April 2012 for both adult salamanders and larval species. Salamander species richness, defined as the total number of species detected among all sampling dates, and salamander abundance, defined as the total number of individuals detected on each sampling date and summed across all sampling dates, were determined (Heyer et al. 1994). Salamander richness and abundance measurements combined both cover board and basket sampler data.

The rapid assessment utilized applies the hydrogeomorphic approach developed for wetlands (Brinson 1993; Smith et al. 1995) and streams (Noble et al. 2010; Rowe et al. 2009; others). The method combines nine variables using a simple multimetric equation (Figure 2, Table 2). Complete variable definitions and sampling methods are described in Noble et al. (2010). In addition to the nine rapid assessment variables collected, forest stand age was also examined using tree cores collected within the dominant riparian canopy layer.

Rapid assessment scores for each catchment alteration category (e.g., forested, forest harvesting, pasture, mining) were compared using ANOVA following testing for normality using the Shapiro-Wilk test (α=0.05). Post Hoc multiple comparisons applied Tukey and LSD tests. Salamander abundance was compared with all 9 rapid assessment variables (Table 2), as well as stand age, using simple linear regression and Pearson

Product Moment Correlation analysis (JMP, SAS Institute 2012). For each regression analysis, the distribution of residuals was tested for normality with the Shapiro-Wilk test. Salamander abundance data was square-root transformed to satisfy normality assumptions, a common procedure for estimates of animal abundance (Sokal and Rohlf 1995). Due to the likelihood of overlap in the variance explained by assessment variables, habitat variables most strongly affecting salamander abundance were determined using forward stepwise regression with tail probability values between 5% and 10% (F to enter = 3.84, F to remove = 2.71, Tolerance = 0.001) (Kutner et al. 2004).

RESULTS AND DISCUSSION

Results demonstrate that the rapid assessment method was capable of differentiating between sites exhibiting different catchment alterations (Figure 2a). Watersheds composed of mature forest exhibited habitat rapid assessment scores >0.87, while areas subject to alteration displayed decreased scores with average habitat assessment scores of 0.72, 0.50, and 0.31 in forest harvesting, conversion to pasture, and mining impacted locations respectively. Results show statistically significant differences in rapid assessment scores between catchment alteration categories ($F(3,9)=34.1$; $P\leq0.001$). Additionally, post hoc multiple comparisons further indicate differences between catchment alteration categories. Due to the small number of sites in this study, we sought to place the 10 sites examined in the current study into a larger regional context by examining rapid assessment results from 84 additional headwater systems across the study area (Figure 2b). Significant differences in habitat rapid assessment scores were also detected between catchment alteration categories ($F(3,84)=107.1$; $P\leq0.001$) in the larger dataset with post hoc comparisons indicating similarity between forest harvesting and agriculture impacted sites, and differences between all other alteration categories. The findings of the current study correspond well with the results from the larger dataset. The fact that both the current dataset and a more statistically robust set of rapid assessment scores responded to a variety of catchment alterations promotes confidence in the current study results.

Results also indicate that the rapid assessment method responds as expected when examining a habitat recovery chronosequence, with recently altered areas exhibiting low rapid assessment scores and older, later seral stage areas displaying higher rapid assessment scores (Figure 2c). Berkowitz et al. (2013) reported similar results for a rapid assessment method evaluating biogeochemical functions in Appalachian headwater ecosystems.

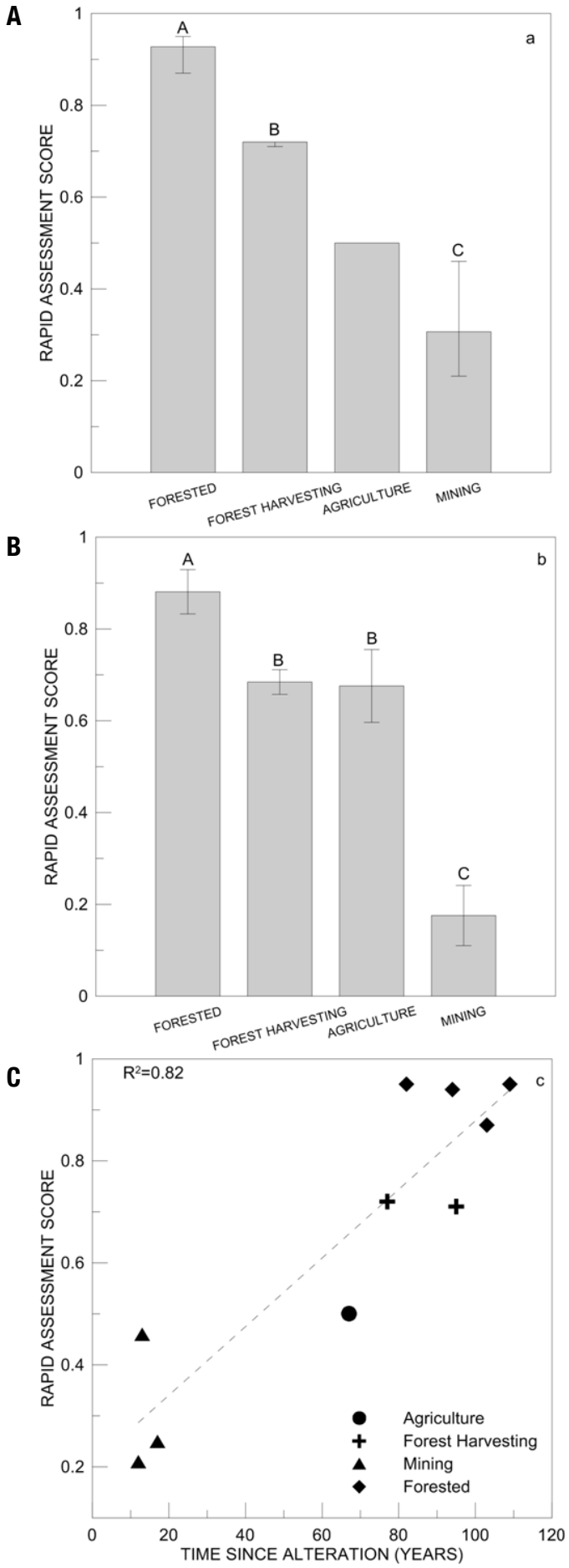
Total salamander abundance ranged from 0 – 36 individuals per site. Salamander abundance was significantly related with six of the nine rapid assessment variables tested as well as stand age (Tables 3 and 4). The high number of rapid assessment variables significantly related to sala-

TABLE 2.
Summary of rapid assessment variables, description and rationale for selection. (Modified from Noble et al. 2010.)

Assessment variable	Description and rationale for selection
1. Percent canopy cover (CCANOPY)	Percent canopy cover over the stream channel affects habitat by altering temperature and nutrient cycling (Todd and Rothermel 2006).
2. Channel substrate embeddedness (EMBED)	Embeddedness estimates the degree to which coarse substrates are covered, surrounded, or buried by fine sediments, which influences available cover for macroinvertebrates and amphibians (Wiederholm 1984).
3. Channel substrate size (SUBSTRATE)	Median size of bed material within the stream channel. Substrate provides cover and habitat for macroinvertebrates and salamanders (Gordon et al. 2006).
4. Large wood (LWD)	Abundance of large wood within stream and riparian area. Large wood provides refuge and cover for a variety of species (Fischenich and Morrow 2000).
5. Riparian area detritus cover (DETRITUS)	Abundance of detrital material covering the riparian surface. Detritus is a source of food and cover for macroinvertebrates and salamanders.
6. Riparian snag density (SNAG)	Number of snags per 30 m of stream reach. Snags provide habitat for many wildlife species (McComb and Muller 1983).
7. Riparian tree diameter at breast height (TDBH)	Average riparian tree diameter at breast height. Tree diameter is used as a surrogate for successional status, which is related with habitat structure (Rheinhardt et al. 2009).
8. Riparian tree species richness (SRICH)	Native tree species diversity per 30 m of stream reach. Diversity of the tallest vegetation layer is an indicator of overall community composition and successional patterns (Rheinhardt et al. 2009).
9. Watershed land use (WLUSE)	Percent forest cover occurring within the headwater catchment. Land use conditions determine the structure and function of downstream environments (Bolstad et al. 2003).

SLIMY SALAMANDER
(*Plethodon glutinonsus*)

FIGURE 2.



mander abundance suggests that the components included in the rapid assessment were selected appropriately.

Tree diameter accounted for the most variation in both salamander abundance and species richness. These results are consistent with Ford et al. (2002), who demonstrated a positive correlation between basal area and species richness, diversity and relative abundance of Desmognathus aeneus and D. quadramaculatus. The significance of tree diameter as a predictor for salamander community metrics points to the importance of mature forest structure, a characteristic which takes decades to develop following disturbance (Petranka et al. 1993). This conclusion is reinforced by the results of the simple linear regression showing a significant relationship between stand age and the salamander community metrics measured. In comparison to tree diameter, the other habitat characteristics measured were less reliable predictors of salamander community metrics, possibly because tree diameter is a better indicator of overall forest stand maturity than characteristics such as canopy cover or detritus which can develop rapidly during stand regeneration (Summers 2010).

