SEVENTH INTERNATIONAL SYMPOSIUM ON THE BIOGEOCHEMISTRY OF WETLANDS

BOOK OF ABSTRACTS

Duke University Wetland Center
Nicholas School of the Environment and Earth Sciences
Duke University
Durham, North Carolina, USA
www.env.duke.edu/wetland

June 17 – 20, 2001
(revised edition)

HOST SPONSOR:

Duke University Wetland Center
Nicholas School of the Environment and Earth Sciences
Duke University
Durham, North Carolina USA
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Abstracts

Letter from the Symposium Chair

I would like to take this opportunity to welcome you to the Seventh International Symposium on the Biogeochemistry of Wetlands sponsored by the Duke University Wetland Center in the Nicholas School of the Environment and Earth Sciences. Additional sponsors include the North Carolina Wetlands Restoration Program, the Society of Wetland Scientists, and the Water Resources Research Institute of the University of North Carolina. Symposium co-sponsors are the Wetlands Biogeochemistry Institute at Louisiana State University, the Wetland Biogeochemistry Laboratory at the University of Florida, and the Duke University Marine Laboratory.

During the past two decades, there has been an increased interest in the role that wetlands play in the biogeochemical cycles of elements such as carbon, nitrogen, phosphorus, and sulfur. It is now clear that wetlands play a key role in the carbon cycle of the globe as well as having major influence on the storage, release, and transformations of nutrients and metals. Attendance and participation at the six previous symposia clearly indicate a worldwide interest in the biogeochemistry of wetlands. During the Seventh Symposium a total of four major symposia and three plenary sessions, along with 79 submitted oral presentations and 15 posters, will be presented over 3 days. The symposium contributors represent 14 countries.

Scientific Sessions: The scientific sessions will be held in the Fuqua School of Business, immediately adjacent to the R. David Thomas Center. Plenary sessions will be held on June 18, 19, and 20, 2001 in Geneen Auditorium. Geneen Auditorium is also the location for the four special symposia. A total of eight concurrent sessions will be held in Classrooms E and F during the Seventh Symposium. Poster papers will be on display throughout the conference in the Fuqua School Concourse. Authors of poster papers will be present at their posters from 5:45 P.M. until 7:00 P.M. on Tuesday evening. Slide, overhead, and computer projectors will be available for the general and concurrent sessions.

Other Activities: There will be a welcome reception for registered symposium participants at the Fuqua School Faculty Lounge Sunday evening from 5:00 to 7:00 P.M. There will also be a banquet dinner Monday night in the R. David Thomas Center Executive Dining Room from 6:45 to 9:30 P.M. On Wednesday afternoon, conference participants who have pre-registered for the optional field trip will gather in Geneen Auditorium prior to departure. All conference attendees are welcome to my pre-trip talk “Wetlands of Coastal North Carolina: An Overview of Pocosins, Carolina Bays, Bottomlands, and Salt Marshes” at 12:00 noon in Geneen Auditorium.

I extend special thanks to our sponsors and cooperators. I would like to thank all the speakers and poster presenters for supporting the Seventh Symposium. The work on conference arrangements by the staffs of the Duke University Wetland Center and the R. David Thomas Center is gratefully acknowledged, especially that of Lisa Blumenthal Rattray and Randy Neighbarger. Thanks are also extended to the session moderators and the graduate students who have worked hard to make this symposium a success.

Curtis J. Richardson
Director, Duke University Wetland Center
June 17, 2001

The Seventh International Symposium on
the Biogeochemistry of Wetlands

Program Agenda

The Seventh International Symposium on the Biogeochemistry of Wetlands

Duke University Wetland Center
Durham, NC USA

June 17-20, 2001

Sunday, June 17, 2001

2:00-8:00 pm	**Registration**	**Fuqua School Concourse**
3:00-5:00 pm	**Poster Set-up**	**Fuqua School Concourse**
4:00-6:00 pm	**Audio-Visual Preparation** with technical support	**Geneen Auditorium and Classrooms D, E, and F**
5:00-7:00 pm	**Welcome Reception**	**Fuqua School Faculty Lounge**

Monday, June 18, 2001

Plenary Session I
Geneen Auditorium

8:15 am
Introduction
Curtis J. Richardson
Director, Duke University Wetland Center

8:25 am
Remarks
Peter Lange
Provost, Duke University

8:35 am
Remarks
Norman Christensen
Dean, Nicholas School of the Environment and Earth Sciences, Duke University

8:45 am
Keynote Address
William H. Schlesinger
Dean-Elect, Nicholas School of the Environment and Earth Sciences, James B. Duke Professor of Biogeochemistry, Department of Biology, Duke University
"Climate change, wetlands and the global carbon cycle"

Special Symposium 1, Part I

"Carbon cycling and sequestration in wetlands"

Chair: **Scott Bridgham**, University of Notre Dame

Geneen Auditorium

9:30 am	**Carbon cycling and dissolved organic matter export in the Everglades** **Robert G. Qualls,** University of Nevada Curtis J. Richardson, Duke University
9:55 am	**Environmental Controls of Organic Carbon Accumulation in Freshwater Wetlands** **Christopher Craft**, Indiana University
	Break, ***Fuqua School Faculty Lounge***
10:45 am	**Nutritional limitations on aboveground net primary productivity in floodplain forests** **Graeme Lockaby** and E.B. Schilling, Auburn University
11:10 am	**The carbon balance in managed wetland forests** **Carl Trettin,** USDA Forest Service; K. Minkkinen and J. Laine, University of Helskinki; M.F. Jurgensen, Michigan Technological University
11:35 am	**The effect of peatland drainage, harvesting and restoration on C cycling in ombrotrophic bogs, eastern Canada** **Tom Moore**, Stephan Glatzel, Mike Dalva, Michele Marinier, Nigel Roulet and Julian Cleary, McGill University
12:00 noon	**Response of a woody plant-soil system to elevated CO_2 and flooding: Carbon allocation to production and methanogenesis** **Patrick Megonigal**, Smithsonian Environmental Research Center; Cheryl Vann, George Mason University
12:25 pm	**The impact of dissimilatory sulfate reduction rates on production of CO_2 and CH_4 in sphagnum-dominated peatlands: A global comparison across an atmospheric sulfur deposition gradient** **Melanie A. Vile** and Scott Bridgham, University of Notre Dame; R. Kelman Wieder, Villanova University; Martin Novák, Czech Geological Survey

1:15-2:15 pm	**Lunch** **R. David Thomas Center Executive Dining Room**

Special Symposium 1, Part II

"Carbon cycling and sequestration in wetlands"

Chair: **Scott Bridgham**, University of Notre Dame

Geneen Auditorium

2:30 pm

Organic chemical control of methane biogeochemistry in northern peatlands
Joseph B. Yavitt, Cornell University

2:55 pm

The carbon balance of bogs and fens in a manipulative climate change experiment
Scott Bridgham and Jason Keller, University of Notre Dame; Jake Weltzin, University of Tennessee; John Pastor, Karen Updegraff, Brad Dewey, and Cal Harth, University of Minnesota; Jiquan Chen, Michigan Technological University

3:20 pm

Potential effects of climate forcing on methane cycling in northern peatlands: Stable isotopic evidence from mesocosms and natural sites
Jeffrey R. White, Indiana University; Robert Shannon, Pennsylvania State University; Scott Bridgham, University of Notre Dame; John Pastor, University of Minnesota

3:45 pm

Preliminary regional carbon budget for the peatland region of Boreal, Continental, Western Canada
R. Kelman Wieder, Villanova University; Linda Halsey and Merritt Turetsky, University of Alberta; Dale Vitt, Southern Illinois University

Break, *Fuqua School Faculty Lounge*

4:40 pm

Modeling short term and long term carbon accumulation in northern peatlands
Steve Frolking, and Patrick Crill, University of New Hampshire; Nigel Roulet and Tim Moore, McGill University; Pierre Richard, Université de Montréal; Jill Bubier, Mount Holyoke College; Peter Lafleur, Trent University

5:05 pm

Carbon exchange in a northern bog
Nigel T. Roulet, Tim Moore, Colin Fraser, and Adam Reimer, McGill University; Peter Lafleur and Stuart Admiral, Trent University; Pierre Richard Université de Montréal; Steve Frolking, University of New Hampshire; Jill Bubier, Mount Holyoke College

5:30 pm

Plant community dynamics, nutrient cycling, and multiple stable equilibria in peatlands
John Pastor and Bruce Peckham, University of Minnesota; Scott Bridgham, University of Notre Dame; Jake Weltzin, University of Tenneesee; Jiquan Chen, Michigan Technological University

Concurrent Session 1

"Coastal Systems"

Moderator: **P.V. Sundareshwar**, Duke University

Classroom A

2:45 pm	**Source water variability within mangrove-dominated ecosystems of Micronesia** **Judy Z. Drexler**, USDA Forest Service; Eric De Carlo, University of Hawaii
3:05 pm	**The impact of metalliferous mining on saltmarsh flora** **Christian Smillie** and Loveday E.T. Jenkin, University of Exeter
3:25 pm	**Coastal salt barren as indicator to recent sea level change and wetland carbon dynamics** **Yuch Ping Hsieh**, Florida A&M University
3:45 pm	**Effects of parasitic plants on sediment biogeochemistry in California salt marshes** **Brenda J. Grewell**, University of California, Davis
	Break, *Fuqua School Faculty Lounge*
4:40 pm	**Sea level rise and carbon sequestration in coastal wetlands** **Yang Wang** and Yonghoon Choi, Florida State University; Yuch-Ping Hsieh and Larry Robinson, Florida A&M University; Peng Gong, University of California, Berkeley
5:00 pm	**Diatom indicators of salinity in Florida Bay, USA** **Jacqueline Huvane**, Duke University

