overing more than 4,300 square miles in Southern Florida, the Everglades are the largest subtropical wilderness in the United States. In recognition of their unique ecological significance, they have been designated an International Biosphere Reserve, a World Heritage Site, a National Park and a Ramsar Wetland of International Importance.

But over the years, human development, agriculture, and urban sprawl in and around the once-remote marshes and peatlands have contributed to radical changes in the Everglades’ water quality and water flow, and they have had far-reaching impacts on animal and plant populations.

A new book by Curtis Richardson, director of the Duke University Wetland Center and Professor of Resource Ecology at Duke’s Nicholas School of the Environment, provides an insider’s view of how scientists have studied these changes and offers practicable insights from their research to aid in the restoration of this vast wetland.

Encyclopedic in scope, The Everglades Experiments: Lessons for Ecosystem Restoration brings together key findings from 14 years of experiments in the Everglades by the Duke University Wetland Center and its partner institutions. The 702-page book was published in April 2008 by Springer Press.

“The findings presented in this book are the result of extensive experimental research from 1989 to 2003 on the effects of water, nutrients, and fire on the Everglades communities,” Richardson says. “It’s a synthesis of what we learned and how it can be applied to managing and restoring this irreplaceable resource.”

In addition to Richardson, 27 other scientists contributed to the writing of this book. A complete list of contributors can be found on page 8 of this issue of WetlandWire.

Written as a resource for scientists, land managers, and ecologists alike, the volume presents new information that covers the structural and functional responses of the Everglades ecosystem via experimental and gradient studies on microbial activity, algal responses, macroinvertebrate populations, macrophyte populations, and productivity as a result of changes to soil and water nutrients, water flow, and wildfire management. Key findings are translated into potential restoration guidelines based on sound ecological principles.

Equally important, the book reclassifies the Everglades, provides a comparison of historic and current ecological processes, and presents a new working hydrologic paradigm for restoring Florida’s “River of Grass” and other similarly degraded peatland and wetland complexes.

Richardson says, “What we found can help answer key questions such as: What are the effects of increased nutrient and water inputs on the native plant and animal communities? What is the long-term nutrient storage capacity of the Everglades? How can water and fire management there be improved to maintain the natural communities?”


News about continuing Everglades-related research by Duke University Wetland Center scientists can be found in articles on pages 5 and 6 of this issue of WetlandWire.
Just a short while ago I was going over the final proofs of the soon-to-be-published Everglades book, I began to think of many topics that I had not covered—for example, the need for more targeted Everglades restoration research and the use of adaptive management techniques to save and restore this great international treasure.

Why more research? We surely know a lot more about the ecology of the Everglades than we did 20 years ago. Countless scientists have spent untold hours traversing the sawgrass plains and tree islands in search of clues about the effects of hydrology, nutrients, and fire on ecosystem function. DUWC researchers were themselves responsible for many of those hours, and the results of our efforts are covered in detail in our recent book and several earlier publications. Yet, in spite of all that scientists have learned about the Everglades in the past two decades, we still need to know even more about the conditions necessary to sustain the various Everglades habitats. But is science enough?

Unfortunately, I saw signs at the Society of Wetland Scientists national meeting in Washington, D.C. this past May that interest in Everglades science and restoration may be waning. There were only a few talks given on the Everglades and, unlike in past years, they were poorly attended.

Is this lack of interest among scientists prompted by indifference outside the academic and scientific communities? A recent bill in Congress to start promised Federal funding for Everglades restoration was vetoed by the White House. True, the state of Florida has spent over two billion dollars on the Everglades, but restoration was vetoed by the White House. True, the state of Florida has spent over two billion dollars on the Everglades, but how much of this has really been spent on Everglades restoration efforts?

Recent lawsuits suggest that the large water reservoirs being built in the Everglades Agriculture Area are not for storing water for Everglades restoration but rather to support farming and development. Many of the current arguments and lawsuits sound just like those being contested back when I started working in the Everglades in late 1989. The more things change...

It is clear that, just by itself, all the detailed scientific work in the world is not going to save the Everglades. When scientists talk about phosphorus cycling, hydroperiod effects, or even bird breeding habitat requirements, the eyes of many of their non-scientist audience members just glaze over. How can science play a role if it doesn't engage the audience?

Maybe we should use the KISS principle (Keep It Simple, Stupid!) more often and simply point out that the futures of both the Everglades ecosystem and the human presence in south Florida are tied to one word—WATER.