Based on stepwise model selection results, percent forested area also provided a significant predictor of salamander abundance. Within the study areas, non-forested land use types consisted of anthropogenic alterations (e.g., mining, roads, and urban development). Welsh and Ollivier (1998) documented a strong negative relationship between watershed disturbance and the number of stream salamanders captured. Maigret et al. (2014) also observed significantly lower abundances of stream (Desmognathus spp.) and riparian (Plethodon glutinosus) salamanders within 5 years of tree harvesting. Mechanisms involved in salamander community changes as a result of watershed alterations include impacts to stream and riparian habitats (Welsh and Ollivier 1998) as well as metapopulation changes caused by reduced habitat continuity (Lowe and Bolger 2002).

TABLE 3.
Results of simple linear regressions[a] relating habitat variables to salamander abundance[b].

Predictor	P	Pearson Correlation
DBH	<0.001	0.91
DETRITUS	0.005	0.81
CANOPY	0.013	0.75
SRICH	0.025	0.70
LWD	0.026	0.70
SNAG	0.065	0.60
SUBSTRATE	0.67	0.15
EMBED	0.46	0.26
WLUSE	0.048	0.64
Stand Age	0.011	0.76

[a]Significance was determined at $\alpha = 0.05$.
[b]Square root transformed. Sample size = 10.

Results suggest that human alterations including surface mining and conversion to pasture negatively impact habitat suitability for salamanders as reported by Riedel et al. (2008), Muncy (2014), and others. Notably, forest harvesting in the stream riparian areas examined in this dataset occurred >77 years ago. These areas exhibited forested watersheds (88-100% forest cover) and high tree diameter values (average diameter = 29.2-33.0 cm). As a result, salamander abundances are within the range observed within unaltered stream catchments. These data agree with the findings of Petranka et al. (1993) and Ford et al. (2002), who indicate that recolonization of deforested sites by salamanders takes at least 50 years, and support the recovery trajectory predicted by the habitat rapid assessment method (Figure 2c).

SUMMARY

Landscape and vegetation alterations such as forest harvesting, mining and conversion to pasture in Appalachian headwater streams negatively affect salamander communities by reducing or eliminating suitable habitat. This study illustrates that the rapid assessment method tested was capable of differentiating between stream catchment alteration categories impacting salamander habitat in both the small dataset examined and in a large 84-site regional dataset. The rapid assessment also provided a useful tool for evaluating habitat recovery and supports the development of restoration trajectory curves. Based on study results, salamander conservation in Appalachian headwater stream and adjacent riparian areas should focus on establishing and maintaining mature forested habitats characterized by large trees. Results showed a significant correlation between rapid assessment outputs and salamander community metrics, reinforcing the utility of rapid assessment methodologies for providing useful measurements of salamander habitat function when time constraints or other factors prohibit salamander surveys. ■

TABLE 4.

Amphibian species observed and total abundance at 10 headwater study locations including Forested (F), Forest Harvesting (FH), Pasture (P), and Mining (M).

	Headwater catchment condition									
Species Observed	**F**	**F**	**F**	**F**	**FH**	**FH**	**P**	**M**	**M**	**M**
Desmognathus fuscus	X			X		X				
D. monticola	X		X	X						
D. ochrophaeus				X		X				
Eurycea bislineata				X	X		X	X		
Gyrinophilus porphyriticus		X		X						
Plethodon cinereus						X				
P. glutinosus	X	X	X	X	X	X	X			
P. richmondi		X			X			X		
Pseudotriton ruber				X		X				
Salamander abundance	5	10	13	34	19	36	2	3	0	0

REFERENCES

Ash, A.N. 1997. Disappearance and return of plethodontid salamanders to clearcut plots in the southern Blue Ridge Mountains. Conservation Biology 11:983-989.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002. Environmental Protection Agency Office of Water, Washington, D. C.

Barr, G.E. and J. Babbitt. 2002. Effects of biotic and abiotic factors on the distribution and abundance of larval two-lined salamanders (Eurycea bislineata) across spatial scales. Oecologia 133:176-185.

Berkowitz, J.F., A.F. Casper and C.V. Noble. 2011. A multiple watershed field test of hydrogeomorphic functional assessment of headwater streams—variability in field measurements between independent teams. Ecological Indicators 11:1472-1475.

Berkowitz, J.F., E.A. Summers, C.V. Noble, J.R. White and R.D. DeLaune. 2013. Investigation of biogeochemical functional proxies in headwater streams across a range of channel and catchment alterations. Environmental Management 53:534-548.

Bolstad, P., J. Vose, and M. Riedel. 2003. Land use, carbon and water in the Southeastern Uplands. NASA LCLUC Progress Report.

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. Technical Report WRP-DE-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brinson, M.M. 1995. The HGM approach explained. National Wetlands Newsletter 17:7-13.

Burton, T.M. and G.E. Likens. 1975. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire. Ecology 56:1068-1080.

Crawford, J.A. and R.D. Semlitsch. 2008. Abiotic factors influencing abundance and microhabitat use of stream salamanders in southern Appalachian forests. Forest Ecology and Management 255:1841-1847.

Fischenich, J.C. and J.V. Morrow. 2000. Streambank habitat enhancement with large woody debris. ERDC TN-EMRRP-SR-13. US Army Engineer Research and Development Center, Vicksburg, MS.

Ford, W.M., B.R. Chapman, M.A. Menzel and R.H. Odom. 2002. Stand age and habitat influences on salamanders in Appalachian cove hardwood forests. Forest ecology and Management 155:131-141.

Gordon, N.D., T.A. McMahon, B.L. Finlayson, C.J. Gippel and R.J. Nathan. 2006. Stream Hydrology - An Introduction for Ecologists. 2nd edition. John Wiley & Sons, New York, NY.

Hagen, E.M., J.R. Webster and E.F. Benfield. 2006. Are leaf breakdown rates a useful measure of stream integrity along an agricultural landuse gradient? Journal of the North American Benthological Society 25:330-343.

Hamilton, M.S. 2002. Effects of developmental activities on streamside salamander communities in Boone County, West Virginia. M. S. thesis, Marshall University, Huntington, WV.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster, eds.1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institute, Washington, D.C.

Hill, A.J., V.S. Neary and K.L. Morgan. 2006. Hydrologic modeling as a development tool for HGM functional assessment models. Wetlands 26:161-180.

Hyde, E.J. and T.R. Simons. 2001. Sampling Plethodontid salamanders: sources of variability. Journal of Wildlife Management 65:624-632.

JMP, Version 10. 2012. SAS Institute Inc., Cary, NC.

Kentula, M.E. 2007. Foreword: monitoring wetlands at the watershed scale. Wetlands 27:412-415.

Klimas, C.V., E.O. Murray, J. Pagan, H. Langson and T. Foti. 2011. A regional guidebook for applying the hydrogeomorphic approach to assessing functions of forested wetlands in the Delta region of Arkansas, lower Mississippi river alluvial valley. ERDC/EL-TR-11-12. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Knapp, S.M., C.A. Haas, D.N. Harpole, and R.L. Kirkpatric. 2003. Initial effects of clearcutting and alternative silvicultural practices on terrestrial salamander abundance. Conservation Biology 17:752-62.

Kutner, M.H., C.J. Nachtsheim, J. Neter., eds. 2004. Applied linear regression models. Fourth Edition. McGraw-Hill Irwin, New York, New York, USA.

Lowe, W.H. and D.T. Bolger. 2002. Local and landscape-scale predictors of salamander abundance in New Hampshire headwater streams. Conservation Biology 16:183-193.

Lowe, W.H., K.H. Nislow and D.T. Bolger. 2004 . Stage-specific and interactive effects of sedimentation and trout on a headwater stream salamander. Ecological Applications 14:164-172.

Mack, J.J., M. Micacchion, L. Augusta and G.R. Sablak. 2000. Vegetation indices of biotic integrity (VIBI) for wetlands and calibration of the Ohio Rapid Assessment Method for wetlands v. 5.0. Final Report to U.S. EPA. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, OH.

Maigret, T.A., J.J. Cox, D.R. Schneider, C.D. Barton, S.J. Price and J.L. Larkin. 2014. Effects of timber harvest within streamside management zones on salamander populations in ephemeral streams of southeastern Kentucky. Forest Ecology and Management 324:46-51.

McComb, W.C. and R.N. Muller. 1983. Snag densities in old growth and second-growth Appalachian forests. Journal of Wildlife Management 47:376-382.

Muncy, B.L. 2014. The effects of mountaintop removal mining and valley fills on stream salamander communities. M. S. thesis, University of Kentucky, Lexington, KY.

Noble C.V., J.F. Berkowitz and J. Spence. 2010. Operational draft regional guidebook for the functional assessment of high-gradient ephemeral and intermittent headwater streams in western West Virginia and eastern Kentucky. ERDC TN-WRAP-10-11. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Ohio Environmental Protection Agency (EPA). 2001. Field evaluation manual for Ohio's primary headwater habitat streams. Ohio EPA, Division of Surface Water, Columbus, OH.

