wetland science & practice

published by the Society of Wetland Scientists
Vol. 32, No. 2 June 2015

FROM THE EDITOR'S DESK

On May 2 I retired from the U.S. Fish and Wildlife Service. After 38 years I've decided to turn the pages to a new chapter in my book of life. My time working on the National Wetlands Inventory (NWI) has been an experience like what the Army seeks to offer young people in its marketing campaign – Be the Best You Can Be … Join the Army. In joining the Service's NWI Program as Regional Wetland Coordinator for the Northeast in April 1977, I was given the opportunity to be the best I could be – to help build a program from the very start. I thank the Service for that opportunity and for the past support for the program. Those of us who have worked on the NWI have been able to provide the Nation with a database and reports that have assisted efforts to improve wetland conservation across the country. The status of wetlands has greatly improved since the 1970s when filling of salt marshes for real estate was a common practice. Early conservation efforts were on getting laws, regulations, and policies in place to reduce wetland losses. Later efforts gave attention to improving wetland delineation practices, restoring and rehabilitating wetlands, while continuing to strengthen regulations and protect wetlands through acquisition. Since my work for the Service has been such an important part of my life and an overwhelmingly positive experience, the thought of retirement was somewhat unsettling. The "completion" of wetland mapping and changing agency priorities made this decision quite a bit easier. I've had several months to prepare for this change. In fact, my response to a notice on the editorship of *Wetland Science & Practice* one year ago was one step in my preparation for retirement…it would keep me engaged in the field.

Ralph Tiner
WSP Editor

At this point I've been editor for one year and while I am pleased with the response to the new look and interest in submitting articles for publication, we still need more folks to contribute. Many of you have presented talks at our annual meeting in Providence and with a little more work, you could turn those presentations into a WSP article that could reach more of our members and eventually many others when the issue reaches its year-old status and is then released for full public access via the internet.

This issue marks the changing of the guard as Jim Perry turns over the Presidential reigns to Kim Ponzio – see their joint letter. Highlights of our current issue include the first state-of-the-science report which addresses floristic quality assessments, articles on wetlands in western Ireland and the use of SLAMM for coastal planning on U.S. National Wildlife Refuges, SWS recommendations on Taiwan Salt Pond wetland restoration and news from the Pacific Northwest Chapter. I've also included some spring observations from my recent travels in "Notes from the Field." Thanks to all who have contributed to this issue.

Hope you all enjoy this issue and get inspired to contribute to future issues.

Happy Swamping. ■

CONTENTS

Vol. 32, No. 2 June 2015

Cover photo:
Mersey River wetlands, Nova Scotia
Photo by Ralph Tiner

www.sws.org

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

PRESIDENT'S MESSAGE

Well, this year has passed so quickly that my head seems to be spinning. A number of issues have been resolved and many more have been taken under consideration. By the time you read this letter, my tenure as SWS Prez will be over and the very competent Prez Kimberli Ponzio will have taken her post as your new leader. Therefore, we have decided that both of us will write the following update.

James E. Perry, PhD, PWS
SWS President

Kimberli Ponzio, PWS
SWS President-elect

SWS Annual Meetings: As we write this, our 2015 meeting in Providence is in great shape. With a theme of "Changing Climate, Changing Wetlands" we have many opportunities to attend symposia, field trips, and workshops. We hope you are able to attend. The SWS 2016 meeting will be held in Corpus Christi, Texas, beginning May 31st, 2016. Contracts have been signed and the South Central Chapter's planning committee, headed by Scott and Jayme Jecker, is in the process of setting up symposiums, sessions, fieldtrips, etc. We are looking forward to our first SWS Annual Meeting in Texas.

The South Atlantic Chapter (SAC) will be hosting the 2017 meeting in Puerto Rico. Staff has identified an appropriate venue and the SAC presented a proposal for the meeting that has been accepted by the Future Meetings Committee and approved by the Executive Board. More on this in the future. We have asked the Future Meetings Committee to:

1. Adopt a rotating SWS Annual Meeting Plan by dividing the US into geographic sectors and assigning those sectors with responsibility for future annual meetings. The geographic sector designation will allow small SWS chapters to align themselves with other chapters in order to be able to propose and sponsor SWS annual meetings.
2. Develop a set of criteria that defines the minimum information necessary to constitute a complete proposal for sponsoring a SWS Annual Meeting. The criteria will be presented in an RFP that can be sent to the Chapters located in a geographic sector that is pre-designated for that year's meeting.

International Regional Meetings: We are working on a plan to develop Regional International Meetings. If SWS truly wishes to become an international society, it needs to align itself closer to INTECOL and other like-minded organizations. Furthermore, we need to support our international Chapters. To do so, we propose that we establish Regional International Meetings (RIM) that will be held in conjunction with future INTECOL and other sister organizations' meetings held outside of the U.S.

continued on page 10

Recommendations for Taiwan Salt Pond Wetland Restoration

James E. Perry, Kimberli J. Ponzio, and John Bourgeois

In October 2014, we were invited to participate in an international wetland workshop hosted by the SWS Asia Chapter and the Taiwan Construction and Planning Agency in Taiwan. The focus of the workshop was wetland restoration of non-active salt ponds found along Taiwan's west-coast. The exchange involved a series of wetland restoration site inspections, as well as, meetings with multiple government agencies, NGOs, academia, and other stakeholders involved in wetland restoration efforts in Taiwan. Following the meeting, we were asked to develop a series of recommendations to advance wetland restoration in Taiwan.

Firstly, we would like to acknowledge the work that has already been accomplished by the cooperating Taiwan organizations that are interested and involved in wetland restoration. These groups have made significant progress in forwarding wetland restoration in Taiwan. While Taiwan may still be facing some challenges, we believe that the Taiwan Construction and Planning Agency (CPA) is currently presented with an excellent opportunity to restore and enhance wetlands and salt ponds of significant importance in the region. The following recommendations, therefore, are made in the spirit of professional cooperation.

RECOMMENDATIONS

ORGANIZATIONAL CONSIDERATIONS

Planning. It is important for ecosystem restoration projects to take a long-term view with regard to project success, and to resist focusing on the monitoring results in any one year. This planning process involves several key steps/concepts:

- *Rules of Engagement* – To leverage the strength of all stakeholders, a series of meetings should be held in a neutral location and may require the help of a professional facilitator to keep the meetings positive, productive, and engaging. This is meant to build trust and foster relationships among stakeholders. When developing a robust planning process, it is critical that everyone feels that they have a voice and that their input will be heard. During the process, respect for all points of view is very important, and open communication is paramount. Intentional communication should be consistent and planned at regular intervals.
- *Goals* - Planning begins with defining the group vision and goals of the restoration project. This may be the MOST important step in a multi-purpose project. When challenges are encountered, referring back to the goal is critical. We recommend using a SMART Goal approach:
  - S = Specific
  - M = Measurable
  - A = Attainable
  - R = Realistic
  - T = Timely

  For example, for the South Bay Salt Pond Restoration Project, a SMART goal would be to "restore natural hydrology and sedimentation patterns that would support the development of vegetated marsh habitat within 15 years". These parameters meet all of the SMART criteria. This would be in contrast to a non-SMART goal of "restoring habitat for the endangered California Clapper Rail", because the return of a single species to a particular site may be due to conditions outside of our control.
- *Roles/ Responsibilities* – The designation of the roles and responsibilities of the entities involved is an important component in the structure of a successful project. This involves multiple engagements with all the stakeholders and may be a lengthy process. In the United States, through trial and error, we have found it most efficient to have a single government agency lead the process, although ultimate decision-making may be shared. We recommend a similar approach in Taiwan.
- *Diversification* – To minimize risk, plan to provide a diversity of habitats, such as salt ponds, mudflats, and vegetated wetlands. See Multi-Species Management section below (under *Scientific Considerations*).

Multi-Use Projects. Cultural, social, political and ecological considerations are not always at odds with each other, and projects should look for ways to achieve multiple benefits that reinforce success to a diverse group of stakeholders. Wetland restoration projects can directly support jobs, but also provide enhanced eco-tourism and unique educational and training opportunities.

Wise-Use. The RAMSAR Convention defines "Wise Use" as: *"…the maintenance of their [wetland] ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development"* (Ramsar 2005).

While it is important to include multi-uses, such as cultural and social considerations, it is also important to note that the Ramsar wise use definition "… *implies that wetland conservation need not exclude the human element but rather make human use a promoting [emphasis ours] factor for the sustainable management of wetlands…. The concept's application is crucial to ensuring that wetlands can continue to fully deliver their vital role in supporting maintenance of biological diversity and human well-being*" (MedWet 2014). We also need to note that when accepting the Ramsar definition of wise use, a government also accepts Ramsar's concept of "wise use management", which emphasizes that the natural properties of the wetlands be maintained (Ferrier and Tucker 2000). Therefore, it is important to find a mix of multi-purpose projects that do not hinder the benefits that the wetland provides to society.

Pilot/Demonstration Projects. We strongly recommend that a small pilot project be undertaken in order to demonstrate how the science and restoration process provides tangible benefits to the people of Taiwan. Small projects that provide an example of what can be accomplished by the organizations involved, will establish trust and build consensus for future projects that may be larger, involve more stakeholders, and be more complex.

Metrics of Success. Monitoring key elements of the restoration project is needed in order to determine if the project meets planned goals. A plan for adaptive management (a mechanism to adjust the course of a project based on science or monitoring results) should be used to ensure the project is brought back-on-track. Build in the expectation for inter-annual variability and have a long-term vision for success.

SCIENTIFIC CONSIDERATIONS

Multi-Species Management. Experience has taught us that it is difficult to manage for a single species. Year-to-year variation in migratory patterns (birds), natural environmental conditions (plants and animals), and natural changes in population patterns, make determination of success of single species difficult, if not impossible. Monitoring of single species is also very difficult as they do not always act predictably.

Multi-species management involves identifying an assemblage of important species (plants and animals) that use the habitat, including umbrella species such as the black-faced spoonbill. Habitat suitability over time can be determined by vegetation processes, water quality, sediments and soil, as well as other environmental characteristics of the site.

Connectivity/Watershed Approach. The physical processes that define a successful wetland restoration do not begin at the boundary of any single project. Opportunities should be pursued to remove the boundaries between habitat types to improve connectivity for aspects such as sediment and nutrient exchange and wildlife movement.

Monitoring Protocol. A monitoring protocol should be developed with the project's metrics of success in mind. Variables that should be considered may include, but are not limited to, characteristics and dynamics of hydrology, water quality, vegetation, invasive species, and fauna. Regular reporting of monitoring results to all stakeholders, regardless of the results, reinforces transparency and trust.

Sustainability/Natural Processes. Minimize reliance on management and design projects to rely, as much is practicable, on natural processes to drive the environmental parameters of the system. Projects that are designed around passive/natural processes will be more resilient, require less maintenance, and are typically less expensive.

Once again, we would like to congratulate the CPA and the Taiwan Wetland Society (TWS) on the great progress that has been made in Taiwan in the field of wetland restoration due to their diligent efforts. We are enthusiastic about the opportunities that we have observed in Taiwan, and we look forward to further collaboration with CPA and TWS to achieve improved wetland habitat functions in the region. ■

REFERENCES

Farrier, D. and L. Tucker. 2000. Wise use of wetlands under the Ramsar Convention: a challenge for meaningful implementation of international law. *Journal of Environmental Law*, Vol. 12(1):21-42.

MedWet accessed 24 Oct 2014: http://medwet.org/aboutwetlands/ramsarconvention/).

Ramsar 2005. Resolution IX.1 Annex E . 9th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971). (accessed on line Oct. 25 2014: http://www.ramsar.org/sites/default/files/documents/pdf/res/key_res_ix_01_annexe_e.pdf)

Pacific Northwest Chapter Update

Nate Hough-Snee, SWS-PNW President

April showers bring May's flowers, so the saying goes. And this year, much of the Pacific Northwest really needed those showers. As we round the corner from early spring into May, the American West's snowpack is amazingly low. In fact, snow-water equivalents are at record lows across much of North America. The USDA/NOAA drought monitor indicates that drought affects *a portion of every state in the West*. At the time of writing, nearly *55-million people are affected by drought* in the American West. Many stream flows have peaked well in advance of their average historic dates while some ephemeral wetlands haven't been wet since the New Year. At least the coastal wetlands have water.

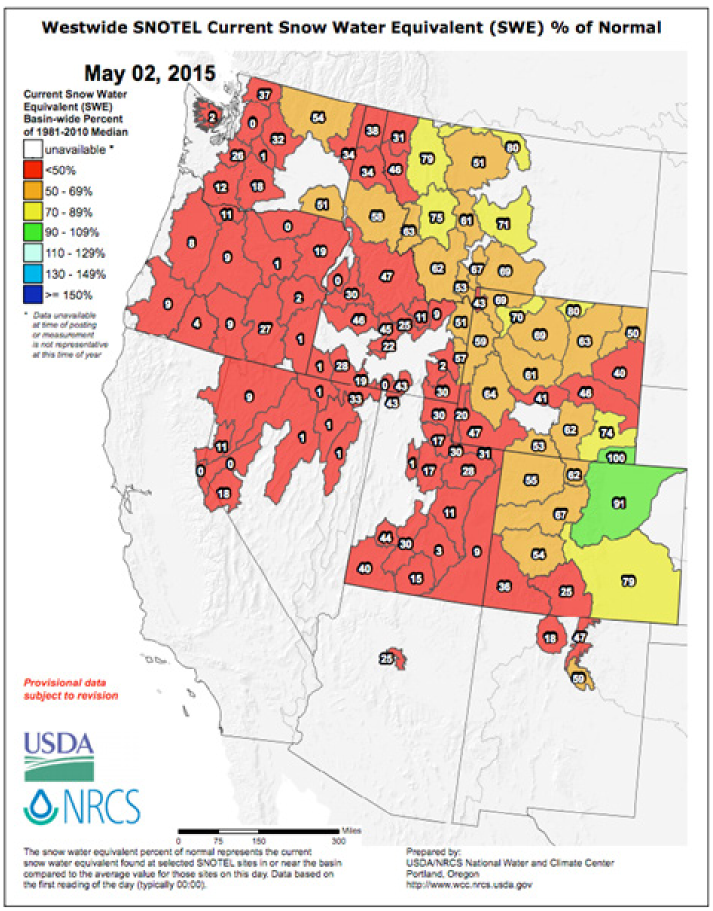


Figure 1. May 2, 2015 snow water equivalents for select basins of the American West. All regions excluding Colorado's northern front range are below average. Low snow areas include all of Washington, Oregon and Idaho. This map updates in real time at: http://www.wcc.nrcs.usda.gov/ftpref/data/water/wcs/gis/maps/west_swepctnormal_update.pdf

If you are a skier within the Pacific Northwest (PNW) chapter's focal regions of Washington, Oregon, and Idaho, then you certainly feel the pain of this hard water year. Ski areas were open as little as forty days in both Washington and Oregon. Backcountry snowpack was centimeters above non-existent. Even usually consistent mountain snowpacks, like those around the famed Mt. Baker Ski Area (WA) and Timberline at Mt. Hood (OR), were at or near record lows. At least the Northwest's other gems, running, kayaking, hiking and cycling were good, right? While this article sounds like it's about skiing, it isn't. Really this discussion is about the West's drought amid an uncertain climate future, especially in the Pacific Northwest chapter's backyard. This article is about weather, climate, and our changing world – and the role that wetland scientists must play in shaping the future moving forward.

As wetland scientists, we often enjoy multiple levels of evidence, and consider as much current science as possible when doing our professional duties. Amid our short-term, day-to-day work though, climate change isn't often the first thing we step up to talk about. We work under regulatory frameworks that strive to accommodate the best available science in real time. We design restoration with reference biological, hydrologic and geomorphic conditions that incorporate how these processes have, should, and could function. We provide information to the public, our clients, and scientific community, striving to be current and accurate. But the world is changing. Quickly.

Our understanding of how global and regional climate shapes weather, like the warm, dry winter that can lead to the red blobs in these figures, is rapidly evolving. A recent paper by Simon Wang and others at the Utah Climate Center showed that warming sea surface temperatures are responsible for anomalous weather like last year's high pressure ridge that allowed California to further dry out to its present state. Last year the Intergovernmental Panel on Climate Change (IPCC) released a new report: climate change is likely irreversible, caused by greenhouse gas emissions, and the effects will be widespread. In the same year, the National Climate Assessment issued their report on how climate change will affect the U.S., with detailed sections on geographic regions' vulnerability to change, including the Northwest. These larger efforts have laid a framework for panels commissioned within the PNW Chapter states of Washington and Oregon among others.

So, in short, climate is changing, it's influencing the weather regimes and hydrogeomorphic processes that shape our region's characteristic streams, rivers, and wetlands. Within the Pacific Northwest Chapter, we're used to state and federal agencies, non-profits, conservation planners, and researchers actively considering the IPCC's technical reports and regional studies in decision-making for over a decade. So what? How does climate change come into my professional identity as a wetland scientist?

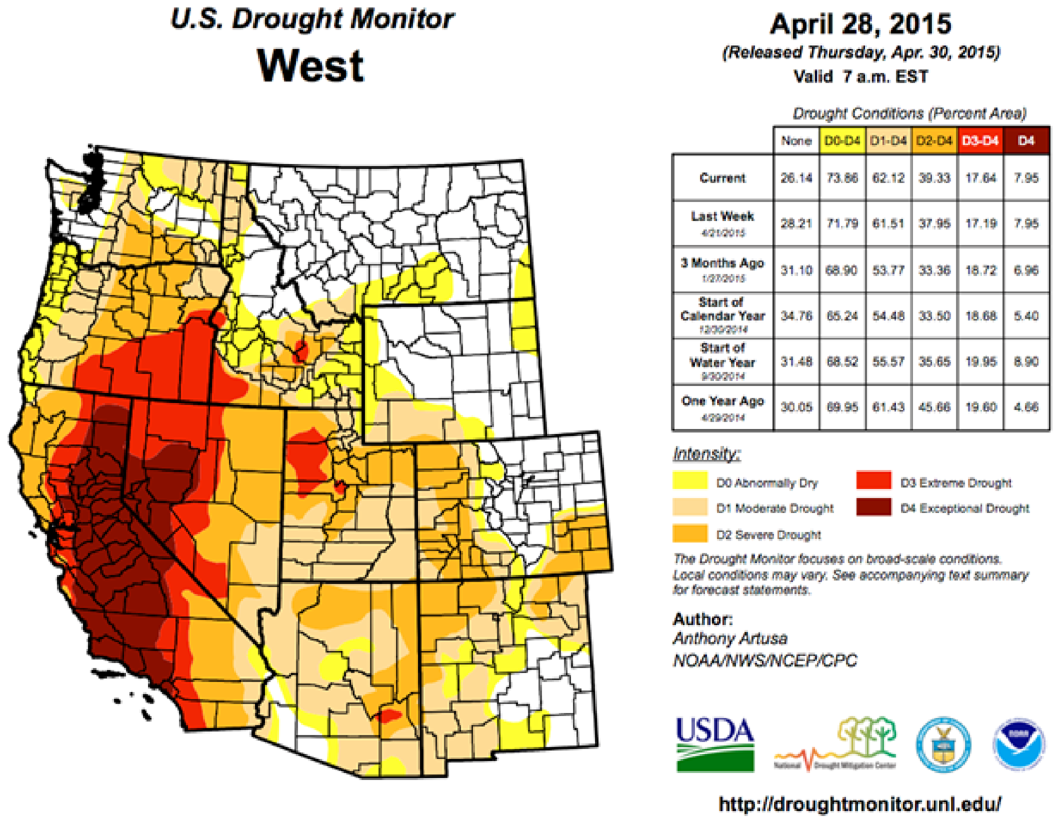


Figure 2. April 28, 2015 drought monitor. Abnormal to moderate drought are the best-case scenario across much of the West. Much of Washington, Oregon, and Idaho have slipped into abnormal, moderate or severe drought. Semi-arid and arid portions of Idaho and Oregon are in extreme drought. This map is available at: http://droughtmonitor.unl.edu/Home/RegionalDroughtMonitor.aspx?west

The mission of the Society of Wetland Scientists (SWS) is "…to promote understanding, conservation, scientifically based management and sustainable use of wetlands throughout the world." Alongside the Society's larger mission, the Pacific Northwest Chapter strives to enhance the professional development of our membership, maintaining the Northwest as a hotbed of highly qualified, cutting-edge wetland scientists. To this end, I encourage our chapter to stay current in how climate change, among other pressures, is shaping and will shape our Northwest.

To this end, I have a few suggestions, many of them reiterations from elsewhere in the literature, on how SWS can fit into this discussion…

Stay current. Many of us jump at the opportunity to familiarize ourselves with updated National Wetland Plant Lists, EPA Rules, and hydric soil field indicators. We should engage the climate change literature and climate-related professional training opportunities with the same fervor. Seek out the wealth of information on how climate change may shape your region, state, and watershed (Lawler et al. 2010).

Stay open-minded. While we often design wetland restoration projects with specific hydrologic and biological targets, such as those required for compensatory mitigation, these targets may be unrealistic under anomalous future conditions. Practitioners and scientists must consider a range of potential trajectories for ecosystems in the future, embracing and communicating uncertainty. Learn from existing projects that build on anomalous weather events and long-term project data (Zedler 2010; Reich and Lake 2014).

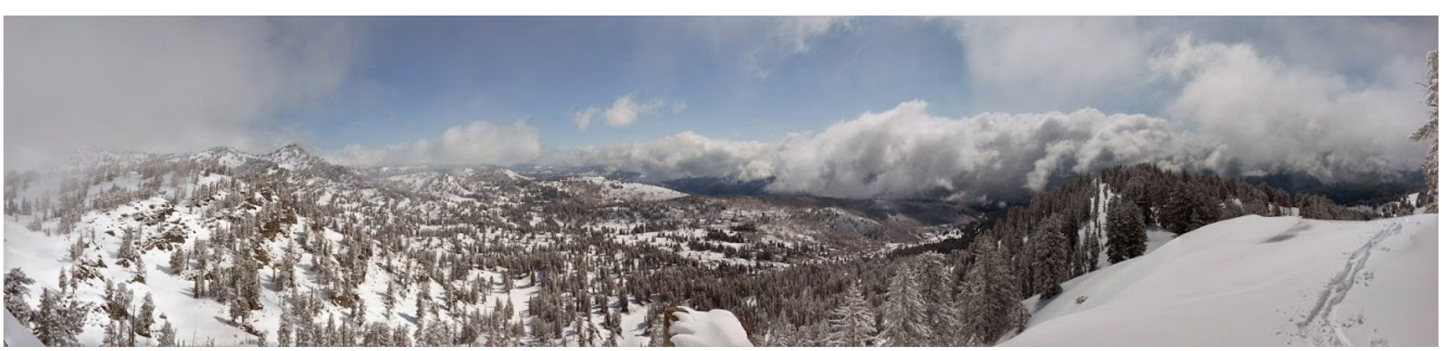


Figure 3. May snow isn't going to undrought figures one and two. Mother's Day 2015 in the Naomi Peak Wilderness, Utah. (True story: I called my Mom from the ridge.)

Stay connected. Wetlands are dynamic systems, and accordingly, they are connected to the landscape through multiple paths. When identifying threats to wetlands and potential conservation opportunities, put wetlands into a broader landscape context alongside the standard hydrogeomorphic contexts (Nadeau and Rains 2007).

Keep the forest in the context of the trees. While climate change has the potential to reshape our wetland and water resources, so do short-term processes including land and water degradation, pollution, and aggressive invasive species. Climate change will not trump these ecosystem effects in the short-term. It will interact with them, perhaps in novel ways (Junk et al. 2013; Herrick et al. 2013).

Get and stay involved If you're reading this, chances are that you're already a member of the Society of Wetland Scientists. In the spirit of my first four suggestions, I recommend getting involved with one of the Society's many sections that are involved in climate and global change issues. Additionally, climate change and global change are recurring themes at our Society's national and chapter meetings. I encourage you to share your work and stay networked with your fellow wetland professionals and students. The current PNW chapter meeting is scheduled for October 6-8 in Olympia, Washington (see below). All information will be disseminated through our chapter's website. Abstracts are currently being accepted and you'll find more details here and in Wetland Science and Practice. ■

A version of this article appears as the President's Corner in a recent version of ***Ooze News****, the newsletter of the SWS Pacific Northwest Chapter.*

Figure 4. Goodell Creek, the uppermost undammed tributary to the Skagit River, WA. Climate and human-use intersect across the world and the Northwest.

REFERENCES

Herrick, J. E., O. E. Sala, and J. W. Karl. 2013. Land degradation and climate change: a sin of omission? *Frontiers in Ecology and the Environment* 11:283–283.

Junk, W. J., S. An, C. M. Finlayson, B. Gopal, J. Květ, S. A. Mitchell, W. J. Mitsch, and R. D. Robarts. 2013. Current state of knowledge regarding the world's wetlands and their future under global climate change: a synthesis. *Aquatic Sciences* 75:151–167.

Lawler, J. J., T. H. Tear, C. Pyke, M. R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, L. Hannah, K. Klausmeyer, A. Aldous, C. Bienz, and S. Pearsall. 2010. Resource management in a changing and uncertain climate. *Frontiers in Ecology and the Environment* 8:35–43.

Nadeau, T.-L., and M. C. Rains. 2007. Hydrological Connectivity Between Headwater Streams and Downstream Waters: How Science Can Inform Policy1: Hydrological Connectivity Between Headwater Streams and Downstream Waters: How Science Can Inform Policy. *JAWRA Journal of the American Water Resources Association* 43:118–133.

Reich, P., and P. S. Lake. 2014. Extreme hydrological events and the ecological restoration of flowing waters. *Freshwater Biology*:n/a–n/a.

Zedler, J. B. 2010. How frequent storms affect wetland vegetation: a preview of climate-change impacts. *Frontiers in Ecology and the Environment* 8:540–547.