Concurrent Session 2

"Plant Communities"

Moderator: **Graeme Lockaby**, Duke University

Classroom B

2:45 pm	**Growth and physiological responses of *Typha. domingensis* and *Cladium jamaicense* to low phosphorus and oxygen availability** **Bent Lorenzen** and Hans Brix, University of Aarhus

3:05 pm | **Spatial dependency of vegetation-environment relationships in an anthropogenically influenced wetland landscape**
Ryan King, Curtis J. Richardson, and Dean L. Urban Duke University

3:25 pm | **Effects of hydrology and phosphorus enrichment on regrowth of sawgrass (*Cladium jamaicense*) and cattail (*Typha domingensis*) after leaf removal**
ShiLi Miao, South Florida Water Management District

3:45 pm | **Plant species richness and phosphorus heterogeneity: an experimental approach**
Carmen Chapin and Barbara Bedford**,** Cornell University

6:45-9:30 pm | **Special Banquet Dinner**
R. David Thomas Center Executive Dining Room

Tuesday, June 19, 2001

Plenary Session II
Geneen Auditorium

8:30 am | **Hans W. Paerl**
Kenan Professor of Marine and Environmental Sciences
Institute of Marine Sciences, University of North Carolina at Chapel Hill
"Natural v. anthropogenic 'new' nitrogen inputs to coastal systems in the 21st century: Evolving sources, scales and consequences"
Hans W. Paerl, David R. Whitall, Benjamin Peierls and Michael F. Piehler

Special Symposium 2

"Biogeochemistry of estuarine systems"

Chair: **James T. Morris**, University of South Carolina

Geneen Auditorium

9:30 am	**Phosphorus dynamics in coastal wetlands** **P.V. Sundareshwar,** Duke University
10:00 am	**Sulfur, iron and phosphorus dynamics in carbonate soils of south Florida wetlands** **Randy Chambers**, College of William and Mary; Dana Madeux and Toru Endo, Fairfield University
	Break, ***Fuqua School Faculty Lounge***
11:00 am	**Denitrification rates in tidal wetlands: Applying a direct N_2 flux technique** **Jeffrey Cornwell**, Kevin Groszkowski, Erik Haberkern, Jennifer Merrill, Michael Owens, Lora Pride and Todd Kana, University of Maryland
11:30 am	**Patterns of nutrient biogeochemistry in mangrove wetlands along Florida coastal Everglades** **Robert R. Twilley**, University of Louisiana at Lafayette
12:00 noon	**Effects of sea level anomalies on biogeochemical processes in coastal wetlands** **James T. Morris**, University of South Carolina

Concurrent Session 3

"Water quality modeling and nutrient status"

Moderator: **Neal Flanagan**, Duke University

Classroom A

9:30 am	**Developing nutrient criteria for wetland systems** **Ifeyinwa Davis**, US Environmental Protection Agency
9:50 am	**Nutrient export from a natural forested wetland on the North Carolina coastal plain** **G.M. Chescheir**, D. M. Amatya, R. W. Skaggs, and J. W. Gilliam, North Carolina State University

10:10 am **Using decision tree models to target wetland restoration sites for watershed-level water quality improvement**
Neal Flanagan and Curtis J. Richardson, Duke University

Break, ***Fuqua School Faculty Lounge***

11:00 am **Effects of agriculture and wetland restoration on hydrology, soils, and water quality of a Carolina bay complex**
Gregory L. Bruland, Matthew F. Hanchey, and Curtis J. Richardson , Duke University

11:20 am **Modeling of biogeochemical processes in subsurface flow constructed wetlands**
Guenter Langergraber and Raimund Haberl**,** University of Agricultural Sciences, Vienna

Concurrent Session 4

"Nitrogen dynamics and cycling, Part I"

Moderator: **R. Kelman Wieder**, Villanova University

Classroom B

9:30 am **Delta ^{15}N as an indicator of N_2-fixation by cyanobacterial mats**
Eliska Rejmánková, University of California, Davis
Jaroslava Komárková , University of South Bohemia

9:50 am **Nitrate removal and denitrification in a stream riparian zone**
K. Dhondt, P. Boeckx, O.Van Cleemput, G. Hofman, and F. De Troch , Ghent University

10:10 am	**Regulation of surface water quality in a Chalk catchment, UK: An assessment of the relative importance of instream and wetland processes.** **Hannah Prior**, University of Reading
	Break, ***Fuqua School Faculty Lounge***
11:00 am	**Tidal simulation chambers for the investigation of nutrient transformation processes and gaseous emissions in intertidal zones** **Martin S.A. Blackwell** and Edward Maltby, Royal Holloway Institute for Environmental Research
11:20 am	**Modeling organic nitrogen uptake by plant and microbial communities in temperate wetlands** **Virginia L. Jin** and Rebecca R. Sharitz, University of Georgia
11:40 am	**Nutrient cycling dynamics after hydrological disturbance in boreal peatlands** **Raija Laiho**, Harri Vasander, and Jukka Laine, University of Helsinki; Tapani Sallantaus, Pirkanmaa Regional Environment Centre

1:15-2:15 pm

Lunch

R. David Thomas Center Executive Dining Room

Special Symposium 3

"Biogeochemical indicators of change in wetlands"

Chair: **K. Ramesh Reddy**, University of Florida

Geneen Auditorium

2:30 pm	**Indicators of biogeochemical functioning – progress in development of procedures for European wetland ecosystems** **Edward Maltby**, Royal Holloway Institute for Environmental Research

3:00 pm	**Biogeochemical fingerprinting of wetland sites as a basis for assessment of nutrient-related functions** **J.T.A. Verhoeven**, Utrecht University
3:30 pm	**Biogeochemical indicators of nutrient responses across the Everglades landscape** **Susan Newman**, South Florida Water Management District K. Ramesh Reddy, University of Florida
	Break, ***Fuqua School Faculty Lounge***
4:30 pm	**Direct and indirect effects of vegetation patterns on biogeochemical processes in emergent wetlands** **William G. Crumpton**, Iowa State University
5:00 pm	**A Comparison of physiological bioindicators of sublethal stress in wetland plants** **James W. Pahl**, Irving A. Mendelssohn, and Tao Kong, Louisiana State University; Karen L. McKee, USGS
5:30 pm	**Analysis of the composition of microbial communities along nutrient gradients in impacted wetlands** **Andrew Ogram**, University of Florida

Concurrent Session 5

"Metals and Pollutants"

Moderator: **Jan Vymazal**, Ecology and Use of Wetlands

Classroom A

2:30 pm	**Wetland plant and fertilization effects on the sediment chemistry of lead-zinc mine tailings** **Donna Jacob** and Marinus Otte, University College, Dublin
2:50 pm	**Biogeochemical dynamics of trace-metals in wetland sediments; simulations and measurements** **Peter R. Jaffe**, Jung-Hyun Choi, and Shangping Xu, Princeton University
3:10 pm	**Distribution of heavy metals in a constructed wetland receiving municipal sewage** **Jan Vymazal**, Ecology and Use of Wetlands, Czech Republic

3:30 pm **Wheal Jane: Modelling bioremediation of acid mine drainage in constructed ecosystems**
Paul Whitehead and Hannah Prior, University of Reading, United Kingdom; Jack Cosby, University of Virginia

Break, ***Fuqua School Faculty Lounge***

4:30 pm **Oxygen constraints on phenol oxidase: Implications for peatland nutrient cycling**
Chris Freeman, Hojeong Kang and Nick Ostle, University of Wales

Concurrent Session 6

"Nitrogen dynamics and cycling, Part II"

Moderator: **Christopher Craft**, Indiana University

Classroom B

2:30 pm **Effects of drawdowns on water and soil chemistry in a managed wetland**
M. M. Fisher, K. J. Ponzio, L.W. Keenan, and K. Snyder, St. Johns River Water Management District; S.V. Rockwood and J. Albury, Florida Fish and Wildlife Conservation Commission

2:50 pm **The role of wetland substrate in maximizing nitrate removal from swine wastewater**
Michael R. Burchell II, R.W. Skaggs, and S. Broome, North Carolina State University; C.R. Lee, USACE–Engineering Research and Development Center

3:10 pm **Monitoring of denitrification in a constructed wetland receiving agricultural runoff**
Amy C. Poe, Suzanne P. Thompson, Michael F. Piehler, and Hans W. Paerl,University of North Carolina at Chapel Hill

Break, ***Fuqua School Faculty Lounge***

4:30 pm

Enhancement of nitrate removal in treatment wetlands using an episediment layer for denitrification
Maia S. Fleming-Singer and Alexander Horne, University of California, Berkeley

4:50 pm

Decomposition and N dynamics in riparian buffer zones along a climatic gradient
Mariet Hefting and Jos Verhoeven, Utrecht University; Piotr Bieñkowski, Polish Academy of Sciences; Jean-Christophe Clement, Université de Rennes; David Dowrick, University of Durham; Claire Guenat, Ecole Polytechnique Fédérale de Lausanne; Ester Nin, University of Barcelona; Sorana Topa, University of Bucharest

5:45-7:00 pm

Poster Session
Fuqua School of Business Concourse

Wednesday, June 20, 2001

Plenary Session III
Geneen Auditorium

8:30 am

R. Wayne Skaggs
William Neal Reynolds and Distinguished University Professor
Department of Biological and Agricultural Engineering,
North Carolina Sate University
"The hydrology of wetlands: Factors affecting water table fluctuations in hydric soils"
R. Wayne Skaggs, G. M. Chescheir and W. F. Hunt, III