Palmer M.A., Bernhardt E.S., Schlesinger W.H., Eshleman K.N., Foufoula-Georgiou E., Hendryx M.S., Lemly A.D., Likens G.E., Loucks O.L., Power M.E., White P.S. and Wilcock P.R. 2010. Mountaintop mining consequences. Science 327:148-149.

Petty, J.T., G. Gingerich, J.T. Anderson and P. F. Ziemkiewicz. 2013. Ecological function of constructed perennial stream channels on reclaimed surface coal mines. Hydrobiologia 720:39-53.

Petranka, J.W., M.E. Eldridge and K.E. Haley. 1993. Effects of timber harvesting on southern Appalachian salamanders. Conservation Biology 7:363-370.

Pond, G.J., J.E. Bailey, B.M. Lowman and M.J. Whitman. 2013. Calibration and validation of a regionally and seasonally stratified macroinvertebrate index for West Virginia wadeable streams. Environmental Monitoring and Assessment 185:1515–1540.

Pough, F.H., E.M. Smith, D.H. Rhodes and A. Collazo. 1987. The abundance of salamanders in forest stands with different histories of disturbance. Forest Ecology and Management 20:1-9.

Riedel, B.L., K.R. Russell, W.M. Ford, K.P. O'Neill and H.W. Godwin. 2008. Habitat relationships of eastern red-backed salamanders (Plethodon cinereus) in Appalachian agroforestry and grazing systems. Agriculture, Ecosystems and Environment 124:229-236.

Rheinhardt, R.D., M. McKenney-Easterling, M.M. Brinson, J. Masina-Rubbo, R.P. Brooks, D.F. Whigham, D. O'Brien, J.T. Hite and B.K. Armstrong. 2009. Canopy composition and forest structure provide restoration targets for low order riparian ecosystems. Restoration Ecology 17:51-59.

Rowe, D.K., S. Parkyn, J. Quinn, K. Collier, C. Hatton, M.K. Joy, J. Maxted and S. Moore. 2009. A rapid method to score stream reaches based on the overall performance of their main ecological functions. Environmental Management 43:1287-1300.

Schneider, D.R. 2010. Salamander communities inhabiting ephemeral streams in a mixed mesophytic forest of southern Appalachia. M. S. thesis, Indiana University of Pennsylvania.

Smith, R.D., A. Ammann, C. Bartoldus and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands and functional indices. Technical Report TR-WRP-DE-9, Waterways Experiment Station, Army Corps of Engineers, Vicksburg, MS.

Smith, R.D., C.V. Noble and J.F. Berkowitz. 2013. Hydrogeomorphic (HGM) approach to assessing wetland functions: guidelines for developing guidebooks (Version 2). U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry: The principles of statistics in biological research, 3rd edn. W.H. Freeman, New York, NY.

Surasinghe, T.D. 2013. Influences of riparian land-uses on habitat use and interspecific competition of stream-dwelling salamanders: evidence from Blue Ridge and Piedmont. M. S. thesis, Clemson University, Clemson, SC.

Spight, T.M. 1967. Population structure and biomass production by a stream salamander. American Midland Naturalist 78:437-447.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.L. Rodrigues, D.L. Fischman and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 305:1783-1786.

Summers, E.A. 2010. Evaluating ecological restoration in Tennessee hardwood bottomland forests. M.S. thesis, University of Tennessee, Knoxville, TN.

Talley, B.L. and T.L. Crisman. 2007. Leaf litterbag sampling for larval Plethodontid salamander populations in Georgia. Environmental Monitoring and Assessment 132:509-515.

Todd, B.D. and B.B. Rothermel. 2006. Assessing quality of clearcut habitats for amphibians: Effects on abundance versus vital rates in the southern toad (Bufo terrestris). Biological Conservation 33:178-185.

United States Department of Agriculture (USDA). 2006. MLRA geographic database, version 4.2. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. United States Department of Agriculture Handbook 296. http://water.usgs.gov/GIS/dsdl/mlra.e00.gz . Accessed 1 Jan 2014.

United States Environmental Protection Agency (EPA). 2002. Methods for evaluating wetland condition: using amphibians in bioassessments of wetlands. EPA-822-R-02-022. Office of Water, U.S. Environmental Protection Agency, Washington, D. C.

Ward, R.L., J.T. Anderson and J.T. Petty. 2008. Effects of road crossings on stream and streamside salamanders. Journal of Wildlife Management 72:760-771.

Wardrop, D.H., M.E. Kentula, D.L. Stevens, S.F. Jensen and R.P. Brooks. 2007. Assessment of wetland condition: an example from the Upper Juniata Watershed in Pennsylvania, U.S.A. *Wetlands* 27:416-431.

Welsh, H.H. and L.M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. Ecological Applications 8:1118-1132.

Whigham, D.F. 1999. Ecological issues related to wetland preservation, restoration, creation, and assessment. Science of the Total Environment 240:31-40.

Wiederholm, T. 1984. Responses of aquatic insects to environmental pollution. In The Ecology of Aquatic Insects, ed. V.H. Resh and D.M. Rosenberg, 508-557. Praeger Publishers, New York, NY.

Willson, J.D. and M.E. Dorcas. 2003. Effects of habitat disturbance on stream salamanders: Implications for buffer zones and watershed management. Conservation Biology 17:763-771.

Willson, J.D. and J.W. Gibbons. 2009. Drift fences, coverboards, and other traps. Pp 229-246 in C. K. Dodd, Jr., ed. Amphibian ecology and conservation: a handbook of techniques. Oxford, Cary, NC.

Wood, P.B. and J.M. Williams. 2013. Impact of valley fills on streamside salamanders in southern West Virginia. Journal of Herpetology 47:119-125.

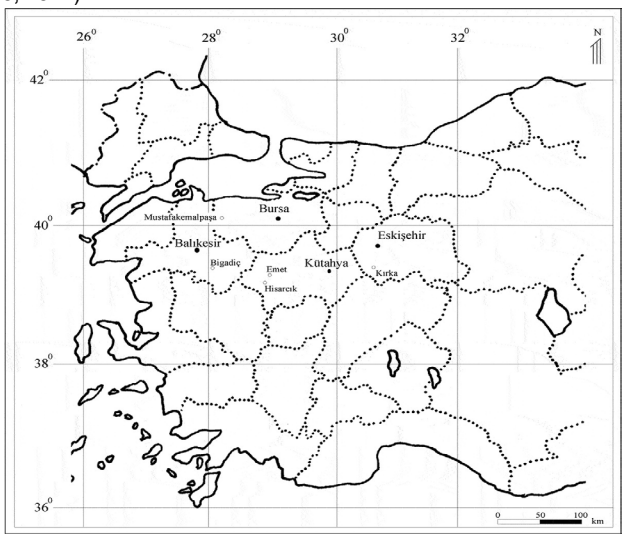
Yeiser, J., A.L. Jones, J. F. Fox and S. Richter. 2010. Desmognathus (Dusky Salamander) as a Stream Health Indicator in Letcher County, Kentucky. Publication RS10.025. Eastern Kentucky Environmental Research Institute, Richmond, KY.

The Use of Wetlands in Boron (B) Remediation in Turkey

Onur Can Türker[1,], Cengiz Türe[2], Harun Böcük[2], Anıl Yakar[2]*

Boron (B) contamination of water sources from mining and other activities have aroused more and more global attention (Wolska and Bryjak, 2013). The known boron (B) mine reserves all over the world are mainly located in Turkey, the United States, China and South America. On the other hand, Turkey contains approximately 70% of total B reserves with 803 million tons, and has supplied the majority of the B used in the world, so that the potential for the contamination of freshwater resources there is high (Turker et al., 2013a). The B reserves in Turkey occur in Western Anatolia, main reserves are speared in Mustafakemalpaşa, Bigadiç (Balıkesir), Bursa, Hisarcık, Emet (Kütahya), dominated by the Kırka (Eskişehir) borax (tincal, $Na_2B_4O_7$) deposit. Boron mining activities in Western Anatolia reach their maximum level, and, thus, around 45000 km square of ecosystem has a large potential for elevated point or non-point of B pollution, which can leak and diffuse into the receiving water body (Türker et al., 2013a; Türker et al., 2013b; Böcük et al., 2013).