SWS-PNW Conference Abstracts Being Accepted Now

SWS Technical Sessions Committee

The Society of Wetland Scientists Pacific Northwest Chapter is pleased to announce that the call for abstracts is open for the 2015 Chapter meeting, *From a Watershed Perspective: Integrating Science into Policy*, in Olympia, WA this October 6-8, 2015. Please submit your abstract directly at: http://www.sws.org/pacific-northwest-chapter.

Abstracts for posters and presentations will be accepted until August 1st, 2015 and notifications of abstract reception and acceptance will occur on a rolling basis. Talks and posters on all wetland and wetland-related topics are welcome. These topics can take the form of research, case studies, methods, policy discussions, etc.

Student volunteer opportunities and scholarships will be available. Presently, we plan to offer four $500 awards to subsidize student attendance at the Chapter Meeting. Student volunteers will have the opportunity to gain a free registration in turn for volunteering at the meeting as moderators, registration or AV assistants.

Please stay tuned to the chapter website for more information.

The conference hashtag on Twitter will be #SWSPNW2015

Email abstract and general conference inquiries to swspnw.meeting@gmail.com. ■

President's Message continued from page 3

SWS will provide support for the regional International SWS Chapter where the INTECOL meeting is being held. This could include, but not be limited to: 1) support for coordinating and organizing the RIM and 2) funds to help support travel, lodging, and/or registration fees for chapter members to attend both RIM and INTECOL meeting. We are currently working with the SWS Asian Chapter, SWS staff, and Julia Cherry, our Treasurer, to identify SWS funds to provide support for a SWS Asian Chapter Meeting in conjunction with INTECOL 2016 in China.

Wetlands: Our flagship journal, *Wetlands*, continues to offer the most up-to-date science on wetland topics from around the world. We are seeing more papers than ever from countries outside the U.S., making it a truly international journal of the highest caliber. In order to bring that resource to you wherever you are, our Chief Editor, Marinus Otte, and Springer are rolling out a *Wetlands* App so that you can access the articles anytime and anywhere.

Policies and Procedure Manual (PPM): Thanks to Steve Faulkner, our past Prez, and Michelle Czosek, our AMPED staff representative, we now have a complete revamp of our Standing Rules and PPM. This has been an on-going process that has taken several years: we'd like to thank them for their diligence and perseverance to get this accomplished.

Strategic Plan: The Strategic Plan ad-hoc committee, chaired by Dr. Jan Keough and comprised of Drs. Frank Day, Christina Zomeren, Jason Smith, and Ms. Michelle Czosek (AMPED staff) has completed their task and presented their proposed a 2015-2020 SWS Strategic Plan. Over 41 of your SWS leaders, including past and current members of the Executive Board, Chapter and Section Chairs, Committee Chairs, Editors, and special representatives, were asked to provide input on a survey produced by the committee explicitly for the purpose of reviewing the strong points of the last strategic plan and working them into a new, productive way forward for SWS.

SWS Logo: Over the past several years there have been a number of requests from members to "update" the SWS logo. Therefore, we decided to allow the membership to decide if they wanted to keep the old logo or to move onto a new one. Staff worked to develop new logos, as well as, designing a sharper version of our existing logo. We then put the question out to the members – do we keep the old or adopt the new? We had 832 members vote: over 73% voted for a new logo. Therefore, we now have an updated logo. It has been added to our letterhead and is also available on SWS apparel that members can proudly wear to show there support of SWS and wetland science. However, the interest in a new logo brought up another point: the old logo had a very significant history. Therefore, in order to keep a record of our history, we have appointed an ad-hoc committee to compile the past history of SWS in a manuscript form. Charlie Newling, a founding SWS member and old timer in his own right, has agreed to head up the committee. We are looking for others who may have knowledge of the founding of SWS to help us preserve our history. So please, if you have any historical information on the humble beginnings of SWS, please let Charlie know.

State of the Science WSP Articles: The first of our State of the Science (SOTS) articles appears in this issue of WSP. These SOTS are designed to provide our members with the most recent thoughts on specific wetland topics and are written by chosen experts in their field. We have another SOTS on the impact of fracking (both positive and negative) coming out in the next WSP. We would like to continue SOTS in the future and will be looking for ideas/authors. It is likely that a SOTS dealing with the topic of Changing Climate - Changing Wetlands will follow soon after the Providence meeting. If you would like to see a specific wetland topic SOTS review, please let your SWS representatives know.

LOOKING TO THE FUTURE

Membership and Students: SWS continues to grow in membership and we now have over 3,200 members. SWS efforts to support students are evident in the number of student members (400+), the engagement of students in the Annual Meeting, and the addition of three new Student Associations at the University of Rhode Island, California State University (our first in the western U.S.), and the Mid-Atlantic Chapter Student Association. In addition, our Gratis membership program, administered by Secretary-General, Loretta Battaglia, remains vibrant. We hope to evaluate the effectiveness of this program in the coming year to determine if there are innovative ways to keep these members active and engaged in SWS even after their gratis terms are over.

Finances: The financial outlook for SWS is looking quite bright. Our new financial investments are paying dividends that can be used to finance several existing programs and new initiatives in the coming year. Under the direction of our treasurer, Julia Cherry, and the Ways and Means Committee, we will be devising ways to evaluate the performance of our investments and a plan to use those funds to fuel a new Chapter Grant program that was discussed by the Board of Directors last year.

Webinars: As we strive to communicate wetland science in a new electronic age, we will go (some of us happily and some of us kicking and screaming) boldly into the world of what we call e-engagement. A team of SWS members that make up the newly formed Webinar Subcommittee, led by Jeff Trulick, will forge ahead with an initiative to begin this adventure with a Webinar Series. All the pieces are falling into place and we are striving to roll it out by fall 2015. Seriously, don't worry…it'll be alright. While this e-engagement will never replace interacting with fellow scientists in person, it will give us a powerful tool to enhance communication and the study of wetlands across countries, oceans, and time zones.

FINALLY…

From Past Prez Jim: Finally, it's time for me to move aside and yield the leadership of SWS to my more than competent (and much better looking) successor. I have truly enjoyed my time as Prez, but honestly have to tell you it would have been an onerous, if not impossible task, without the help of many people. SWS staff, especially Michelle, Brittany, Lynda, and Greta, have worked hard to keep me on task (one hel# of a task!). Executive board members Steve Faulkner, Kim Ponzio, Julia Cherry, and Loretta Battaglia have always been there when I needed guidance (which was quite often!). And the most important point – thanks to the many members who volunteered, offered advice, and called me out onto the carpet. Without you SWS would not exist!

From New Prez Kim: As the incoming President, I think I have some very big shoes to fill by following Jim (I mean kayaking sandals)! I have appreciated his advice and consensus-building attitude and look forward to the year ahead. We have a great team of volunteers on the Executive Board, the Board of Directors, Committees, Sections, and SWS Members and together with the dedicated staff at AMPED, we have exciting times ahead of us. I look forward to the opportunity to lead this team in defining SWS and its members as the leaders in wetland science. ■

ADDITIONAL RESOURCES

Subscribe to Wetland Breaking News

The Association of State Wetland Managers produces a monthly newsletter that summarizes current events on wetlands – *Wetland Breaking News*. This is largely a collection of news clips addressing wetland issues. Access the latest issue at: http://aswm.org/news/wetland-breaking-news/892-current-issue#national. Past issues can also be accessed there. Sign up to be put on the mailing list.

Video Available to Aid in Using Wetlands Mapper

The U.S. Fish and Wildlife Service has produced a video tutorial to help people use the National Wetlands Inventory's "Wetlands Mapper." To access, go to: https://www.youtube.com/watch?feature=player_detailpage&v=CB398gj3O04

Past Issues of *Wetland Science & Practice* to Go Public

On February 6, the Society's Board of Directors voted to allow free public distribution of past issues of WSP. This means that all issues published prior to the June 2014 issue will soon be available via the internet. More recent issues will also be phased in for distribution as they reach the one-year threshold. This means that the audience for WSP articles is virtually limitless. Such availability will hopefully stimulate more interest in contributing to the journal. We are working out the details for distribution and welcome this opportunity that will promote the good work done by our members.

STATE-OF-THE-SCIENCE REPORT
Trends in Floristic Quality Assessment for Wetland Evaluation

Douglas A. DeBerry[1], Department of Biology/Environmental Science and Policy Program, College of William and Mary,Williamsburg, VA, Sarah J. Chamberlain, Riparia, Pennsylvania State University, University Park, PA, and Jeffrey W. Matthews, Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, Urbana, IL

Over the past two decades, much has been written about the use of bioassessment tools to evaluate wetland condition. Interest in bioassessment has originated from a need to establish parameters for "biological integrity" in wetland ecosystems, whether for scientific research, natural areas assessment, inventory and monitoring, or in response to regulatory mandate. On the latter point, the need has been, in part, a reaction to Clean Water Act directives to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. §1251). For wetland scientists and managers, identifying a sampling focus for chemical or physical integrity (e.g., dissolved oxygen, temperature) has been a much more straightforward task than finding adequate methods for measuring biological integrity, an ambiguous concept that defies precise definition (Cronk and Fennessy 2001). This puts scientists and managers in the difficult position of attempting to express a *qualitative* construct (biological integrity) in *measurable* or *quantitative* terms. Even more challenging for wetland practitioners is the decision about which model organisms to use among the diversity of biota that inhabit wetland systems.

In wetlands, vegetation is one component of the biota that is frequently studied to evaluate wetland condition. Metrics describing biological integrity in terms of *in situ* vegetation are desirable for several reasons (U.S. EPA 2002): 1) plants are ubiquitous in wetland environments; 2) vegetation is a defining characteristic of wetland systems both from an ecological and a regulatory context; 3) sampling protocols for vegetation are well known; 4) plant communities express sensitivity to ecological disturbance and environmental stressors in measurable ways; and, 5) plants are not motile. To this end, Floristic Quality Assessment (FQA) has been identified as a potentially useful tool for wetland assessment. Proponents have cited FQA as a suitable approach for this purpose because its quantitative outputs – the Floristic Quality Index (FQI) and related metrics – are calculated from "Coefficients of Conservatism" (*C*-values) that are assigned by an independent panel of botanical experts knowledgeable about the flora of a particular region (see Boxes 1 and 2). The *C*-value list for a given region provides a foundation for the FQA approach, which is regarded by many as a non-biased analog for biological integrity in wetlands that is "dispassionate, cost-effective, and repeatable" (Swink and Wilhelm 1994). However, others have cited some concerns with traditional application of FQA to wetland assessment (Francis et al. 2000; Matthews 2003; Cohen et al. 2004; Miller and Wardrop 2006; Bried et al. 2013; DeBerry and Perry 2015). Our objective is to provide an overview of this broad spectrum of scientific opinion on FQA research, specifically with the intent of summarizing the benefits and challenges of the FQA approach to wetland assessment.

FQA RESEARCH IN WETLANDS: REGIONAL TRENDS

Table 1 provides a somewhat comprehensive list of published research on the use of FQA in North American wetland studies. We say "somewhat comprehensive" because in our attempts to include all relevant published literature some studies may have been inadvertently left out. Notwithstanding such an oversight, the list in Table 1 is provided as a resource for the reader who wishes to examine this topic in more detail. Although there is a much wider literature base on use of FQA in general, the studies cited in this table are specific to scientific research in which FQA was tested in wetlands directly, or in which it was used indirectly as part of a larger study in wetland environments. The remainder of this review focuses on the former (i.e., studies where FQA was tested directly to determine its suitability for use in wetland evaluation), which are identified in boldface type in Table 1. Note that this table does not include published studies on development of regional *C*-value lists, but we provide an overview of the listing process in Box 2.

As explained in Box 1, FQA originated in the Chicago region, so it is not surprising that an inordinate amount of the research listed in Table 1 has occurred in the north-central U.S. states and adjacent Canadian provinces (e.g., Illinois, Michigan, Wisconsin, Ohio, Indiana, North Dakota, South Dakota, and Ontario). The *C*-value lists for many of these regions have been in place longer, and some state agencies have developed regulatory programs incorporating FQA into wetland evaluation programs dating back to the late 1990s (e.g., Ohio, see Fennessy et al. 1998a,b). Other

[1]Corresponding author, email: dadeberry@wm.edu

"hot spots" for FQA research in wetlands have included Mid-Atlantic states (e.g., Pennsylvania, Virginia, West Virginia), the Southeast (e.g., Florida, Mississippi, Louisiana), and the Northeast (e.g., New York). There has also been some recent research originating from the Midwest, the Eastern Intermountain Region (e.g., Oklahoma, Colorado, and Montana) and western Canada (e.g., Alberta).

Across the geographic domain of FQA application, the approach is being used in a variety of ways to evaluate wetland condition. Examples include ambient monitoring and assessment, targeting and prioritizing sites for conservation, assessment for impact analysis in wetland regulatory programs, performance evaluation for wetland mitigation sites, identification of reference sites for functional assessment, and incorporation into larger assessment models such as IBIs (Cronk and Fennessy 2001; Miller et al. 2006; Medley and Scozzafava 2009; Chamberlain et al. 2013). Further, FQA methods have been developed for a broad and growing geographic range engaging a diversity of wetland habitats types within which the method has been tested for research purposes.

The following summary is outlined in a format that will allow quick access to the primary findings from the literature. As mentioned above, the focus is specifically on research that has tested the efficacy of FQA as an evaluative tool in wetland ecosystems. Readers interested in reviewing the subject further are encouraged to read the primary literature in more detail, particularly the studies denoted in boldface type in Table 1.

BENEFITS OF USING FQA IN WETLAND EVALUATION

FQA Reflects Ecological Condition Of all the aspects of FQA cited in the literature, the consistent finding that FQA reflects ecological condition is perhaps the most compelling rationale for its use in wetland evaluation. This has been tested in various ways: 1) through a "dose-response" analysis that plots the FQA metric against a pre-determined anthropogenic disturbance gradient and tests for significant correlations (e.g., Fennessy et al. 1998a; Miller et al. 2006; Bried et al. 2013); 2) through ecosystem modeling using community ordination techniques (e.g., Miller et al. 2006; Bowers and Boutin 2008; Cariveau and Pavlacky 2009; DeBerry and Perry 2015); 3) through comparisons with other biological integrity metrics such as species richness, diversity, evenness, percent native species, or related community indices (e.g., Matthews 2003; Ervin et al. 2006; Matthews et al. 2009b); or 4) through comparison with ecosystem condition variables such as soil physiochemistry, site age, biomass, etc. (e.g., Nichols 1999; Lopez and Fennessy 2002; DeBerry and Perry 2015).

The majority of the studies that tested FQA in wetlands (Table 1) cited a significant correlation with wetland condition using one or more of the approaches outlined above, concluding that FQA was a useful tool for wetland evaluation. The primary point of departure among these studies is

TABLE 1 List of studies that used FQA in wetlands. References in bold face type tested the performance of FQA metrics in wetland evaluation.

Author(s)	*Wetland Type*
Ahn and Dee 2011	mitigation wetlands
Alix and Scribailo 1998	lacustrine fringe (emergent/aquatic)
Allain et al. 2004	wet prairie
Balcombe et al. 2005	mitigation and reference wetlands (emergent/scrub-shrub)
Boughton et al. 2010	wet pasture (agricultural)
Bourdaghs et al. 2006	coastal wetlands (lacustrine)
Bowers and Boutin 2008	streambanks (riparian)
Bried and Edinger 2009	pine barrens vernal ponds
Bried et al. 2013	non-forested vernal pond/sedge meadow/shrub swamp
Bried et al. 2014	"reference" emergent/scrub-shrub
Cariveau and Pavlacky 2009	playas
Chamberlain et al. 2012	review
Chu and Molano-Flores 2013	wetlands in pre- and post-development landscapes
Cohen et al. 2004	isolated depressional marsh
Cretini et al. 2011	coastal marshes
DeBerry 2006	created wetlands, natural forested wetlands
DeBerry and Perry 2015	created wetlands, natural forested wetlands
DeBoer et al. 2011	mitigation wetlands
Dee and Ahn 2012	mitigation wetlands
DeKeyser et al. 2003	prairie wetlands (seasonal, non-forested)
Ervin et al. 2006	depressional, lacustrine fringe, riverine
Euliss and Mushet 2011	prairie pothole wetlands
Fennessy et al. 1998a	riparian wetlands (forested, scrub-shrub, emergent)
Fennessy et al. 1998b	depressional wetlands (forested, scrub-shrub, emergent)
Forrest 2010	created stormwater wetlands
Francis et al. 2000	"woodlands" (non-tidal, forested)
Hargiss et al. 2008	prairie wetlands (temporary, seasonal, semi-permanent)
Hartzell et al. 2007	natural and created depressional wetlands (non-forested)
Herman 2005	natural and created emergent wetlands
Herman et al. 1997	review (FQI development and application)
Johnson et al 2014	floodplain forest
Johnston et al. 2008	open-coast, riverine, protected (predominantly emergent)
Johnston et al. 2009	open-coast, riverine, protected (predominantly emergent)
Johnston et al. 2010	open-coast, riverine, protected (predominantly emergent)
Kowalski and Wilcox 2003	sedge fen

BOX 1: FLORISTIC QUALITY ASSESSMENT EXPLAINED

Floristic Quality Assessment (FQA) is the term given to the calculation and subsequent analysis of weighted metrics originally developed in the Chicago region for evaluating the "quality" of native plant communities (Swink and Wilhelm 1979, 1994). Quality is a relative term used to approximate similarity of a particular plant species assemblage to pre-settlement conditions in a similar habitat type (Maser 1990). Implicit in its application is the notion that areas with species assemblages closer to those of pre-settlement times (i.e., prior to European colonization of North America) are more reflective of high quality habitat (Swink and Wilhelm 1994; Nichols 1999), and the assumption that anthropogenic disturbance represents a mode of introduction for "non-conservative" (e.g., invasive or cosmopolitan) species. It is important to note that "disturbance" is in itself a relative term that could be used to describe the types of disturbances known to occur during pre-settlement times, such as incendiary fires set by Native Americans to clear patches of ground – activities that would also be categorized as "anthropogenic" (Noss 1985). However, the concept of disturbance as it relates to FQA is most often associated with post-settlement; that is, anthropogenic disturbance following European occupation of the North American continent.

The FQA approach is based on the concept that different plant species have evolved varying degrees of tolerance to human-induced disturbance (Chapin 1991), exhibiting varying degrees of fidelity to specific habitat integrity (Mushet et al. 2002). This combination of tolerance and fidelity is parameterized in FQA through the concept of "species conservatism" (Swink and Wilhelm 1979, 1994), which is specified by the "coefficient of conservatism" (C), a numerical assignment between 0 and 10 applied to plant species by a panel of experts on the native flora of a particular region (Cronk and Fennessy 2001). A species with a C-value of 10 always occurs within high quality habitats (i.e., habitats most closely resembling "remnant" or pre-settlement conditions), and a species with a C-value of 0 is not found in high quality habitats and, in general, is highly tolerant of anthropogenic disturbance (Swink and Wilhelm 1994). On several state or regional C-value lists, the value of C=0 is arbitrarily assigned to non-native species. Below is an example of types of assignment categories used in creating a regional C-value list (Chamberlain and Ingram 2012):

0–3 Plants with a broad range of ecological tolerances that are found in a variety of plant communities
4–6 Plants with an intermediate range of ecological tolerances that are associated with a specific plant community
7–8 Plants with a narrow range of ecological tolerances that are associated with advanced successional stage
9–10 Plants with a high degree of fidelity to a narrow range of pristine habitats

Once C-values for a given region are assigned, they can then be used to generate the functional output of FQA – the Floristic Quality Index or "FQI" (also referred to as Floristic Quality Assessment Index, "FQAI", or simply "I"). As originally conceived by Swink and Wilhelm (1979, 1994), the index is calculated according to the following equation:

$FQI = \bar{C}\ (\sqrt{N})$

where $\bar{C}$ represents the average coefficient of conservatism for native species, and N is native species richness. Note also that $\bar{C}$ by itself can be used as an index of floristic quality. Further, because of the unitless property of both metrics (FQI and $\bar{C}$), several modified versions have been proposed. Examples include FQI and $\bar{C}$ calculated from all species present (i.e., native and non-native) (Rocchio 2007; Cariveau and Pavlacky 2009), FQI weighted by species abundance (e.g., Cretini et al. 2012; DeBerry and Perry 2015) similar to a prevalence index (see Tiner 1999), FQI as a percentage of a maximum attainable index score based on the species present (Miller and Wardrop 2006), FQI and $\bar{C}$ expressed as ratios between different vegetation layers in forested wetlands (Nichols et al. 2006), and FQI adjusted to account for changes due to latitude (Johnston et al. 2010). Details on the relative merits of these approaches are discussed in the text. Equations for some of the more commonly used FQA metrics are listed in the table below (see Swink and Wilhelm 1994; Cohen et al. 2004; Bourdaghs et al. 2006; Miller and Wardrop 2006; Cariveau and Pavlacky 2009).

FQA Metric	Equation	Coefficients and Constants
Mean Coefficient of Conservatism ($\bar{C}$) (native species only)	$\bar{C} = \frac{\sum_{i=1}^{n} C_i}{N}$	C_i = *C*-value for *i*th species N = native species richness
Floristic Quality Index (FQI) (native species only)	$FQI = \bar{C}\ (\sqrt{N})$	
Mean Coefficient of Conservatism ($\bar{C}_{all}$) (all species)	$\bar{C}_{all} = \frac{\sum_{i=1}^{n} C_i}{S}$	S = species richness
Floristic Quality Index (FQI_{all}) (all species)	$FQI_{all} = \bar{C}_{all}\ (\sqrt{S})$	
[1]Abundance-weighted $\bar{C}$ ($\bar{C}_{adj}$)	$\bar{C}_{adj} = \frac{\sum_{i=1}^{n} x_i C_i}{\sum_{i=1}^{n} x_i}$	x_i = abundance value for *i*th native species
[1]Abundance-weighted FQI (FQI_{adj})	$FQI_{adj} = \bar{C}_{adj}\ (\sqrt{N})$	
[2]Richness-corrected FQI (FQI')	$FQI' = \left(\frac{\bar{C}}{10}\ \frac{\sqrt{N}}{\sqrt{S}}\right) \times 100$	10 = maximum *C*-value correction factor

[1]Note that $\bar{C}_{adj}$ and FQI_{adj} may also be calculated for all species (not just natives) by substituting √S and coefficients from $\bar{C}_{all}$ into these equations.
[2]The richness-corrected factor calculates FQI' as a percentage of the maximum attainable FQI (Miller and Wardrop 2006).

in the mode that FQA should take for this type of analysis (i.e., FQI, $\bar{C}$, or modified index versions; see Box 1 and index discussion below). Irrespective of the specific index chosen, the general trends suggest that it is the conservatism concept itself that provides the basis for consistency in condition evaluation, the foundation of which is vetted through expert opinion in the *C*-value listing process (see Box 2) (Swink and Wilhelm 1994; Chamberlain and Ingram 2012; Chamberlain et al. 2013). Studies showing significant negative correlations between FQA metrics and a gradient of anthropogenic disturbance abound (e.g., Fennessy et al. 1998a; Cohen et al. 2004; Miller and Wardrop 2006; Bried et al. 2013), indicating that higher FQA index values routinely correspond to a lower incidence of disturbance in wetlands, and vice versa. Further, several researchers have noted correlations with soil chemical parameters, plant biomass, or aquatic fauna communities (Fennessy et al. 1998b; Lopez and Fennessy 2002; Miller et al. 2009; DeBerry and Perry 2015), interpreting these relationships as an indication that FQA is able to signal ecological differences among wetland sites as a reflection of relative habitat degradation. Still others have noted that FQA provides results that are consistent with ecological succession theory in regenerating or restored wetland sites (Matthews et al. 2009b; Spyreas et al. 2012; DeBerry and Perry 2015), suggesting that the approach has some practical application in wetland mitigation assessment.

The "Challenges" section presents some conclusions about limitations of *C*-value lists, FQA indices, and sampling-related issues, all important considerations when applying FQA to wetland evaluation. However, suffice it to mention that even in light of these challenges, the majority of the studies listed in Table 1 concluded that, in one form or another, FQA serves as a general analog for biological integrity in wetlands.

FQA is Robust Another characteristic of the FQA approach is the relative consistency of the results achieved by researchers over different sampling seasons and under various sampling regimes. This observation has been made in the context of season-to-season comparisons (i.e., spring vs. summer sampling; Fennessy et al. 1998a; Francis et al. 2000; Lopez and Fennessy 2002; Cariveau and Pavlacky 2009; Bried et al. 2013), species list generation versus plot-based data collection methods (DeBerry and Perry 2015), sampling using different plot sizes (DeBoer et al. 2011), and in some cases, when comparing different wetland community types (Bried et al. 2013; Spyreas 2014).