Politicians, the public, land developers, and farmers—as well as conservationists—need to wake up and realize that a sustained Everglades ecosystem is not just a collection of plants and birds and alligators. The Everglades is the "hydrologic freshwater reservoir and pump" for south Florida. With Florida's fresh water aquifers already threatened with salt water intrusion from projected sea level rise during this century, further damaging the Everglades "pump" is inviting disaster. Hoarding water in reservoirs and pumping it below ground instead of providing sufficient water to the Glades is tantamount to committing slow suicide. Yes, in the short term more water may be available for immediate human use. But in the long run the resulting massive, non-sustainable development would eventually run out of water, and the chance to save the Everglades will have been lost.

This tragic outcome can still be avoided, but it will take political will, public willingness to pay the costs, and scientific knowledge.

—Curtis J. Richardson

Director, Duke University Wetland Center

Curtis J. Richardson, DUWC Director, gave the talk "A restoration approach to integrating wetland and stream functions on the landscape" at the May 2008 Society of Wetland Scientists Annual Meeting in Washington, D.C. The talk, based in part on research from the DUWC Stream and Wetland Assessment Management Park (SWAMP) near Duke University’s West Campus, presented an innovative approach to wetland stream connectivity.

Neal E. Flanagan, DUWC Research Associate, gave the presentation "Demonstration of water quality functions in a restored headwater riparian system" at the May 2008 Society of Wetland Scientists Annual Meeting in Washington, D.C. Flanagan’s talk, also based on research from SWAMP, demonstrated an offline system designed to replicate the function of natural floodplain swamps in capturing, retaining, and treating storm flow.
DUWC Receives EPA Grant to Study Relationships Among Climate Change, Land Use, and Invasive Plants

Duke University Wetland Center researchers Curtis Richardson, Neal Flanagan, and Song Qian have received an EPA STAR Grant of $598,000 in support of a research project entitled "Ecological impacts from the interactions of climate change, land use change and invasive species."

Future climate scenarios for the southeastern U.S. predict that surface water temperatures will rise as air temperature rises. Stream flows will probably decrease, with a greater proportion of annual watershed hydrologic yield coming from major storm events. Land use changes (for example, as forested areas become increasingly urban) have also been shown to raise water temperature and to increase pulsed water releases during storms.

The DUWC project's primary objective is to assess how these predicted changes of hydrologic flux and temperature regimes in floodplain ecosystems would affect the vulnerability of plant communities to the establishment and spread of invasive species. Another goal is to study how these changes will affect ecosystem functions and services. Studies of how an ecosystem responds to such disturbances have important implications for the development of management decisions.

North Carolina flood plain communities face a host of invasive plant species. Prominent among these are the semi-deciduous shrub species Chinese Privet (Ligustrum sinense) and the graminoid species Microstegium vimineum. These plants often form dense monocultures below the forest canopy, which reduces diversity and may suppress the regeneration of native canopy species as well as alter the hydrologic and nutrient cycling functions of floodplain systems.

Specifically, the project will focus on the relationships among native species composition, diversity, productivity, and invasibility of floodplain ecosystems affected by alterations of water temperature and annual hydrographs driven by climate change and land use change (urban, forested and agricultural). Researchers will use a combination of varying scale experimental studies and one novel large scale regional study to verify experimental and threshold modeling results.

There will be four distinct levels of experimental study, three of which will take place at the DUWC Stream and Wetland Assessment Management Park (SWAMP) in Duke Forest.

First, a field-based warming experiment will allow direct evaluation of treatment-effects of temperature and hydrology on species invasions, community composition, and ecosystem services of an experimental (restored) floodplain ecosystem.

Secondly, 99 diversity plots on a floodplain will be used to test how species richness effects species invasions.

The third experimental level will be 102 permanent vegetation plots distributed over 3 hydrogeomorphic zones in the floodplain (stream bank, low terrace, and high terrace). These will be used to assess how species invasions are affected by pulsed waters and flood inundation frequency.

Finally, a novel large-scale regional study of wetlands downstream of both surface-releasing and bottom-releasing dams will be used to assess pulsed water and temperature effects on invasive species. These data will be compared with analogous information from control rivers.

At each experimental level, the researchers will assess how feedbacks from invasive species alter ecosystems services such as flood control, sediment retention, and maintenance of water quality.
Duke University Wetland Center researchers will take part in a study entitled "Exploration of the mechanistic basis and biogeochemical implications of differential nutrient limitation among trophic levels" funded by a $930,000 National Science Foundation grant. Principal investigators for the project are DUWC Director Curtis J. Richardson; Scott C. Neubauer, Assistant Director of the Baruch Marine Field Laboratory, University of South Carolina; and P.V. Sundareswar of the Institute of Atmospheric Sciences, South Dakota School of Mines and Technology (and a DUWC postdoctoral research associate from 2000 to 2003).