FIGURE 1.
Boron (B) mine reserve area in Turkey (with a permission by Böcük and Türe, 2014)



[1] Faculty of Science and Letters, Department of Biology, Aksaray University, Aksaray, Turkery
[2] Faculty of Science, Department of Biology, Anadolu University, Eskişehir, Turkey
* Corresponding Author, Phone: +90 382 288 21 85, Fax: +90 382 280 12 46, E-mail: octurker@gmail.com

To provide an ecological context, wetland projects supported by the Scientific and Technological Research Council of Turkey and Scientific Research Funds of Anadolu University to understand remediation of boron mining areas with wetlands. The usage of wetland systems for B wastewater remediation is a relatively new technology and created wetlands have never before been specifically designed and used for the prevention and control of boron pollution to protect surrounding natural areas. Therefore, our idea is to remediate boron pollution using wetlands positioning in the landscape to intercept boron before it can enter into adjacent natural water bodies and wetlands. The remediation program was performed from 2010 to 2015 at largest Borax mine reserve area (39° 17' N, 30° 30' E) in all over the world (Kırka country - Eskişehir in Turkey) under natural climatic conditions. Ten types of wetland systems were established using different vegetation structure and plant combination in order to test wetland boron remediation efficiency in the boron remedial program. The wetland systems consisted of a chamber 2 m in length, 1m in width, 0.6 m in depth (water depth is 0.4 m) with a surface area 2 m^2, and employed gravity feed using 1.5°.

A doctorate thesis study conducted by Böcük (2010) researched the natural plant diversity of all boron reserve areas in Turkey as well as the status of their adjacent environments, their tolerance to boron and the potential phytoremediation capacities of some boron-tolerant plants. Following Böcük's work, we chose four native local macrophyte species, which can grow in boron rich environment, to test for the remediation program: *Typha latifolia* L., *Typha angustifolia* L. (Typhaceae), *Phragmites australis* (Cav.) Trin. ex Steud. (Poaceae) and *Juncus gerardii* Loisel. subsp. *gerardii* (Juncaceae). These sepcies were collected from natural wetlands surrounding the Kırka B mine reserve area. After collecting healthy rhizomes of the plants were immediately transported into the wetlands.

FIGURE 2.
The largest Borax mine reserve area in the world is in Kırka county – near Eskişehir, Turkey)

FIGURE 3.
Volunteers collected the plants' rhizomes from wetlands surrounding the Kırka B mine reserve area and transported the plants into the wetland systems.

In this remedial program, the ability of wetlands for the preventions and controlling of boron pollution under the actual environmental conditions was assessed and tested within the largest boron reserve area all over the world. Furthermore, crucial information about optimum plant selection investigated for B phytoremediation to simulate the actual a wetland system as closely as possible. In this way, the growth characteristics and boron phytoremediation capability were screened to determine if these species were effective in removing boron from the water. This research is critical for developing approaches to purify contaminated wastewater and to address a critical pollution problem in mining areas.

Our study found that the presence of plants in these created wetlands had a positive effect on water quality of the wastewater that flows into wetland systems. These plants take up boron directly and store it in their tissues. This process leads to higher levels of sorption or adsorption around the rhizopshere and sediment. Because our work may also be of interest to researchers, we have written several articles.

Another major aim in this remedial project is to train masters and PhD students in this remediation technique. Berkan Aras who is the volunteer student in the B remedial program emphasized that "I learned how a wetland systems remediate B in the wastewater before the B can reach the receiving water body such as surface water source. I also gained an understanding of the scientific method and used crucial elements of the method in the B remediation process". Master students Nurcan Gür and Ömer Fatih Gündüz concluded that "this remediation project offered much potential for testing a wetland system for B remediation.

As master students; we learned to evaluate this innovative method in field conditions and learned to work in collaborative teams". Overall, our work has provided valuable research and student training in the area of boron mine reclamation and wastewater treatment. ■

ACKNOWLEDGMENT

This work was financially supported by the Scientific and Technological Research Council of Turkey (Project Number: 113Y335) and Scientific Research Funds of Anadolu University, Turkey (Project Number: 1403F098).

REFERENCES

Böcük, H., A. Yakar, O.C. Türker. 2013. Assessment of *Lemna gibba* L. (duckweed) as a potential ecological indicator for contaminated aquatic ecosystem by boron mine effluent. *Ecological Indicators* 29:538-548.

Böcük, H. 2010. Investigation of natural plant diversity on the soils with high boron concentrations in terms of soil-plant relations in west Anatolia. Ph. D. Thesis, Anadolu Univ., Graduate School of Sciences, Eskişehir, Turkey.

Böcük, H. and C. Türe. 2014. Phytoremediation possibilities of boron-contaminated environments by wild plants growing on boron reserve areas in Turkey, *Communications in Soil Science and Plant Analysis* 45(13):1784-1798.

Türe, C. and R.W. Bell. 2004. Plant distribution and its relationship to extractable boron in naturally-occurring high boron soils in Turkey. *Isr. J. Plant Sci.* 52:125-132.

Türker, O.C., H. Böcük, and A. Yakar. 2013a. The phytoremediation ability of a polyculture constructed wetland to treat boron from mine effluent. *J. Hazardous Mater.* 252-253:132-141.

Türker, O.C., C. Türe, H. Böcük, and A. Yakar. 2013b. Constructed wetlands as green tools for management of boron mine wastewater. *Int. J. of. Phytoremediation* 16(6):537-553.

Wolska, J. and M. Bryjak.. 2013. Methods for boron removal from aqueous solutions: a review. *Desalination* 310:18-24.

FIGURE 4.
Wetland systems for the B remedial program in the Kırka B mine reserve area

FIGURE 5.
Researchers and students measured plant height and determined B toxicity symptoms during the remediation study.

An Overview of Research Supporting Wetland and Ordinary High Water Mark Delineation

Robert W. Lichvar[1], Jennifer J. Gillrich[1], Matthew K. Mersel[1], Cristina E. McKernan[1], and Betsy L. Bultema[1]

Over the past 25 years, researchers at the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) have addressed a wide range of technical issues pertaining to identification and delineation of aquatic resources under §404 of the Clean Water Act (CWA) (US Congress 1977). Research focuses on topics related to wetland and stream delineation, such as identifying ecological relationships between hydrophytic vegetation, hydric soil, and wetland hydrologic conditions, developing and maintaining an accurate and robust National Wetland Plant List (NWPL), and developing ordinary high water mark (OHWM) delineation methods and technical guidance for rivers and streams. NWPL wetland indicator status ratings of plant species, along with soil and hydrologic conditions, are used to define federal jurisdictional limits in wetlands (33 U.S.C. 1344), while the OHWM defines the lateral extent of federal jurisdiction in non-tidal Water of the U.S., in the absence of adjacent wetlands. This work is led by a research group at the USACE-ERDC Cold Regions Research and Engineering Laboratory (CRREL) and performed in collaboration with the National Technical Committee for Wetland Vegetation (NTCWV), whose members represent six federal agencies and four universities, and with the National Technical Committee for the OHWM (NTCOHWM), which has representation from USACE, the U.S. Environmental Protection Agency (EPA), and academia. Both of these technical committees provide scientific insight, guidance, peer-review, and a diversity of perspectives from different agencies, regions, and fields of expertise. Research is primarily funded through the USACE Wetlands Regulatory Assistance Program in a continual effort to provide scientific and technical support for the USACE Regulatory Program. Here we present an overview of ongoing research efforts in these topic areas.

Our wetland delineation research supports the wetland regulatory program by enhancing technical procedures consistent with advances in wetland ecology. We evaluate wetland delineation methods to provide accurate field indicators by examining vegetation formulas (e.g., Lichvar et al. 2011; Wakeley and Lichvar 1997; Gillrich et al. 2011; Lichvar and Gillrich 2014a; Lichvar and Gillrich 2014b) and evaluating groups of plants as wetland vegetation indi-

TABLE 1
Summary table of recent studies that support NWPL and Wetland Regulatory Programs

Research Area	Project	Significant findings	Specific support for NWPL and Regulatory
NWPL	Indicator Status Challenges	Indicator status ratings for Colorado blue spruce (Picea pungens) and eastern hemlock (Tsuga canadensis) varies at landscape scales.	Provides methodology for future NWPL indicator status challenges
NWPL	NWPL ratings trends across the US	Appalachian Mountains and Arid West have low wetland densities yet high wetland plant species richness.	Regional and National Panels in these regions can reevaluate ratings and revise mitigation efforts
Wetland delineation	Remote Sensing (RS) Boundaries	Preliminary results suggest high variability in boundaries for different vegetation types.	Creates guidelines for assessment of RS tools for determining wetland boundaries

[1] U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory; correspondence author: Robert.W.Lichvar@erdc.dren.mil

cators (e.g., Lichvar et al. 2009; Lichvar and Fertig 2011; Gillrich and Lichvar 2010; Gillrich and Bowman 2010; Lichvar and Gillrich in prep-a) (Table 1). Additionally, through collaborations with remote sensing and geographic information systems (RS/GIS) experts at CRREL we compare RS/GIS models of wetland boundaries to field delineations across the U.S (e.g., Gillrich and Lichvar 2014; Lichvar et al. 2008; Lichvar et al. 2006a) (Table 1).