It is important to note that certain FQA metrics do not follow this trend in all circumstances. For example, some studies have noted a strong seasonal effect on species richness in wetland communities, which indirectly influences the FQI metric due to the square root of N transformation (see Box 1; Matthews 2003; Miller and Wardrop 2006). However, even with these effects, FQA has been shown to

TABLE 1, CONTINUED

Author(s)	*Wetland Type*
Larkin et al. 2012	emergent marsh (Typha dominant, Typha absent)
Laughlin 2001	various
Lishawa et al. 2010	coastal wetlands (emergent)
Lopez and Fennessy 2002	depressional wetlands (forested, scrub-shrub, emergent)
Matthews 2003	floodplain forest, wet shrubland, sedge meadow, marsh
Matthews 2015	restored wetlands
Matthews et al. 2005	floodplain wetlands (forested, shrub, emergent, pond)
Matthews et al. 2015	floodplain forest, herbaceous wetlands
Matthews et al. 2009a	mitigation wetlands
Matthews et al. 2009b	mitigation wetlands
Medley and Scozzafava 2009	status review for use in NWCA
Miller and Wardrop 2006	headwater complex (riparian wetlands)
Miller et al. 2006	headwater wetlands (riparian)
Miller et al. 2009	riparian
Mushet et al. 2002	prairie potholes (natural and restored)
Nedland et al. 2007	restored wetlands (emergent, scrub-shrub, aquatic bed)
Nichols 1999	lacustrine (aquatic macrophytes)
Nichols 2001	lacustrine (aquatic macrophytes)
Nichols et al. 2006	hardwood flats
Niemi et al. 2011	coastal wetlands (open coastal, riverine, barrier)
Raab and Bayley 2012	emergent marsh reclamation (oil sands)
Reiss 2006	forested depressional wetlands
Reiss and Brown 2007	palustrine depressional wetlands (emergent, forested)
Rocchio 2007	various
Rooney et al. 2012	shallow open-water marsh wetlands
Rothrock and Homoya 2005	various (FO, SS, EM, aq), also included upland habitats
Spieles et al. 2006	mitigation bank wetlands
Spyreas 2014	various
Stanley et al. 2005	coastal wet meadow (lacustrine)
Tulbure et al. 2007	coastal wetlands (lacustrine, non-forested)
Wardrop et al. 2007	various (predominantly forested)
Werner and Zedler 2002	sedge meadow
Wilcox et al. 2002	lacustrine fringe
Wilson and Bayley 2012	emergent and aquatic bed prairie wetlands
Wilson et al. 2013a	wet meadow
Wilson et al. 2013b	stormwater, reclamation, & reference marsh wetlands

provide the same relative differences between sites (i.e., consistent site ranks based on conservatism) irrespective of differences in absolute index values between seasons (Herman 2005). With respect to species richness, perhaps the more important consideration is that of the species-area relationship, the effect of wetland size on richness, and the associated effect of area on FQA metrics (see the "Challenges" section below for further discussion).

Some researchers have concluded that FQA metrics should only be used to compare wetlands with similar habitat classifications (Francis et al. 2000; Matthews et al. 2005; Rocchio 2007), citing inconsistency in results when FQA is applied across habitat types. This recommendation is best taken in the context of the purpose for which wetlands are being evaluated. If the intent is to use FQA to identify sites with high conservation value (Swink and Wilhelm 1994), then FQA can be applied in a "categorical" sense to identify wetlands with "high", "medium", or "low" quality across habitat types. Some regions have used this approach to established index thresholds for targeting natural habitats in the "high" category for preservation (e.g., FQI>45 or $\bar{C}$>4.5; Swink and Wilhelm 1994; Rothrock and Homoya 2005; see comments under "Challenges" regarding use of FQA thresholds for wetland regulatory purposes). However, if the intent is to draw direct comparisons between wetlands to make inferences about relative ecological condition, then just based on the differences in habitat-specific ecological tolerances of the inhabiting species alone, direct comparisons between wetlands of different community types (e.g., forested vs. emergent) could lead to false conclusions about functional similarities or differences derived from FQA index scores (Matthews 2003). Interestingly, the categorical approach can be used to index biotic integrity in a similar manner to that described above for conservation value. In several studies, FQA has been used effectively as a component of a vegetation-based Index of Biotic Integrity (IBI), which generally separates sites along similar "high", "medium", and "low" condition class lines (e.g., Miller et al. 2006; Euliss and Mushet 2011; Raab and Bayley 2012; Wilson and Bayley 2012). In such cases, IBIs are region-specific and generally developed for a particular wetland habitat type.

FQA is Easy A common theme among wetland regulatory programs across the U.S. is the need for wetland assessment tools that are quick, easy to use, and reproducible (Medley and Scozzafava 2009; MPCA 2014). The authors of the FQA approach (Swink and Wilhelm 1979, 1994) identified this as a primary goal of the conservatism concept in their methodology, and by most researchers' standards that goal has been achieved in theory and in practice (Cohen et al. 2004; Bourdaghs et al. 2004; Rocchio 2007; Breid et al. 2013; Spyreas 2014). In fact, the most labor intensive aspect of FQA is the *C*-value listing process (Box 2); once this step is achieved, sampling and calculation of the FQA metrics are reasonably straightforward since all that is required is a species list for a given area (see Box 1). Some researchers have "complicated" the approach by applying different mathematical weights or adjustments to the FQA metrics to address specific research questions, with variable results (Cohen et al. 2004; Bourdaghs et al. 2006; Ervin et al. 2006; Miller and Wardrop 2006; Nichols et al. 2006; Cariveau and Pavlacky 2009; Cretini et al. 2012;DeBerry and Perry 2015). The implications of these approaches will be discussed further under "Challenges" below. An important point, however, is that the original FQA metrics (FQI, $\bar{C}$) are unitless, which means that they are easily incorporable into these types of modifications, an illustration of FQA's ease of use and versatility in evaluating wetland condition.

CHALLENGES OF FQA IN WETLAND EVALUATION

FQA Lacks Comparability across Regions A consistent criticism of FQA is the observation that results are not comparable across geographic regions. In other words, given absolute values for a metric like FQI that is calculated from two different *C*-value lists for two different geographic areas, some researchers suggest that there is minimal benefit gained by attempting to draw comparisons between the two, even if the community types are similar (Rothrock and Homoya 2005; Deboer et al. 2011). This has much to do with the *C*-value lists themselves. For example, some states have different listing criteria when compared to their neighbors (Medley and Scozzafava 2009). In addition, some states include non-native species in the listing process, whereas others do not (Matthews et al. 2015). Clearly, two or more lists that do not take a congruent approach to the *C*-value assignment process run the risk of producing different results just based on the potential for single species to have different *C*-values in different regions.

Most researchers that have addressed this problem suggest that FQA is best applied on a regional or statewide basis, and that comparisons between regions should be avoided (Rothrock and Homoya 2005; Bourdaghs et al. 2006; Reiss 2006). Others have advocated developing regional lists using ecoregions rather than state boundaries (Bourdaghs et al. 2006; Bried et al. 2013), an approach that has been undertaken in areas such as the Mid-Atlantic region (Chamberlain and Ingram 2012) and the Northeast region (Bried et al. 2012). Still others have evaluated the effect of latitude on FQA, suggesting that correction factors can be built into the method to account for natural variability across latitudinal gradients (Johnston et al. 2010; Spyreas 2014). Based on these observations, the regional specificity of existing and future *C*-value lists should be viewed as the *modus operandi* for FQA in wetland evaluation. Further, because the overall FQA approach generally provides the same relative results across boundaries (i.e., based on conservatism ranks), this should not be viewed as a disadvantage of the approach (Rothrock and Homoya

2005). Given the advent of the Regional Supplements to the Corps of Engineers Wetland Delineation Manual (Wakeley 2002) as well as the use of ecological regions to revise the National Wetland Plant List (Lichvar and Minkin 2008), the "regional paradigm" is also consistent with current trends in wetland regulation.

The inclusion or exclusion of non-native species in FQA bears mentioning because it is an important consideration that has been the subject of some debate in the literature. The authors of the FQA approach reject the notion of including non-native species, maintaining that the presence of non-natives will be measured indirectly by their negative effect on the abundance of native species through competition and habitat modification (Swink and Wilhelm 1994). Others have argued that accounting for non-native species in site evaluation provides a better overall understanding of ecosystem health, and results from several tests of FQA in wetland habitats suggest that FQA indices perform better when non-native species are included (Cohen et al. 2004; Herman 2005; Bourdaghs et al. 2006; Miller and Wardrop 2006; Rocchio 2007; Cariveau and Pavlacky 2009; Forrest 2010).

One problem with incorporating non-native species is the way in which they are treated in the *C*-value listing process. In some cases, non-native species are simply left off of the list, which precludes their use in FQA metrics. In other cases, non-natives are assigned an arbitrary value of *C*=0 – the lowest possible conservatism rank (see Box 1). The latter situation creates a problem in the calculation of the index when several non-native species are present, because the *C*-value for these species has been assigned based on nativity and not on degree of fidelity to natural areas *per se* (DeBerry and Perry 2015; Matthews et al. 2015). This is analogous to the "zero truncation problem" in ecological studies, where the mere absence of a species gives no information about how unfavorable the environment is for that species. Just as no negative abundance values are possible in a sample, there is no negative *C*-value scale to account for the relative differences of non-native species in a floristic quality sense, and the scale is "truncated" at zero (DeBerry and Perry 2015). Some authors have considered use of negative *C*-values, including an early version of FQA proposed by Swink and Wilhelm (1979), but to the best of our knowledge this approach has yet to be implemented effectively. In Virginia, DeBerry (unpublished data) has recently evaluated multiple data sets in a proposal to assign the values –5, –3, and –1 to non-native species on the Virginia *C*-value list corresponding to state-assigned categories of "high", "medium", and "low" invasion risk, respectively (Heffernan et al. 2014). Using this approach, negative values would be able to account for the relative differences in the degree to which different invasive species reflect ecological integrity without the need to modify the *C*=0 assignments for the remaining non-invasive exotic plants on the Virginia *C*-value list (see Matthews et al. 2015 for further discussion on negative values).

FQA Issues in Forested Wetlands A quick survey of the studies cited in Table 1 will show that the majority of the research on FQA in wetlands has been conducted in non-forested habitat. Studies that have evaluated FQA performance in forested wetlands have produced mixed results (Fennessy et al. 1998b; Francis et al. 2000; Nichols et al. 2006; DeBerry and Perry 2015). The primary concern with FQA in forested systems is that woody plants do not express the same type of responses to ecological disturbance as herbaceous species. Trees exhibit a property

BOX 2: CREATING A REGIONAL C-VALUE LIST – LESSONS LEARNED

The recent popularity of FQA in wetland monitoring and management has led to an increased desire to develop lists of coefficients for either regional or statewide floras. As those who have attempted such an endeavor can attest, the process of assigning coefficients can be challenging in the pre-planning, implementation, and post-assignment phases. We can learn much from our colleagues who have successfully navigated this process and emerged with an effective and informative product.

There are many planning considerations that must be addressed before assignment can take place. These include selecting a taxonomic authority and addressing nomenclature issues such as synonymy, hybrids, and whether to assign values to subspecies and varieties. In regions that cover large areas, there may be a need to address taxa that are native to only a part of the region. Assignment also involves selecting and vetting the botanists that will form the committee. Collectively, the botanical committee must provide sufficient expertise and coverage of the target geographical area. Equally important is the need to choose botanists that will work well together as a team to ensure the project is completed with minimal conflicts and delays.

When it comes to assigning coefficients, there are generally two models that have been followed. The first model is to allow botanists to assign values independently and then meet face to face to discuss the subset of taxa where disagreement falls above a set threshold. For example, taxa with coefficients that vary more than two standard deviations from the median would be tabled and reevaluated. The second model involves convening the committee and assigning values in situ by consensus. In both models, decision rules for the assignment of values are imperative to ensure consistency. The use of previously-assigned coefficients can serve to inform and expedite the process. Some project managers have also required their botanists to assign a confidence rating to each value as an added measure of validity.

Once values are assigned, there is typically more work to be done to finalize coefficient lists. During the assignment process, there may be issues with synonymy and nomenclature that require further review, taxa that are unfamiliar to the committee that need additional research, and disputed values that must be resolved. Such tasks may take an additional three to six months to complete and should be factored into project timelines and budgets. Another consideration is how to transfer the information to wetland managers so the values can be used. Some regions have developed online interactive calculators to facilitate calculation of FQA metrics.

Finally, there are logistical issues to contend with including where to hold committee meetings, whether to pay committee members for their participation, and how to follow-up with committee members after meetings are completed. Those considering embarking on FQA for their region should not only reflect on the observations presented here, but also reach out to those individuals who have successfully completed similar projects to ensure they achieve a positive outcome.

termed "ecological inertia" characterized by slower growth and a life history strategy focused on allocating resources to structural tissue for long-term survival (Chapin 1991; Lopez et al. 2002). By contrast, herbaceous species allocate resources differently, with a life history strategy that typically results in short-term survival in comparison with trees (Grime 1977). In this respect, herbaceous species are more likely to show the effects of short-term disturbance when compared to woody species (DeBerry and Perry 2015; Matthews et al. 2015). Some studies noted better performance of FQA when individual community layers were separated out in the analysis (e.g., herbaceous, shrub, sapling, and tree), emphasizing that the herbaceous layer indices were most often correlated with ecological condition, whereas tree layer indices provided limited information (Nichols et al. 2006; DeBerry and Perry 2015; Matthews et al. 2015).

One interesting consideration is the potential effect of these properties on FQA performance in regenerating forest communities like wetland mitigation sites. DeBerry (2006; DeBerry and Perry 2015) described a phenomenon referred to as "*C*-value inflation" in which younger mitigation sites were typically planted with highly conservative species (e.g., C>5) due to planting requirements imposed by regulatory agencies, whereas older sites followed a more natural successional trend characterized by dominance of tree species with lower conservatism values. A common observation on mitigation sites is that planting "late successional" (i.e., highly conservative) tree species on young mitigation sites results in high mortality and eventually a natural turnover in which the regenerating tree layer is replaced by "early successional" (i.e., lower *C*-value) species (McLeod et al. 2001; Matthews et al. 2009b; DeBerry and Perry 2012). Research in mitigation systems has emphasized the importance of species composition in success monitoring (DeBerry and Perry 2004, 2012; Spieles 2005; Matthews et al. 2009b), which makes FQA a desirable tool for assessment since composition is indirectly indexed through the each species' unique *C*-value. However, when regulatory agencies impose FQA metric thresholds (e.g., FQI>25 or $\bar{C}$ >3.5; see DeBoer et al. 2011), they may be arbitrarily setting sites up for failure regardless of the target ecosystem (e.g., forested, scrub-shrub, or emergent wetlands) due to the combination of *C*-value inflation and the natural successional trajectories of wetland mitigation sites (Matthews et al. 2009b; DeBerry and Perry 2015). A better approach may be to simply evaluate FQA metrics for the herbaceous layer in mitigation sites (DeBerry 2006), or to set realistic target thresholds based on comparison to a large number of reference sites identified within a regional landscape setting (Matthews et al. 2009b).

The Species-Area Problem and Index Form The most commonly cited criticism of FQA is that the square root of N (native species richness) transformation in the equation for FQI (see Box 1) results in an index that focuses more on *area* than *condition* (Bried et al. 2013). This is due to the fact that species richness tends to increase with increasing wetland size (i.e., species-area relationship), so that a small wetland with a few highly conservative species (e.g., $\bar{C}$>5) could end up with a *lower* FQI than a large wetland with high species richness but low-ranking *C*-value species (e.g., $\bar{C}$<2). The relative conservation status of these two wetlands might be subject to debate, but few would deny the fact that there are many unique small wetlands supporting rare species that would be undervalued by a straight FQI comparison with larger wetlands just based on the species-area relationship and the dependence of FQI on richness (Mushet et al. 2002; Cohen et al. 2004; Matthews et al. 2005; Miller and Wardrop 2006; Chu and Molano-Flores 2013). For example, vernal ponds are small, often isolated wetland sites that tend to be low in species richness but high in habitat quality and species conservatism (Bried et al. 2013), whereas mineral flats can be large, expansive sites with high species richness but low conservatism (Nichols et al. 2006). Direct FQI comparisons between these two types of wetland habitats might result in the erroneous conclusion that the former (potentially lower FQI due to low richness) lacks conservation potential in comparison to the latter (potentially higher FQI due to high richness).

Several correctives have been proposed to minimize the species-area problem in FQA. Examples include standardization of sample area size within each wetland (Bourdaghs et al. 2006; DeBoer et al. 2011; DeBerry and Perry 2015), collecting data from standard plot sizes within each wetland (Rocchio 2007), focusing on $\bar{C}$ as the primary index rather than FQI since $\bar{C}$ is independent of species richness (Cohen et al. 2004; Rocchio 2007; Bried et al. 2013), introducing modifications that relativize the index to reduce the effect of species richness (Miller and Wardrop 2006), and calculating abundance-weighted versions of FQI to normalize the species-area influence (Cretini et al. 2012; DeBerry and Perry 2015).

Effective use of some of these approaches will depend on the type of analysis being performed. For example, when comparing natural wetlands within a specific habitat classification across a state or region, standardizing sampling area would be beneficial as it would ensure sampling balance across the domain of study sites. Further, index modifications like the one proposed by Miller and Wardrop (2006), or just using $\bar{C}$ for data analysis, can be applied in any situation where FQA is used. Plot-based sampling is typically a regulatory requirement for compliance monitoring in wetland mitigation sites, so a standardized plot sampling approach could be a easily incorporated into mitigation assessment (Herman 2005; DeBoer et al. 2011; DeBerry and Perry 2015). Along the same lines, abundance data are also usually required as a component of mitigation monitoring, so abundance weights can be easily integrated into a modified FQI for created and restored wetland sites

(DeBerry 2006). It should be noted that most researchers who tested an abundance-weighted FQI in natural habitats suggested that performance of the abundance-weighted index did not warrant the additional effort required to collected data on species cover, density, frequency, etc. (Francis et al. 2000; Cohen et al. 2004; Bourdaghs et al. 2006; Rocchio 2007; Cariveau and Pavlacky 2009). However, some have noted that abundance weights are useful because of their stabilizing effect on the species-area problem (Cretini et al. 2012), and also because abundance-weighted FQIs have been shown to preserve the conservatism ranks of wetland sites while providing more information about relative ecological condition based on quantitative measures of the inhabiting species (DeBerry and Perry 2015).

This leads to another challenge that wetland practitioners are faced with when attempting to apply FQA in wetland evaluation, namely, that the FQA approach does not produce a single index that is considered "best" in all circumstances. As previously stated, although both FQI and $\bar{C}$ were originally intended to be the sole product of FQA (Swink and Wilhelm 1994), the unitless property of these two metrics has allowed researchers to devise novel and creative modifications to answer specific research questions. For some, the answer to the question, "Which index should I use?" is straightforward: all of them. In other words, because metrics like FQI, $\bar{C}$, and related modifications are easy enough to compute, and because they are each intended to answer related but slightly different questions, some researchers are recommending that scientists and wetland managers should report all relevant FQA metrics (Rocchio 2007). Certainly for FQA testing within specific wetland community types or on a statewide or regional basis, researchers should evaluate the performance of all FQA-related metrics deemed appropriate for the research questions being addressed and make recommendations accordingly.

The "Botanical Acumen" Problem The FQA approach is limited to some extent by the field experience of the wetland scientists and botanists collecting the data. The accurate identification of several wetland plant taxa, such as grasses and sedges, requires a high level of field botanical skill that is often not consistently represented across the population of scientists and wetland managers who routinely perform wetland evaluations (U.S. EPA 2002). This presents the problem of consistency – if many conservative species are "overlooked" due to difficulty of identification, then FQI values can be artificially lowered by sampling bias irrespective of the actual conservatism of the community being sampled. The research cited in Table 1 generally does not address this "botanical acumen" problem (DeBerry 2006), but it is a concern because of the importance of species composition in the FQA approach and the critical role that *species identity* plays in the application of *C*-values to the FQA metrics. Although restricting FQA to well-known or dominant taxa has been proposed as a rapid approach that most wetland practitioners would be qualified to perform (e.g., MPCA 2014), there is evidence that targeting only abundant taxa reduces the level of certainty in FQA indices (Cohen et al. 2004). Of course, the best approach would be to ensure that FQA assessment teams are comprised of competent field botanists, and that quality assurance measures (e.g., voucher submittals to herbaria) are included in the work plan for a wetland evaluation program. The extent to which this can be implemented in practice, though, is questionable.

CONCLUSION

In our review of FQA trends in wetland evaluation, we have been careful to include the broad range of opinion on the applicability of this assessment tool in a wide array of wetland habitats across North America. In doing so, we have discussed both the benefits and challenges of the FQA approach as interpreted by wetland scientists and practitioners who have "put FQA to the test" in wetland environments. At this point, it is important to reiterate that regardless of the various challenges and potential weaknesses noted above, in the majority of FQA studies conducted to date in wetland habitats, researchers have concluded that FQA is a useful tool for wetland evaluation. Below are some key summary points for consideration by those anticipating use of the method in future research, or for those actively engaged in using FQA to evaluate wetlands:

The conservatism concept, which is captured in the *C*-value assignments for a given region, is a powerful idea that lends itself to versatility in practice. The emphasis on state or regional applications seems most appropriate given the differences in ecological tolerances that even a single species can exhibit over different geographic areas. The regional approach is consistent with current trends in wetland delineation and regulatory programs, and the use of ecoregions in the *C*-value listing process may ultimately be the most ecologically-relevant approach to cataloguing conservatism.

Although the FQA approach does not produce a single index that is appropriate for all situations, ease of use allows wetland practitioners to calculate any number of FQA metrics with minimal effort. Researchers are encouraged to consider all potential FQA metrics that could be ecologically relevant within a given region, and to then test those metrics for applicability using the methods described above. As the research in Table 1 demonstrates, in some cases $\bar{C}$ "works better" than FQI and vice versa, and in other cases modified indices can provide a more consistent and reliable prediction of ecosystem condition.

Careful consideration should be given to the specific research questions being asked before study design and data collection methods are finalized for a typical FQA project. While a species list is all that is needed to compute $\bar{C}$ and FQI, researchers may want to minimize the species-area influence on richness by standardizing sample area or plot size, by introducing index modifications, or by accounting for relative abundance in the FQA metrics. Researchers may also want to control sampling season for multi-year research in which inter-site comparisons will be made, or in which time-dependent community changes will be evaluated (e.g., wetland mitigation monitoring).

Although FQA has been used to compare wetlands from different community types (e.g., forested vs. emergent), this approach should be discouraged even in studies that are designed to identify natural habitats for conservation. In practice, targeting habitats for conservation is more appropriately informed by establishing habitat-specific thresholds of conservatism value (e.g., FQI>45, $\bar{C}$>4.5) rather than making relative comparisons between different wetland types.

Non-native species should be regionally reviewed for use in FQA due to the additional ecological information provided by including non-natives in FQA metrics. For states or regions considering developing or revising a *C*-value list, we recommend avoiding the practice of indiscriminately assigning *C*=0 to *all* non-natives across the board. An arbitrary value of zero does not account for the relative differences among non-native species with respect to floristic quality (e.g., invasive and non-invasive plants are not equivalent in expressing ecological integrity). It is not apparent what the best approach would be to differentiate floristic quality for the non-native species within a geographic area, but research is ongoing. At a minimum, FQA studies should be clear in documenting how non-native plants are treated in the analysis.

Establishing absolute FQA metric thresholds for wetland mitigation success criteria (e.g., FQI>25 or $\bar{C}$>3.5) is discouraged. While this practice in theory should encourage wetland managers to maintain mitigation sites with high conservatism values, it does not account for normal successional trajectories or the influence of factors like *C*-value inflation (see text under "FQA Issues in Forested Wetlands"). FQA success thresholds have been described as unrealistic given the early successional state of the typical wetland mitigation site. This could result in large and unnecessary expenditures of time and money "fixing problems" on sites that don't meet their FQA criteria but that are actually just following normal successional patterns of vegetation development based on our current scientific understanding in these systems. A better approach may be to establish realistic thresholds that account for different stages of successional development as a site matures, or to set thresholds based on comparison to a large number of regional reference sites.

More research is needed to test the performance of FQA indices in forested wetlands. At a minimum, wetland practitioners are encouraged to calculate vegetation layer-based FQA metrics in addition to the overall community metrics, with an emphasis on the herbaceous layer due to its efficacy in differentiating ecological condition under FQA analysis.

Finally, one area where FQA is likely to gain additional use is in the development of regional, vegetation-based IBIs for specific wetland classes. This is a beneficial use of FQA because it incorporates the robust conservatism concept in a format that promotes rigorous testing and selects only metrics with significant correlations to *a priori* disturbance gradients (e.g., dose-response analysis). ■

ACKNOWLEDGMENTS

The Society of Wetland Scientists Board of Directors has reviewed and approved this state-of-the-science report for publication. The authors would specifically like to thank Dr. Jim Perry and Ralph Tiner for comments on the manuscript.

REFERENCES

Ahn, C. and S. Dee. 2011. Early development of plant community in a created mitigation wetland as affected by introduced hydrologic design elements. *Ecological Indicators* 37:1324-1333.

Alix, M. S. and R. W. Scribailo. 1998. Aquatic plant species diversity and floristic quality assessment of Saugany Lake, Indiana. *Proceedings from the Indiana Academy of Science* 107:123-139.

Allain, L., L. Smith, C. Allen, M. F. Vidrine, and J. B. Grace. 2004. A Floristic Quality Assessment system for the coastal prairie of Louisiana. Proceedings of the 19th North American Prairie Conference. Paper 62.

Balcombe, C. K., J. T. Anderson, R. H. Fortney, J. S. Rentch, W. N. Grafton, and W. S. Kordek. 2005. A comparison of plant communities in mitigation and reference wetlands in the mid-Appalachians. *Wetlands* 25:130-145.

Boughton, E. H., P. F. Quintana-Ascencio, P. J. Bohlen, D. G. Jenkins, and R. Pickert. 2010. Land-use and isolation interact to affect wetland plant assemblages. *Ecography* 33:461-470.

Bourdaghs, M., C. A. Johnston, and R. R. Regal. 2006. Properties and performance of the Floristic Quality Index in Great Lakes coastal wetlands. *Wetlands* 26:718-735.

Bowers, K. and C. Boutin. 2008. Evaluating the relationship between floristic quality and measures of plant biodiversity along stream bank habitats. *Ecological Indicators* 8:466-475.

Bried, J. T. and G. J. Edinger. 2009. Baseline floristic assessment and classification of pine barrens vernal ponds. *Journal of the Torrey Botanical Society* 136:128-136.

Bried J. T., K. L. Stout, and T. Portante. 2012. Coefficients of conservatism for the vascular flora of New York and New England: Interstate comparisons and expert opinion bias. *Northeastern Naturalist* 19(SI6):101–114.

Bried, J. T., S. K. Jog, and J. W. Matthews. 2013. Floristic quality assessment signals human disturbance over natural variability in a wetland system. *Ecological Indicators* 34:260-267.

Bried, J. T., S. K. Jog, A. R. Dzialowski, and C. A. Davis. 2014. Potential vegetation criteria for identifying reference-quality wetlands in the south-central United States. *Wetlands* 34:1159-1169.