The structure and function of ecosystems is governed by the patterns of nutrient limitation of the primary producers (e.g., plants) and heterotrophs (e.g., soil microbes). Often, these groups of organisms are limited by the same nutrient (e.g., phosphorus or nitrogen). However, an increasing body of evidence indicates that different nutrients can limit primary producers and heterotrophs in some ecosystems; this is known as differential nutrient limitation (DNL).

This study will examine why DNL occurs in some ecosystems but not others and what the consequences of DNL are with respect to utilization vs. storage of carbon.

These questions will be tested in four wetlands ranging from Rhode Island to Georgia, including both freshwater and saline systems. At each site, a network of field-fertilized experimental plots will be utilized to influence the nature of nutrient limitation. A standardized sampling approach at all sites will emphasize measurements of plant and microbial productivity, phosphorus cycling, and ecosystem metabolism. It is expected that DNL will occur in ecosystems with higher rates of phosphorus mineralization and that DNL will result in less storage of carbon.

This study has implications for ecosystem management and theories of ecosystem development. The research provides a conceptual framework to integrate ecological studies at multiple scales by understanding how ecological stoichiometry (i.e., nutrient ratios) affects the biogeochemical cycles that govern ecosystem energetics.

This project includes a commitment to students from under-represented groups (including American Indians and African-Americans) through a field research-mentoring program that will encourage and advance the participation of these groups in ecosystem studies.

Related Articles


Student News
Ariana Sutton-Grier received her Doctor of Philosophy degree in Ecology at Duke University’s Spring Commencement exercise in May 2008. Her dissertation, The Role of Plant Functional Diversity and Soil Amendments in Regulating Plant Biomass and Soil Biogeochemistry in Restored Wetland Ecosystems in the North Carolina Piedmont, addressed questions related to restoration ecology, including how plant functional diversity affects two ecosystem functions, biomass nitrogen accumulation, and denitrification potential. Sutton-Grier was recently appointed as a post-doctoral researcher at the Smithsonian Environmental Research Center in Edgewater, MD.

The Duke University Wetland Center was well-represented at the Society of Wetland Scientists 2008 annual meeting in Washington, DC this past May, with three doctoral student giving presentations during the week-long conference. The students and their presentation titles were:

Amani McHugh: Sustainable water resource management at college campuses
Michael Osland: Impact of seasonal flooding and disturbance on soil seed bank composition and emergence in a seasonal neotropical wetland (Palo Verde National Park, Costa Rica)
Ariana Sutton-Grier: Plant functional diversity and the restoration of riparian wetland ecosystem function
DUWC Researchers Estimate Ecological Thresholds for Phosphorus in the Everglades

In a recent article published in the journal *Environmental Science and Technology*, Duke University Wetland Center researchers and additional co-authors have written about a non-traditional statistical approach to determine the level of phosphorus additions the Florida Everglades ecosystem may be able to tolerate (Richardson et al. 2007). This new approach, based on earlier work by Curtis J. Richardson and Song S. Qian (1999) could be a useful tool in wetland restoration and management.

Over the past 3 to 4 decades, eutrophication and a significant shift in native Everglades flora and fauna caused by phosphorus from agricultural runoff and Lake Okeechobee outflow has taken place, to date mainly in the northern Everglades. Determining the amount of phosphorus the ecosystem can absorb without undergoing such changes in plant and animal populations is an important goal of Everglades restoration efforts.

As part of their larger, multi-year study of the Everglades, DUWC researchers constructed an experimental facility with 10-meter channels (“flumes”) in an interior portion of the Everglades undisturbed by P additions. The flumes were constructed in open-water sloughs, a habitat known to be sensitive to P-enrichment, in a north-to-south alignment with the ecosystem’s natural water flow. While one flume was used as a baseline control, DUWC researchers treated the remaining flumes at the northern ends with varying doses of soluble reactive phosphate, creating phosphorus gradients down the lengths of the flumes. From 1992 to 1998, researchers monitored several species of plants and macroinvertebrates to observe responses to phosphorus level shifts. The resulting data, representing more than 50 ecological indicators (e.g., population density, number of species present), were put through a Bayesian statistical model to calculate a weighted tipping point of change over time. The Bayesian changepoint analysis showed that exceeding a surface water geometric mean TP threshold concentration range of 12 to 15 micrograms per liter (controversially, higher than the current 10 micrograms per liter EPA-approved criterion) would result in ecological imbalance in algal, macrophyte, and macroinvertebrate assemblages as well as slough community structure.

The Bayesian approach DUWC researchers have used in the Everglades is applicable to determining thresholds and stable states in other aquatic ecosystems.