Our research group manages the NWPL through applied research on wetland indicator status ratings, overseeing periodic updates to the NWPL, and administration of the NWPL website (http://wetland_plants.usace.army.mil). The NWPL is a multi-agency effort involving the U.S. EPA, U.S. Fish and Wildlife Service, and the U.S. Department of Agriculture Natural Resources Conservation Service. Our research improves the NWPL by examining the accuracy of wetland indicator status ratings for individual and groups of species using spatial data and field studies. For example, by analyzing GIS data of wetland density for the conterminous U.S. (Dahl & Griffin, submitted for publication) and county level species presence/absence data (Kartesz 2013; Lichvar et al. 2014) we've identified areas where NWPL wetland species richness is unexpectedly high or low relative to available wetland habitat across the U.S. (Figure 1; Table 1). Additionally, through our collaborations with the NTCWV and Colorado State University, we have completed two of the first studies that use statistically sound methods of collecting and analyzing frequency data to determine wetland frequency for individual NWPL species challenges (Lichvar and Gillrich in prep-b; Gage et al. in press; Table 1). Our research uses empirical field data to investigate how groups of species respond to abiotic factors other than hydrologic gradients, such as saline soils (halophytes) or a deep water table (phreatophytes) that may influence wetland plant occurrence and distribution patterns at various landscape scales. Our ongoing research helps to clarify the wetland fidelity of groups of problematic plant species, in particular halophytes, phreatophytes, and three problematic Alaskan birch taxa. We've developed guidelines for challenge studies, reevaluation of NWPL indicator status ratings by regional panels, and updating NWPL ratings and descriptions of rating categories (e.g., Lichvar and Minkin 2008; Lichvar and Gillrich 2011; Lichvar et al. 2012).

Additionally our research group addresses challenges related to OHWM delineation in fluvial systems and develops OHWM delineation technical guidance aimed at increasing the accuracy and consistency of OHWM delineations across the country. Our research focuses on identifying robust physical and biological OHWM indicators (e.g., Lichvar and Wakeley 2004; Mersel et al. 2014) by assessing relationships between streamflow recurrence and field indicators (e.g., Lichvar et al. 2006b; Curtis et al. 2011; Mersel et al. in prep), identifying variability in OHWM indicators and hydrologic conditions across the U.S. (e.g., Wohl et al. in prep), and exploring the use of additional tools and data such as remote sensing, hydraulic modeling, and stream gage data to assist with field delineations (e.g., Gartner et al. 2016a, 2016b, and 2016c in press). This work has supported our development of OHWM delineation manuals for the Arid West (Lichvar and McColley 2008) and Western Mountains, Valleys, and Coast (Mersel and Lichvar 2014) USACE regions, and we are currently developing additional regional and national technical resources to support and improve OHWM delineation practices across the entire U.S.

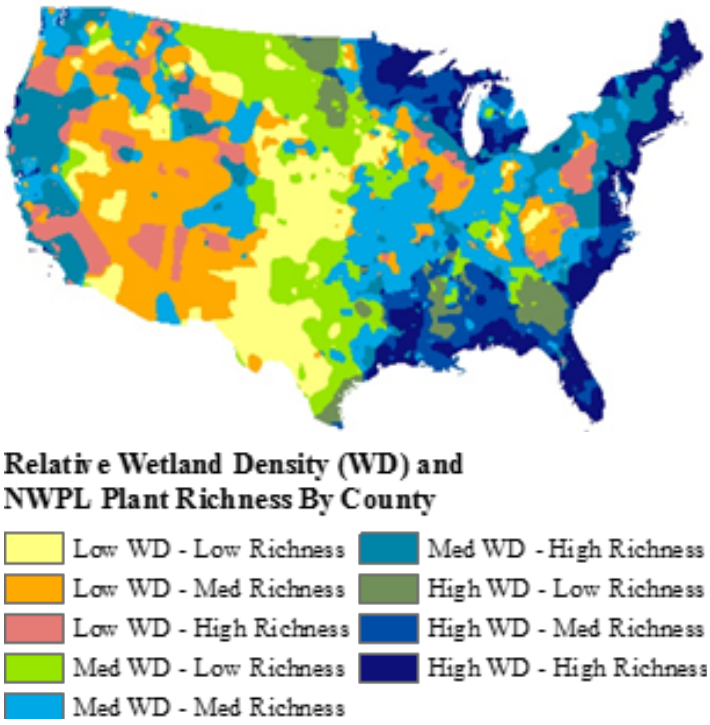
Further information on the NWPL and OHWM delineation, including technical reports, manuals, and other resources, can be found online at http://wetland_plants.usace.army.mil and http://www.erdc.usace.army.mil/OHWM. ■

ACKNOWLEDGEMENTS

This work was made possible by the Wetlands Regulatory Assistance Program (WRAP) of the U.S. Army Corps of Engineers. We thank David Cate, Michael Ericsson, John Klein, Lindsey Lefebvre, Shawn McColley, Walter Ochs, and Corinna Photos for their hard work and their dedication to this research.

FIGURE 1

Relationship between relative wetland density and wetland plant species richness in the continental United States. Initial analysis shows patterns of low wetland density and high wetland plant species richness in the Appalachian Mountains and Arid West. Relative Wetland Density (WD) Categories: Low: 0.0002 - 0.02, Med: 0.02 - 0.1, High: 0.1 - 1.0. Wetland density is the ratio of wetland area to upland area. Plant Richness (Count of all NWPL species/County) Categories: Low: 29 - 395, Med: 395 - 675, High: 675 – 1259. Data for relative wetland density obtained from Griffin & Dahl, submitted for publication. Data for plant species count per county from Kartesz 2013.



REFERENCES

Curtis, K.E., R.W. Lichvar, and L.E. Dixon. 2011. Ordinary high flows and the stage-discharge relationship in the Arid West region. ERDC/CRREL TR-11-12. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Gage, E.A., D.J. Cooper, B.L. Bultema, C.E. McKernan, R.W. Lichvar. In press. Developing a field-tested wetland indicator rating for blue spruce (Picea pungens) in the western U.S. Wetlands.

Gartner J.D., M.K. Mersel, L.E. Lefebvre, and R.W. Lichvar. 2016a. In press. The benefits and limitations of hydraulic modeling for ordinary high water mark delineation. ERDC/CRREL TR-16-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Gartner J.D., M.K. Mersel, and R.W. Lichvar. 2016b. In press. Hydrologic modeling and flood frequency analysis in ordinary high water mark delineation. ERDC/CRREL TR-16-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Gartner J.D., R.W. Lichvar, M.K. Mersel, and L.E. Lefebvre. 2016c. In press. Modeling the ordinary high water mark in arid and semi-arid regions for the Clean Water Act and other applications. ERDC/CRREL TR-16-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Gillrich, J.J., B.P. Allen, and R.W. Lichvar. 2011. The effect of a low-cover stratum—woody vines—on vegetation determinations made during wetland delineations. Wetlands 31:865–873.

Gillrich, J.J. and K.C. Bowman. 2010. Use of bryophytes as indicators of hydric soils and wetland hydrology during wetland delineations in the United States. ERDC/CRREL TN-10-09. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

Gillrich, J.J. and R.W. Lichvar. 2010. Sphagnum as an indicator of wetland hydrology in the Atlantic and Gulf Coastal Plain region. ERDC/CRREL TN-10-2. Cold Regions Research and Engineering Laboratory, Hanover NH.

Gillrich, J.J. and R.W. Lichvar. 2014. Use of LiDAR to assist in delineating waters of the United States, including wetlands. ERDC/CRREL TN-03-14. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Griffin, R.K. and T.E. Dahl. Submitted for publication. Wetland density of the conterminous United States. Physical Geography.

Kartesz, J.T. 2013. Floristic Synthesis of North America, Version 1.0 Biota of North America Program (BONAP). In press.

Lichvar, R.W., M.L. Butterwick, N.C. Melvin, and W.N. Kirchner. 2014. The National Wetland Plant List: 2014 update of wetland ratings. Phytoneuron 2014-41:1-42.

Lichvar, R. and W. Fertig. 2011. Epiphytes and the National Wetland Plant List. Phytoneuron 2011-17:1–31.

Lichvar, R.W., D.C. Finnegan, M.P. Ericsson, and W.R. Ochs. 2006b. Distribution of ordinary high water mark (OHWM) indicators and their reliability in identifying the limits of 'Waters of the United States' in arid southwestern channels. ERDC/CRREL TR-06-5. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

Lichvar, R.W., D.C. Finnegan, S. Newman, and W. Ochs. 2006a. Delineating and evaluating vegetation conditions of vernal pools using spaceborne and airborne remote sensing techniques, Beale Air Force Base, CA. ERDC/CRREL TN-06-3. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

Lichvar, R.W., and J.J. Gillrich. 2011. Final protocol for assessing wetland indicator status ratings during the National Wetland Plant List update. ERDC/CRREL TR-11-1. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., and J.J. Gillrich. 2014a. Field testing new plot designs and methods for determining hydrophytic vegetation during wetland delineations in the United States. ERDC/CRREL TN-14-1. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., and J.J. Gillrich. 2014b. Examining discrepancies among three methods used to make hydrophytic vegetation determinations for wetland delineation purposes. ERDC/CRREL TR-14-2. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., and J.J. Gillrich. In prep-a. Determining the reliability of four morphological adaptations as indicators of hydrophytic vegetation at the wetland boundary ERDC/CRREL TR-16-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., and J.J. Gillrich. In prep-b. Testing methods for challenging the National Wetland Plant List. ERDC/CRREL TR-16-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., and J.J. Gillrich. In prep-c. Examining discrepancies in wetland frequency produced by data collected at wetland boundaries and data collected across the landscape ERDC/CRREL TR-16-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., J.J. Gillrich, and W.R. Ochs. 2011. Discrepancies in hydrophytic determinations produced by three vegetation formulas used for wetland delineations. Wetlands 31:603–611.