Cariveau, A. B. and D. Pavlacky. 2009. Floristic quality and wildlife habitat assessment of playas in eastern Colorado: Final Report to the United States Environmental Protection Agency and the Colorado Division of Wildlife, Rocky Mountain Bird Observatory, Brighton, CO.

Chamberlain, S. J and H. M. Ingram. 2012. Developing coefficients of conservatism to advance floristic quality assessment in the Mid-Atlantic region. *Journal of the Torrey Botanical Society* 139:416-427.

Chamberlain, S. J., D. W. Heller, M. S. Fennessy, and D. A. DeBerry. 2013. Hydrophytes of the Mid-Atlantic Region: Ecology, Communities, Assessment, and Diversity. pp. 159-258. In: Brooks, R.P. and D.W. Heller (eds.) *Mid-Atlantic Freshwater Wetlands: Advances in Wetlands Science, Management, Policy, and Practice*. Springer, New York.

Chapin, F. S., III. 1991. Integrated responses of plants to stress. *Bioscience* 41:29-36.

Chu, S. and B. Molano-Flores. 2013. Impacts of agricultural to urban land-use change on floristic quality assessment indicators in Northeastern Illinois wetlands. *Urban Ecosystems* 16: 235-246.

Cohen, M. J., S. Carstenn, and C. R. Lane. 2004. Floristic quality indices for biotic assessment of depressional marsh condition in Florida. *Ecological Applications* 14:784–794

Cretini, K. F., J. M. Visser, K. W. Krauss, and G. D. Steyer. 2012. Development and use of a floristic quality index for coastal Louisiana marshes. *Environmental Monitoring and Assessment* 184:2389-2403.

Cronk, J. K. and M. S. Fennessy. 2001. *Wetland Plants: Biology and Ecology*. Lewis Publishers, Boca Raton, Florida.

DeBerry, D. A. 2006. Floristic Quality Index: ecological and management implications in created and natural wetlands. Ph.D. Dissertation, College of William and Mary, Williamsburg, VA.

DeBerry, D.A. and J.E. Perry. 2012. Vegetation dynamics across a chronosequence of created wetland sites in Virginia, USA. *Wetlands Ecology and Management* 20:521-537.

DeBerry, D.A. and J.E. Perry. 2015. Using the floristic quality concept to assess created and natural wetlands: ecological and management implications. *Ecological Indicators* 53:247-257.

DeBoer, L. S., P. E. Rothrock, R. T. Reber, and S. A. Namestnik. 2011. The use of Floristic Quality Assessment as a tool for monitoring wetland mitigations in Michigan. *The Michigan Botanist* 50:146-165.

Dee, S. and C. Ahn. 2012. Soil properties predict plant community development of mitigation wetlands created in the Virginia piedmont, USA. *Environmental Management* 49:1022-1036.

DeKeyser, E. S., D. R. Kirby, and M. J. Ell. 2003. An index of plant community integrity: development of the methodology for assessing prairie wetland plant communities. *Ecological Indicators* 3:119-133.

Ervin, G. N., B. D. Herman, J. T. Bried, and D. C. Holly. 2006. Evaluating non-native species and wetland indicator status as components of wetlands floristic assessment. *Wetlands* 26:1114-1129.

Euliss Jr., N. H., and D. M. Mushet. 2011. A multi-year comparison of IPCI scores for Prairie Pothole Wetlands: implications of temporal and spatial variation. *Wetlands* 31:713-723.

Fennessy, M. S., R. Geho, B. Elifritz, and R. D. Lopez. 1998a. Testing the floristic quality assessment index as an indicator of riparian wetland disturbance. Ohio Environmental Protection Agency, Division of Surface Water, Columbus, Ohio.

Fennessy, M. S., M. A. Gray, and R. D. Lopez. 1998b. An ecological assessment of wetlands using reference sites. Volume 1: Final Report. Ohio Environmental Protection Agency, Division of Surface Water, Columbus, Ohio.

Forrest, A. S. 2010. Created stormwater wetlands as wetland compensation and a floristic quality approach to wetland condition assessment in central Alberta. MS Thesis, University of Alberta, Edmonton, Alberta.

Francis, C. M., M. J. W. Austen, J. M. Bowles, and W. B. Draper. 2000. Assessing floristic quality in Southern Ontario Woodlands. *Natural Areas Journal* 20:66-77.

Grime, J. P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *American Naturalist* 111:1169-1194.

Hargiss, C. L. M., E. S. DeKeyser, D. R. Kirby, and M. J. Ell. 2008. Regional assessment of wetland plant communities using the index of plant community integrity. *Ecological Indicators* 8:303-307.

Hartzell, D., J. R. Bidwell, and C. A. Davis. 2007. A comparison of natural and creation depressional wetlands in central Oklahoma using metrics from indices of biological integrity. *Wetlands* 27:794-805.

Heffernan, K., E. Engle, and C. Richardson. 2014. Virginia Invasive Plant Species List. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Natural Heritage Technical Document 14-11. Richmond, VA.

Herman, B. 2005. Testing the Floristic Quality Assessment Index in natural and created wetlands in Mississippi, USA. Thesis. Mississippi State University, Mississippi, USA.

Herman, K. D., L. A. Masters. M. R. Penskar, A. A. Reznicek, G. S. Wilhelm, and W. W. Brodowicz. 1997. Floristic Quality Assessment: development and application in the State of Michigan (USA). *Natural Areas Journal* 17:265-279.

Johnson, S.E., E.L. Mudrak, and D.M. Waller. 2014. Local increases in diversity accompany community homogenization in floodplain forest understories. *Journal of Vegetation Science* 25: 885–896.

Johnston, C. A., D. M. Ghioca, M. Tulbure, B. L. Bedford, M. Bourdaghs, C. B. Frieswyk, L. Vaccaro, and J. B. Zedler. 2008. Partitioning vegetation response to anthropogenic stress to develop multi-taxa wetland indicators. *Ecological Applications* 18:983-1001.

Johnston, C. A., J. B. Zedler, M. G. Tulbure, C. B. Frieswyk, B. L. Bedford, L. Vaccaro. 2009. A unifying approach for evaluating the condition of wetland plant communities and identifying related stressors. *Ecological Applications* 19:1739-1757.

Johnston, C. A., J. B. Zedler, M. G. Tulbure. 2010. Latitudinal gradient of floristic condition among Great Lakes coastal wetlands. *Journal of Great Lakes Research* 36:772-779.

Kowalski, K. P. and D. A. Wilcox. 2003. Differences in sedge fed vegetation upstream and downstream from a managed impoundment. *American Midland Naturalist* 150:199-220.

Larkin, D. J., M. J. Freyman, S. C. Lishawa, P. Geddes, and N. C. Tuchman. 2012. Mechanisms of dominance by the invasive hybrid cattail *Typha* x *glauca*. *Biological Invasions* 14:65-77.

Lichvar, R. W. and P. Minkin. 2008. Concepts and Procedures for Updating the National Wetland Plant List. ERDC/CRREL TN-08-3, U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Lishawa, S. C., D. A. Albert, and N. C. Tuchman. 2010. Water level decline promotes *Typha* x *glouca* establishment and vegetation change in Great Lakes coastal wetlands. *Wetlands* 1085-1096.

Lopez, R. D. and M. S. Fennessy. 2002. Testing the floristic quality assessment index as an indicator of wetland condition. *Ecological Applications* 12:487-497.

Lopez, R.D., C.B. Davis, and M.S. Fennessy. 2002. Ecological relationships between landscape change and plant guilds in depressional wetlands. *Landscape Ecology* 17:43-56.

Maser, C. 1990. On the “naturalness” of natural areas: a perspective for the future. *Natural Areas Journal* 10:129-133.

Matthews, J. W. 2003. Assessment of the Floristic Quality Index for use in Illinois, USA, wetlands. Natural Areas *Journal* 23: 53-60.

Matthews, J. W. 2015. Group-based modeling of ecological trajectories in restored wetlands. *Ecological Applications* 25:481-491.

Matthews, J. W., P. A. Tessene, S. M. Wiesbrook, and B. W. Zercher. 2005. Effect of area and isolation on species richness and indices of floristic quality in Illinois, USA wetlands. *Wetlands* 25:607-615.

Matthews, J. W., A. L. Peralta, D. N. Flanagan, P. M. Baldwin, A. Soni, A. D. Kent, and A. G. Endress. 2009a. Relative influence of landscape vs. local factors on plant community assembly in restored wetlands. *Ecological Applications* 19:2108-2123.

Matthews, J. W., G. Spyreas, and A. G. Endress. 2009b. Trajectories of vegetation-based indicators used to assess wetland restoration progress. *Ecological Applications* 19:2093-2107.

Matthews, J. W., G. Spyreas and C.L. Long. 2015. A null model test of Floristic Quality Assessment: Are plant species' Coefficients of Conservatism valid? *Ecological Indicators* 52:1-7.

McLeod, K. W., M. R. Reed, and E. A. Nelson. 2001. Influence of a willow canopy on tree seedling establishment for wetland restoration. *Wetlands* 21:395-402.

Medley, L. and M. Scozzafava. 2009. Moving toward a national Floristic Quality Assessment: considerations for the EPA National Wetland Condition Assessment. *National Wetland Newsletter* 31:6-9.

Miller, S. J. and D. H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. *Ecological Indicators* 6:313-326.

Miller, S. J., D. H. Wardrop, W. M. Mahaney, and R. P. Brooks. 2006. A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania. *Ecological Indicators* 6:290-312.

Miller, S.J., Wardrop, D.H., and M.M. Harlan. 2009. Riparian plant communities as predictors of instream condition: a case study in the Upper Penns Creek Watershed, Pennsylvania. *Bartonia* 64:19-35.

Minnesota Pollution Control Agency (MPCA). 2014. Rapid Floristic Quality Assessment Manual. wq-bwm2-02b. Minnesota Pollution Control Agency, St. Paul, MN

Mushet, D. M., N. E. Euliss, Jr., and T. L. Shaffer. 2002. Floristic quality assessment of one natural and three restored wetland complexes in North Dakota, USA. *Wetlands* 22:126-138.

Nedland, T. S., A. Wolf, and T. Reed. 2007. A reexamination of restored wetlands in Manitowoc County, Wisconsin. *Wetlands* 27:999-1015.

Nichols, S. A. 1999. Floristic Quality Assessment of Wisconsin lake plant communities with example applications. *Journal of Lake and Reservoir Management* 15:133-141.

Nichols, S. A. 2001. Long-term change in Wisconsin lake plant communities. *Journal of Freshwater Ecology* 16:1-13.

Nichols, J. D., J. E. Perry, and D. A. DeBerry. 2006. Using a Floristic Quality Assessment technique to evaluate plant community integrity of forested wetlands in southeastern Virginia, USA. *Natural Areas Journal* 26: 360-369.

Niemi, G. J., E. D. Reavie, G. S. Peterson, J. R. Kelly, C. A. Johnston, L. B. Johnson, R. W. Howe, G. E. Host, T. P. Hollenhorst, N. P. Danz, J. J. H. Ciborowski, T. N. Brown, V. J. Brady, and R. P. Axler. 2011. An integrated approach to assessing multiple stressors for coastal Lake Superior. *Aquatic Ecosystem Health and Management* 14:356-375.

Noss, R. F. 1985. On characterizing presettlement vegetation: how and why. *Natural Areas Journal* 5:5-19.

Raab, D. and S.E. Bayley. 2012. A vegetation-based Index of Biotic Integrity to assess marsh reclamation success in the Alberta oil sands, Canada. *Ecological Indicators* 15: 43–51.

Reiss, K. C. 2006. Florida Wetland Condition Index for depressional forested wetlands. *Ecological Indicators* 6:337-352.

Reiss, K. C. and M. T. Brown. 2007. Evaluation of Florida palustrine wetlands: application of USEPA levels 1, 2, and 3 assessment methods. *EcoHealth* 4:206-218.

Ricchio, J. 2007. Floristic Quality Assessment indices for Colorado plant communities. Technical Report prepared for the Colorado Department of Natural Resources and the U.S. Environmental Protection Agency. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Rooney, T. P. and D. A. Rogers. 2002. The modified floristic quality index. *Natural Areas Journal* 22:340-344.

Rooney, R.C., S. E. Bayley, I. F. Creed, M. J. Wilson. 2012. The accuracy of land cover-based wetland assessments is influenced by landscape extent. *Landscape Ecology* 27: 1321-1335.

Rothrock, P. E. and M. A. Homoya. 2005. An evaluation of Indiana's Floristic Quality Analysis. *Proceedings of the Indiana Academy of Science* 114:9-18.

Spieles, D. J. 2005. Vegetation development in created, restored, and enhanced mitigation wetland banks of the United States. *Wetlands* 25:51-63

Spieles, D. J., M. Coneybeer, and J. Horn. 2006. Community structure and quality after 10 years in two central Ohio mitigation bank wetlands. *Environmental Management* 38:837-852.

Spyreas, G. 2014. An examination of temporal trends, regional variation, and habitat-type differences in site-level floristic quality scores. Dissertation. University of Illinois, Urbana, Illinois.

Spyreas, G., S. J. Meiners, J. W. Matthews, and B. Molano-Flores. 2012. Successional trends in floristic quality. *Journal of Applied Ecology* 49:339-348.

Stanley, K. E., P. G. Murphy, H. H. Prince, and T. M. Burton. 2005. Long-term ecological consequences of anthropogenic disturbance on Saginaw Bay coastal wet meadow vegetation. *Journal of Great Lakes Research* 31:147-159.

Swink, F. and G. Wilhelm. 1979. *Plants of the Chicago Region*. 3rd ed. Morton Arboretum, Lisle. 922 pgs.

Swink, F. and G. Wilhelm. 1994. *Plants of the Chicago Region*. 4th ed. Indiana Academy of Science, Indianapolis, IN. 921 pgs.

Tiner, R. W. 1999. *Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification, and Mapping.* Lewis Publishers, Boca Raton, FL. 392 pp.

Tulbure, M. G., C. A. Johnston, and D. L. Auger. 2007. Rapid invasion of a Great Lakes coastal wetland by non-native *Phragmites australis* and *Typha*. *Journal of Great Lakes Research* 33:269-279.

U.S. EPA. 2002. *Methods for Evaluating Wetland Condition: Using Vegetation to Assess Environmental Conditions in Wetlands*. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-020.

Wakeley, J. S. 2002. *Developing a 'Regionalized' Version of the Corps of Engineers Wetlands Delineation Manual: Issues and Recommendations*. ERDC/EL TR-02-20, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

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

Werner, K. J. and J. B. Zedler. 2002. How sedge meadow soils, microtopography, and vegetation respond to sedimentation. *Wetlands* 22:451-466.

Wilcox, D. A., J. E. Meeker, P. L. Hudson, B. J. Armitage, M. G. Black, and D. G. Uzarski. 2002. Hydrologic variability and the application of Index of Biotic Integrity metrics to wetlands: a Great Lakes evaluation. *Wetlands* 22:588-615.

Wilhelm, G. and D. Ladd. 1988. Natural area assessment in the Chicago Region. *Transactions of the North American Wildlife and Natural Resources Conference* 53:361-375.

Wilson, M. J., and S. E. Bayley. 2012. Use of single versus multiple biotic communities as indicators of biological integrity in northern prairie wetlands. *Ecological Indicators* 20:187-195.

Wilson, M. J., Bayley, S. E. and Rooney, R. C. 2013a. A plant-based index of biological integrity in permanent marsh wetlands yields consistent scores in dry and wet years. *Aquatic Conservation: Marine and Freshwater Ecosystems* 23: 698–709.

Wilson, M.J., A. S. Forrest, and S. E. Bayley. 2013b. Floristic quality assessment for marshes in Alberta's northern prairie and boreal region. *Aquatic Ecosystem Health & Management* 16: 288-299.

Inventory and Mapping of Wetland Plant Communities in Burren National Park, Ireland

Daniel A. Sarr , U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ and Lorin Groshong, Department of Environmental Studies, Southern Oregon University, Ashland, OR

WETLAND LANDSCAPES OF THE BURREN REGION, IRELAND

The West of Ireland is one of the world's richest wetland landscapes. Many parts of the region are cloaked in reedswamps, bogs, fens, and turloughs, often within complex mosaics created by varied climate, hydrology, and geology (Otte 2003). The Burren (from the Irish 'Boíreann' or rocky place) is a stark, glaciated limestone plateau in the far west of Ireland that is one of the most distinctive and diverse landscapes in northwest Europe. Despite a hyper-oceanic climate with over 200 precipitation days a year, extensive limestone and high soil pH limit the dominance of *Sphagnum* and thus the extent of Atlantic blanket bog, which characterizes much of west Ireland (Otte 2003). The scenery and spectacular plant diversity of the limestone pavements in the Burren are world-renowned, yet the wetlands have received less intense interest by scientists and the public than the adjacent uplands. Nonetheless, a rich variety of wetland plant communities have been described in the Burren region, including distinctive marl (calcium carbonate-rich mud), turlough, fen, bog, and reedswamp communities (Praeger 1932, Webb 1964, Ivimey-Cook and Proctor 1966, and O'Connell et al. 1984).

Generally, Irish wetland types can be differentiated by the depth, duration, reliability of flooding, and chemistry of the water within them (O'Connell et al. 1984). Reedswamps (marshes in North America) occur in areas with standing water during the growing season, and are most common around permanent lakes and depressions. As in other cool, hyperhumid regions, western Ireland is especially rich in peatlands. Peatlands (chiefly bogs and fens) tend to have moist to saturated soils through the year, usually with the water table at or below the ground surface. Bogs are peatlands that typically have low pH (generally < 5), low Ca^{2+}, Cl^- and SO_4^- as the dominant anions present, with vegetation dominated by *Sphagnum* mosses, ericaceous shrub species, and calcifuge (calcium fleeing) graminoids (grasslikes plants such as grasses, sedges, and rushes; Proctor 2010). In contrast, fens have higher pH (usually > 6.0), high Ca^{2+} and HCO_3^-, calcicole (calcium loving) graminoids, many herbs and brown mosses. Wheeler and Proctor (2000) emphasized that the distinction between bog and fen is not abrupt, and actual wetlands may have intermediate characters. General classifications of peatland vegetation types have been summarized for Ireland by O'Connell (1984) and Feehan and O'Donovan (1996).

Turloughs are globally unique groundwater-dependent wetlands that occur in limestone depressions in the karst landscape of the west of Ireland (Sheehy Skeffington et al. 2006). The flooding regime of turloughs is linked to precipitation patterns, and flooding can occur at any time of the year during high rainfall events. However, flooding occurs between October and April in most years (Coxon 1987; Moran et al. 2008). Turloughs are traditionally important summer grazing pastures with the substrate and grazing management being important factors in determining species distribution (Goodwillie 2003).

As with most of the Irish National Parks, Burren National Park (BNP) is a relatively new addition to a long settled landscape (Sarr et al. 2014). The BNP is located

Figure 1. Zonation along shore of Skaghard Lough (Lake), looking southwest toward Mullaghmore Mountain, Burren National Park, Ireland.

[1] Corresponding author, email: dsarr@usgs.gov

near the eastern edge of the Burren, and contains a series of interconnected wetland complexes that include deep limestone ponds, more extensive, but shallow lakes, fens, bogs, and turloughs. These wetlands form important habitat for native and migratory wildlife, and add greatly to the scenery of the Park (Figure 1).

DESIGNING A WETLANDS INVENTORY

In spring 2008, we met with the scientists and managers of the National Parks and Wildlife Service at Burren National Park to discuss collaborative wetland research needs. At the meeting, it was decided that a broad wetland inventory would be a useful addition to the Park's resource management knowledge, and possibly also of interest for interpretive and educational programs. Although an increasing amount of research has focused on Irish wetlands, and the Burren, in recent years (e.g., O'Connell et al. 1984; Ó Críodáin and Doyle 1997; Sheehy Skeffington et al. 2006; Regan et al. 2007), site specific knowledge about the status and extent of the wetland plant communities of the Burren National Park was identified as a critical information need. A more comprehensive technical report describes the larger inventory effort and detailed floristic analyses (Sarr et al. in Press). This paper chronicles our effort to conduct a rapid wetland inventory, with limited field work and by leveraging remote sensing and Geographic Information System (GIS) analyses.

Prior to the inventory, we met with park staff to discuss possible survey options for the Park. We obtained a copy of the most recent aerial photograph of the Park and surrounding area, a set of digital color infrared orthophotos from 2005, from the Irish Ordnance Survey at 1 m resolution, which provided a clear overview of the major wetlands complexes in the Park, as well as impressive detail within each wetland complex (Figure 2). We determined that up to six weeks of field sampling would be available in late spring 2008, allowing collection of no more than about 100 relevé samples. Target sample sizes for each wetland complex were apportioned from this maximum total based on the square root of the wetland complex area as well as the complexity in plant communities visible in the aerial photograph.

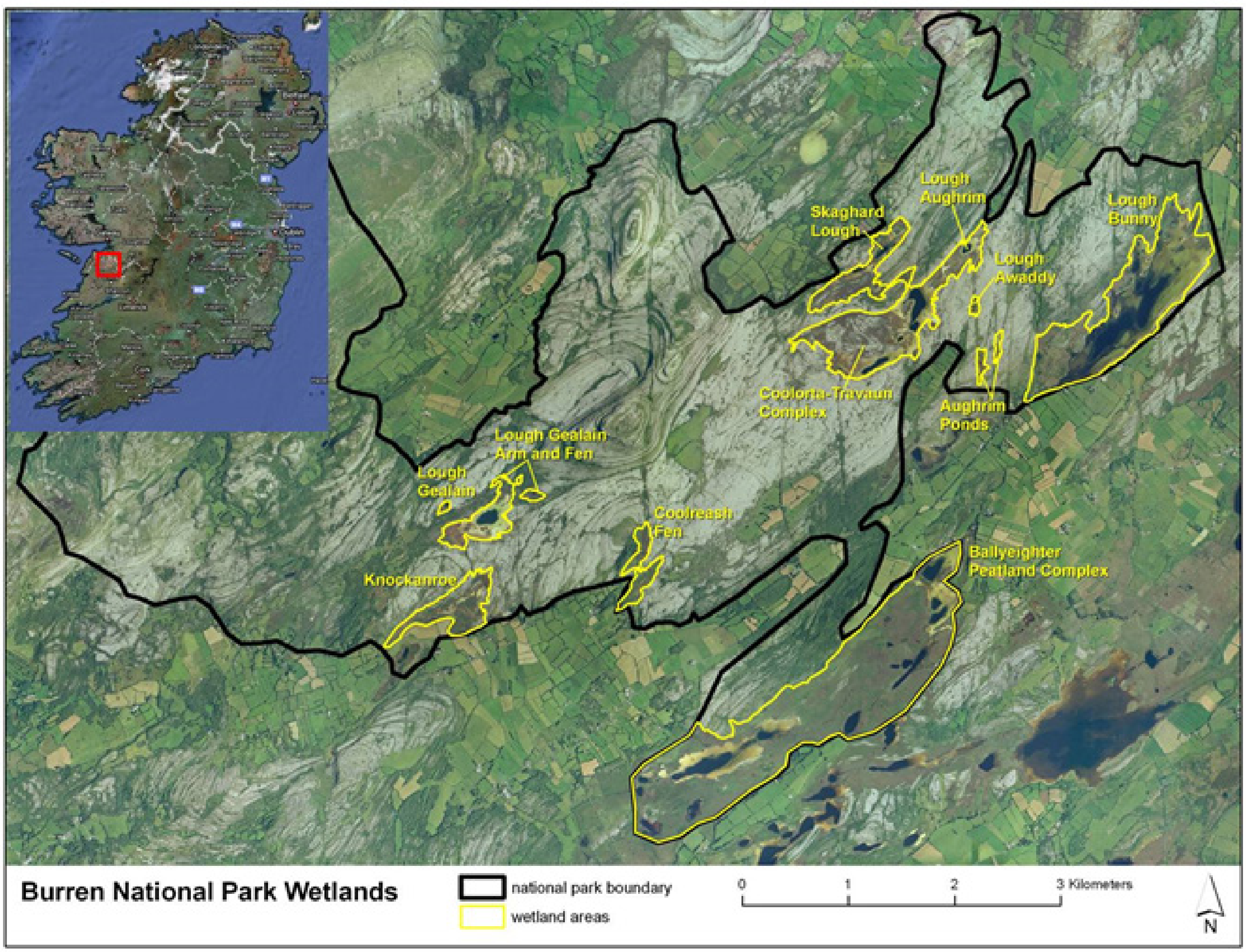


Figure 2. Insert: Location of study area in Republic of Ireland. Burren National Park, with major wetland complexes in the park labeled.

FIELD DATA COLLECTION

Between May 20 and June 25, 2008, vegetation and environmental information were collected in 2 m x 2 m relevés (quadrats), at 96 locations along 32 centripetal transects within wetlands complexes distributed throughout the Park. Each centripetal transect ran from just inside the high water flood mark (as evidenced by flotsam and shoreline moss layers) towards the center of the wetland, and was stratified into three zones, each composing a third of the total length. The relevés were placed a random distance into each zone, creating a balanced sample of high, medium, and low sites along the topographic moisture gradient. Deep water habitats (sites with over 1 m of standing water at the time of sampling) were not sampled. At each relevé, the percentage cover of all vascular plant species, *Sphagnum* (if present), other bryophytes, leaf litter, bare ground, and exposed rock were visually estimated and recorded. All vascular plant species were identified to species, if possible.

Geographic coordinates of each relevé were obtained from a Garmin GPSMAP CSx60 global positioning (GPS) unit. Each relevé was attributed with a relative elevation (1-low, 2-medium, 3-high) based on its position on the centripetal transect

IDENTIFICATION OF MAPPING UNITS

The vascular plant species frequency and environmental data were analyzed with the multivariate analysis packages PC-Ord and PRIMER to determine floristic groups and the relationship between species distributions and the environmental variables sampled. A hierarchical agglomerative cluster analysis based on Bray-Curtis similarity in floristic composition among relevés was used to identify wetland types. In this paper we describe the identification and mapping of major wetland types through parallel floristic and image analyses.