**DUWC’s experimental flume facility in the Everglades was the site of a 6-year experiment studying the effects of elevated phosphorus levels on ecosystem stability.**

**Photo by Curtis J. Richardson, DUWC.**

**Related Articles**


**Other Recent Publications by DUWC Authors and Collaborators**


Using part of the results from their larger, multi-year study of the Everglades, Duke University Wetland Center researchers Curtis J. Richardson and Song S. Qian won an EPA Science to Achieve Results (STAR) grant in 2005 to develop a Bayesian hierarchical modeling approach for estimating ecological thresholds. The hierarchical modeling approach is built on the Bayesian change point methods of Qian et al. (2003, 2004) for single species/metric. Single metric methods have been successfully used in the Everglades research (as described on page 5 of this issue of *Wetland Wire*). Richardson and Qian’s STAR research is focused on the interaction among multiple metrics within the ecosystem of interest.

Initially, DUWC researchers discovered that the TP threshold for the Everglades varies by metrics. Even for a single metric, the estimated threshold varies over time. For example, Figure 1 shows how the bladderwort (*Utricularia purpurea*) stem density drops suddenly when TP concentration exceeds a certain value (the threshold) and that the threshold changes over time and season. To understand the factors affecting the changes in TP threshold, conventional mathematical and statistical methods are insufficient and the Bayesian hierarchical modeling approach is necessary. This is because traditional methods can only analyze the threshold response using data specifically for a single metric observed from a single sampling event. There is no easy way to combine data from multiple metric and dates without some ecologically unrealistic assumptions. As part of the effort, Qian studied the application of the hierarchical (or multilevel) analysis of variance in ecological data analysis, publishing his results in a paper in the journal *Ecology* (Qian 2007). This effort led to a new statistical method for analyzing combined threshold data from multiple metrics and multiple sampling events. The new method preserves individual (metric, sampling event) specific features and can be used to study there interaction. Using this method, Qian and Richardson re-analyzed the bladderwort stem count data from all sampling events. They found that the varying threshold value is slowly converging to a stable value (Figure 2).

The STAR project is nearing the end of the funding period. Researchers are preparing documents that will summarize several important findings:

1) The use of Bayesian hierarchical change point method for detecting and quantifying ecological threshold is feasible. This finding is an important contribution to the field in that it provides a series of quantitative methods for combining data from multiple sources to understand ecological responses at both individual metrics and ecosystem levels.

2) The Bayesian hierarchical method can also be used to account for interactions among species.

3) The hierarchical modeling approach also introduces an ecosystem-level response that can be easily integrated into a decision-making process.

—Song Qian
Nicholas School of the Environment

Visit the Wetland Center on the Web.

http://www.nicholas.duke.edu/wetland
Figure 1: Observed total *Utricularia* stem counts are plotted against the previous 6 month average total phosphorus concentrations. The stem counts vary greatly by year and season. The stem counts also respond to the changes in phosphorus concentration, and the count is generally small when phosphorus concentration is high. A threshold is apparent in most year-seasons.

Figure 2: Estimated year-season interaction effects on TP threshold of total *Utricularia* stem count show the differences of year/season-specific thresholds from the overall average. The figure shows that the estimated year/season-specific threshold are gradually converging towards the overall mean, suggesting that the dosing system was gradually mature after initial dose of phosphorus.

**Related Articles**


CONTRIBUTING AUTHORS

M. Lee Barber, National Guard Bureau
Marek Bastl, University of South Bohemia
Mark Bush, Florida Institute of Technology
Sherri R. Cooper, Bryn Athyn College
Christopher B. Craft, Indiana University
Alisa Dickson, National Guard Bureau
Michele Goman, Cornell University
Sarah Goslee, USDA-ARS
Patrick N. Halpin, Duke University
Mengchi Ho, Duke University
Kirsten Hofmockel, University of Michigan
Jacqueline K. Huvane, Quintiles Transnational Corp.
Jeffrey Johnson, DUWC
Robert R. Johnson, South Florida Water Management District
Jan Kašťovský, University of South Bohemia
Ryan S. King, Baylor University
Jaroslava Komářková, Czech Academy of Sciences
James W. Pahl, Louisiana Department of Natural Resources
Song S. Qian, Duke University
Robert G. Qualls, University of Nevada, Reno
Klara Reháková, Czech Academy of Sciences
Curtis J. Richardson, Duke University
Edwin A. Romanowicz, State University of New York, Plattsburgh
Craig A. Stow, NOAA/Great Lakes Environmental Research Lab
P.V. Sundareshwar, South Dakota School of Mines & Technology
Panchabi Vaithiyanathan, Divers Alert Network
Jan Vymazal, ENKI
John G. Zahina, South Florida Water Management District

The Duke University Wetland Center is dedicated to providing sound scientific knowledge that will lead to sustainable wetland functions and services for the nation and for the world. The center works towards this goal by conducting, sponsoring, and coordinating research and teaching on critical wetlands issues.