Lichvar, R.W., G.A. Laursen, R.D. Seppelt, and W.R. Ochs. 2009. Selecting and testing cryptogam species for use in wetland delineation in Alaska. Arctic, 62:119-225.

Lichvar, R.W., and S.M. McColley. 2008. A Field Guide to the identification of the ordinary high water mark (OHWM) in the Arid West region of the Western United States. ERDC/CRREL TR-08-12. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R.W., N.C. Melvin, M.L. Butterwick, and W.N. Kirchner. 2012. National Wetland Plant List indicator rating definitions. ERDC/CRREL TR-12-1. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar, R., and P. Minkin. 2008. Concepts and procedures for updating the National Wetland Plant List. ERDC/CRREL TN-08-03. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lichvar R., W. Ochs, and S. Gains. 2008. Evaluation of surface features for delineating the ordinary high water mark on playas of the arid western United States. Wetlands 28:68-80.

Lichvar, R.W., and J.S. Wakeley. 2004. Review of ordinary high water mark indicators for delineating arid streams in the southwestern United States. ERDC TR-04-1. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Mersel, M.K., and R.W. Lichvar. 2014. A guide to ordinary high water mark delineation in non-perennial stream systems in the U.S. Western Mountains, Valleys, and Coast region. ERDC/CRREL TR-14-13. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Mersel, M.K., R.W. Lichvar, J.J. Gillrich, and L.E. Lefebvre. 2014. Occurrence and distribution of ordinary high water mark indicators in in non-perennial stream systems in the U.S. Western Mountain region. ERDC/CRREL TR-14-11. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Mersel, M.K., R.W. Lichvar, and L.E. Lefebvre. In prep. Exploring ordinary high water mark (OHWM) indicators and hydrology in the northeastern United States. ERDC/CRREL TR-XX-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

U.S. Congress. 1977. Federal Water Pollution Control Act. 33 U.S.C. § § 1251–1387 et seq. (amended 27 December 1977). 95th Congress. http://www.gpo.gov/fdsys/pkg/STATUTE-91/pdf/STATUTE-91-Pg1566.pdf (accessed November 2015).

Wakeley, J.S., and R.W. Lichvar. 1997. Disagreements between plot-based prevalence indices and dominance ratios in evaluations of wetland vegetation. Wetlands 17:301–309.

Wohl E. and others. In prep. The scientific context for the ordinary high water mark. ERDC/CRREL TR-XX-XX. U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

National Scale Research Assistance Request: Comparison of Wetlands Mapped by the National Wetlands Inventory and Following the Three-factor Corps Approach

Several federal programs provide guidance for wetland identification, but differences in definitions and mapping protocols have the potential to produce different outcomes for the same site. Section 404 of the Clean Water Act, administered by the U.S. Army Corps of Engineers (Corps), provides the primary framework for regulating wetlands at the federal level. To manage permitting activities, the Corps has developed offsite and onsite procedures for identifying and delineating wetlands that are detailed in their wetlands delineation manual and regional supplements. The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service is another important federal wetland program. NWI uses remote sensing techniques (e.g., aerial photo interpretation with limited ground-truthing) to produce geospatial data for displaying the general location of wetlands on aerial imagery or base maps via an online mapping tool – the wetlands mapper. Disclaimers accompanying NWI data clearly state that they are not intended for regulatory purposes, but to the public, the distinction between the Corps' jurisdictional wetlands and NWI wetlands is not always clear. To better understand the overlap of NWI mapped wetlands and Corps based wetland delineations by region, wetland type and year of mapping, we are conducting a national scale study. While NWI digital data are readily available nationwide, the results of onsite wetland delineations based on the Corps manual and regional supplements are not. Consequently we are seeking Corps-approved wetland delineations to compare with NWI data. Any paper maps, or preferably digital geospatial data of wetland polygons created using Corps onsite wetland delineation methods are extremely valuable for this evaluation. We will acknowledge the source of all data used in this comparative study. This research is funded by the U.S. Army Corps of Engineers and will be conducted by David Cooper and Edward Gage, Department of Forest and Rangeland Stewardship, Colorado State University. If you can contribute or have questions, please contact us by email at David.Cooper@colostate.edu or Edgage@rams.colostate.edu. ■

This section is intended to inform readers about ongoing wetland research by various universities, government agencies, NGOs and others. When studies are completed, WSP invites short articles that address key findings, while more technical papers are submitted to Wetlands or other peer-reviewed journals. Researchers interested in posting short or more detailed summaries of their investigations are encouraged to contact the WSP editor (please include "WSP Research News" in the email subject box).

Geographically Isolated Wetlands News

Geographically isolated wetlands (GIWs) – wetlands completely surrounded by upland (Tiner 2003) – continue to be the source of much controversy regarding regulation. The term was coined in response to the Supreme Court's decision on SWANCC (No. 99–1178, January 9, 2001) to emphasize the fact that "isolated wetlands" when mapped following standard delineation practices are surrounded by nonwetland ("geographically isolated"), yet this did not mean they were not ecologically significant or connected to surface or ground waters. The September 2003 issue of *Wetlands* was devoted to reporting the significance of GIWs. Whether the term itself should be used by scientists or not is a point of contention (Leibowitz 2015; Mushet et al. 2015). Nonetheless, it has raised awareness to the plight of these wetlands. In fact, EPA's state-of-the-science report on connectivity of wetlands and streams (U.S. EPA 2015) highlighted the need for more research on GIWs, while urging cautious use of the term (e.g., not to imply lack of hydrologic or biological connectivity or functional significance). New research on their importance, especially their hydrologic linkage, is being published (e.g., Golden et al. 2015; Marton et al. 2015; Rains et al. 2015; Singh 2015) and more is expected in the immediate future. ■

REFERENCES

Gala, T.S. and D. Young. 2015. Geographically isolated depressional wetlands – hydrodynamics, ecosystem functions and conditions. Applied Ecology and Environmental Sciences 3: 108-116.

Golden, H.E., H.A. Sander, C.R. Lane, C. Zhao, K. Price, E. D'Amico, and J.R. Christensen. 2015. Relative effects of geographically isolated wetlands on streamflow: a watershed-scale analysis. Ecohydrology (February 2015). Doi 10.1002/eco.1608.

Leibowitz, S. 2015. Geographically isolated wetlands: why we should keep the term. *Wetlands* 35:997-1003.

Marton, J.M., I.F. Creed, D.B. Lewis, C.R. Lane, M.J. Cohen, and C.B. Craft. 2015. Geographically isolated wetlands are important biogeochemical reactors on the landscape. *BioScience* 65:408-418.

Mushet, D.M., A.J.K. Calhoun, L.C. Alexander, M.J. Cohen, E.S. DeKeyser, L.G. Fowler, C.R. Lane, M.W. Lang, M.C. Rains, and S. Walls. 2015. Geographically isolated wetlands: rethinking a misnomer. *Wetlands* 35:423-431.

Rains, M.C., S.G. Leibowitz, M.J. Cohen, I.F. Creed, H.E. Golden, J.W. Jawitz, P. Kalla, C.R. Lane, M.W. Lang, and D.L. McLaughlin. 2015. Geographically isolated wetlands are part of the hydrological landscape. *Hydrological Processes* 2015, online, DOI:10.1002/hyp.10610.

Singh, M. 2015. Isolated wetlands: assessing their values and functions. *Journal of Aquatic Science* 3: 6-13.

Tiner, R.W. 2003. Geographically isolated wetlands of the United States. *Wetlands* 23:494-516.

U.S. Environmental Protection Agency. 2015. Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence. Final Report. Washington, D.C. EPA/600/R-14/475F.

Student Research Grant Projects Underway, Part II

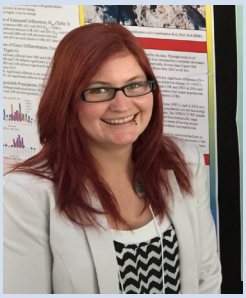
Every year, the Society awards grants through a competitive process to partially support student research in wetlands. For information on the program, visit: http://www.sws.org/Awards-and-Grants/student-research-grants.html. In the September issue, six of the 12 student projects funded in 2015 were featured. Now the remaining six are summarized. For more information on these project, contact the student investigator.