Irish Odnance Survey orthophotos were mosaicked and projected to the TM65_Irish_Grid. GPS data collected at the 96 sample relevé points were used to classify pixels at those locations. The imagery was not taken during the same time period as the field data and therefore it is important to note that some vegetation phenology may be different in field photos taken on the ground in 2008. The GPS has a horizontal accuracy of approximately 10m.

The imagery were subset to the wetlands of interest in the Burren National Park boundary to avoid confusion with agricultural land or large limestone outcrops. A supervised classification was conducted in ERDAS Imagine using training pixels that were selected from GPS data and field photos for each of 10 possible classes (described in subsequent sections) of wetland community types. The classified data were smoothed with the Neighborhood tool in ERDAS's GIS Analysis toolset in order to minimize the speckled ("salt and pepper") appearance of mapped classes. The final, smoothed classification had a minimum mapping unit of approximately 0.01 hectares (10m x 10m).

The floristic and environmental data plus two scales of imagery (photographs taken at each site and the landscape scale orthophoto) were used to identify consistent and interpretable mapping units. Such a-weight-of-evidence approach suggested that some of the floristically distinctive units were not mappable and were therefore aggregated into larger, recognizable mapping units, and that some of the floristic units were placed in the wrong mapping units. Also clearly mappable units were not always floristically homogenous. Nine relevés that were transitional in character were moved from their initial floristic classes and assigned to a broader map class. After inspecting plot maps, five samples were moved to the Turlough Floor Meadow, which had been classified as either reedswamp or sedge meadow based on floristic composition. This mapping unit seemed important enough on a parkwide basis, and was a sufficiently discrete and mappable type, to warrant separate description, even though it was floristically heterogeneous.

WETLAND COMMUNITY TYPES OF BURREN NATIONAL PARK

A total of nine mappable vegetation types were recognized from the inventory and classification (Figure 3), along with an obvious open water type. These community types

TABLE 1. HYDROLOGIC AND NUTRIENT STATUS OF MAJOR MAPPING UNITS IN BURREN NATIONAL PARK.

Hydrologic Class	*Nutrient Class*	*Community Type*	*Characteristic Species*
Temporarily Flooded	Ombrotrophic	Raised Bog	*Molinia caerulea, Myrica gale, Erica tetralix, Calluna vulgaris, Sphagnum sp.*
Temporarily Flooded	Minerotrophic	Limestone Shrubland	*Potentilla fruticosa, Rhamnus cathartica, Thymus polytrichus*
Temporarily Flooded	Minerotrophic	Limestone Meadow	*Carex flacca, Agrostis sp.*
Seasonally Flooded	Minerotrophic	Carnation Sedge Fen	*Carex panicea, Cirsium dissectum, Carex hostiana*
Seasonally Flooded	Minerotrophic	Black Bogrush Fen	*Schoenus nigricans*
Seasonally Flooded	Minerotrophic	Wet Sedge-Horsetail Fen and Flush	*Carex vesicaria, Equisetum arvense, Caltha palustris, Eleocharis palustris*
Seasonally Flooded	Minerotrophic	Turlough Floor Meadow	*Carex viridula, Carex elata, Baldellia ranunculoides, Ranunculus flammula*
Semi-permanently Flooded	Minerotrophic	Sawsedge Fen	*Cladium mariscus*
Semi-permanently Flooded	Minerotrophic	Bulrush-Common Reed Reedswamp	*Schoenoplectus lacustris, Phragmites australis*
Semi-permanently Flooded	Minerotrophic	Sparsely Vegetated Marl Flat	*Litorella uniflora, Eleocharis multicaulis*
Permanently Flooded	Oligotrophic	Open Water (Aquatic)	NA

Figure 3. Major wetland community types of Burren National Park: a.) Raised Bog, b.) Flooded Limestone, c.) Carnation Sedge Fen, d.) Black Bogrush Fen, e.) Wet Sedge Fen and Flush, f.) Turlough Floor Meadow, g.) Sawsedge Fen, h.) Bulrush-Common Reed Reedswamp (along shoreline), i.) Sparsely Vegetated Marl Flat. All photos were taken by senior author.

generally formed a gradient from temporally flooded fen and shrubland community types at the upper edges of the wetlands to seasonally and semipermanently flooded types deeper in the wetland basins. They were placed into aggregate classes based on hydrologic and nutrient status (Table 1). The floristic classification recognized three temporarily flooded upper wetland community types that corresponded to two mapping units: *Raised Bog*, *Limestone Shrubland*, and *Limestone Meadow* (the latter was indistinguishable as a mapping unit and collectively forms the *Limestone Type*). Seasonally flooded types at intermediate elevations included *Carnation Sedge Fen*, *Black Bogrush Fen*, *Wet Sedge Fen and Flush*, and *Turlough Floor Meadow*. At the lowest relative elevations (i.e., the bottoms of the wetland basins), three types were recognized semipermanently and permanently flooded *Sawsedge Fen*, *Bulrush-Common Reed Reedswamp*, and *Sparsely Vegetated Marl Flat* (Table 1). The flora of the Park is composed of a matrix of perennial graminoids, with interspersed annual and perennial forbs that are often quite showy (Figure 4).

The supervised classification produced clear mapping units in the Park that were easily identifiable by color and texture in the original orthophoto and interpretable from field photos (Figure 5; embedded images in Figure 6). As an example of the mapping results, Figure 6 shows a tessellated digital map for the Skaghard-Coolorta-Travaun-Aughrim Wetland Complex, an interconnected set of wetland basins within the Park.

The major wetland complexes studied totaled over 520 ha, or approximately one third of the area of the entire park (Table 2). The wetland complexes are typically represented by a half dozen or more wetland types, and often with considerable open water habitat. In aggregate, the various fen types formed the largest share (48.9%) of wetland area. Raised Bog, in contrast, composed only 2% of the area, which is very unusual in far west Ireland. Turloughs and open water habitats each composed nearly a fifth of the Park. Turlough Floor Meadow was fairly extensive and easily recognizable, but it contained a floristically heterogeneous mosaic of marl flat, fen, and reedswamp plant species. Reedswamp was a relatively minor element (1.1%), occurring only around permanent deepwater habitats, although Sawsedge Fen, characterized by 2 m high monotypic stands of sawsedge (*Cladium mariscus*), is arguably similar to reedswamp in form and distribution. Open water was largely centered in Lough Bunny, a large, shallow limestone lake. The Ballyeighter Peatland complex was the most heterogeneous and diverse wetland in the Park, containing all nine wetland vegetation mapping units, as well as considerable open water habitat (Table 2).

INTERPRETING BURREN NATIONAL PARK WETLANDS

This modest inventory and monitoring effort demonstrated that Burren National Park contains a number of distinctive and clearly recognizable community types. These elements are clues to a more holistic and dynamic interpretation of wetlands in BNP. This study, and especially the seminal wetland research of Dr. Michael Proctor over nearly five decades (Ivimey-Cook and Proctor 1966, Proctor 2010), suggest that the wetland landscape of BNP is an expression of diverse hydrologic, ecological, and human interactions over time. Within the BNP, Mullaghmore Mountain (Figure 1) forms both the visual centerpiece and the driving hydrogeomorphic feature, where orographic precipitation peaks, and where rains and occasional snows percolate downward to recharge the karst aquifers underlying the Park. Ground and surface water flow from the mountain southeast through the Park into the River Fergus system draining into the Shannon Estuary. Along these varied and largely occult paths, porous limestone bedrock and lacustrine deposits with different degrees of free drainage and hydraulic conductivity yield considerable complexity in wetland hydrology. At highest elevations on the mountain slopes, fens predominate (Figures 3c, d, g, and e), due to consistent groundwater discharge. These fens yield steady flow into the larger turlough basins downslope (Figures 3f, i), with corresponding increases in hydrologic variability. Examples include the Lough Gealáin Fen, which empties into the larger, more complex Lough Gealáin, which in turn feeds Knockanroe Lough and Ballyeighter Peatland before leaving the Park. Due to the porous limestone, much of the connection is below ground during drier periods in summer, and lake surfaces are expressions of the local water table (Figure 1). Proctor (2010) suggests that areas at the easternmost part of the Park, which empty into Lough Bunny, eventually reach Galway Bay through subterranean paths.

Within the individual wetland complexes of BNP (Figure 2), the gradients in soil moisture and flood duration from edge to center were associated with relatively predict-

TABLE 2. AREA OF EACH MAPPING UNIT IN THE MAJOR WETLAND COMPLEXES OF BURREN NATIONAL PARK.

Mapping Unit	*Ballyeighter Peatland*	*Coolreash*	*Knockanroe*	*Skaghard Lough*	*Coolorta*	*Lough Awaddy / Aughrim Ponds*	*Lough Bunny*	*Lough Gealainn*	*All Wetland Complexes*	
	Area (ha)									**Percent of Total Area**
Wet Sedge Fen and Flush	1.9	2.9				0.1	8.9	0.5	14.3	2.7
Raised Bog	10.7								10.7	2.0
Carnation Sedge Fen	24.8	5.5	3.2	3.1	1.8	0.3			38.7	7.4
Black Bogrush Fen	112.6	0.5	9.3	8.5	14.5			5.0	150.4	28.8
Sawsedge Fen	26.5	0.9	0.1	2.0	8.3	1.1	12.1	1.5	52.3	10.0
Sparsely Vegetated Marl Flat	22.2		1.2		14.7	0.5		6.1	44.7	8.6
Flooded Limestone	10.6		5.6	3.6	16.4	0.4	9.1	2.2	48.0	9.2
Turlough Floor Meadow	17.0	1.7	8.2	7.7	13.4	0.4		5.6	54.1	10.3
Reed-Bulrush Reedswamp	1.3	0.0		0.9	1.5	0.7	0.5	0.7	5.5	1.1
Open Water	21.0	0.1	0.1	1.4	4.8	0.0	74.2	2.4	104.1	19.9
Cumulative Totals	**248.6**	**11.7**	**27.7**	**27.1**	**75.5**	**3.5**	**104.7**	**23.9**	**522.8**	**100.0**
Number of Vegetation Mapping Units	**9**	**6**	**6**	**6**	**7**	**7**	**4**	**7**		

Figure 4. Common wetland plant of Burren National Park: a) Tufted sedge (*Carex elata*), b) Early Marsh-orchid (*Dactylorhiza incarnata*), c) Black bog rush (*Schoenoplectus nigricans*), d) Tormentil (*Potentilla erecta*), e)Bog thistle (*Cirsium dissectum*), and f) Creeping buttercup (*Ranunculus repens*). All photos were taken by senior author.

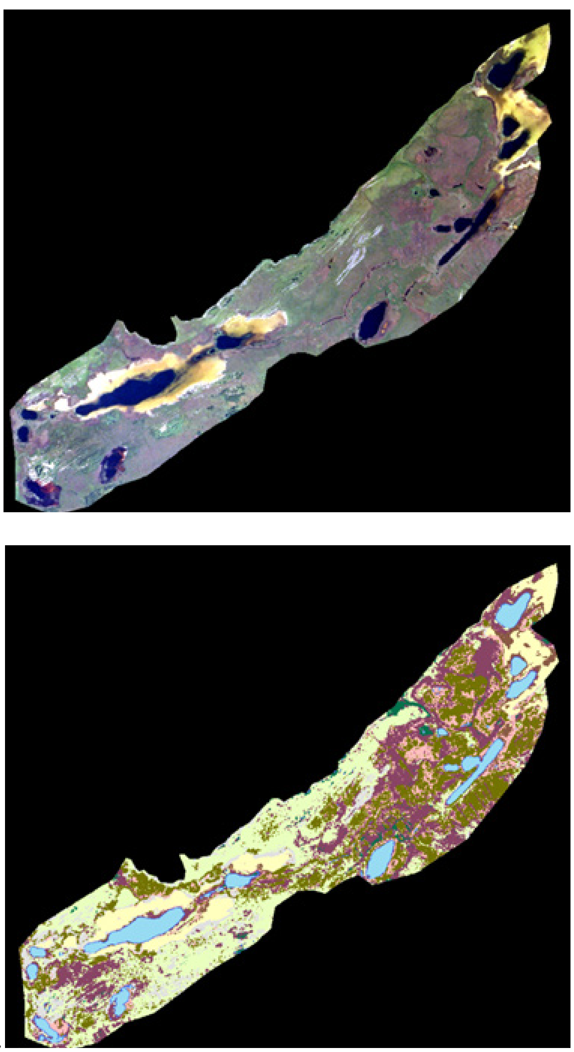


Figure 5. Image classification of Ballyeighter Peatland Complex: a) original orthophoto and b) ERDAS Imagine image classification.

able changes in plant community type. However, there appears to be considerable floristic overlap in many of the widespread types in the Park, suggesting that perhaps establishment effects or other factors play a role in the current distribution of the major types.

Proctor (2010) also suggests that the wetlands of the Park and environs have been highly dynamic over time, with evidence of major geomorphic changes as well as accumulation, erosion, and human extraction of peat resources in several of the wetland basins, such as Lough Gealáin and Ballyeighter. The delineation of relatively discrete mapping units, therefore, although a great help in describing the major wetland types, should be not be interpreted as defining fixed and immutable units. Rather, they may be best viewed as extant clues to the origins, patterns, and dynamics of an ever changing wetland landscape.

INVENTORY CONCLUSIONS

This collaborative mapping from approximately 5 weeks of fieldwork, with subsequent floristic and image analyses, provided a clear and interpretable wetland map for Burren National Park. A second visit was not possible, and the sample size was modest, so an accuracy assessment was not conducted. Therefore, this map must be viewed as a rapid assessment effort that would undoubtedly be improved with more detailed effort. Nonetheless, it provides an overview of the elements and distributions of the park wetland resources, and a number of new insights.

First, wetlands and lacustrine environments cover over one third of the total area of Burren National Park, and are composed of diverse landscape mosaics that are undoubtedly important for biodiversity. Second, the wetlands are dominated by fens, turloughs, and shallow limestone lakes, which are highly distinct in the larger region. In particular, the relatively large extent of turlough types suggests BNP is an ideal place for the study of these globally distinctive wetlands. Third, concurrent floristic and image (orthophoto) classification can provide meaningful and information-rich wetland maps, if the number of types is modest and the boundaries between them fairly distinct, as they are at BNP. And finally, collaborative inventory and mapping efforts can provide excellent opportunities to learn about new wetland landscapes, while providing important new resources for park managers. ■

ACKNOWLEDGEMENTS

The authors appreciate salary support from the U.S. National Park Service Klamath Network Inventory and Monitoring Program, U.S. Geological Survey, and Southern Oregon University. Travel, lodging, logistics, and partial salary support for the senior author were provided by a fellowship from the Irish-American Fulbright Commission. Emma Glanville, Seamus Hassett, and Tim O'Connell of the National Parks and Wildlife Service provided excellent guidance and an orientation to Burren National Park wetlands and management issues. John Curtin and Micheline Sheehy Skeffington of National University of Ireland helped with fieldwork and vegetation analyses. Joel Sankey of U.S. Geological Survey provided comments that greatly improved an earlier version of this manuscript.

LITERATURE CITED

Coxon, C. 1987. An examination of the characteristics of turloughs, using multivariate statistical techniques. *Irish Geography* 20, 24–42.

Feehan, J, and G. O'Donovan. 1996. *The bogs of Ireland: an introduction to the natural, cultural and industrial heritage of Irish peatlands.* Dublin Environmental Institute. 533 pp.

Goodwillie, R. 2003. Vegetation of Turloughs. In: M.L. Otte (ed.): *Wetlands of Ireland: Distribution, ecology, uses and economic value.* University College Dublin Press, Dublin.

Ivimey-Cook, R.B. and Proctor, M.C.F. 1966. The plant communities of the Burren, Co. Clare. *Proceedings of the Royal Irish Academy* 64B, 211–301.

Moran, J., Kelly, S., Sheehy Skeffington, M. and Gormally, M. 2008. The influence of hydrological regime and grazing management on the plant communities of a karst wetland (Skealoghan turlough) in Ireland. *Applied Vegetation Science* 11, 13–24.

O'Connell, M. O. J.B. Ryan, and B. A. MacGowran. 1984. Wetland communities in Ireland: a phytosociological review. pp 303-364 In P.D. Moore (ed) *European Mires*. Academic Press, London, UK.

O'Criodain, C., and G. J. Doyle. 1997. *Schoenetum nigricans*, the *Schoenus* fen and flush vegetation of Ireland. *Biology and Environment.* 94B(2): 127-144.

Otte, M.L. 2003. *Wetlands of Ireland: Distribution, ecology, uses and economic value.* University College Dublin Press, Dublin.

Praeger, R. L. 1932. The flora of the turloughs: A preliminary note. *Proceedings of the Royal Irish Academy* 41B, 37-45. Dublin: Royal Irish Academy.

Proctor, M. 2010. Environmental and vegetational relationships of lakes, fens and turloughs in the Burren. *Biology and the Environment: Proceedings of the Royal Irish Academy* 110(1): 17-34.

Regan, E.C., Sheehy Skeffington, M. and Gormally, M.J. 2007. Wetland plant communities of turloughs in southeast Galway/north Clare, Ireland in relation to environmental factors. *Aquatic Botany* 87, 22–30.

Sarr, D., C. Clotworthy, and R. Millar. 2014. Restoring Biodiversity in Ireland's National Parks. *Park Science* 31(1):120-123.

Sarr, D. M. Sheehy Skeffington, J. Curtin, and L. Groshong. In Press. An Inventory of Wetland Plant Communities in Burren National Park, Ireland. NPS Natural Resource Report NPS/KLMN/NRR—2015/XXX. National Park Service, Fort Collins, CO. 124 pp.

Sheehy Skeffington, M., Moran, J., O Connor, Á., Regan, E., Coxon, C.E., Scott, N.E. and Gormally, M. 2006. Turloughs—Ireland's unique wetland habitat. *Biological Conservation* 133, 265–90.

Webb, D.A. 1964. Some micro-habitats in the Burren, their micro-environments and vegetation. *Proceedings of the Royal Irish Academy* 63B 16, 291-302.

Wheeler, B. D. and M. C. F. Proctor. 2000. Ecological Gradients, Subdivisions and Terminology of North-West European Mires. *Journal of Ecology* 88(2):187-203.

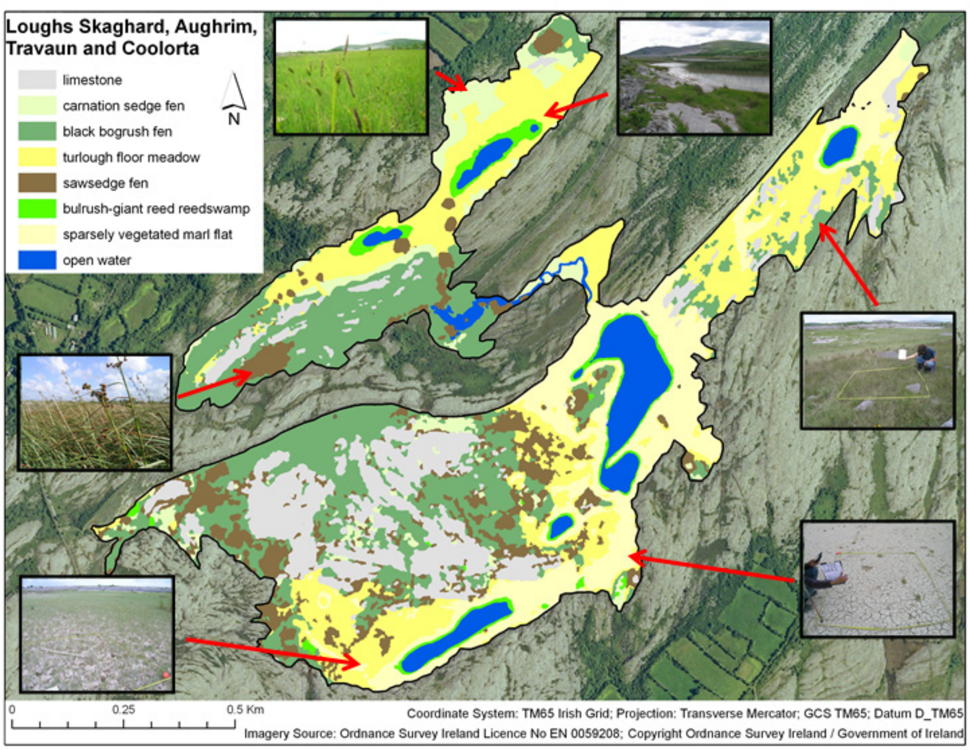


Figure 6. Overview of major wetland community types of the Skaghard-Travaun-Coolorta Turlough complex.

Coastal Planning on the U.S. National Wildlife Refuge System with the Sea Level Affecting Marshes Model (SLAMM)

Brian Czech , U.S. Fish and Wildlife Service, National Wildlife Refuge System, Falls Church, VA

The U.S. National Wildlife Refuge System (Refuge System) includes 173 marine coastal refuges that provide exceptional benefits for fish and wildlife as well as valuable ecosystem services to local and regional economies. Many of these refuges have historic and cultural significance. For example, Pelican Island (FL) was the first national wildlife refuge (NWR), Chincoteague NWR (VA) has the visitation of a national park, and Dungeness NWR (WA) remains a stronghold of tribal culture. Most coastal refuges, with notable exceptions primarily in Oregon and Alaska, also have gently sloping shoreline topography, leaving them vulnerable to sea-level rise.

Global sea levels rose 10-25 cm during the 20th century (Douglas et al. 2000). A commonly cited range of sea-level rise projections for the 21st century is 0.13-0.69 m. This range corresponded to the "A1B" family of scenarios identified by the Intergovernmental Panel on Climate Change in its Third Assessment (IPCC 2001). However, several peer-reviewed projections exceed 0.69 m by 2100. For example, Chen et al. (2006) and Monaghan et al. (2006) found that eustatic sea-level rise is progressing more rapidly than the IPCC estimates, probably due to the dynamic changes in ice flow omitted from the IPCC calculations. Higher estimates are consistent with the fact that the rate of sea-level rise increased in recent decades and continues to accelerate (Grinsted et al. 2009; Cazanave and Llovel 2010). Vermeer and Rahmstorf (2009) projected sea-level increases from 0.75-1.90 for the period 1990–2100. Grinsted et al. (2009:469) found that "all IPCC scenarios produce sea level rise about a factor of three smaller than our predictions." Pfeffer et al. (2008) posited that 2 m of sea-level rise is at the upper end of 21st Century plausible scenarios due to physical limitations on glaciological conditions and trends, while Levermann et al. (2013:1) emphasized post-2100 sea-level rise scenarios in which, over the next two millennia, "we are committed to a sea-level rise of approximately 2.3 m" for every 1 °C increase in global mean temperature.

Rates of relative sea-level rise may differ greatly from global eustatic rates due to a variety of geological, ecological, and oceanic processes (Sallenger et al. 2012; Stammer et al. 2013). For example, isostatic rebound is fast enough at some Alaskan refuges that land-building occurs despite eustatic sea-level rise. On the other hand, for many refuges erosion and subsidence exacerbate the effects of sea-level rise. Due to a combination of factors, some of the highest rates of coastal land loss in the world occur in Louisiana, including at refuges such as Breton, Delta, and Shell Keys (Tidwell 2003).

Most coastal refuges were established due to the value of their tidal ecosystems to migratory waterfowl, shorebirds, anadromous fishes, marine mammals, sea turtles, and other species of special concern. Many of these are federally or state-listed threatened or endangered species or are otherwise imperiled, due largely to the economic geography of coastal regions (Czech 2002). The intensive economic activity along coastlines replaces and impacts remaining wildlife habitats, simultaneously contributing disproportionately to the greenhouse gas emissions associated with global warming and sea-level rise (Czech et al. 2000).

The high value of coastal refuges along with their geographic and topographic vulnerability calls for planning for sea-level rise on the Refuge System. Such planning was required no later than January 19, 2001, when Secretarial Order No. 3226 called for Department of the Interior agencies to "consider and analyze potential climate change impacts when undertaking long-range planning exercises, when setting priorities for scientific research and investigations, when developing multi-year management plans, and/or when making major decisions regarding the potential utilization of resources under the Department's purview" (Babbitt 2001:1). Such consideration and analysis was to be manifest in, among other things, "management plans and activities developed for public lands." By now, there are numerous additional policies and directives requiring the Refuge System to plan for climate change and sea-level rise. One of the most relevant for Refuge System staff is the U.S. Fish and Wildlife Service (FWS) climate change strategic plan, Rising to the Urgent Challenge, which calls for conducting "sea level rise modeling (e.g., Sea Level Affecting Marshes Model) for all coastal refuges and expand modeling to additional coastal areas, as practicable, to determine the vulnerability of these areas" (FWS 2010:24).

[1]Email: brian_czech@fws.gov. The findings and conclusions in this article are those of the author and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

The purpose of this article is to explore what the Refuge System has done thus far with regard to sea-level rise planning. The focus is on the Refuge System's use of the Sea Level Affecting Marshes Model (SLAMM) due to its prominence in wildlife-oriented sea-level rise planning. The discussion includes historical and technical overviews of SLAMM, its use on the Refuge System, limitations of SLAMM, and suggestions for improving SLAMM.

SEA LEVEL AFFECTING MARSHES MODEL (SLAMM)

History SLAMM has been the predominant model for sea-level rise planning on the Refuge System. It accounts for the major processes involved in wetland conversion and shoreline modification during long-term sea-level rise (www.warrenpinnacle.com/prof/SLAMM). The first version of SLAMM was developed in the 1980s by Dick Park at Butler University with a grant from the U.S. Environmental Protection Agency (EPA) (Park et al. 1989). Park continued developing SLAMM over the next 15 years with colleagues including Manjit Treham (Version 2) at Butler and Jay Lee (Version 3) at Indiana University. During the late 1990s Jonathan Clough of Warren Pinnacle Consulting (Waitsfield, VT) became involved in the development of SLAMM 4 and has been the primary SLAMM developer and modeler through versions 5 and 6.