Special Symposium 4

"Hydric soils and biogeochemical indicators"

Chair: **Michael J. Vepraskas**, North Carolina State University

Geneen Auditorium

9:30 am **Applications of biogeochemistry to hydric soil identification**
Michael J. Vepraskas, North Carolina State University

10:00 am **Kinetics of nitrous oxide and methane production in relation to soil redox potential and mitigation of their emissions from irrigated rice fields**
Kewei Yu and William H. Patrick, Jr., Louisiana State University; Guanxiong Chen, Chinese Academy of Sciences

Break, ***Fuqua School Faculty Lounge***

10:50 am **The effects of additions of available C and P on Eh and pH in an Everglades histosol**
Paul Benzing and Curtis J. Richardson, Duke University

11:20 am **Enumeration of Fe-oxidizing and Fe-reducing bacteria in the wetland plant rhizosphere: Implications for a rhizosphere Fe cycle**
Johanna V. Weiss and Stephanie Backer, George Mason University: J. Patrick Megonigal, SERC; David Emerson, American Type Culture Collection

Concurrent Session 7

"Carbon dynamics and cycling"

Moderator: **R.G. Qualls**, University of Nevada

Classroom A

9:30 am **Controls of organic matter characteristics on the dynamics of CO_2 and CH_4 in a northern peatland**
Charlotte L. Roehm and Nigel T. Roulet, McGill University

9:50 am **Centimeter-scale Dynamics of Carbon Mineralization in Peatland Soils after Flooding and Drying Events**
Christian Blodau, and Tim Moore McGill University,

10:10 am	**Temporal variation in the responses of peatland carbon cycling to temperature** **Nathalie Fenner** and Christopher Freeman, University of Wales, Bangor; Brian Reynolds, Center for Hydrology and Ecology, Bangor
	Break, ***Fuqua School Faculty Lounge***
10:50 am	**Permafrost thaw increases peat accumulation: The role of mosses and microbes** **Merritt R. Turetsky**, University of Alberta
11:10 am	**Zymogenic bacteria: Are they predictors of CH_4 production potential in flooded rice fields and natural wetlands?** **A.X. Hou,** W.H. Patrick, Jr., and R.J. Portier, Louisiana State University
11:30 am	**Profiling of complex microbial communities in a boreal, continental, western Canadian peatland** **John A. Navaratnam** and R. Kelman Wieder, Villanova University
11:50 am	**Decomposition of cattail litter under different water regimes** **Robin L. Miller** and Roger Fujii, United States Geological Survey
12:10 pm	**Carbon source limitation in a wetland treating acid rock drainage** **James Harrington**, Shepherd Miller, Inc.

Concurrent Session 8

"Phosphorus cycling and transformations"

Moderator: **Mark R. Walbridge**, George Mason University

Classroom B

9:30 am	**Phosphorus retention in forested riparian wetlands of the Southeastern United States** **Mark R. Walbridge**, Arlene K. Darke, Rebecca B. Wright, and Dianna M. Hogan, George Mason University; Josephine R. Axt, U.S. Army Corps of Engineers

10:10 am	**Phosphorus cycling and partitioning in oligotrophic and enriched Everglades wetland ecosystems** **Gregory Noe**, Leonard Scinto, Daniel Childers, and Ronald Jones, Florida International University
	Break, ***Fuqua School Faculty Lounge***
10:50 am	**Enzymatic hydrolysis of organic phosphorus in the surface water of the Everglades Stormwater Treatment Areas** **Hari K. Pant** and K. R. Reddy, University of Florida; F.E. Dierberg and T.A. DeBusk, DB Environmental Laboratory, Inc.
11:10 am	**Predicting bioavailability of phosphorus to cattail and sawgrass in Everglades soils** **Matthew F. Hanchey** and Curtis J. Richardson, Duke University
11:30 am	**Diatom species composition as predictor of soil phosphorus concentrations in the Everglades - A Bayesian hierarchical modeling approach** **Song S. Qian**, The Cadmus Group; Yangdong Pan, Portland State University
11:50 am	**Preliminary comparison of water quality trends in Stormwater Treatment Areas (STA-1W and STA-6) with the Everglades Protection Area** **Jana Majer Newman**, Tammy Lynch, and Susan Newman, South Florida Water Management District

12:00 noon	**Special Field Trip Presentation** **"Wetlands of Coastal North Carolina: An Overview of Pocosins, Carolina Bays, Bottomlands, and Salt Marshes"** **Curtis J. Richardson**, Duke University **Geneen Auditorium** **(open to all participants)**

The Seventh International Symposium on
the Biogeochemistry of Wetlands

Abstracts

Keynote Address, Plenary Session I
Monday, June 18, 2001 8:45 A.M.
Geneen Auditorium

"Climate Change, Wetlands and the Global Carbon Cycle"

William H. Schlesinger

Nicholas School of the Environment and Earth Sciences,
James B. Duke Professor of Biogeochemistry, Department of Biology,
Duke University

Climate Change, Wetlands and the Global Carbon Cycle

William H. Schlesinger
Duke University, Durham, North Carolina, USA

Wetland soils contain the largest proportion of the global pool of organic carbon in soils. Wetland soils accumulate carbon at rates of 10 to 100 $g/m^2/yr$, whereas rates for upland areas range between 1 to 5 $g/m^2/yr$—the lower rate reflecting more efficient aerobic decomposition processes on land. Using the Holocene climatic warming as an analog, one might postulate a greater rate of carbon accumulation in wetlands with global warming, based on the carbon that accumulated in northern peatlands following deglaciation. Indeed, in modern peatlands, rates of carbon accumulation are often greater in warmer regions. Alternatively, one might postulate that rising temperatures, by raising the rate of soil respiration, would lead to a loss of carbon from wetland soils, which are likely also to dry as a result of global warming. Should the rate of soil respiration in wetlands increase, the global flux of CO_2 from soils to the atmosphere would add significantly to the flux from fossil fuel emissions. Understanding these changes in wetlands and potentially managing them for effective carbon sequestration are critical human responses to global climate change.

Special Symposium 1, Part I
Monday, June 18, 2001   9:30 A.M.
Geneen Auditorium

Carbon Cycling and Sequestration in Wetlands

Moderator: *Scott Bridgham*
Department of Biological Sciences, The University of Notre Dame

Carbon Cycling and Dissolved Organic Matter Export in the Everglades

Robert G. Qualls
University of Nevada
Reno, Nevada, USA

Curtis J. Richardson
Duke University Wetland Center
Nicholas School of the Environment and Earth Sciences
Durham, North Carolina, USA

Carbon cycling in the unenriched area of the Everglades is characterized by a NPP which is relatively average for wetlands, slow decomposition of litter due to high lignin content of sawgrass and P deficiency, low peat accretion rates, the emission of most CO_2 from peat because of this slow initial decomposition, and relatively low methane emission. Phosphorus enrichment results in a general acceleration of carbon cycling. Compared to the unenriched area, in the P enriched area NPP and litterfall is almost doubled, production of soluble organic C in senescent litter is nearly tripled, decomposition rate of litter is nearly doubled due to P enrichment and the low lignin content of cattail, total respiration from first year litter is four times higher, peat accretion is higher, and methane emission is likely to be over 4 times as high. Furthermore, a much greater proportion of the total respiration of litter plus peat is channeled into respiration during the first year when litter is exposed to aerobic conditions. The effects of P enrichment on the carbon cycle are largely due to direct effects of P on plants and microbes as a limiting nutrient. Furthermore, the species change to cattail results in higher quality detritus, which affects decomposers, probably produces more fermentation products for methanogens, and allows efficient methane venting due to the characteristics of cattail.

Environmental Controls of Organic Carbon Accumulation in Freshwater Wetlands

Christopher Craft
School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana, USA

Organic carbon (C) accumulation was measured in a variety of freshwater peatlands and organic rich wetland soils along a latitudinal gradient to evaluate the role of global (temperature) versus local control of wetland C accumulation. Organic C accumulation was determined by radiometric dating (^{137}Cs, ^{210}Pb) of soil cores collected along a latitudinal gradient from Minnesota to south Florida. There was a no relationship between latitude, used as a proxy for mean annual temperature, and organic C accumulation. When only acidic (pH<5.5) wetlands were used, the relationship improved dramatically (r^2=0.55). Acidic wetlands (133 g/m^2/yr) had higher C accumulation than circumneutral peatlands (58 g/m^2/yr). Nutrient enriched wetlands (180 g/m^2/yr) also had higher C accumulation than unenriched wetlands (28 g/m^2/yr). There were clear differences in C accumulation between *Sphagnum* dominated wetlands (165 g/m^2/yr) and herbaceous dominated wetlands (38 g/m^2/yr) that probably reflect underlying differences in environmental factors, like soil acidity. Although climate is the "master" variable controlling C accumulation worldwide, in wetlands, it is often overridden by local factors like soil acidity and nutrients.

Nutritional Limitations on Aboveground Net Primary Productivity in Floodplain Forests

B. G. Lockaby and E. B. Schilling
School of Forestry and Wildlife Sciences, Auburn University, Alabama, USA

Often 'floodplain forests' are discussed as a homogenous ecosystem type when, in reality, considerable variation may exist in terms of production and biogeochemistry among various systems. Few investigations to date have examined nutritional differences among floodplain forests and, thus, our understanding of their role within landscapes remains generic. It has been suggested that some insight may be gained through examination of N:P ratios in floodplain vegetation. Based on these ratios, there may be indications of potential levels of net primary production (NPP) as well as nutritional constraints on productivity. We explored these possibilities through investigation of nutrient cycling and aboveground NPP on the floodplains of two rivers that are quite distinct biogeochemically. Study sites were selected near Jesup, GA on the floodplains of the Altamaha River, a redwater system, and the Satilla River, a blackwater system. In general, the NPP and nutrient stocks of the forests on the Altamaha floodplain are considerably greater than those of the Satilla. N, P, K, Ca, and Mg turnover in litterfall, decomposition, and for N and P only, retranslocation and microbial immobilization were examined relative to three microsite types on both floodplains. Annual aboveground NPP and hydroperiod were also evaluated.