Development and application of a health indicator for vernal pool-breeding amphibians: Assessing larval physiological and morphological responses to urbanizing landscapes

Carly Eakin, University of Maine
carly.eakin@gmail.com

Throughout the northeastern USA there are conflicts between vernal pool conservation and economic development resulting from vernal pool regulations. Tragically, these same regulations do not adequately protect pool breeding amphibian habitat, and often displace development pressure to rural areas. Anthropogenic development (i.e., urbanization) is linked to diminution in the breeding populations, body condition, and survival rates of vernal pool amphibians. Characterizing amphibian health in association with various intensities of development can lead to better understanding of the pool conditions necessary to maintain healthy populations as well as the discovery of indicators of negative population response to urbanization. White blood cell (WBC) differentials can be used as a surrogate to measure the physiological (metabolic and immune condition) of amphibians. However, amphibian blood collection and slide creation methods are poorly described in the literature and typically do not detect enough WBCs to conduct statistically robust analyses. To identify the tools necessary to increase the understanding of amphibian health, I will systematically test multiple blood sampling and slide creation techniques for small larval amphibians. Additionally, I will assess the performance of the identified blood sampling technique(s) in the field, and I will submit for publication a methods paper in this new method for blood sampling techniques for relatively small larval amphibians. Development of a successful larval blood sampling technique is needed to create within-pool health profiles that incorporate measures of metabolic and immune condition. By providing a means to assess the physiological health of larval amphibians, this technique will help assess the relationship of pool condition, vegetation structure, and hydrology across urbanizing landscapes to larval amphibian health. ■

Relationship of Sphaeroma quoyanum to native invertebrate community and sediment dynamics in a southern California salt marsh



Morgan Brown, California State University, Long Beach
brown192@mail.chapman.edu

As wetland area has been lost or degraded, important functions derived from those wetlands have also been lost. Many wetland functions are tied to sediment dynamics, which are largely governed by infaunal invertebrate communities. These sediment dynamics are sensitive to changes in sediment structure and to colonization by non-native species. In a southern California salt marsh, the non-native Australian isopod Sphaeroma quoyanum has been observed, creating dense networks of burrows within the marsh banks. Since this isopod has been shown to significantly increase erosion in many areas, its possible contribution to habitat loss in this already-scarce southern California ecosystem is an important and potentially time-sensitive question. In addition to increasing erosion, this invasive species has the potential to alter invertebrate communities and sediment dynamics in areas it colonizes. By examining the population numbers and potential impacts of S. quoyanum colonization in southern California, this study will provide a baseline for future management including prioritizing eradication or restoration planning. ■

Harnessing the Interaction of Plants and Bacteria in Wetland Systems to Remediate Trichloroethylene Contaminated Groundwater

Camille Warner,
SUNY College of Environmental Science and Forestry
cwarner9642@gmail.com

Constructed wetlands have been designed to serve a variety of functions within water quality management. One of the major groundwater contaminates is the chlorinated solvent trichloroethylene (TCE). Exposure can cause damage to the liver and kidneys and it has been labeled a carcinogen by the Environmental Protection Agency (EPA). Wetlands designed to target TCE have demonstrated some level of success but the mechanism behind the degradation process is still unknown. To fill that void, this research focuses on the efficiency of uptake and degradation of TCE by wetland plants. Greenhouse microcosms will be set up with a standard wetland substrate, with and without plants. Before the addition of any plants, the substrate will be tested to determine how the abiotic and microbial components interact with TCE. Post exposure, the plant tissue will be analyzed by gas chromatography for TCE and its

metabolites while the bacterial community will be analyzed for changes in community structure. Serial dilutions will be employed to detect shifts in the soil microbial community populations. This research will shed light on the role of these mechanisms for treatment of TCE in wetland systems. The overall hypothesis is that the degradation of TCE in wetland systems is done through the interaction between abiotic, microbial and plant activities. ■

Integrating tidal freshwaters into conceptual frameworks for how hydrology structures benthic communities in wetlands

Jack McLachlan,
University of Maine
jack.mclachlan@maine.edu

Tidal freshwater wetlands (TFWs) are not well integrated into conceptual wetland ecology. Benthic communities in TFWs are apparently depauperate, but the mechanisms driving community structure are poorly understood. Twice-daily water level changes allow close examination of how hydroperiod structures wetland communities. Integrating TFWs with community models of seasonal inland wetlands provides an excellent framework for reconciling tidal and non-tidal wetland community ecology. Drying and inundation cycles exert a strong selective pressure on the traits of benthic wetland invertebrates. In ephemeral wetlands that dry and refill predictably, and remain inundated for longer than invertebrate generation time, taxa will have niche-specific life history adaptations that maximize fitness, such as seasonal emergence cues. In non-seasonal wetlands, that dry and refill unpredictably, taxa will have physiological tolerances against desiccation that allow persistence in sporadic habitats. When wetland permanence is sufficient for fish persistence, predation pressure will surpass abiotic stressors as the driver of benthic community structure. How the predictable high-frequency tidal cycles of TFWs might influence community structure is not clear. I hypothesize that the low benthic diversity of TFWs results from the dual pressures of twice daily wetting and drying, and predation by fish that can follow tides. Alternatively, variation in hydroperiod associated with tidal height may promote beta-diversity in TFWs, with uneven marsh topography providing refugia from desiccation and predation. I will manipulate drying frequency and predators in artificial mesocosms to identify shifts in community structure based on species' traits. This manipulation will be paired with multi-season surveys of benthic communities along transects of tidal-marsh height in Merrymeeting Bay, Maine – a nationally important wetland conservation area and one of the largest contiguous TFW areas in the northeast. Results from these approaches will be combined in conceptual and statistical models of how spatiotemporal variation in wetland hydroperiods influence broader scale patterns of benthic community diversity. My results will 1.) advance current understanding of how abiotic and biological drivers interact to structure communities in dynamic wetlands, 2.) help predict wetland communities responses to forecasted environmental change (e.g. sea-level rise), and 3.) unify community ecology theory across wetland types. ■

Identifying source water contributions to floodplain forest vegetation across seasonal and hydrological connectivity gradients

Mary Grace Lemon,
Louisiana State University
mlemon7@tigers.lsu.edu

Floodplain wetlands are commonly recognized as high diversity ecosystems that provide many services such as wildlife habitat and nutrient retention. In floodplain wetlands, surface water, soil water, and aquifers form an interconnected system that varies temporally and spatially, affecting the sources of water available in the soil for vegetation use. Continued degradation of floodplain river connectivity through river modification and increased human water use can significantly alter these existing hydrological networks. In southeastern bottomland hardwood forests (BLH) of the US, there is a lack of process understanding of how the composition of vegetation source water changes through time and space across a floodplain. In order to maintain ecosystem integrity under further water resource development, the temporal and spatial variation of soil moisture source water must be further investigated. We propose to test the following hypotheses (1) the influence of flood recharge on soil moisture and xylem water decrease through the growing season as soil water becomes dominated by rainfall and groundwater; and (2) the dominant hydrological processes controlling soil moisture and xylem water vary by reach, which differ in degree of river entrenchment. We will test these hypotheses by measuring the sources of water to the rooting zone and xylem using stable isotopes at White River National Wildlife Refuge (NWR). White River NWR provides a unique setting to look at the effects of degraded connectivity on subsurface hydrology due to its location within a large regulated watershed. Spatial and temporal variations in the relative importance of various sources of water (precipitation, surface flooding, groundwater) to the rooting zone and in the xylem will provide information about potential threats of further water development to floodplain vegetation. ■

Using North American beaver (Castor Canadensis) to create wetlands: the ecology, hydrology, and geomorphology of semi-arid streams restored by beave dam building activity

Nate Hough-Snee,
Utah State University
nate@natehough-snee.org

North American beaver (*Castor canadensis*) are a widespread ecosystem engineer that modify streams and create wetlands across their range. Beaver build dams from rocks, mud and herbaceous and woody vegetation, impounding streams and creating physically and biologically diverse stream-wetland complexes. These dams often provide hydraulic and hydrologic diversity that shape the ecology and geomorphology of stream networks. In the arid and semi-arid American West, these dams may create expansive wetlands in otherwise dry landscapes. Because of the many positive feedbacks between beaver dams, valley-bottom wetland evolution, and aquatic habitat diversity, beaver are being reintroduced within their native range to restore degraded streams and wetlands. Here we ask the question: how do stream channel form, and riparian vegetation develop in incised stream reaches following beaver emulation and reintroduction? Our objective is to characterize the evolution of Basin Creek, an incised stream in northern Utah (USA), as it develops during hydrogeomorphic and ecological restoration from beaver dam building activities. Pre-restoration monitoring was undertaken in the summer of 2014 with base measurements for stream discharge, channel form, geomorphic units, and vegetation control points being collected. Stream restoration occurred in October 2014 with 40 beaver dam analogs being installed and one beaver reintroduced to the watershed. The project will be monitored at several reaches using geomorphic change detection, stream surveys, and remote-sensing to assess vegetation change. We anticipate that sets of beaver emulating dam analogs (BDAs), each designed with specific hydrogeomorphic hypotheses, will work in concert to accumulate sediment and aggrade the channel bed. Similarly, we expect BDAs designed to be colonized by beaver, built up by beaver, creating large pools that also accumulate sediment and aggrade channel beds. Increased water retention behind beaver emulating and beaver colonized BDAs will likely increase riparian water tables, and are anticipated to increase aerial wetland vegetation cover in some restoration areas. These multiple levels of evidence will allow UDWR and the larger stream/wetland restoration communities to identify how quickly incised streams aggrade following beaver reintroduction and emulation, allowing project designers to set realistic goals for restoration when using beaver-based restoration approaches. ■

FROM THE FIELD

This section provides SWS members with an opportunity to post some of their favorite wetland photos. The intent is to display pictures recently taken, but we'll welcome any outstanding images you want to share with readers. The number of pictures displayed will be limited so all your submissions may not be posted in one issue. We'll see how this works over time.