In 2005 the Conservation Biology Program of the Refuge System initiated a cooperative project with the University of Maryland's Conservation Biology and Sustainable Development Program (CONS). CONS graduate students were challenged to develop a sea-level rise model for use on the Refuge System. This model was tentatively called the Zonal Inundation and Marsh Model (ZIMM), but background research revealed that SLAMM was already well-suited for Refuge System planning purposes. Furthermore, it was found to be readily accessible and relatively affordable, and the Refuge System already had the capacity to perform or contract for SLAMM analysis.

Shortly after the CONS project, the National Wildlife Federation (NWF) and the Florida Wildlife Federation (FWF) published An Unfavorable Tide, a SLAMM-based report on the projected effects of sea-level rise on fisheries in Florida (NWF and FWF 2006). Building on the report and in collaboration with the Conservation Biology Program, Sean McMahon (NWF and Virginia Tech) parsed out portions of the report specific to national wildlife refuges (McMahon 2007). Simultaneously, fellow Virginia Tech graduate student Delissa Padilla used SLAMM to model the effects of sea-level rise at Vieques NWR (Puerto Rico; Padilla 2008). Padilla was later hired by FWS and performed SLAMM analysis for several Atlantic and Gulf Coast refuges, including an advanced SLAMM analysis of Chincoteague NWR tailored to addressing the beach dynamics of Assateague Island.

By 2009, SLAMM had become the "workhorse model" for sea-level rise planning on the Refuge System due to

TABLE 1. REFUGES WITH SLAMM ANALYSIS.

National Wildlife Refuge	*FWS Region*	*State*	*Year of SLAMM Analysis*	*Year of SLAMM Reanalysis*	*SLAMM Version (Most Recent Analysis)*
ACE Basin	4	SC	2008	2013	6
Alligator River	4	NC	2008	2013	6
Amagansett	5	NY	2009		5
Anahuac	2	TX	2011		6
Aransas	2	TX	2010		6
Archie Carr	4	FL	2010		6
Back Bay	5	VA	2011		6
Bandon Marsh	1	OR	2010		6
Bayou Sauvage	4	LA	2008	2012	6
Bayou Teche	4	LA	2008		5
Big Boggy	2	TX	2011		6
Big Branch Marsh	4	LA	2008	2012	6
Blackbeard Island	4	GA	2008	2012	6
Blackwater	5	MD	2009		5
Block Island	5	RI	2009		5
Bombay Hook	5	DE	2010		6
Bon Secour	4	AL	2008		5
Brazoria	2	TX	2011		6
Breton	4	LA	2011		6
Cabo Rojo	4	PR	2008		5
Caloosahatchee	4	FL	2008		5
Cape May	5	NJ	2009	2011	6
Cape Romain	4	SC	2008		5
Cedar Island	4	NC	2010		6
Cedar Keys	4	FL	2011		6
Chassahowitzka	4	FL	2008		5
Chincoteague	5	VA	2009		5
Conscience Point	5	NY	2009		5
Crocodile Lake	4	FL	2010		6
Crystal River	4	FL	2008		5
Culebra	4	PR	2007		5
Currituck	4	NC	2010		6
Delta	4	LA	2011		6
Don Edwards San Francisco Bay	8	CA	2010		6
Dungeness	1	WA	2010		6
Eastern Neck	5	MD	2009		5
Eastern Shore of Virginia	5	VA	2009		5
Edwin B. Forsythe	5	NJ	2008	2012	6
Egmont Key	4	FL	2012		6
Elizabeth A. Morton	5	NY	2008		5
Featherstone	5	VA	2010		6
Fisherman Island	5	VA	2009		5
Grand Bay	4	MS	2011		6
Grays Harbor	1	WA	2011		6
Great Bay	5	NH	2009		5
Great White Heron	4	FL	2011		6
Green Cay	4	VI	2008		5

a unique combination of characteristics. Most notably, it was a long-tested, freely available, transparent, spatially explicit model which was necessary for producing maps. It was applicable at the refuge, regional, and national level and conducive to systematic usage and economies of scale. Furthermore, it was tailored to use with the FWS's wetland classification system (Cowardin et al. 1979). (Note: In 1996 the updated Cowardin et al. system was designated as the national standard - "FGDC-STD-004" - for wetland classification; FGDC 2013). The use of this system in SLAMM was important for technical and administrative reasons, as the Cowardin et al. system had a long history of development by FWS and a well-developed program – the National Wetlands Inventory (NWI) – dedicated to maintaining a spatially explicit inventory of nation's wetlands.

In their review of sea-level rise models useful for conservation purposes, Mcleod et al. (2010) evaluated numerous types of models and featured three for detailed assessment, including SLAMM. No models besides SLAMM were found to have the suite of characteristics noted in the preceding paragraphs. For example, the Dynamic Interactive Vulnerability Assessment (DIVA) "is designed for global, regional, and national-level assessments" and "not appropriate for local scale coastal management" (Mcleod et al. 2010:510). Another model, SimCLIM, is used more in international affairs and academic settings than for conservation purposes in the United States. It has been used primarily in Southeast Asia and Australia and is a broad-based climate change software package. SimCLIM may be used in coastal areas and has several features in common with SLAMM, but it requires licensing and training courses. Mcleod et al. (2010) briefly discussed simple types of inundation models including "bathtub ring models" that project future shorelines based entirely on eustatic sea-level rise and topography. They can be useful for a quick, preliminary assessment of

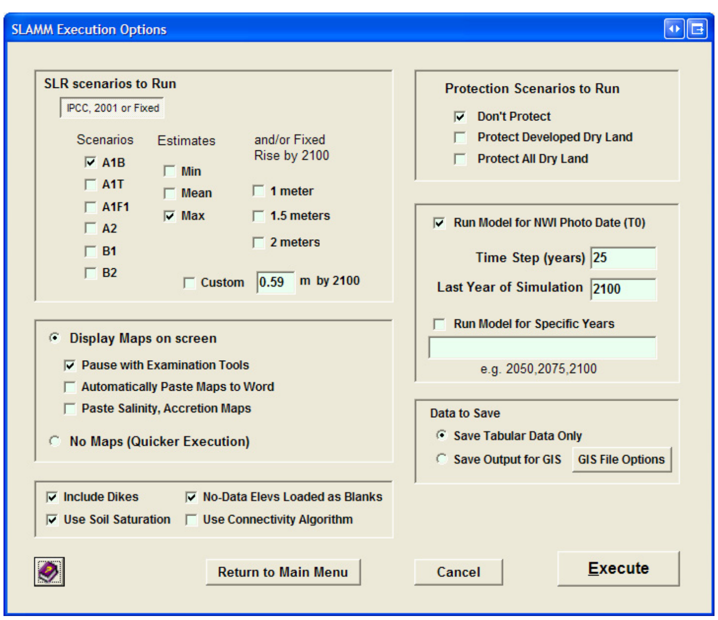


Figure 1. Sea-level rise scenario menu in SLAMM, a typical interface for the SLAMM modeler.

vulnerability, but provide no detail on habitat transitions except at the crudest level of land to open water. Mcleod et al. (2010:510) also described a category of "ecological landscape spatial simulation models" such as the Barataria-Terrebonne ecological landscape spatial simulation, which was developed to predict wetland habitat change in the Mississippi Delta over a 30-year period. Some of these models (inundation and ecological) will be of use to particular refuges. A common problem, however, is that they require substantial expertise to run, due to model complexity, and "can be extremely expensive" (Mcleod et al. 2010:510). The findings of Mcleod et al. (2010) corroborate the FWS rationale for the selection of SLAMM for most sea-level rise planning on the Refuge System. Although Rising to the Urgent Challenge (FWS 2010:24) did not mandate the use of SLAMM for modeling the effects of sea-level rise, it did recommend modeling the impacts of sea-level rise, and SLAMM was the only model noted.

The identification of SLAMM as a model of choice in systematic FWS planning also resulted partly from intra-agency collaboration. The National Wetlands Inventory (NWI) had taken an early interest in the use of the model and, along with the Division of Fisheries and Habitat Conservation, was helpful in funding much of the early Refuge System SLAMM work. NWI also scheduled their wetland map updates based partly on Refuge System SLAMM analysis needs. NWI remains a key partner in Refuge System SLAMM analysis and plays the leading role in facilitating the use of SLAMM-View, a web-based SLAMM-analysis viewer that enables the reader to modify input variables and compare SLAMM results.

SLAMM has also been one of the most widely used models of sea-level effects on coastal marshes beyond the Refuge System as well. Earlier and recent versions of SLAMM were applied to numerous sites along U.S. coastline by the EPA, NWF, Ducks Unlimited, The Nature Conservancy, Indiana University, University of Florida, State of Delaware, and the Gulf of Mexico Alliance, along with numerous partners. Most SLAMM reports would be classified as "gray literature" (e.g., Titus et al. 1991; Lee et al. 1992; Park et al. 1993; NWF and FWF 2006; McMahon 2007; Glick et al. 2007; Padilla 2008). However, several peer-reviewed articles based on or about SLAMM analysis have also been published (Galbraith et al. 2002; Craft et al. 2009; Chu-Agor et al. 2011; Traill et al. 2011; Geselbracht et al. 2011; Glick et al. 2013). Several of the peer-reviewed studies incidentally but directly benefited the Refuge System. For example, SLAMM reports for nine refuges were parsed out of the analysis conducted by Craft et al. (2009), and one for Delta NWR was parsed out of the analysis conducted by Glick et al. (2013).

How SLAMM Works SLAMM is a menu-driven program allowing the modeler to enter GIS data and values for the input variables (Figure 1). The SLAMM interface is functional with Microsoft Windows (the standard operating system used by FWS). Some of the key input variables include wetland type, elevation, tidal range, and accretion rate. These and other variables are either mapped as continuous functions on the landscape (e.g., elevation) or in discrete units (e.g., wetland type) (Figure 2). SLAMM incorporates investigative tools for purposes of quality control and model calibration (Figures 3 and 4).

The modeler must also select which sea-level rise scenarios or schedules to run SLAMM with. Scenarios are typically run out to the year 2100, with results shown at several increments such as 2025, 2050, 2075 and 2100. On the Refuge System, scenarios selected for analysis usually include 0.39 m (A1B Mean), 0.69 m (A1B Max), 1 m, 1.5 m, and 2 m, reflecting the range of sea-level rise literature reviewed in the introduction. Although numerous scenarios are selected for SLAMM analysis, Refuge System personnel typically focus on the 1-1.5 m range for planning and management purposes (Czech et al. 2014).

The primary processes that SLAMM models and integrates are inundation by saltwater, erosion of shoreline, vertical accretion of sediments and plant material, barrier island overwash, and saturation of uplands with fresh water resulting from rising water tables. Each of these processes is instrumental in determining the development or devolution of coastal marshes and related habitats (including beaches, mudflats, and swamps) in response to sea-level rise. Details of the logical structure, assumptions, equations and algorithms represented in SLAMM are found in the technical documentation (Clough et al. 2010).

The NWI data used as SLAMM inputs are converted into 26 output categories (Clough et al. 2010). These categories represent distinct combinations of geomorphology, physiognomy, tidal regime, salinity, and vegetative composition. They are also labeled in a manner that is conducive to efficient communication among wildlife managers. Basic habitat characteristics of a SLAMM category such as "cypress swamp" are immediately recognizable; such is not the case with its corresponding NWI alpha-numeric code used for mapping - PFO2C. For wetland scientists and certain wildlife management applications, however, SLAMM categories can be relatively coarse, since there are well over a thousand NWI wetland types that are converted into the 26 SLAMM categories. Occasionally SLAMM is tailored to produce maps and tables with finer categories than the basic 26, sometimes using insights from other land classification systems such as the National Vegetation Classification (http://usnvc.org/).

One recent development warrants some elaboration here to address concerns about how SLAMM processes accretion rates. In earlier versions of SLAMM, accretion rates were held constant for particular SLAMM categories. Recent research suggests that increasing inundation leads to higher sediment deposition and organic-matter production

TABLE 1. REFUGES WITH SLAMM ANALYSIS. ***(CONTINUED)***

National Wildlife Refuge	*FWS Region*	*State*	*Year of SLAMM Analysis*	*Year of SLAMM Reanalysis*	*SLAMM Version (Most Recent Analysis)*
Guadalupe-Nipomo Dunes	8	CA	2008		5
Guam	1		2010		6
Harris Neck	4	GA	2008	2011	6
Hobe Sound	4	FL	2010		6
Huleia	1	HI	2010		6
Humboldt Bay	8	CA	2011		6
Island Bay	4	FL	2008		5
J.N. `Ding` Darling	4	FL	2011	2013	6
James River	5	VA	2010		6
John H. Chafee	5	RI	2009		5
John Heinz	5	PA	2009		5
Julia Butler Hansen	1,8	OR,WA	2011		6
Kakahai'a	1	HI	2010		6
Key West	4	FL	2011		6
Kilauea Point	1	HI	2010		6
Laguna Atascosa	2	TX	2011		6
Lewis and Clark	1	WA	2011		6
Lido Beach WMA	5	NY	2009		5
Lower Rio Grande Valley	2	TX	2011		6
Lower Suwannee	4	FL	2011		6
Mackay Island	4	NC	2010		6
Mandalay	4	LA	2008		5
Marin Islands	8	CA	2010		6
Martin	5	MD	2009		5
Mashpee	5	MA	2009	2012	6
Mason Neck	5	VA	2010		6
Matlacha Pass	4	FL	2008		5
McFaddin	2	TX	2011		6
Merritt Island	4	FL	2008	2011	6
Mississippi Sandhill Crane	4	MS	2012		6
Monomoy	5	MA	2009	2012	6
Moody	2	TX	2011		6
Moosehorn	5	ME	2008		5
Nansemond	5	VA	2009		5
Nantucket	5	MA	2009		5
National Key Deer Refuge	4	FL	2008		5
Nestucca Bay	1	OR	2010		6
Ninigret	5	RI	2009		5
Nisqually	1	WA	2011		6
Nomans Land Island	5	MA	2009		5
Occoquan Bay	5	VA	2010		6
Oyster Bay	5	NY	2009		5
Parker River	5	MA	2009		5
Passage Key	4	FL	2008		5
Pea Island	4	NC	2008		5

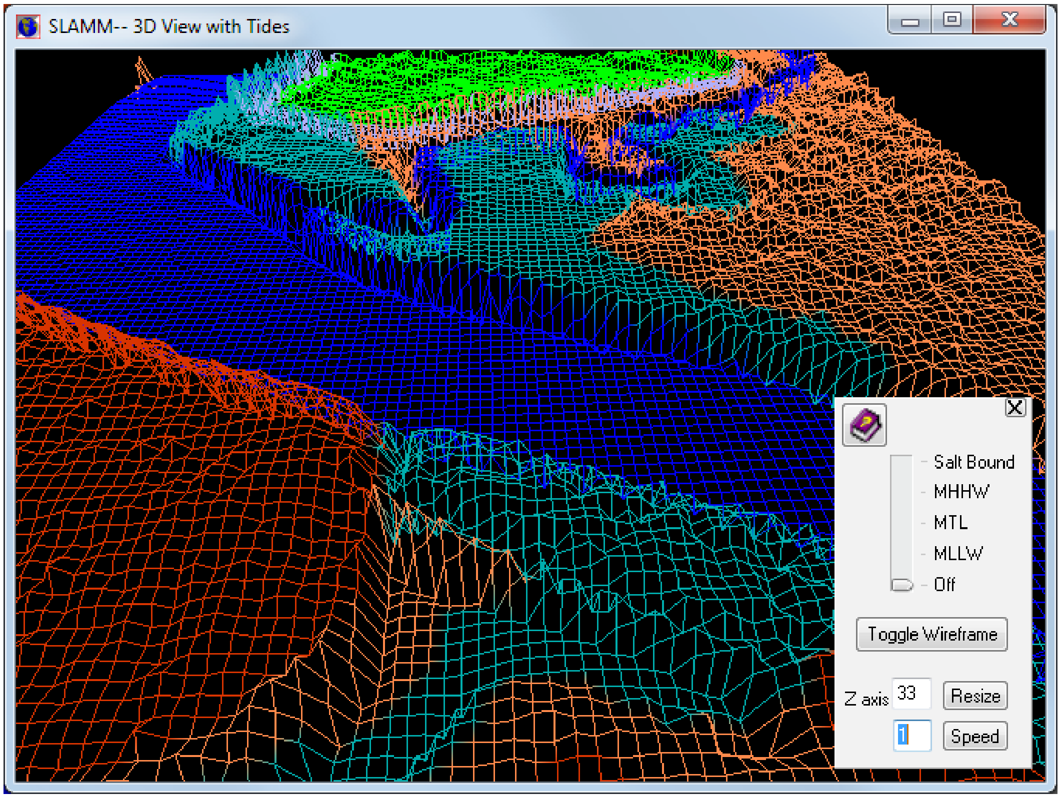


Figure 2. Three-dimensional viewing capability of SLAMM allows modelers to review wetland and elevation conditions.

which can help tidal wetlands keep up with sea-level rise (Kirwan et al. 2010). This relationship has been incorporated into SLAMM since version 6 was released in 2009. Within SLAMM, for tidal marsh and tidal swamp categories, a user can specify relationships between wetland platform elevations (representing frequency of inundation) and vertical rates of accretion. The relationships between elevations and accretion rates may vary spatially and by vegetation category and may be specified via mechanistic accretion-rate modeling or empirical relationships when data are available.

The primary SLAMM outputs are land cover maps and tables (Figure 5). Several other outputs, products, and interpretive tools are optional. For example, a recently developed roads module produces maps of projected road (and other transportation infrastructure) inundation for assistance in transportation planning. An uncertainty module may be used to generate probability distributions of most input and output variables, giving modelers and managers insights to the sensitivity of SLAMM to particular variables and the robustness of results. The related SLAMM Uncertainty Viewer is useful for concise briefings of decision makers. Meanwhile the web-based platform noted above, SLAMM-View, allows non-modelers at various levels of expertise to investigate SLAMM results interactively. A user's manual is available to assist modelers with the use of SLAMM (Warren Pinnacle Consulting 2010). The SLAMM Uncertainty Viewer (http://www.warrenpinnacle.com/prof/SLAMM/SLAMM_Uncertainty.pdf) and SLAMM-View (http://www.slammview.org/) are separate, stand-alone products.

What SLAMM Doesn't Do

SLAMM has numerous limitations pertaining to the physical processes affecting coastlines and their ecosystems. For example, SLAMM does not model storm surge patterns, intensities, or changes in the context of climate change. SLAMM is not a sediment balance model and does not forecast the movements of sediments along the coastline. Nor does SLAMM differentiate among coastal substrates that may influence subsurface processes such as the salt-wedging upward of inland aquifers that causes saturation of inland soils and the formation of freshwater marshes. SLAMM also does not incorporate complex hydrodynamic modeling, and does not have the ability to forecast the convoluted channelization that may spread through an inundated marsh platform (Kirwan and Guntenspergen 2010). It also has limitations pertaining to the ecological transformations caused by sea-level rise. For example, it does not model any species' distributions. Nor does it provide any indication of the condition or health of a wetland or other ecosystem; it simply assigns an ecosystem category to each cell.

As with any model, the accuracy and precision of SLAMM analysis is a function of input data quality. Examples of crucial input variables are elevation, accretion rates, and wetland types. At this point in the development and use of SLAMM, it is not usually worthwhile to run the model in the absence of elevation data derived from LiDAR (Light Detection and Ranging) technology, but care must also be taken to ensure that LiDAR data were properly processed to accurately derive elevations (Gesch 2009). Since accretion rates may be highly variable within a study area and can be difficult to ascertain, monitoring accretion with sedimentation-erosion tables (SETs) is recommended (Cahoon et al. 1995, 2002; Callaway and Siegel 2002). Wetland types must be monitored and mapped over large areas and with reasonably fine resolution; a challenge to NWI and related programs in an age of fiscal austerity.

SLAMM ANALYSIS ON THE REFUGE SYSTEM

Extent of SLAMM Analysis Detailed SLAMM results are found in all refuge-specific reports, which may be downloaded at the Refuge System planning website (http://www.fws.gov/refuges/planning/seaLevelRise.html). Cumulative analyses are also underway. For example, Refuge System staff and partners are analyzing the cumulative SLAMM results from Atlantic Coast refuges for informing Atlantic Flyway planning decisions, among other purposes. The results of specific SLAMM analyses are not provided in this paper except for two refuges – Bayou Sauvage (LA) and St. Marks (FL); see Figures 5 and 6, respectively.

Of the 173 marine coastal refuges, SLAMM is not significantly applicable to 26 refuges where rocky islands are the predominant feature (most common in the Pacific Northwest). Also, SLAMM is not applicable or appropriate for the foreseeable future for the ten Alaskan coastal refuges (with some localized exceptions) or Palmyra Atoll (central Pacific Ocean) because of a lack of high-quality elevation and wetlands data. That leaves 136 coastal refuges for which SLAMM is applicable, and each of these refuges has a SLAMM analysis (Table 1). From 2007 to 2012, the Refuge System produced more SLAMM reports than were done by all other parties combined.

The large number of Refuge System SLAMM reports is, of itself, not a measure of success in sea-level rise planning or adaptation, much less mitigation. However, it ensures that each coastal refuge for which sea-level rise is a significant issue is equipped with an analysis based on sound science. A SLAMM analysis allows refuge managers and planners to readily meet the charge of Secretarial Order 3226, the FWS Climate Change Strategic Plan, and other policies calling for climate change and sea-level rise planning (Czech et al. 2014).

SLAMM and Comprehensive Conservation Planning Every refuge is required to prepare a 15-year Comprehensive Conservation Plan (CCP) pursuant to the National Wildlife Refuge System Improvement Act of 1997 (16 USC § 668dd). The first round of CCPs is near completion and some refuges are preparing their second iteration. Although many coastal CCPs were published prior to SLAMM analysis, SLAMM analysis clearly helped later CCP authors address sea-level rise, even in cases where SLAMM results were not explicitly incorporated. As Babko et al. (2012:10) noted, "In 2007, around the time FWS started employing the SLAMM model, the number of CCPs including sea-level rise as a threat began to increase." Some of these CCPs incorporated SLAMM results explicitly (e.g., Cape Romain NWR), while other refuges received SLAMM reports slightly too late for incorporation but included some sea-level rise information based partly on SLAMM analysis (e.g., Back Bay NWR). A small fraction of coastal refuges are still in the process of developing first-round CCPs, and several of these will include significant discussion on sea-level rise with the use of SLAMM results (e.g., Chincoteague NWR). Even refuges lacking SLAMM analyses during CCP preparation are nevertheless now using SLAMM reports for planning purposes. For example, at Blackwater NWR, SLAMM analysis is used in land protection planning as well as habitat management.

TABLE 1. REFUGES WITH SLAMM ANALYSIS. *(CONTINUED)*

National Wildlife Refuge	*FWS Region*	*State*	*Year of SLAMM Analysis*	*Year of SLAMM Reanalysis*	*SLAMM Version (Most Recent Analysis)*
Pearl Harbor	1	HI	2010		6
Pelican Island	4	FL	2010		6
Petit Manan	5	ME	2010		6
Pinckney Island	4	SC	2008	2012	6
Pine Island	4	FL	2011		6
Pinellas	4	FL	2008		5
Plum Tree Island	5	VA	2009		5
Presquile	5	VA	2009		5
Prime Hook	5	DE	2009		5
Protection Island	1	WA	2011		6
Rachel Carson	5	ME	2008		5
Rappahanock River Valley	5	VA	2009		5
Sabine	4	LA	2008		5
Sachuest Point	5	RI	2009		5
Salinas River	8	CA	2008		5
San Bernard	2	TX	2011		6
San Diego Bay - South Bay	8	CA	2009		5
San Diego Bay – Sweetwater Marsh	8	CA	2009		5
San Juan Islands	1	WA	2011		6
San Pablo Bay	8	CA	2010		6
Sandy Point	4	VI	2008		5
Savannah	4	GA	2008	2012	6
Seal Beach	8	CA	2008		5
Seatuck	5	NY	2009		5
Shell Keys	4	LA	2008		5
Siletz Bay	1	OR	2010		6
St. Marks	4	FL	2008	2012	6
St. Vincent	4	FL	2008		5
Stewart B. McKinney	5	CT	2009		5
Supawna Meadows	5	NJ	2009		5
Swanquarter	4	NC	2007	2012	6
Target Rock	5	NY	2009		5
Ten Thousand Islands	4	FL	2011		6
Texas Point	2	TX	2011		6
Tijuana Slough	8	CA	2009		5
Trustom Pond	5	RI	2009		5
Tybee	4	SC	2008	2012	6
Vieques	4	PR	2007		5
Waccamaw	4	SC	2008		5
Wallops Island	5	VA	2009		5
Wassaw	4	GA	2008	2012	6
Wertheim	5	NY	2008		5
Willapa	1	WA	2010		6
Wolf Island	4	GA	2008	2012	6

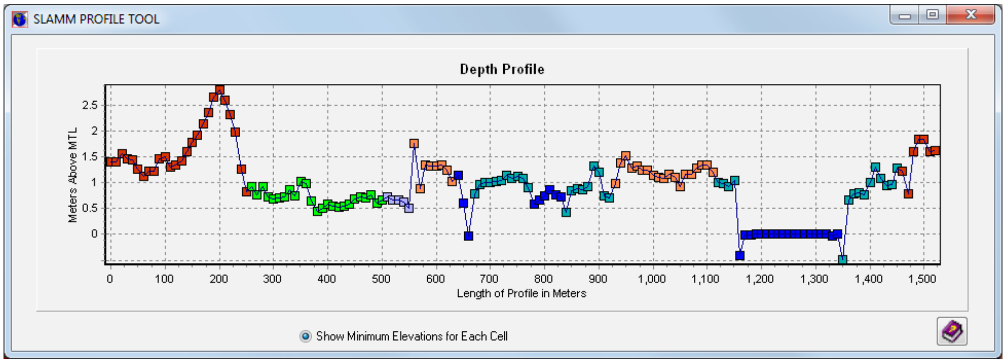


Figure 3. Profiling tool describes a cross-section of the study area, giving insights to hydraulic connectivity. For example, "A" indicates a hill or a levee that may block hydraulic connectivity, while "B" indicates that some low-lying irregularly-flooded marsh (orange) is located at the same elevation as regularly-flooded marsh (green) and may be converted when the SLAMM conceptual model is applied. Indications such as these may be investigated in the field if necessary, and SLAMM may be calibrated to fit the actual conditions.