The Carbon Balance in Managed Wetland Forests

C. C. Trettin
Center for Forested Wetlands Research, USDA Forest Service, Charleston, South Carolina.

K. Minkkinen and J. Laine
Dept. of Forest Ecology, University of Helsinki, Finland.

M. F. Jurgensen
School of Forestry and Wood Products, Michigan Technological Univ., Houghton, Michigan.

Disturbance regimes associated with silvicultural practices in wetlands are usually considered to cause a negative C balance. The loss of soil carbon is usually attributable to increased organic matter oxidation following changes in temperature, moisture and aeration. That paradigm has been largely developed from drainage studies in organic soils ranging from boreal to the tropical forests. It has also served to shape the general consideration of the effects of silvics on the C balance in wetland soils. Recent work in Finland on organic soils and northern Michigan on histic-mineral soils has shown that soil C pools can be resilient, to the extent that gains are possible on productive sites. A common factor is that changes in productivity and stand composition must be considered. Silvicultural practices can also cause a change in C emissions. Although there is relatively little data on methane emissions from forested wetlands, indications are that management or stand-induced changes in water table can change CH_4 fluxes. On sites where the water table is reduced, CH_4 emissions are lowered, and conversely increased surface saturation or flooding following harvesting may increase emissions. Accordingly, changes in the C cycle are certain, but the cumulative effect in terms of C pools or global warming potential is dependent on the interactions of site type, productivity, and hydrologic regime.

The Effect of Peatland Drainage, Harvesting and Restoration on C cycling in Ombrotrophic Bogs, Eastern Canada

Tim Moore, Stephan Glatzel, Mike Dalva, Michele Marinier, Nigel Roulet and Julian Cleary
Department of Geography and Centre for Climate & Global Change Research, McGill University, Montréal, Québec, Canada

Peat harvesting covers over 150 km^2 in eastern Canada, produces 700 x 10^3 t yr^{-1} and intensive, vacuum-harvesting techniques leave a peat surface that is slow to re-vegetate, frequently with species that were not important members of the original bog. Measurements of carbon dioxide (CO_2), methane (CH_4) and dissolved organic carbon (DOC) fluxes were made in 1999 and 2000 at 8 sites near Rivière du Loup, Qué: a "pristine" bog, an actively harvested (vacuum method) site, sites experimentally restored in 1995, 1997 and 1999, a block cut site (*ca.* 25 yr after abandonment and ditch closure), an inundated block cut and a site abandoned *ca*. 25 years ago.

At the "pristine" bog, hummocks and hollows showed marked differences in CO_2 net ecosystem exchange (NEE) and respiration, but the site was close to a balance between uptake and release of CO_2.The actively harvested site emitted little CO_2 (5 g CO_2 m^{-2} d^{-1}). At the abandoned site, areas without vegetation released 16 g CO_2 m^{-2} d^{-1}. At the block cut sites, CO_2 production was greater than consumption, but losses were least except where the site was inundated. At the experimentally restored sites, net CO_2 loss was greater than at the harvested site and depended on vegetation. Clumps of cotton grass (*Eriophorum spissum*) showed high rates of CO_2 uptake and release and appeared to "prime" the peat, increasing the rates of decomposition. *Sphagnum* and ericaceous communities at the restored sites behaved more conservatively.

At sites where the water table was low, CH_4 fluxes were small, averaging between -0.5 and 5 mg CH_4 m^{-2} d^{-1}. Where the water table was higher, such as the inundated block cut and the block cut drains, larger fluxes occurred (< 80 mg CH_4 m^{-2} d^{-1}). The dominant influence on CH_4 emission rates within sites was the presence of *E. spissum*. At the experimentally restored sites, collars containing cotton grass emitted 4 to 97 mg CH_4 m^{-2} d^{-1}, higher than the bare peat, shrub or moss collars (-0.5 to 2.5 mg CH_4 m^{-2} d^{-1}). At the inundated block cut, collars with the water table close to the surface and containing *E. spissum*, emitted 1 to 1.3 g CH_4 m^{-2} d^{-1}, compared to 14 to 87 mg CH_4 m^{-2} d^{-1} where dominated by *Sphagnum*. Pore water DOC concentrations ranged from 50-100 mg l^{-1}, except at depths of 1 and 1.5 m at the block cut site, where it was < 500 mg l^{-1}. Within the peat profile, all sites except block cut have larger concentrations of DOC above 0.5 m depth and smaller concentrations of DOC below 0.5 m depth. At no site did we detect a seasonal change in DOC concentrations.

These results suggest that the effect of restoration is to increase the release of C to the atmosphere as CH_4 and CO_2, at least in the short term. Cotton grass has a profound effect on C cycling, through stimulating peat decomposition and increasing CH_4 emission rates.

Response of a Woody Plant-Soil System to Elevated CO_2 and Flooding: Carbon Allocation to Production and Methanogenesis

Patrick Megonigal
Smithsonian Environmental Research Center, Edgewater, Maryland, USA

Cheryl Vann
George Mason University, Fairfax, Virginia, USA

About 60% of global wetlands are dominated by woody vegetation, yet there are no studies on the response of woody plants to elevated CO_2. We grew *Taxodium distichum* seedlings for 3 months at two CO_2 levels (350 and 700 ppmv) crossed with two water level depths (+5 cm and –8 cm) in replicated glasshouses. We expected to observe a CO_2-induced increase in growth in non-flooded soils where O_2 was relatively abundant, but not in flooded soils due to an O_2 limitation on root production.

Photosynthetic rates were higher in the elevated CO_2 treatment. This caused an increase in root biomass in the non-flooded treatment, but not in the flooded treatment. There was a non-significant trend ($P<0.10$) of increased shoot biomass and total biomass in the non-flooded treatment, but no trend in the flooded treatment. These results suggest that some factor related to flooding was limiting the biomass response of the flooded plants to elevated CO_2.

Elevated CO_2 increased methane emissions by 50 to 85%, with the largest absolute increase in the flooded treatment. We propose that elevated CO_2 is likely to cause a net increase in radiative forcing when acting on woody wetland systems.

The Impact of Dissimilatory Sulfate Reduction Rates on Production of CO_2 and CH_4 in Sphagnum-Dominated Peatlands: A Global Comparison Across an Atmospheric Sulfur Deposition Gradient

Melanie A. Vile and Scott Bridgham
University of Notre Dame, Notre Dame, Indiana, USA

R. Kelman Wieder
Villanova University, Villanova, Pennsylvania, USA

Martin Novák
Czech Geological Survey, Prague, Czech Republic

Peatlands represent carbon reservoirs that can act as either a source or sink. Sulfate reduction is one anaerobic carbon mineralization pathway that can affect the source/sink status. Methanogenesis is thought to be the more important carbon mineralization pathway, especially in regions where input of sulfate is low. We determined rates of sulfate reduction, and CO_2 and CH_4 production in peatlands spanning a wide atmospheric sulfur gradient in central Alberta, Canada (BLB) and Cervené Blato (CER) and Oceán (OCE), The Czech Republic. Rates of sulfate reduction followed the atmospheric sulfur gradient, with rates at both Czech sites higher than at BLB. Our results suggest that sulfate reduction rates increase with increasing rates of atmospheric deposition. CH_4 production was higher at BLB than at either of the Czech sites, suggesting inhibition of methanogenesis by elevated sulfate concentrations. There was only a marginally significant increase in total CO_2 production, suggesting that despite differences in sulfur deposition, increased sulfate reduction did not lead to increased CO_2 production. At CER and OCE, between 49 and 33 % of total CO_2 production originated from sulfate reduction, respectively, with less than 0.01% from methanogenesis. Even though both sulfate reduction and methane production at BLB were low, carbon flow was 24 times greater through sulfate reduction (1.2 %) than through methanogenesis (0.05%). These results suggest that although peatlands are important global sources of CH_4, methanogenesis is responsible for a small proportion of anaerobic carbon cycling.

Special Symposium 1, Part II
Monday, June 18, 2001   2:30 P.M.
Geneen Auditorium

Carbon Cycling and Sequestration in Wetlands

Moderator: *Scott Bridgham*
Department of Biological Sciences, The University of Notre Dame

Organic Chemical Control of Methane Biogeochemistry in Northern Peatlands

Joseph B. Yavitt
Cornell University, Ithaca, New York, USA

The question whether organic matter quality, environment, and (or) climate controls organic matter decomposition is a fundamental problem in ecosystem ecology. The situation is particularly important in northern peatlands in which tremendous amounts of soil organic matter have accumulated and where profound climatic changes are expected. I used an experimental approach to examine the question. I took peat samples from peatlands in three different climatic regions (Bleak Lake Bog, Alberta, Canada; Bog 979, Ontario, Canada; Big Run Bog, West Virginia, USA) and incubated them for two years in six peatland sites situated along the same environmental gradient. The samples were retrieved and assayed for potential rates of methanogenesis and microbial respiration and for changes in organic matter quality. Analyses indicated significant effects of incubation site, origin of the peat, as well as the site X peat origin interaction on methanogenesis and microbial respiration. Temperature regime of the site had no effect. Differences in organic matter quality, particularly lignin chemistry, helped explain the results. In particular, methanogenesis exhibited a positive relationship with lignin derived from *Carex* sedges. The study showed the problem trying to predict effects of climatic change on peatland carbon storage and methane production if organic matter quality is not accounted for.