This issue contains a couple of photos from Dr. David Cooper's trip to China and images highlighting fall foliage in New Jersey, and a photo of a young diamondback terrapin by Michael Payton. ■

CHINA FENS, PHOTOS BY DAVID COOPER, COLORADO STATE UNIVERSITY

Site of climate warming study in alpine meadows and fens being conducted by Dr. Yongheng Gao, Chinese Academy of Sciences, Chengdu, China. 3800 m elevation.

Grazed and ungrazed fen - fence line shows contrast of heavy yak grazing in alpine fen, Hongyuan County, located on the eastern Qinghai-Tibetan Plateau, China. This fen extends to the distant mountains. 3850 m elevation.

FALL FLORA IN NEW JERSEY, PHOTOS BY RALPH TINER

ARROWWOOD
(*Viburnum dentatum*)

BLACK GUM
(*Nyssa sylvatica*)

DANGLEBERRY
(*Gaylussacia frondosa*)

FETTERBUSH, in flower due to warm weather
(*Eubotrys racemosa*)

GRAY BIRCH
(*Betula populifolia*)

HIGHBUSH BLUEBERRY
(*Vaccinium corymbosum*)

LEATHERLEAF
(*Chamaedaphne calyculata*)

MALEBERRY
(*Lyonia ligustrina*)

PIN OAK
(*Quercus palustris*)

POISON IVY
(*Toxicodendron radicans*)

RED CHOKEBERRY
(*Aronia arbutifolia*)

RED MAPLE
(*Acer rubrum*)

SASSAFRAS
(*Sassafras albidum*)

SWEET GUM
(*Liquidambar styraciflua*)

SWEET PEPPERBUSH
(*Clethra alnifolia*)

WINTERBERRY, ripe with berries
(*Ilex verticillata*)

SOME ANIMALS OBSERVED IN NEW JERSEY WETLANDS

DIAMONDBACK TERRAPIN
(*Malaclemys terrapin*)
Photo credit: Michael Payton

RED-BELLIED TURTLE OR COOTER
(*Pseudemys rubriventris*)
Photo credit: Ralph Tiner

SPRING PEEPER
(*Pseudacris crucifer*)
Photo credit: Ralph Tiner

WETLAND BOOKSHELF

The following are a list of some recent publications that may be of interest. If you know of others please send the information to the WSP Editor (rtiner@eco.umass.edu) for inclusion in future editions of Wetland Science and Practice.

BOOKS

- 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 http://www.pineapplepress.com/ad.asp?isbn=978-1-56164-687-6
- 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

ONLINE PUBLICATIONS

U.S. ARMY CORPS OF ENGINEERS

- 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

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-onestop/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.
- 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/

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

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 http://link.springer.com/journal/11273

NEWSLETTERS

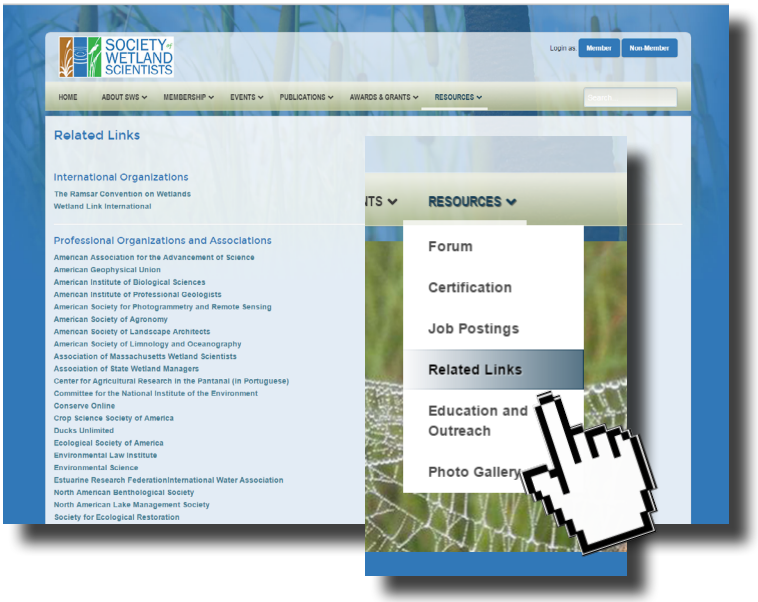
- Biological Conservation Newsletter (this monthly newsletter contains a listing of articles that include many that address wetland issues – current and others back to 1991 in the "Archives") http://botany.si.edu/pubs/bcn/issue/latest.htm#biblio
- Wetland Breaking News (Association of State Wetland Managers) http://aswm.org/news/wetland-breaking-news
- National Wetlands Newsletter (Environmental Law Institute) http://www.wetlandsnewsletter.org/welcome/index.cfm

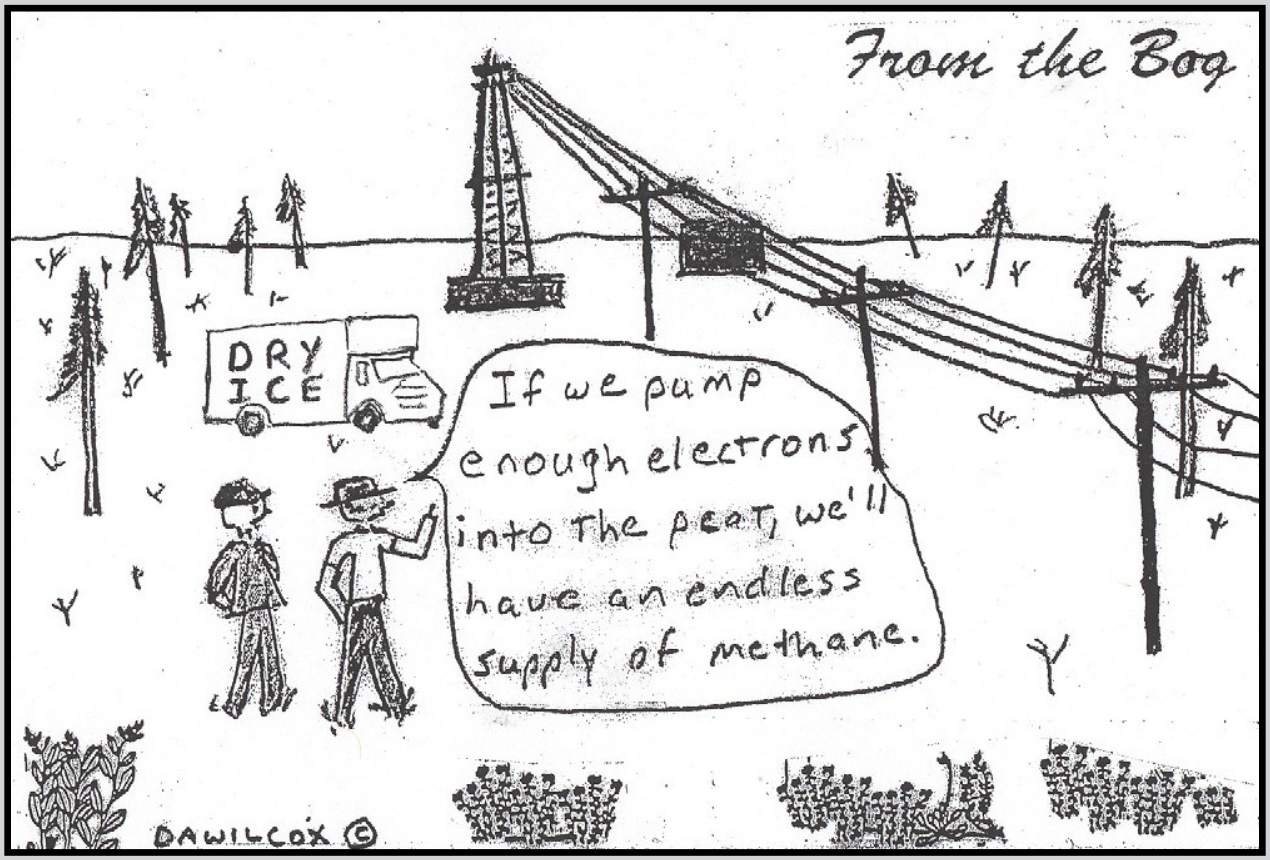
WEB TIP

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 **at sws.org.**





Electrofracking for methane

wetland science & practice

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