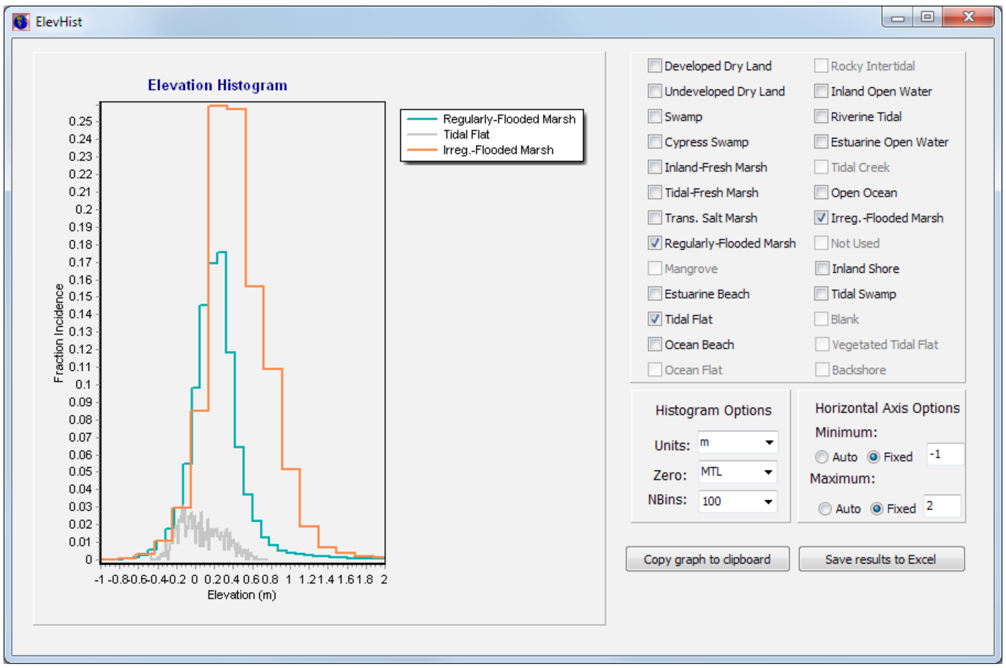


Figure 4. Histograms of the elevations of wetland categories provide visual information to support adjustments to the SLAMM conceptual model.

SLAMM and Land Acquisition Planning Perhaps the clearest use for SLAMM is in land acquisition planning. To facilitate this use, refuge-specific SLAMM analyses include appendices with wetland projection maps that cover large areas inland and upland of coastal refuges and surrounding locale (Figure 6). In the context of comprehensive conservation planning, land acquisition is addressed primarily in the Land Protection Plan (LPP), which often appears as an appendix to the CCP but may also constitute a stand-alone NEPA document (e.g., FWS 2011). For coastal refuges where land acquisition is proposed within or close to the tidal range, the LPP should reflect sea-level rise considerations as informed by SLAMM analysis (Figure 6).

Land acquisition planning activity takes place before or outside of the comprehensive conservation planning process, too. For example, the Land Acquisition Priority System is used to rank land acquisition proposals for Land and Water Conservation Fund appropriations (FWS 2012). A sea-level rise component has been proposed for the Land Acquisition Priority System such that, all else being equal, land acquisition proposals are ranked higher if wetland losses are projected to be less severe.

SLAMM and Landscape Conservation Design A recent development in FWS is the formal adoption of landscape-level planning through the use of landscape conservation designs (LCDs). LCDs are intended to "effectively serve as 'pre-planning' umbrella documents for the wide variety of plans written by the Service" (FWS 2013:3). The LCDs will be produced through Landscape Conservation Cooperatives (LCCs), which comprise "a network of public-private partnerships that provide shared science to ensure the sustainability of America's land, water, wildlife and cultural resources" (http://www.doi.gov/lcc/index.cfm). LCDs are well-suited to planning for climate change and sea-level rise. As climates and habitats shift across the landscape, the periodic preparation of LCDs and their revisions provides an iterative approach to determining where to refocus conservation efforts for long-lasting results.

Combining the range-shifting effects of climate change with the wetland-loss effects of sea-level rise, pre-planning in a coastal LCD will entail identifying coastal wetlands further north and further inland for protection to maintain populations of particular species. SLAMM analyses will be useful for such pre-planning, with maps and tables fit for LCDs. Some efforts to integrate SLAMM analysis into LCDs are already underway. For example, the Gulf Coast Prairie LCC is working with its partners to coordinate a Gulf Coast-wide SLAMM analysis for use by the four LCCs in the region - Gulf Coast Prairie, Gulf Coastal Plains and Ozarks, Peninsular Florida, and South Atlantic (B. Bartush, Gulf Coast Prairie LCC, personal communication). This precedent-setting landscape project will leverage multi-LCC funding to identify potential wetland migration corridors in the context of sea-level rise.

"Re-SLAMMing" Most refuge-specific SLAMM analysis in the foreseeable future will take the form of "re-SLAMMing" - reapplication of the model. Re-SLAMMing may be appropriate when: 1) better input data (e.g., elevation, accretion, tidal range, and upgraded NWI data) become available, 2) when SLAMM is upgraded, 3) when the factors affecting relative sea-level rise (e.g., subsidence) have changed significantly, or 4) when wetland conditions have been altered dramatically (e.g., by a hurricane). Re-SLAMMing is sometimes called for when managers want to investigate the projected effects of additional sea-level rise scenarios, different inputs such as accretion rates (which in some cases can be managed), or new infrastructure such as dikes. Major new land acquisition proposals near existing refuges may also serve as rationale for re-SLAMMing. Often the decision for re-SLAMMing is based on multiple factors, such as the availability of new data simultaneously with a new land acquisition proposal.

Re-SLAMMing of refuges commenced in 2011 and twenty refuges have been re-SLAMMed (Table 1), primarily due to recent availability of relatively high-resolution LiDAR data. All refuges where SLAMM 4 or an earlier version was applied have been re-SLAMMed. As of July 15, 2012, SLAMM 5 has been applied to 62 refuges and SLAMM 6 to 74 refuges (Table 1).

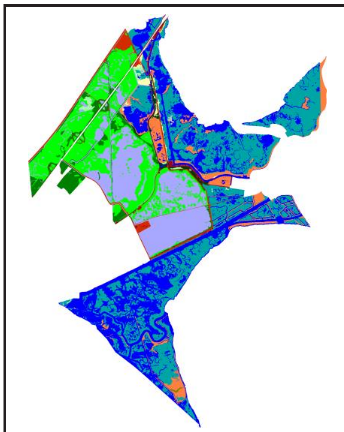
SUGGESTIONS FOR IMPROVING SLAMM AND ITS APPLICATION

Model Improvement SLAMM improvement has been ongoing for most of the past decade and is expected to continue for the foreseeable future. The most recent substantial improvement (completed during the writing of this manuscript) was conversion from a 32-bit to a 64-bit program. This conversion allows for greater memory utilization and therefore modeling of larger areas and/or with higher resolution. Many additional improvements have been identified and several are described below.

One increasingly obvious limitation of SLAMM is the failure to address the formation, development or "migration" of seagrasses and other submerged aquatic vegetation (SAV). Because low-lying coastal habitats over many and large areas are submerging, what transpires in the areas of submergence is vital for fish and wildlife resources and nearshore ecology. Given bathymetric data and sound assumptions pertaining to seagrass ecology, a useful SAV module is feasible for development. Indeed, while this article was in preparation, a SAV module was developed and is now undergoing testing by the U.S. Geological Survey (D. Reusser, USGS, personal communication).

The value of coastal ecosystem services is also of increasing interest to scientists, managers, and policy-makers. Craft et al. (2009) set a precedent by using SLAMM to assess threats of sea-level rise to ecosystem services. However, the assessment was exogenous - performed outside the model per se. For certain ecosystem services (e.g., freshwater provision, carbon sequestration, and fisheries production), economic estimates of the impact of sea-level rise should become endogenous to the model – at least as an optional module for use when economic data are available – if SLAMM is to be widely used in ecological economics.

Existing SLAMM modules pertaining to dikes, erosion, soil saturation, and barrier island overwash are other likely candidates for improvement. These modules are based on relatively coarse assumptions. For example, while dike heights may accounted for, dike failure is assumed only when sea levels cause inundation once per 30 days or more frequently. This is a "conservative" approach in the sense that habitats currently protected by dikes are modeled to remain as they are for unreasonably long periods. In reality, dikes are often compromised in stages (e.g., leakage or partial breaching) and as a function of dike age, condition, and construction specifications. The dike module should be



		Initial	2025	2050	2075	2100
	Regularly-flooded Marsh	3964	3244	1579	377	178
	Estuarine Open Water	3243	3997	4938	6784	8465
	Inland Open Water	2204	2203	2202	2202	2202
	Inland Fresh Marsh	2148	2144	2121	2117	1614
	Irregularly-flooded Marsh	768	563	297	198	142
	Swamp	533	511	442	395	331
	Undeveloped Dry Land	358	335	320	300	256
	Developed Dry Land	98	98	98	98	98
	Tidal Swamp	89	81	66	59	51
	Estuarine Beach	79	68	47	45	32
	Tidal Fresh Marsh	60	59	57	55	38
	Tidal Flat	15	259	1390	925	141
	Transitional Salt Marsh	11	8	13	15	22
	Total (incl. water)	**13571**	**13571**	**13571**	**13571**	**13571**

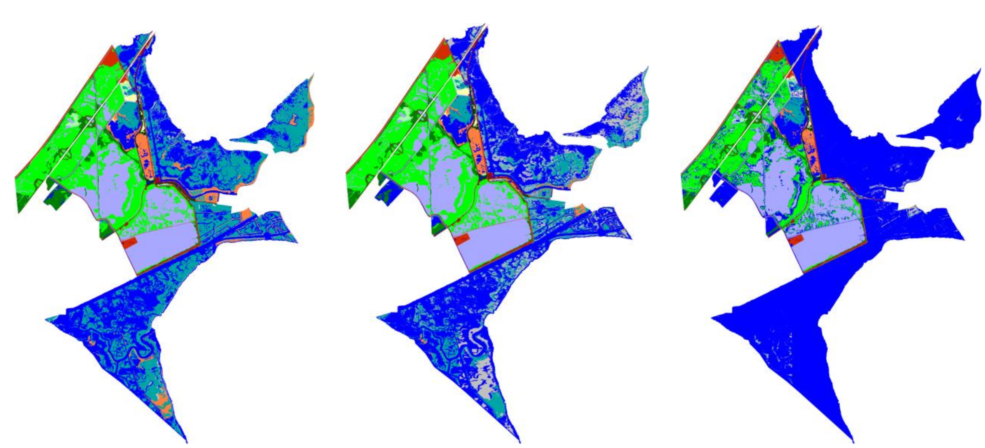


Figure 5. SLAMM results for Bayou Sauvage National Wildlife Refuge, Louisiana. Initial wetland distribution (upper left) and SLAMM output table (upper right) with results in hectares. Projections of wetland distributions are mapped for 2025, 2050, and 2100 (lower row, left to right). These projections are based on a sea-level rise schedule of 1 m from 1990-2100.

improved to incorporate such factors because information on these factors is often readily available. As with the dike module, ideas for improving the erosion, soil saturation, and barrier island overwash modules are already conceived. The limiting factor for module improvement is funding. For each of the variables involved, background research must be conducted to support module refinement. SLAMM must then be tested for smooth integration of module refinements, and ideally tested for performance with hindcasting (see e.g., Geselbracht et al. 2011).

A different type of model improvement would be the integration of a flexible wetland transformation flowchart. This would allow users to add and remove wetland categories and to reconfigure how categories are converted to others. A flexible flowchart would allow expert users to tailor the model to diverse types of coastal ecosystems from Gulf of Mexico Chenier Plains to Alaskan coastal wetlands.

Improving Data Inputs Re-SLAMMing should occur in all instances where SLAMM was applied in the absence of high-quality LiDAR data, especially if the original SLAMM analysis raised concerns about maintaining refuge purposes. SLAMM users should invest in LiDAR coverage in cases where none is forthcoming from other sources.

In many circumstances, the accretion rate is a key variable in determining the future of marshes. The most reliable data for accretion rates in specific areas come from the use of SETs (Cahoon et al. 2002). Approximately 20-30 refuges have functional SETs that are monitored periodically. All else being equal, more SETs are better, and ideally distinctive wetland units within a refuge are equipped with SETs. In the absence of SETs, well-communicated insights from field personnel and modelers are required for estimating appropriate accretion rates.

One more variable closely related to accretion is noteworthy. To capitalize on research pertaining to the relationship between inundation and sediment deposition, data sets on suspended sediment concentrations (SSC) are needed. In modeling threshold rates of sea-level rise, “above which marshes are replaced by subtidal environments,” SSC is a key variable (Kirwan et al. 2010:3). Especially in cases where SLAMM has been run and where SSC is thought to be substantial and not already accounted for in the SLAMM analysis, re-SLAMMing may be appropriate based on the procurement of SSC data. The SLAMM accretion module may be tailored on a case-by-case basis to account for SSC.

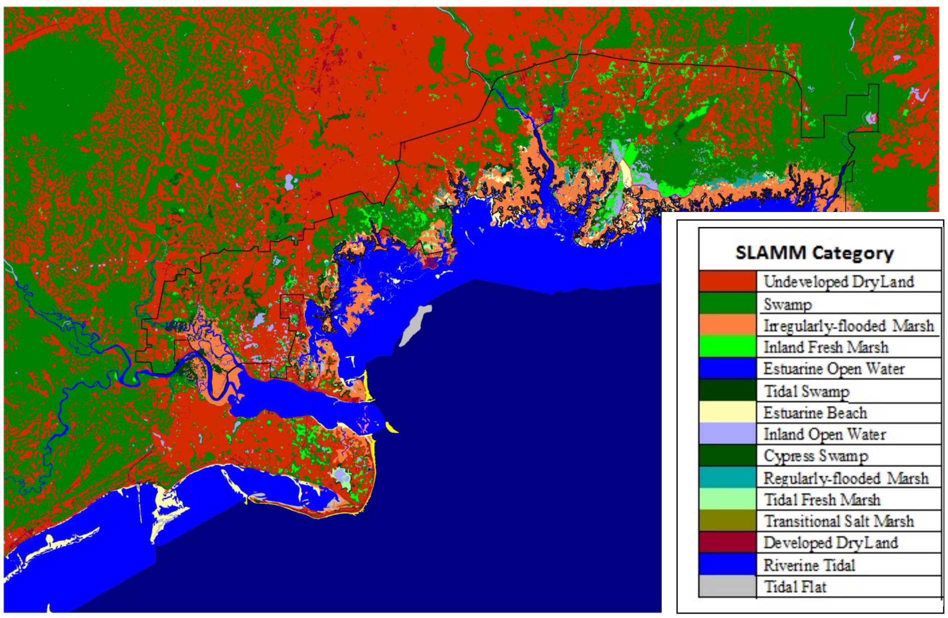
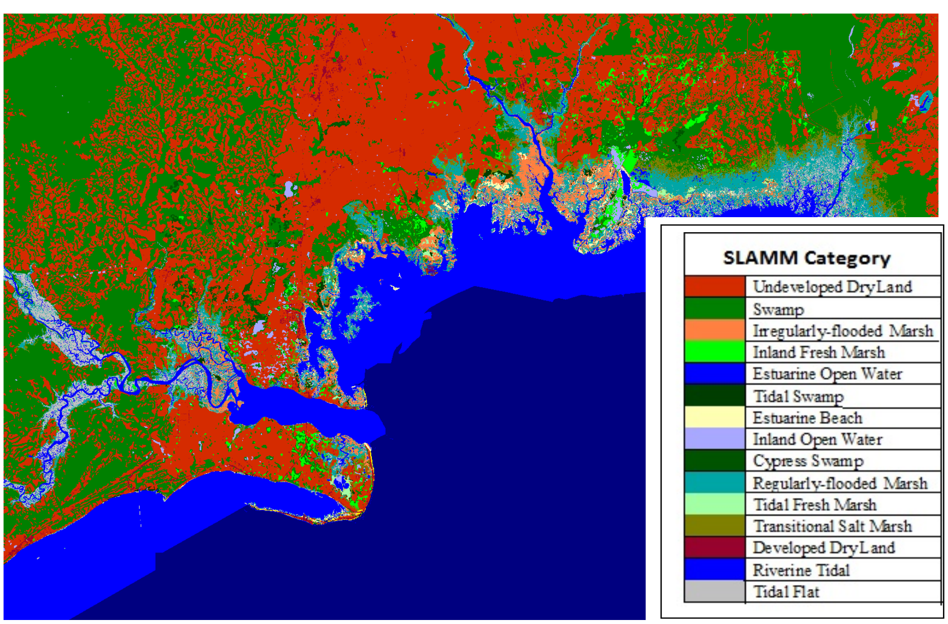


Figure 6. SLAMM contextual maps for St. Marks National Wildlife Refuge, Florida. Initial conditions are mapped above, with refuge boundary indicated by fine black line. Projections of wetland distributions are mapped for 2100 below based on the 1 m sea-level rise scenario.



CONCLUSION

As with most models, SLAMM will never be viewed as completed or perfect. It will be improved as wetland and sea-level rise science produces findings that clarify relationships among the numerous input variables. SLAMM will also change with the needs of coastal managers and the resources available for modeling. The need for adding processing capability, addressing additional issues, and developing more detailed algorithms must be balanced with the need to keep SLAMM transparent, wieldy, flexible, and affordable at the refuge, landscape, Regional, and Washington Office levels.

Despite the challenging uncertainties associated with sea-level rise, and even with SLAMM's limitations, this much appears certain: SLAMM is a useful tool in assessing the implications of sea-level rise on the Refuge System and meeting the mandates for climate change planning on coastal refuges. ■

ACKNOWLEDGEMENTS

J. Clough, T. Dahl, P. Glick, L. Hinds, E. Mcleod, A. Polaczyk, M. Whitbeck, and B. Wilen contributed to the quality of the manuscript and the research entailed thereby.

DISCLAIMER

The use of trade names and reference to proprietary software is for informational purposes only and does not constitute endorsement by the U.S. Fish and Wildlife Service.

REFERENCES

Babbitt, B. 2001. Evaluating climate change impacts in management planning. Order No. 3226, U.S. Department of the Interior, Office of the Secretary, Washington, DC. 1p. http://elips.doi.gov/ELIPS/0/doc/291/Page1.aspx (accessed August 27, 2014).

Babko, A., M. Gray, M. Kennedy, L. Liu, and S. Wambugu. 2012. Assessing national wildlife refuges' planning for climate change: what Are SMART refuges doing? Indiana University, School of Public and Environmental Affairs, Bloomington, Indiana. Unpublished report for the U.S. Fish and Wildlife Service. 25pp.

Cahoon, D.R., G.R. Guntenspergen, and S. Baird. 2010. Do annual prescribed fires enhance or slow the loss of coastal marsh habitat at Blackwater National Wildlife Refuge? Final Report to Joint Fire Science Program. http://www.firescience.gov/projects/06-2-1-35/project/06-2-1-35_blackwater_burn_final_report_mar_31_2010.pdf (accessed August 27, 2014).

Cahoon, D.R, J.C. Lynch, P. Hensel, R. Boumans, B.C. Perez, B. Segura, and J.W. Day Jr . 2002. High-precision measurements of wetland sediment elevation. I. Recent improvements to the sedimentation–erosion table. *Journal of Sedimentary Research* 72:730-733.

Cahoon, D.R., D.J. Reed, and J.W. Day Jr. 1995. Estimating shallow subsidence in microtidal salt marshes of the southeastern United States: Kaye and Barghoorn revisited. *Marine Geology* 128:1-9.

Callaway, J, and S. Siegel. 2002. Data collection protocol: sedimentation-erosion tables (SET's). Pages 1-6 in Wetlands Regional Monitoring Program Plan 2002, part 2: data collection protocols. San Francisco Bay Area Wetlands Regional Monitoring Program, San Francisco, California. http://wrmp.org/docs/protocols/Sedimentation.pdf (accessed August 27, 2014).

Chen, J.L, C.R. Wilson, and B.D. Tapley. 2006. Satellite gravity measurements confirm accelerated melting of Greenland Ice Sheet. Science 313:1958-1960.

Chu-Agor, M.L, R. Munoz-Carpena, G. Kiker, A. Emanuelsson, and I. Linkov. 2011. Exploring vulnerability of coastal habitats to sea level rise through global sensitivity and uncertainty analyses. *Environmental Modelling & Software* 26:593-604.

Clough, J, D. Park, and R. Fuller. 2010. SLAMM 6.0.1 Technical Documentation. Warren Pinnacle Consulting, Waitsfield Vermont. http://warrenpinnacle.com/prof/SLAMM6/SLAMM6_Technical_Documentation.pdf (accessed August 27, 2014).

Cowardin, L.M, V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. U.S. Fish and Wildlife Service, Washington, DC. http://www.npwrc.usgs.gov/resource/wetlands/classwet/ (accessed August 27, 2014).

Craft, C., J. Clough, J. Ehman, S. Joye, D. Park, S. Pennings, H. Guo, and M. Machmuller. 2009. Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services. *Frontiers in Ecology and the Environment* 7:73-78.

Czech, B. 2002. A transdisciplinary approach to conservation land acquisition. *Conservation Biology* 16(6):1488-1497.

Czech, B, P.R. Krausman, and P.K. Devers. 2000. Economic associations among causes of species endangerment in the United States. *Bioscience* 50(7):593-601.

Czech, B., S. Covington, T.M. Crimmins, J.A. Ericson, C. Flather, M. Gale, K. Gerst, M. Higgins, M. Kaib, E. Marino, T. Moran, J. Morton, Neal Niemuth, H. Peckett, D. Savignano, L. Saperstein, S. Skorupa, E. Wagener, B. Wilen, and B. Wolfe. 2014. Planning for climate change on the National Wildlife Refuge System. U.S. Fish and Wildlife Service, National Wildlife Refuge System, Washington, DC. 132pp.

Douglas, B., M.S. Kearney, and S.P. Leatherman (editors). 2000. *Sea Level Rise, Volume 75: History and Consequences*. Academic Press, New York.

FGDC. 2013. Classification of wetlands and deepwater habitats of the United States. Federal Geographic Data Committee, Washington, DC. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/wetlands/ (accessed August 27, 2014).

FWS. 2010. *Rising to the urgent challenge: strategic plan for responding to accelerating climate change*. Washington, DC: U.S. Fish and Wildlife Service. http://www.fws.gov/home/climatechange/pdf/ccstrategicplan.pdf (accessed August 27, 2014).

FWS. 2011. Final Environmental Assessment and Land Protection Plan for the Expansion of St. Marks National Wildlife Refuge. U.S. Fish and Wildlife Service, Southeast Region, Atlanta, Georgia. 63 pp. http://www.fws.gov/saintmarks/media/pdf/St%20Marks%20FINAL%20EA%20LPP%20edited%20Formatted.pdf (accessed August 27, 2014).

FWS, Warren Pinnacle Consulting. 2012. Application of the Sea Level Affecting Marshes Model (SLAMM 6) to St. Marks NWR. U.S. Fish and Wildlife Service, National Wildlife Refuge System, Washington, DC. http://warrenpinnacle.com/prof/SLAMM/USFWS/SLAMM_St_Marks_2012.pdf (accessed August 27, 2014).

FWS. 2012. Land Acquisition Priority System. U.S. Fish and Wildlife Service, National Wildlife Refuge System, Washington, DC. http://www.fws.gov/refuges/realty/laps.html (accessed August 27, 2014).

FWS. 2013. Final report: a landscape-scale approach to Refuge System planning. U.S. Fish and Wildlife Service, National Wildlife Refuge System, Washington, DC.

Galbraith, H., R. Jones, R. Park, J. Clough, S. Herrod-Julius, B. Harrington, and B. Page. 2002. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds 25:173.

Geselbracht, L., K. Freeman, E. Kelly, D.R. Gordon, and F.E. Putz. 2011. Retrospective and prospective model simulations of sea level rise impacts on Gulf of Mexico coastal marshes and forests in Waccasassa Bay, Florida. *Climatic Change* 107:35–57.

Gesch, D.B. 2009. Analysis of lidar elevation data for improved identification and delineation of lands vulnerable to sea-level rise. *Journal of Coastal Research* (53):49–58.

Glick, P., J. Clough, and B. Nunley. 2007. Sea-level Rise and coastal habitats in the Pacific Northwest: an analysis for Puget Sound, southwestern Washington, and northwestern Oregon. National Wildlife Federation. http://www.tribesandclimatechange.org/docs/tribes_152.pdf (accessed August 27, 2014).

Glick, P., J. Clough, A. Polaczyk, B. Couvillion, and B. Nunley. 2013. Potential effects of sea-level rise on coastal wetlands in southeastern Louisiana. *Journal of Coastal Research* 63:211-233.

Grinsted, A., J.C. Moore, and S. Jevrejeva. 2009. Reconstructing sea level from paleo and projected temperatures 200 to 2100 AD. *Climate Dynamics* 34:461-472.

IPCC. 2001. Appendix II: SRES Tables. Pages 799-826 in Climate change 2001: the scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (eds.)]. Cambridge University Press, Cambridge (UK) and New York. http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/index.htm (accessed August 27, 2014).