The Carbon Balance of Bogs and Fens in a Manipulative Climate Change Experiment

Scott Bridgham and Jason Keller
University of Notre Dame, Notre Dame, Indiana, USA

Jake Weltzin
University of Tennessee, Knoxville, Tennessee, USA

John Pastor, Karen Updegraff, Brad Dewey, and Cal Harth
University of Minnesota, Duluth, Minnesota, USA

Jiquan Chen
Michigan Technological University, Houghton, Michigan, USA

We constructed a large mesocosm facility in northern Minnesota to examine the effects of climate change on peatlands. Twenty-seven intact peat monoliths (2.1 m^2, 60-cm depth) were removed each from a bog and intermediate fen and subjected to three infrared-loading treatments and three water-table treatments beginning in 1994. Net ecosystem respiration occurred predominantly as CO_2 flux, increased with warmer soil temperatures, and did not differ between bog and fen plots. There were large heating and water-table treatment effects on above- and belowground net primary production, but the individual effects tended to compensate for each other so that overall changes in NPP were muted.

The overall carbon budgets of the plots were determined by changes in peat volume and through an empirical model of net ecosystem exchange of carbon based upon flow-through chamber data. Both independent data sets suggest that the fens either have no change or are losing carbon, whereas the bogs are gaining carbon. Wetter conditions enhance carbon storage in the bogs and reduce carbon losses in the fens. There has been a large drop in carbon storage in the bogs over time, with the water-table treatments becoming more similar, suggesting a rapid equilibration of bogs with climate.

Overall, our results suggest large effects of climate on the carbon balance of peatlands, with important community-specific effects.

Potential Effects of Climate Forcing on Methane Cycling in Northern Peatlands: Stable Isotopic Evidence from Mesocosms and Natural Sites

Jeffrey R. White
Indiana University, Bloomington, Indiana, USA

Robert D. Shannon
Pennsylvania State University, State College, Pennsylvania, USA

Scott D. Bridgham
University of Notre Dame, Notre Dame, Indiana, USA

John Pastor
University of Minnesota Duluth, Duluth, Minnesota, USA

In boreal peatlands, rates of carbon mineralization and release of methane are affected by interactions between climate variables and plant community composition. Changes in the rates and pathways of carbon cycling in peatland soils, which contain nearly one third of the global pool of soil carbon, could significantly affect atmospheric concentrations of CO_2 and CH_4. Yet, little is known about the response of peatland plant communities to climate change.

We will present two years of results from mesocosm studies that quantify changes in soil temperature, hydrology, plant community dynamics and carbon flow in bog and fen ecosystems. The site of this work is the University of Minnesota Fens Research Facility near Duluth, MN, USA. We measured coexisting isotopic compositions of $\delta^{13}C_{CH4}$, $\delta^{13}C_{CO2}$, δD_{CH4} and δD_{H2O} in porewater and in emitted methane. An array of plant community and productivity variables was also measured. We will present evidence of significant changes in methane cycling in bogs and fens as controlled by complex interactions of plant communities with climate variables, soil heating and water table.

Preliminary Regional Carbon Budget for the Peatland Region of Boreal, Continental, Western Canada

R. Kelman Wieder
Villanova University, Villanova, Pennsylvania, USA

Linda A. Halsey and Merritt R. Turetsky
University of Alberta, Edmonton, Alberta, Canada

Dale H. Vitt
Southern Illinois University, Carbondale, Illinois, USA

In continental, western Canada (Alberta, Manitoba, Saskatchewan), peatland ecosystems cover 365,157 km^2, store 41.8 Tg of C, and at an assumed current net C accumulation rate of 23 g C m^{-2} yr^{-1}, would represent a regional C sink of 8.4 Tg. However, at least two types of disturbance affect regional peatland C balance: ongoing melting of permafrost at its southern limit, and fire. Permafrost melting, at a rate of 263 km^2 yr^{-1}, may actually enhance the regional net C sink. Fire, which burns an estimated 1470 km^2 of peatland in the region, diminishes the regional net C sink, both from direct losses during combustion and from the time post-fire that it takes to reestablish pre-fire net primary production. Western Canadian peatlands may or may not represent a regional net C sink.

Modeling Short Term and Long Term Carbon Accumulation in Northern Peatlands

Steve Frolking and Patrick Crill
University of New Hampshire, Durham, New Hampshire, USA

Nigel Roulet and Tim Moore
McGill University, Montréal Québec, Canada

Pierre JH Richard
Université de Montréal, Montréal Québec, Canada

Jill Bubier
Mount Holyoke College, S. Hadley Massachusetts, USA

Peter Lafleur
Trent University, Peterborough, Ontario, Canada

We present results from two peatland ecosystem models. To test the hypothesis that long-term peat accumulation can be related to contemporary carbon flux dynamics, we developed a new model (Peat Decomposition Model—PDM) of long-term peat accumulation. Decomposition rates of the deeper peat are directly related to observable decomposition rates of fresh vegetation litter. Plant root effects (sub-surface oxygenation and fresh litter inputs) are included. PDM considers two vegetation types (vascular and non-vascular) with different decomposition and above:below ground litter input rates. We use PDM to investigate sensitivities of peat accumulation in bogs and fens to productivity, root:shoot ratio, tissue decomposability, root and water table depths, and climate. With a very general parameterization, PDM fen and bog age:depth profiles are similar to data from the most recent 5000 years at three bog cores and a fen core in eastern Canada, but overestimate accumulation at three other bog cores in that region.

We also have developed the Peatland CARbon Simulator (PCARS), a process-oriented model of the contemporary carbon balance of northern peatlands. Components of the ecosystem model are: (1) vascular and non-vascular plant photosynthesis and respiration, net above- and below-ground production and litterfall; (2) aerobic and anaerobic decomposition of organic matter in the peat profile; (3) production, oxidation, and net flux of methane; and (4) dissolved organic carbon (DOC) loss with drainage water. The model operates with an hourly/daily time step, and is driven by air and soil temperatures, water table depth, and drainage, either from observational data or from a peatland parameterization of the Canadian Land Surface Scheme (CLASS) coupled to a Local Climate Model (LCM). Simulations predict a complete peatland C balance for one season to several years. Model evaluation uses eddy covariance tower (CO_2) and/or surface chamber flux (CO_2 and CH_4) measurements from Mer Bleue Peatland near Ottawa, Ontario, and Sallie's Fen in Barrington, NH, USA.

Carbon Exchange in a Northern Bog

Nigel T. Roulet, Tim Moore, Colin Fraser, and Adam Reimer
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Peter Lafleur and Stuart Admiral
Department of Geography, Trent University, Peterborough Ontario, Canada.

Pierre Richard
Département de géographie, Université de Montréal, Montréal, Québec, Canada.

Steve Frolking
Complex System, University of New Hampshire, Durham, New Hampshire, USA

Jill Bubier
Environmental Studies Program, Mont Holyoke College, South Hadley, Massachusetts, USA

The contemporary and past carbon dynamics of a large (28 km^2), raised, shrub, bog, called Mer Bleue, located 15 km southeast of Ottawa, Ontario, Canada has been studies for the last four years. Peat accumulation began at Mer Bleue 8,000 years on lacustrine sediments left over from the glacial Lake Champlain. In its initial phase Mer Bleue was a fen and the transition to bog occurred approximately 6,500 years. Analysis of a 5.5 m peat core for carbon content, bulk density, and a chronology based on corrected ^{14}C dates indicates a carbon has accumulated at a rate of < 20 g C m^{-2} yr^{-1} while Mer Bleue has been a bog. The contemporary carbon budget of Mer Bleue was determined from estimates of net ecosystem exchange (continuous measurements by eddy covariance), the exchange of methane (periodic enclosure measurements) and the export of dissolved inorganic (DIC) and organic (DOC) carbon (based on continuous discharge and frequent samples of water chemistry). Analysis of the contemporary carbon budget based on two complete years of observations (1998 – 1999 & 1999 – 2000) reveal an annual carbon sink of > 60 g C m^{-2} yr^{-1}. Both years were relatively dry with the summertime water tables < 0.5 m below the surface, hence we hypothesized that the carbon sequestration was a low estimate. Preliminary analyses of the 2000 summer fluxes show a much greater net uptake than the previous two years confirming this hypothesis. The 2000 summer was wetter with a mean water table was approximately 0.3 m below the surface. The three years of observations indicate the contemporary sink for carbon is at least three times larger than the long-term accumulation rate. Changes in the annual rate of

accumulation rate are due to changes in the difference between net primary production and peat decomposition. Year-to-year variations in climate can explain the inter-annual variability in net carbon balance, but can not explain the larger, persistent rate of carbon accumulation. Currently observational, experimental, and modelling studies are being undertaken to test various hypotheses in an attempt to find explanations for this increased sequestration of carbon.

Plant Community Dynamics, Nutrient Cycling, and Multiple Stable Equilibria in Peatlands

John Pastor
Natural Resources Research Institute, University of Minnesota, Duluth, Minnesota, USA

Scott Bridgham
Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana, USA

Bruce Peckham
Department of Biology, University of Minnesota, Duluth, Minnesota, USA

Jake Weltzin
Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Tennessee, USA

Jiquan Chen
School of Forest and Wood Products, Michigan Technological University, Houghton, Michigan, USA

Peatlands store one-third of the world's soil carbon and nitrogen pools and are located almost entirely in northern regions where climatic warming is expected to be greatest in the coming decades. Despite their importance to the world's global carbon and nutrient cycles, the way that carbon and nutrients flow through peatlands is poorly understood. In particular, very little is known about the roles that different species, particularly mosses, play in carbon and nutrient flux and storage. We construct and analyze a model of peatlands, which sheds some light on this problem. The model is a set of six coupled differential equations for moss, vascular plants, their litters, peat, and an inorganic nutrient resource pool. Mosses take up nutrients from precipitation and eventually transfer them to the resource pool through the decay of their litter and the peat. Vascular plants take up nutrients from the resource pool. Mosses and vascular plants also reduce each other's growth through competition for light. Analytical and numerical solutions of the model mimic many dynamical features of peatland development. The model predicts two equilibrium communities, a moss monoculture resembling moss lawns seen in real peatlands, and a community where mosses and vascular plants coexist. The stabilities of these two communities switch depending on the magnitudes of the input/output budget of the peatland and life history traits of the plants, including the turnover rates of their live biomass, the uptake rate of nutrients from the resource pool, and the competitive effect of mosses on vascular plants. Competition between the two species also

determines the sizes of all compartments and equilibrium nutrient fluxes through the ecosystem. Finally, the model also mimics the broad features of successional development of peatlands from fens to bogs and the successional dynamics of mosses and vascular plants within bogs. The dynamics of peatland ecosystems appear to be governed by interactions between nutrient input/output budgets and the life history characteristics of their constituent species. Central to these dynamics is the unique and sometimes dominant role of mosses in net primary production and in delaying the transfer of incoming nutrients into the rest of the ecosystem.

Concurrent Session 1
Monday, June 18, 2001   2:45 P.M.
Classroom A

Coastal Systems

Moderator: *P.V. Sundareshwar*
Duke University Wetland Center

Source Water Variability within Mangrove-dominated Ecosystems of Micronesia

Judy Z. Drexler
USDA Forest Service, Honolulu, Hawaii, USA

Eric De Carlo
SOEST, University of Hawaii, Honolulu, Hawaii, USA

Mangroves may receive a variety of freshwater inflows depending on their climate regime and hydrogeomorphic setting. Little is known about source water contributions to such flow, even though freshwater has been strongly linked to productivity of mangroves. In this study, we used geochemical tracers to estimate the relative proportion of source waters within two Micronesian mangroves ecosystems. We sampled drinking water wells, a spring, rain, a river, seawater, and groundwater within piezometers in an interior mangrove system on the island of Kosrae. In an estuary on the island of Pohnpei, we sampled a drinking water well, a spring, rain, a stream, and seawater. At both sites, either seawater or rain-derived flow dominated groundwater flow. Groundwater inputs averaged 20% (sd=11.02) at the site on Kosrae and 5% (sd=5.45) at the estuary on Pohnpei. The level of hydrological connectivity between mangroves and adjacent upstream or downstream ecosystems varied daily with the tide and rainfall. Long-term patterns of such variability may be characteristic of geomorphic setting.

The Impact of Metalliferous Mining on Saltmarsh Flora

Christian Smillie and Loveday E.T. Jenkin
Camborne School of Mines, University of Exeter, Redruth, Cornwall, United Kingdom

Estuaries within Cornwall, UK have been accepting metal-rich tailings and water from mining for hundreds of years. Over time, saltmarsh ecosystems have developed on metal-rich sediments. Previous work at CSM has indicated that the floristic composition of these saltmarshes varies from characteristic British assemblages. Our hypothesis is metal-sensitive species are unable to colonise, leading to an abundance of metal-tolerant species. Some saltmarsh species have the ability to accumulate metals without harm. Such plants may be able to indicate availability at metal-rich sites.

This research has classified the floristic communities of a number of saltmarshes in Cornwall. The zones within each marsh have been compared to various environmental factors. The influence of these is currently being assessed but nutrient status, pH and trace metals do not appear to be the prime reasons for community differences.

Metal concentrations within the roots and shoots of *Salicornia*, taken from one of the most metal-contaminated estuaries in Europe, have been measured over the past year and compared with sediment concentrations to assess seasonal differences in uptake and the relationship to levels in the sediment.

Results so far indicate that metal-rich saltmarshes may contain distinct assemblages of plants which are adapted to the special conditions. These unique ecosystems need more detailed study to assess their role in containing metals within the environment and conserving distinct ecotypes.

Coastal Salt Barren as Indicator to Recent Sea Level Change and Wetland Carbon Dynamics

Yuch Ping Hsieh
Wetland Ecology Program, Florida A&M University, Tallahassee, Florida, USA

Coastal salt barrens are narrow, distinctive, non-vegetative belts found in the midst of, otherwise, lush coastal marshes. The striking feature of a salt barren is almost inescapable by any observer yet the cause of its formation remains unexplained. I investigated the salt barrens in the coastal marshes of north Florida, USA. The results indicate that salt barrens were formed by a hypersaline condition developed slightly above the mean high water (MHW) level and its formation is controlled by the tidal level, water salinity and climate conditions. The location of a salt barren is dictated by the mean sea level (MSL). That is, as the MSL rises, falls or stays stationary the location of the salt barren moves landward, seaward or stationary accordingly. The sediment profile property of a salt barren records the recent history of sea level changes and the dynamics of soil organic matter formation. Salt barrens are also clear indicators to the boundary of coastal marsh zones in the interpretation of coastal aerial photographs and satellite images.

Effects of Parasitic Plants on Sediment Biogeochemistry in California Salt Marshes

Brenda J. Grewell
University of California, Davis, Davis, California, USA

Parasitic plants occupy discrete intertidal zones within Pacific Coast salt marshes, and can be locally abundant. Studies suggest parasitic plants may enhance community diversity and alter ecotones, but the modification of sediment biogeochemical conditions within habitats by parasites has not been considered. Parasitic plant – host interactions may play a functional role in habitat amelioration due to physiological mechanisms for salinity tolerance and resource acquisition. My objective was to examine the effects of root hemiparasites (*Cordylanthus mollis* ssp. *mollis*, *Cordylanthus maritimus* ssp. *palustris*, Scrophulariaceae)and the holoparasite (*Cuscuta salina*, Cuscutaceae) on soil salinity, aeration, and mineral nutrients. Experimental bare patches, artificially shaded bare patches, and parasite removal patches across intertidal zones were compared to controls with parasites. Plant composition, soil salinity, redox potential, pore water cations, and soil nutrient concentrations were measured as response variables. The results suggest parasitic plants ameliorate salinity and anoxic conditions within their habitat, and the parasite-host association provides a sink for soil mineral nutrients. Greater understanding of biological interactions coupled with abiotic factors may improve our ability to restore salt marshes.

Sea Level Rise and Carbon Sequestration in Coastal Wetlands

Yang Wang and Yonghoon Choi
Department of Geological Sciences, Florida State University and NHMFL, Tallahassee, Florida, USA

Yuch-Ping Hsieh
Wetland Research Program, Florida A&M University, Tallahassee, Florida, USA

Peng Gong
Department of ESPM, University of California, Berkeley, California, USA

Larry Robinson
Environmental Sciences Institute, Florida A&M University, Tallahassee, Florida, USA

Carbon isotopic analyses of plants and soil organic matter in a coastal wetland in north Florida indicate that significant ecological changes occurred in the past 100 years or so due to sea level rise. Because of sea level rise, forest in the area retreated and gave way to salt-tolerant *Spartina patens* (the dominant species in the transitional zone between high marsh and the upland forest), which was then replaced by *Juncus roemerianus* - the dominant species in the marsh, as salinity increased further. Analysis of archived aerial photographs of the area also shows that the upper boundary of this wetland migrated inland by 3 – 8 meters during the period of 1951-1997. The combined evidence indicates that this wetland has expanded significantly inland over the last century. This change seems to be continuous perhaps to the present day. Soil carbon inventory data suggest that the conversion of forest to high marsh and high marsh to low marsh, due to sea level rise, increases carbon sequestration in soils. The ecological changes observed in our study area could be occurring along other coasts, and these changes could have important consequences for the global carbon cycle and various functions of coastal wetlands.

Diatom Indicators of Salinity in Florida Bay, USA.

Jacqueline Huvane
Duke University Wetland Center, Durham, North Carolina, USA

Preliminary investigations of the diatom flora from 17 monitoring sites in Florida Bay reveal that several taxa can be used as indicators of salinity levels. The relationship between diatom assemblages from surface sediment samples and average salinity at each site was explored.

Surface sediment diatom assemblages from the most saline sites were fairly similar. The less saline sites were more distinct in terms of their diatom assemblages. This is probably due to greater fluctuations in salinity at these sites, and the influx of diatoms from nearby creeks. Several taxa were associated with low salinity. These included *Nitzschia granulata* and *Cocconeis disculoides*. Taxa indicative of higher salinity included *Syndera* sp. A and *Grammatophora* cf. *oceanica* var. *macilenta*. This information can be applied to paleoecological diatom studies of Florida Bay in order to reconstruct past salinity.

Concurrent Session 2

Monday, June 18, 2001   2:45 P.M.

Classroom B

Plant Communities

Moderator: *Graeme Lockaby*

School of Forestry and Wildlife Sciences, Auburn University

Growth and Physiological Responses of *Typha domingensis* and *Cladium jamaicense* to Low Phosphorus and Oxygen Availability.