Kirwan, M.L., G.R. Guntenspergen, A. D'Alpaos, J.T. Morris, S.M. Mudd, and S. Temmerman. 2010. Limits on the adaptability of coastal marshes to rising sea level. *Geophysical Research Letters* 37, L23401, doi:10.1029/2010GL045489.

Kirwan, M.L., and G.R. Guntenspergen. 2010. The influence of tidal range on the stability of coastal marshland. *Journal of Geophysical Research - Earth Surface* 115, F02009, doi:10.1029/2009JF001400.

Kirwan, M.L., and G.R. Guntenspergen. 2012. Feedbacks between inundation, root production, and shoot growth in a rapidly submerging brackish marsh. *Journal of Ecology* 100:764–770.

Lee, J.K., R.A. Park, and P.W. Mausel. 1992. Application of geoprocessing and simulation modeling to estimate impacts of sea level rise on the northeast coast of Florida. *Photogrammetric Engineering and Remote Sensing* 58:1579–1586.

Levermann, A., P.U. Clark, B. Marzeion, G.A. Milne, D. Pollard, V. Radic, and A. Robinson. 2013. The multimillennial sea-level commitment of global warming. *Proceedings of the National Academy of Sciences of the United States of America,* Early edition:1-6. doi: 10.1073/pnas.1219414110.

Mcleod, E., B. Poulter, J. Hinkel, E. Reyes, and R. Salm. 2010. Sea-level rise impact models and environmental conservation: A review of models and their applications. *Ocean and Coastal Management* 53:507-517.

McMahon, S. 2007. Predicted impacts of sea-level rise on national wildlife refuges in Florida. Capstone paper for the degree requirements of Master of Natural Resources, Virginia Tech, National Capitol Region.

Monaghan, A.J., D.H. Bromwich, R.L. Fogt, S.-H. Wang, P.A. Mayewski, D.A. Dixon, A. Ekaykin, M. Frezzotti, I. Goodwin, E. Isaksson, S.D. Kaspari, V.I. Morgan, H. Oerter, T.D. Van Ommen, C.J. Van der Veen, and J. Wen. 2006. Insignificant change in Antarctic snowfall since the International Geophysical Year. *Science* 313:827-831.

NWF, and FWF (National Wildlife Federation and Florida Wildlife Federation). 2006. *An unfavorable tide: global warming, coastal habitats and sportfishing in Florida.* Washington, DC: National Wildlife Federation. http://www.broward.org/NaturalResources/ClimateChange/Documents/AnUnfavorableTideReport.pdf (accessed August 27, 2014).

Padilla, D. 2008. Coastal habitat change at Vieques National Wildlife Refuge, Puerto Rico. Capstone paper for the degree requirements of Master of Natural Resources, Virginia Tech, National Capitol Region.

Park, R.A., J.K. Lee, and D.J. Canning. 1993. Potential Effects of Sea-Level Rise on Puget Sound Wetlands. *Geocarto International* 8:99.

Park, R.A., M.S. Trehan, P.W. Mausel, and R.C. Howe. 1989. The effects of sea level rise on U.S. coastal wetlands. In *The potential effects of global climate change on the United States*, ed. Environmental Protection Agency, 1-1 to 1-55 (Appendix B - sea-level rise). Washington, DC: U.S. Environmental Protection Agency. http://papers.risingsea.net/federal_reports/rtc_park_wetlands.pdf (accessed August 27, 2014).

Pfeffer, W.T., J.T. Harper, and S. O'Neel. 2008. Kinematic constraints on glacier contributions to 21st-Century sea-level rise. *Science* 321:1340-1343.

Sallenger, A.H. Jr, K.S. Doran, and P.A. Howd. 2012. Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nature Climate Change* 2:884-888.

Stammer, D., A. Cazenave, R.M. Ponte, and M.W. Tamisiea. 2013. Causes for contemporary regional sea level changes. *Annual Review of Marine Science* 5:21-46.

Stevenson, J.C., M.S. Kearney, and E.C. Pendleton. 1985. Sedimentation and erosion in a Chesapeake Bay brackish marsh system. *Marine Geology* 67:213-235.

Tidwell, M. 2003. *Bayou farewell: the rich life and tragic death of Louisiana's Cajun coast.* Pantheon, New York. 348pp.

Titus, J.G., R.A. Park, S.P. Leatherman, J.R. Weggel, M.S. Greene, P.W. Mausel, S. Brown, C. Gaunt, M. Trehan, and G. Yohe. 1991. Greenhouse effect and sea level rise: the cost of holding back the sea. *Coastal Management* 19:171–204.

Traill, L.W., K. Perhans, C.E. Lovelock, A. Prohaska, S. McFallan, J.R. Rhodes, and K.A. Wilson. 2011. Managing for change: wetland transitions under sea-level rise and outcomes for threatened species. *Diversity and Distributions* 17:1225–1233.

Vermeer, M., and S. Rahmstorf. 2009. Global sea level linked to global temperature. *Proceedings of the National Academy of Sciences of the United States of America* 106(51):21527-21532.

Warren Pinnacle Consulting. 2010. SLAMM 6.0.1 beta users manual. Warren Pinnacle Consulting, Waitsfield, Vermont. http://warrenpinnacle.com/prof/SLAMM6/SLAMM_6_Users_Manual.pdf (accessed August 27, 2014).

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).

Ecologist Races to Save Endangered Cypress from Extinction: Discovery of a Lifetime in Remote Swamps of Laos

The following news comes from a 2/11/15 article by Ed Carpenter, Web News Content Coordinator & USF Magazine News Editor (Courtesy of the University of San Francisco).

University of San Francisco (USF) ecologist [and SWS member] Gretchen Coffman is leading an international rescue effort to save an endangered cypress tree on the verge of extinction. Coffman, a restoration ecologist, compares the Southeast Asia cypress to California's majestic redwoods, and National Geographic is funding her campaign. She's hired Robin Hunter, a USF master's in environmental science student as a research assistant, and partnered with renowned international scientists.

The swamp cypress and California redwoods are close relatives. And like its West Coast cousin, the cypress is a vital part of the forest canopy system where it grows, reaching heights above 100 feet, said Coffman, an assistant professor of environmental science and environmental management. Only about 250 of the swamp cypress were known to live in the wild, nearly all of them in Vietnam, until Coffman and Robin Hunter tripled that number on a recent expedition to Laos. The discovery included an ancient stand estimated at more than 500 years old with trees 145 feet tall and more than three meters in diameter. Coffman first discovered the swamp cypress in Laos on a trek to explore the Nakai-Nam Theun National Biodiversity

Conservation Area in 2007, stunning the scientific community who had no idea it grew there.

"I literally tripped over the trees' roots. And when I stood up to look, I knew it instantly," Coffman said. A DNA sample confirmed it was *Glyptostrobus pensilis*. The species is listed as critically endangered, one step from extinct in the wild, by the International Union for Conservation of Nature and Natural Resources (http://www.iucnredlist.org/details/32312/0). It is thought to be extinct in China, where it once flourished. The 200-plus trees in Vietnam are in decline and no longer bear viable seeds. So, Coffman's rescue mission, seven years in the making, may be the species last chance at survival.

It is a race against time and a growing list of threats. An unknown number of the cypress trees drowned in Laos in 2010 under a newly constructed reservoir built to generate hydroelectric power. Others have been cut down by farmers to enlarge their fields or by loggers, who cross in nighttime raids from Vietnam, and drag the timber back across the border — where it's sold at exorbitant prices.

"The wood is treasured for its unique scent and for constructing high-end furniture because it is resistant to water, weather, and rot," Coffman said.

With early-stage research funding from National Geographic (http://www.nationalgeographic.com/), Coffman, Hunter, and their teams just returned from Laos where they mapped, measured, and gathered data on about 500 previously unknown cypress trees and began to implement a national conservation plan to educate locals about the cypress and to propagate the tree in nurseries so that a new generation can carry the species forward.

"The trip was fantastic and a great learning experience!" said Hunter, who mapped the trees using GPS and created a geographic information system (GIS) database. "I learned a lot about the steps involved in planning and carrying out a large field expedition."

It took four days travel from San Francisco to reach the swamp, an unforgiving environment infested with leaches. The team had to be on alert for roaming elephants, Bengal tigers, cobras, and poachers. Worse, there were unexploded landmines along the nearby border, which was part of Ho Chi Minh Trail during the Vietnam War.

None of that phased Coffman and Hunter. "We worked with scientists from the Laos federal government, the National University of Laos, and the Royal Botanic Garden of Edinburgh, as well as local villagers," Coffman said. "This was an opportunity of a lifetime."

The team's work could take a decade or more to see measurable conservation results, but it has already achieved an important milestone — successfully propagating a handful of the cypress trees from seedlings to saplings, something no one else has done, Coffman said. ■

WETLAND PRACTICE

REGULATION, POLICY AND MANAGEMENT

THE NICARAGUA GRAND CANAL

The Nicaragua Grand Canal is a $50 billion project backed by a Chinese businessman and supported by the Nicaraguan government. While some people see the economic benefits of this project to the Western Hemisphere's second poorest county, the project may produce drastic ecological impacts to wetlands and nature reserves including massive dredging of the largest lake in Central America. For more on this project, read Chris Kraul's article posted at Yale Environment 360 website: http://e360.yale.edu/feature/nicaragua_canal_a_giant_project_with_huge_environmental_costs/2871/

CALIFORNIA DROUGHT – GROUNDWATER BANKING

Also posted at the Yale Environment 360 website is an article by Erica Gies on "groundwater banking" as a possible solution to California's water problems related to drought: http://yale.us1.list-manage.com/track/click?u=b70b711355cbb09eb9f5e5702&id=659f4bc70c&e=73c5fcd561

RAMSAR PUBLISHES REPORT ON STATE OF THE WORLD'S WETLANDS

In preparation for the 12th meeting of the Conference of the Parties to the Convention on Wetlands, the Convention's Scientific and Technical Review Panel has compiled an overview of wetland status and trends and the loss of ecosystem services from existing analyses. This information was intended to help assess the effectiveness of the Convention in its wetland conservation efforts. The report can be accessed at: http://www.ramsar.org/sites/default/files/documents/library/cop12_doc23_bn7_sowws_e_0.pdf

Other Ramsar documents prepared for the June 1-9 meeting of the Convention at Punta del Este, Uruguay can be found at: http://www.ramsar.org/news/12th-meeting-of-the-conference-of-the-parties-cop12

WINNERS OF THE RAMSAR WETLANDS AWARDS 2015

On February 16, the Secretariat of the Ramsar Convention announced winners of Ramsar Awards 2015. The awards will be given to the winners at the 12th meeting of the Conference of Ramsar's Contracting Parties in June 2015 (Uruguay). The awards and winners follow.

1. The Ramsar Convention Award for Wetland Wise Use was presented to Ms. Giselle Hazzan, Manager, Ein Afek Nature Reserve (EANR) in Israel. The Acre Valley wetlands were drained in the 1920s and pumping from the aquifer began in 1960 for agricultural use and drinking water. In 2002 Giselle Hazzan became the new Manager of the EANR, the first Arab woman to be a Manager of a nature reserve in Israel. She has remodelled EANR's entire water management by initiating actions at different levels with participation from local stakeholders, weir operations and new national legislation. By changing the EANR from stop-gap temporary water management measures to carefully planned long-term projects, Ms. Hazzan has saved the EANR ecosystem and made it a vital wetland in a dry country.

2. The Ramsar Convention Award for Wetland Innovation was given to Oceanium, Dakar, Senegal. Oceanium is an organization established to actively protect Senegal's marine environment since the late 1990s. It has recently undertaken the world's largest mangrove reforestation and eco-system restoration with and by local people. This is a rare example of large-scale participatory restoration. The project increases resilience to climate change by the rehabilitation and planting of mangroves in marine degraded areas and the development of related sustainable socio-ecological and economical activities, using modern technology. Oceanium has replanted and restored thousands of hectares of mangroves and has successfully restored degraded rice fields in Tobor and returned the land to traditional rice growing. The project involves using solar and wind-powered water pumps; the replanting of mangroves to help in desalinization and coastline stabilization; and the development of more ecologically-sustainable rice culture.

3. The Ramsar Convention Award for Young Wetlands Champions was presented to Fundación Humedales Bogotá, Colombia. The Wetland Foundation Bogota is a non-profit organization dedicated to saving wetlands around the city of Bogota, and to highlight the constant threats the area is under. The Foundation started in 2011 and has since developed an interactive website which has become the main medium of information on wetlands in Bogota. The Foundation has a network of volunteers who promote wetland conservation through active citizenship. Their participative community approach to management and the organization of innovative and creative events to raise awareness of the projects - for example, cycling events, an environmental fair, free courses on wetlands, community events to restore the wetlands of Bogota, observing migratory birds - has proven to be hugely successful.

4. The Ramsar Convention Award for Merit was presented to two scientists and one organization: Professor William Mitsch (Director, Everglades Wetland Research Park, USA), Professor Gea Jae Joo (Pusan University, Republic of Korea), and Tour du Valat (France).

Dr. Mitsch is the senior author of the innovative textbook *Wetlands*, which has been described as the "wetland bible". The book has essentially defined the field of wetland science since its first edition in 1986. Professor Mitsch also designed, built and managed from 1992-2012 one of the most productive riverine wetland research laboratories in the world. In 2008 the Olentangy River Wetland Research Park became the 24th Ramsar site in the USA. In 2012 he became a professor and Eminent Scholar at Florida Gulf Coast University and Director of Everglades Wetland Research Park in Florida. The laboratory has already established a reputation as a major destination for visiting wetland scientists from around the world and a place to address large-scale ecosystem restoration in areas such as the Florida Everglades.

Professor Gea Jae Joo has worked in wetland conservation and wise use for over 25 years in different fields. He is the author of over 100 publications on wetlands. He was one of the founders and organizers of the Korea-China-Japan "Komodo" wetland events (exchanges and other activities for children focusing on wetlands and Ramsar sites). He is devoted to sharing wetland information and wetland culture in the East-Southeast Asia region and has, in particular, been involved in the development of three wetland centers in Korea as well as the establishment of the Ramsar Cultural Centre at Junam and Ramsar Regional Centre-East Asia, of which he is Honorary Director. In this role has been a fervent supporter of both the Youth Model Ramsar Convention and of the use of culture as a tool for wetland education.

Tour du Valat, France is a research center for the conservation of Mediterranean wetlands. Its mission is to halt and reverse the loss and degradation of Mediterranean wetlands and promote their wise use. The center develops integrated research and management programs, which promote exchanges between scientists and wetland users. Transfer of knowledge is a central tool to achieve its mission. A large part of the Tour du Valat estate, located in the Camargue Ramsar Site is classified as a Regional Nature Reserve. The Tour du Valat library is a unique documentation center in the Mediterranean region, specialized in wetland ecology and visited by many scientists, students and teachers. It was one of the institutions which participated in the creation of the MedWet Initiative in 1991, and has contributed to the implementation of Ramsar principles in the whole Mediterranean basin. This award coincides with the celebration of the Tour du Valat's 60th anniversary. ■

*If you know of other books and reports on wetlands, please send information to Ralph Tiner, Editor of Wetland Science & Practice at: rtiner@eco.umass.edu. Your cooperation is appreciated. * indicates a new listing below.*

During the past two months, three new wetland books came to my attention. The first is the latest edition (5th) of "Wetlands" by William Mitsch and James Gosselink (Wiley). It includes five streamlined chapters on wetland ecosystems (tidal marshes, mangroves, freshwater marshes and swamps, and northern peatlands), four updated chapters on ecosystem services covering the interrelations among wetlands, society, and climate change, plus updates on the world's most important wetlands, including case studies from North America, Europe, Asia, and beyond. The book is available from John Wiley & Sons, Inc. at: http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118676823.html (you can download Chapter 1 for free). The second is a free e-book by Joy Zedler entitled "Salt Marsh Secrets: Who Uncovered Them and How?" published by the Tijuana River National Estuarine Research Reserve (Imperial Beach, CA). This book is a summary of research on Southern California tidal marshes conducted by Dr. Zedler and her collaborators many of whom were affiliated with what is now called the Pacific Estuarine Research Lab, San Diego State University. The book is available at: http://trnerr.org/SaltMarshSecrets/. The third book is "Remote Sensing of Wetlands: Applications and Advances" (co-edited by Megan Lang, Vic Klemas and myself) – a collaborative effort of more than 50 scientists using satellite imagery, radar, LiDAR, and other remote sensors to inventory wetlands for a variety of purposes. The full-color book contains 25 chapters that focus on remote sensing applications for mapping different types of wetlands around the globe. It is available in hardback and e-copy formats through CRC Press, Boca Raton, FL (https://www.crcpress.com/product/isbn/9781482237351).

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-one-stop/5044-nwi-reports*

- Preliminary Inventory of Potential Wetland Restoration Sites for Long Island, New York http://www.aswm.org/wetlandsonestop/restoration_inventory_long_island_ny_021715.pdf*
- Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors. Version 3.0. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA.
- 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

I've been making some observations during my travels over the past few months and the more notable ones are outlined below.

SOUTHEAST

Georgia

March 9-11 – Camden and Glynn Counties – many deciduous trees were starting to leaf out. Yellow jasmine (*Gelsemium sempervirens*) in full flower. Upper edge of tidal marsh along Satilla River - samaras already present on red maple (*Acer rubrum*), while flowers were found on sweet gum (*Liquidambar styraciflua*) and willow (*Salix* sp.). In the oligohaline marsh - arrow arum (*Peltandra virginica*) basal leaf fully open; basal leaves of arrowhead (*Sagittaria*) emerged, swamp dock (*Rumex cf. verticillata*) in flower; basal leaves of blue flag (*Iris virginica*) were about 1.5 feet tall; young shoots of big cordgrass (*Spartina cynosuroides*) emerging nearly 1 foot tall. Redbud (*Cercis canadensis*) in flower in upland.

Yellow jasmine (*Gelsemium sempervirens*)

Willow (*Salix* sp.)

NORTHEAST

Massachusetts

Observations from Leverett (Franklin County) unless noted otherwise; cold wet spring – first ten days of April barely reached 40 degrees F.

April 12 – wood frogs chorusing in vernal pool.

April 16 – spring peepers calling from buttonbush pond in Sunderland; in western Massachusetts - red maple, American elm (*Ulmus americana*), and quaking aspen (*Populus tremuloides*) are in flower and male catkins open in speckled alder (*Alnus incana* ssp. *rugosa*).

April 18 – snow is gone and ice is off vernal pools; in small pond – pickerelweed (*Pontederia cordata*) leaves beginning to unfurl underwater; red leaves of water lilies (*Nymphaea*) about 6 inches high underwater; blue flag (*Iris versicolor*) leaves about 2 inches tall; buds breaking on shining rose (*Rosa nitida*) and on highbush blueberry (*Vaccinium corymbosum*). In red maple seepage swamp, leaves (about 4 inches tall) emerging from tussock sedge (*Carex stricta*).

April 20 – spring peepers beginning to call from vernal pool.

April 21 – along Rt. 116 in Hadley, noticed that willow branches are now green (orange through winter). Wood frog egg masses observed in small pond; huge chorus of spring peepers from vernal pool.

April 22 – skunk cabbage (*Symplocarpus foetidus*) leaves about 6 inches tall in red maple swamp.

May 1 – leatherleaf (*Chamaedaphne calyculata*) beginning to flower along pond margin; cranberry vines are still red; water lily leaves still have not reached surface.

May 8 – heard first call of gray tree frog; leaves opening on shining rose; red leaves of water lily have reached the surface; pickerelweed and blue flag leaves have emerged from shallow water; cranberry leaves beginning to turn green.

May 16 – water lily leaves turning green; fringed loosestrife (*Lysimachia ciliata*) about 6 inches tall with purplish leaves; leatherleaf forming seeds.

May 22 - at pond edge, buttonbush (*Cephalanthus occidentalis*) leaves beginning to emerge on older branches, younger branches at base of plant with more developed leaves; spikerush (*Eleocharis*) and Labrador tea (*Ledum groenlandicum*) in bloom along pond shore; more green water lily leaves at surface but most still reddish in color. Observed green frog in pond and young pickerel frog along shoreline; newts have been in pond for some time now.

New Jersey

May 10 – High Point State Park (Sussex County) – highbush blueberry in full bloom; fetterbush (*Eubotrys racemosus*) with mostly dried flowers; spicebush (*Lindera benzoin*) still in flower but leaves emerged and expanding; pink azalea (*Rhododendron periclymenoides*) flowers nearly ready to bloom along marsh edge (only one of many flowers open); skunk cabbage leaves fully formed and covering the floor of many wetlands; yellow rocket (*Barbarea vulgaris*) in full bloom in cattail-skunk cabbage marsh; poison ivy (*Toxicodendron radicans*) leaves reddish bronze color (about 6 inches tall); a few starflower (*Trientalis borealis*) in bloom in hemlock-Atlantic white cedar swamp; Canada mayflower (*Maianthemum canadense*) in full bloom; fertile fronds/leaflets developing in ferns (*Osmunda cinnamomea*, *O. claytoniana*, and *O. regalis*); wild calla (*Calla palustris*) leaves emerged about 6 inches tall, no flowers yet; along trail, black huckleberry (*Gaylussacia baccata*) flowers developed but not open.

May 12 – Great Swamp including Great Swamp National Wildlife Refuge (Somerset County) – berries forming in shadbush (*Amelanchier canadensis*); black haw (*Viburnum prunifolium*) past flowering; black chokeberry (*Aronia melanocarpa*), spatterdock (*Nuphar luteum*) and golden ragwort (*Packera aurea*) in bloom; maleberry (*Lyonia ligustrina*) flowers developing but not in bloom; Long's sedge (*Carex folliculata/lonchocarpa*) flower spikes beginning to develop; turtlehead (*Chelone glabra*) about 1 foot tall. Saw box turtle near wet meadow at Great Swamp NWR.

May 13 - Wallkill River National Wildlife Refuge (Sussex County) – Pennsylvania bitter cress (*Cardamine pensylvanica*), cuckooflower (*Cardamine pratensis*), swamp buttercup (*Ranunculus septentrionalis*), false mermaid (*Floerkea proserpinacoides*), Jack-in-the-pulpit (*Arisaema triphyllum*), violets (*Viola* spp.), and wild black current (*Ribes americanum*) in bloom; purple-stem angelica (*Angelica atropurpurea*) from 1.5-3.0 feet tall not flowering; spring beauty (*Claytonia virginica*) still blooming but most spent; leaves just starting to emerge from black walnut (*Juglans nigra*) on floodplain. Mayapple (*Podophyllum peltatum*) in bloom along trail on high ground. At High Point State Park – mountain holly (*Ilex* [*Nemopanthus*] *mucronata*), pink azalea, and black chokeberry in bloom; wild calla just starting to bloom. ■


Highbush blueberry


Spicebush (*Lindera benzoin*)


Pink azalea (*Rhododendron periclymenoides*)


Shadbush (*Amelanchier canadensis*)


Swamp buttercup (*Ranunculus septentrionalis*)

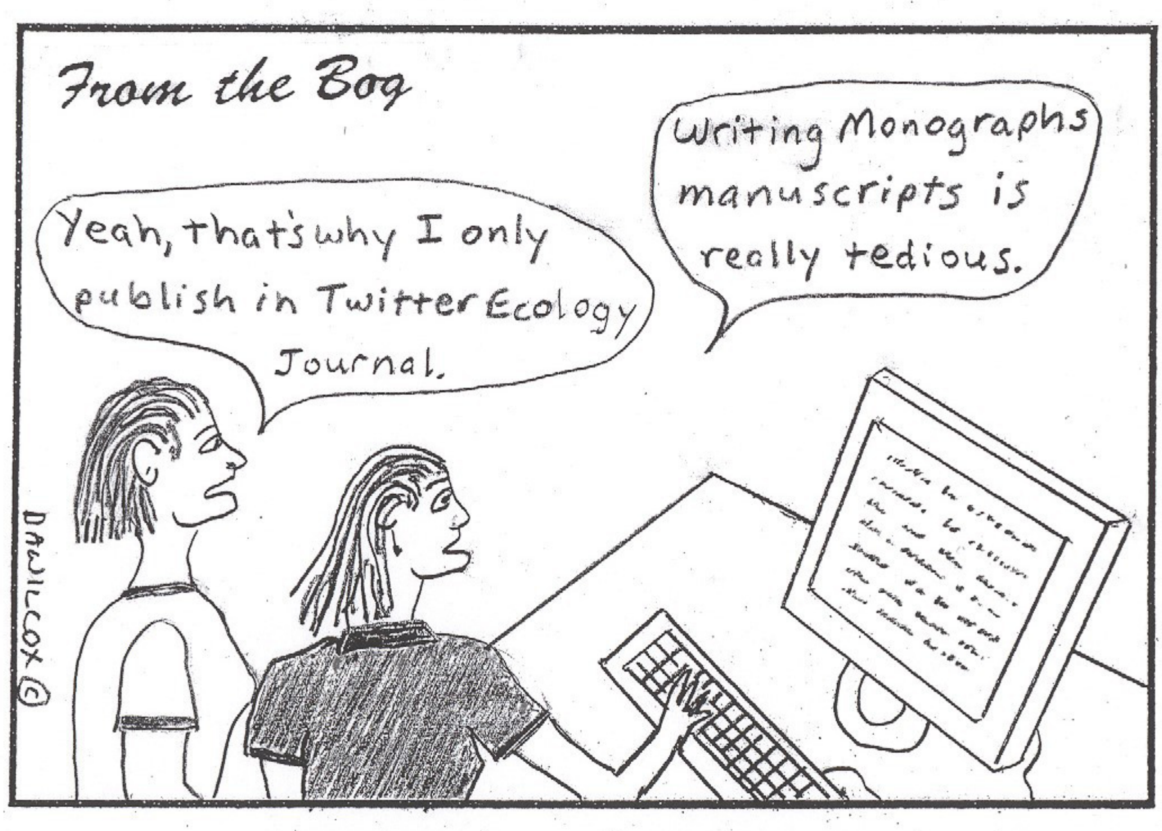

Jack-in-the-pulpit (*Arisaema triphyllum*)

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.**



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.