Bent Lorenzen and Hans Brix
University of Aarhus, Denmark

One of the major changes to the emergent macrophyte communities in the northern Everglades has been the increased dominance of *Typha*, at the expense of *Cladium*. The intrusion of *Typha* has been linked to increased phosphorus loading and changes in hydrology. However, *Cladium* and *Typha* co-exist in the undisturbed oligotrophic Everglades, and both species are able to complete their lifecycles in an extreme low phosphorus environment. A series of controlled experiments have demonstrated differential abilities of the two species to adjust growth, resource allocation, and nutrient uptake kinetic to low phosphorus and root oxygen availability. The species used different strategies to compete in a low P environment. *Cladium* had a high P utilization efficiency due to slow growth rate, low nutrient requirements, a high retention of acquired resources and a balanced allocation of resources between the different tissue types. At P deprived conditions, *Typha* allocate most acquired resources to search roots and vegetative propagation to increase both the volume the plants can search for nutrient and the P acquisition efficiency, a less efficient strategy in an extreme low phosphorus environment.

Spatial Dependency of Vegetation-environment Relationships in an Anthropogenically Influenced Wetland Landscape

Ryan S. King, Curtis J. Richardson, and Dean L. Urban
Duke University, Durham, North Carolina, USA

Spatial patterns of Everglades vegetation have been affected by an array of anthropogenic influences. Although restoration of natural vegetation patterns is dependent on our understanding of species-environment relationships, few studies have examined the relative importance of environmental variables other than phosphorus (P) inputs from canals, or the importance of spatial factors such as scale and autocorrelation in describing these relationships. Using a spatially explicit, multivariate approach, we estimated the relative contribution of spatial and environmental variables in structuring vegetation composition along a 10-km eutrophication gradient in the Everglades. Clusters of plots were stratified among three distinct zones of impact (impacted, transition, and unimpacted), a feature which allowed us to contrast diversity, composition, and spatial pattern as a function of human influence at multiple scales. We found that trends in species diversity were scale-dependent—at fine and coarse scales, the impacted zone was most diverse despite dominance of *Typha* (cattail), but the intermediately productive transition zone had the most species at a landscape scale. Partial Mantel tests showed that landscape-scale variables, soil P and frequency of severe drought, and fine-scale variables, soil N and K, were significant predictors of vegetation composition after accounting for spatial autocorrelation and variance explained by all other variables. However, the pure-partial effect of distance from canal accounted for more variation than any other variable, followed closely by a purely spatial component that was highly suggestive of dispersal or other contagious determinants. Contrasting vegetation pattern at fine scales, the unimpacted landscape was a heterogeneous mosaic characterized by stands of *Cladium* interlaced with slough communities. This pattern gradually converged toward homogeneity with increased anthropogenic influence, as invasive vegetation dampened pattern locally. However, moving across scales, the unimpacted mosaic converged upon homogeneity at a coarse scale, as fine-scale pattern was hierarchically nested. In the presence of greater human impact, coarse pattern diverged from unimpacted and was highly heterogeneous. Our results have implications for Everglades and other wetland restoration efforts, and show that alterations to hydrology and trophic status have perturbed the natural coupling between pattern and process by changing trajectories of vegetation composition across multiple scales.

Effects of Hydrology and Phosphorus Enrichment on Regrowth of Sawgrass (*Cladium jamaicense*) and Cattail (*Typha domingensis*) after Leaf Removal

ShiLi Miao
South Florida Water Management District, West Palm Beach, Florida, USA

Hydrologic fluctuations and natural disturbances such as fire and herbivory are major forces that shaped the dominance and spatial distribution of vegetation in the historical Everglades. Recent phosphorus (P) enrichment and altered hydrological regimes have fundamentally modified the process of vegetation recovery after natural disturbances. Several experiments were conducted using sawgrass (*Cladium jamaicense*) and cattail (*Typha domingensis*) to examine the effects of hydrology, P enrichment, and their interaction on plant regrowth after leaf removal. Both species studied are large clonal freshwater wetland plants, but adapted to different nutrient environments. The research focused on the speed of plant recovery, the critical water depth affecting regrowth, and the importance of timing and length of flooding after leaf removal. The following hypotheses were tested: 1) P enrichment would enhance plant regrowth of both species, but cattail should have a quicker and greater response. 2) Sawgrass regrowth would require a shallower water depth than cattail. 3) Timing of flooding after leaf removal was critical and would alter the optimum water depth of both species. 4) Following leaf removal cattail would survive flooding conditions longer than sawgrass. Results from these studies will provide information valuable in the development of water management strategies to control cattail expansion, restore sawgrass vegetation, and maintain the spatial distribution of native vegetation in the Everglades.

Plant Species Richness and Phosphorus Heterogeneity: An Experimental Approach

Carmen Chapin and Barbara Bedford
Cornell University, Ithaca New York, USA

Recent studies have shown that phosphorus (P) may control plant community structure in some rich fens. Because these wetlands receive high inputs of ground water rich in dissolved cations, P tends to be sequestered in relatively insoluble geochemical pools. As P often limits productivity in these rich fens, many plant species may have developed mechanisms for obtaining mineral-bound P. Correlation between calcium-bound P and species richness indicated that the species richness of these high cation fens is controlled by the degree of geochemical buffering. Mechanistically, this geochemical buffering of P maintains resource heterogeneity, which, in turn, may regulate species diversity.

As an experimental test of this hypothesis, we added P to two cation-rich fens in labile, mineral-bound, and organic forms. We measured nutrient changes in soil-nutrient pools and plant tissue, and compared changes in plant community composition. Results indicate that calcicoles within the plant community respond to calcium-bound phosphorus additions by increasing the concentration of P in leaf tissue. Other species responded to different forms of P, suggesting mechanistic responses other than direct uptake of ortho-P can occur.

Plenary Session II
Tuesday, June 19, 2001   8:30 A.M.
Geneen Auditorium

“Natural v. Anthropogenic ‘New’ Nitrogen Inputs to Coastal Systems in the 21st Century: Evolving Sources, Scales and Consequences”

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Natural vs. Anthropogenic "New" Nitrogen Inputs to Coastal Ecosystems in the 21st Century: Evolving Sources, Scales and Consequences.

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Nitrogen (N) is the "currency" of estuarine and coastal plant production. Urban, agricultural and industrial expansion in the coastal zone have greatly increased external or "new" N loading, causing accelerating production (eutrophication), water quality and habitat declines (nuisance algal blooms, toxicity, hypoxia, fish kills). The sources, magnitudes, scales and environmental impacts of anthropogenic "new" N inputs are undergoing dramatic changes. For example, atmospheric deposition of N (AD-N), much of it from fossil fuel combustion and agricultural emissions, has increased 10 fold in the past century and now accounts for 10 to over 40% of total "new" N loading to coastal ecosystems. AD-N may originate within or far outside watersheds, making this a regional and global issue. Compounding this are climatic changes, including a predicted period of elevated hurricane activity, affecting delivery and fate of natural and anthropogenic "new" N. Chemical forms of N discharged to coastal waters are also changing, including increases in reduced N (NH_x) loading from agricultural watersheds and airsheds. Quantitative and qualitative changes in "new" N input may promote major biotic changes, including harmful algal bloom expansion. The large contribution and biogeochemical impacts of diffuse "new" N require attention from local and regional air/watershed nutrient management perspectives.

Special Symposium 2
Tuesday, June 19, 2001   9:30 A.M.
Geneen Auditorium

Biogeochemistry of Estuarine Systems

Moderator: *James T. Morris*
Department of Biological Sciences, University of South Carolina

Phosphorus Dynamics in Coastal Wetlands

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Abiotic and biotic processes within the sediment chemical environment of seven wetlands were examined to understand inter-site differences in phosphorus biogeochemistry and to evaluate the susceptibility of natural processes to changes in surface water quality. The trend of increasing concentration of the pore water Soluble Reactive Phosphorus (SRP) seaward on the urbanized Cooper River Estuary is partly due to decline in the phosphorus sorption capacity of the respective marsh sediments. The phosphorus binding capacity, a function of sediment surface area, cation exchange capacity and mineral composition, is sufficient to explain phosphorus limitation in freshwater wetlands and SRP surplus in salt marshes. Bioassays of phosphorus limitation and biotic production in a pristine oligotrophic estuary (North Inlet) reveal that, in such ecosystems, there is a differential nutrient limitation of important trophic compartments. This work challenges the conventional opinion that salt marshes are limited solely by the availability of nitrogen and shows that though the plant productivity in such marshes is limited by availability of nitrogen, the microbial compartment is clearly limited by the availability of phosphorus. Further, fertilizing this marsh with phosphorus resulted in a reduction in nitrogen fixation rates and potential denitrification rates in this coastal wetland. Overall, findings support the Redfield model and imply that denitrification rates in coastal ecosystems will be more sensitive to N-loading rates where heterotrophic bacteria are limited by phosphorus rather than by nitrogen. This has important ecological implications as interactions between these biotic components and the biogeochemical cycles of phosphorus and nitrogen ultimately control the overall fertility of the marsh. In addition to these natural processes, phosphorus dynamics of an ecosystem is also influenced by human impacts and phosphorus loading in an estuary can occur in many forms. Analysis of marsh sediments using ^{31}P Nuclear Magnetic Resonance Spectrometry reveals heretofore unreported occurrence of pyrophosphate (PPi) in estuaries. PPi has wide industrial applications and correspondingly, its occurrence is related to the degree of anthropogenic impact around a site. This smallest chemical form of polyphosphate is biologically available and hence has the potential to subsidize nutrient demands of the biotic components, as influenced by abiotic reactions. Together, these data suggest that intrinsic sediment characteristics and biotic activity are important

determinants of phosphorus availability in a wetland. However, these processes are influenced by anthropogenic perturbations that not only alter the phosphorus cycling in an estuary but also impact the biogeochemical cycles of other nutrients such as nitrogen and carbon.

Sulfur, Iron and Phosphorus Dynamics in Carbonate Soils of South Florida Wetlands

Randy Chambers
College of William & Mary, Williamsburg, Virginia, USA

Dana Madeux and Toru Endo
Fairfield University, Fairfield, Connecticut, USA

As part of the Florida Coastal Everglades LTER, we are measuring sulfur, iron and phosphorus concentrations in surface sediments along transects from Everglades freshwater marshes, through estuarine mangrove wetlands and into seagrass meadows of hypersaline Florida Bay. Iron sulfides in these wetland soils are dominated by pyrite and range in concentration from 5 to 300 µmoles S per g dry weight of sediment, with higher concentrations typically measured near creekbanks of mangrove wetlands. Concentrations of iron and phosphorus from ashed sediments extracted with 1N HCl are not closely correlated. Phosphorus concentrations range from 1 to 50 µmoles P gdw^{-1} and are lowest in the freshwater Everglades marshes. Iron concentrations range from 15 to 100 µmoles Fe gdw^{-1} and are lowest in seagrass-vegetated sediments where pyrite formation is iron-limited. The estuarine mangroves appear to function as a sediment sink for the sulfur, iron and phosphorus delivered to these fringing wetland environments from disparate sources along the salinity gradient.

Denitrification Rates in Tidal Wetlands: Applying a Direct N_2 Flux Technique

Jeffrey Cornwell, Kevin Groszkowski, Erik Haberkern, Jennifer Merrill, Michael Owens, Lora Pride and Todd Kana
University of Maryland CES, Horn Point Laboratory, Cambridge, Maryland, USA

In nitrogen-enriched estuarine ecosystems, the processes of denitrification and nitrogen burial represent the major internal sinks for nitrogen. Nitrogen flux estimates from water/chemical mass balances identify major features of nitrogen cycling, but there remains a strong need to directly measure nitrogen retention. Although soil nitrogen retention is readily measured, the estimation of denitrification has been hindered by microbial and biogeochemical techniques that are hard to apply and, in some cases, have serious flaws. The purpose of this presentation is to show our experiences with a direct N_2 flux technique as it has been applied to a range of wetland environments. We have applied the mass spectrometric analysis of N_2:Ar ratios to sediment-water exchange experiments in 1) mangrove sediments in Florida, 2) tidal freshwater, oligohaline and mesohaline marsh sediments in the Chesapeake Bay and 3) tidal freshwater sediments on the Hudson River. The strengths and limitation of this approach will be discussed, particularly with regard to the influence of edaphic algae and flooding regime.

Patterns of Nutrient Biogeochemistry in Mangrove Wetlands along Florida Coastal Everglades

Robert R. Twilley
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Inventories of carbon (C), nitrogen (N) and phosphorus (P) in the vegetation and soils of mangrove wetlands along the Shark River estuary in the Florida Everglades demonstrate distinct patterns of nutrient sinks and regeneration in response to nutrient resource gradients. Soil C:N ratios ranged from 25 to 23 at four sites that are 1.8 to 18.2 km from mouth of the estuary, while N:P ratios at these sites ranged five-fold from 18 to 90 in response to higher loading of P at the mouth of the estuary. Soil P inventories ranged from 152 to 26 g/m^2 (to depth of 40 cm), while C and N was similar at each site at about 2000 and 1000 g/m^2, respectively. Biomass was 250 Mg/ha at the more fertile site compared to 80 Mg/ha at the site further upstream, and nutrient accumulation in vegetation tracked this range with 25 to 8 gP/m^2 compared 375 to120 gN/m^2 along the fertility gradient. Soils dominated nutrient pools compared to vegetation for all three nutrients, and the relative amounts in each of the two compartments were similar along the entire fertility gradient.

Changes in the size of each nutrient pool were analyzed using estimates of annual vegetation growth and rates of sedimentation. Accumulation rates are similar in both vegetation and sediment pools in the more fertile sites, but annual soil storage is greater at the less fertile sites upstream. Preliminary data suggest that this pattern can be explained based on the relative contribution of belowground production to nutrient accumulation at each site, particularly for C and N. At the more fertile site, inorganic sedimentation explains patterns of higher P accumulation at the mouth of the estuary. Differences in soil nutrient ratios are generally not reflected in the canopy, since species differences are greater than site differences. Nutrient use efficiency (NUE) of P was higher at sites with lower N:P ratios, but NUE of N was similar; and resorption efficiency of both nutrients is > 50%. The accumulation of carbon is linked to plant production, nitrogen to litter immobilization, and phosphorus to sediment deposition. The latter controls plant biomass and the influence of vegetation dynamics on nutrient biogeochemistry. Shift in species composition altered relative nutrient storage in the vegetation; and the amount of nutrient returned to the soil compartment from the canopy. Shifts in N:P ratio of soil influence the effects of vegetation dynamics on nutrient biogeochemistry of these coastal wetland forests.

Effects of Sea Level Anomalies on Biogeochemical Processes in Coastal Wetlands

James T. Morris
University of South Carolina, Columbia, South Carolina, USA

Inter-annual and seasonal variations in mean sea level affect carbon and nutrient cycling and material exchanges between the intertidal zone and open waters. Mean annual sea level varies from year to year along the southeast coast by nearly an order of magnitude greater than the long-term trend, and mean monthly sea level varies seasonally with an average range of 24 cm. These tidal components change the frequency of flooding of intertidal salt marshes, the area of marsh flooded at high tide, and hydraulic gradients. One effect is a change in the salt balance of intertidal sediments. When sea level is anomalously low, salt marsh primary production decreases because of an increase in pore water salinity. The net aboveground production of the salt marsh grass *Spartina alterniflora* varies yearly by a factor of two and correlates negatively with summer pore water salinity. Changes in mean sea level also modify exchanges of nutrients and sediments between the vegetated intertidal zone and open water. The vegetated intertidal areas of North Inlet are long-term sinks for sediment and net sources of nutrients to the tidal creeks. However the magnitude of the source and sink terms depends on relative mean sea level.

Concurrent Session 3
Tuesday, June 19, 2001   9:30 A.M.
Classroom A

Water Quality Modeling and Nutrient Status

Moderator: *Neal Flanagan*
Duke University Wetland Center

Developing Nutrient Criteria for Wetland Systems

Ifeyinwa Davis
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The goal of the US Environmental Protection Agency's (EPA) program on nutrient criteria is to establish numeric nutrient criteria for specific parameters on an ecoregional and waterbody-specific basis that will help reduce overenrichment of the nation's waters. Ultimately, EPA expects States/Tribes to adopt nutrient criteria into State water quality standards. The nutrient criteria program is driven by the President's Clean Water Action Plan (CWAP) and the fact that nutrients are consistently identified as a major cause of use impairment in the nation's waters. As an update to the presentation made at the past biogeochemical meeting, the EPA has published two waterbody-specific technical guidance manuals–for Lakes and Reservoirs and for Rivers and Streams. The manuals for Estuaries and Coastal Marine Waters, as well as for Wetlands, will be completed in the near future. The approach to developing criteria is still consistent with the original plan: to develop default criteria for the fourteen delineated nutrient ecoregions of the United States (Omernik 1998) by waterbody type. The EPA met its goals, as stated in the Nutrient Strategy, by developing and recommending nutrient criteria values for most of the fourteen nutrient ecoregions. A total of seventeen criteria documents (eight for Lakes and Reservoirs, eight for Streams and Rivers, and one for Wetlands) were produced. Each criteria document has a number of subecoregions, based on the Level III Ecoregions of the Continental United States (Omernik, 1987) for which criteria have also been recommended. All told, almost 400 new nutrient criteria, covering 75% of the U.S. have been published. In the coming years, EPA is further committed to developing more criteria for the remaining ecoregions and waterbody types.

There is much progress in the effort to produce wetlands modules that will facilitate sampling of wetland ecosystems and serve as the basis for the wetlands technical guidance manuals. Developing nutrient criteria for wetlands will likely be more complicated when compared to other waterbody types due to the fact that wetlands are more complex systems and a set of standard indicators that represent overall ecosystem health does not exist. Also, extensive data regarding hydrologic, biogeochemical, and vegetative parameters may be required for criteria development. To date, very little data on wetlands-nutrients/biological effects have been amassed. The methodologies for collecting this information are complex and are yet to be developed. Thus, the EPA has an enormous task to publish the guidance manual; but also to support and develop identified sampling modules for effective wetlands monitoring. A set of proposed indicators has been decided upon that provide sufficient information regarding the nutrient loading related to ecosystem health. The EPA is combining its nutrient and biological assessment program resources to produce these method sampling modules which can be consulted independently.

Nutrient Export from a Natural Forested Wetland on the North Carolina Coastal Plain

G. M. Chescheir, D. M. Amatya, R. W. Skaggs, and J. W. Gilliam
North Carolina State University, Raleigh, North Carolina, USA

Exports of nitrogen and phosphorus from a natural forested wetland were quantified in a three-year field study. The research site was located on one of the few remaining, undrained nonriverine, palustrine forested hardwood wetlands on the lower coastal plain of North Carolina. A 137 ha watershed within the 350 ha wetland was selected for intensive field study. Weir and flume structures were installed at the two watershed outlets to quantify the flow of surface water from the site. Automatic samplers were located at the outlets to collect daily water quality samples for NO_3-N, NH_4-N, TKN, ortho-PO_4-P, and TP. Rainfall during the first year of the study was 180 mm below average resulting in very low nutrient exports for that year. For the entire study, the average annual TN export from the site was 2.3 kg/ha and varied between 0.9 and 4.5 kg/ha for different study years. Average annual TP export from the site was 0.12 kg/ha and varied between 0.02 and 0.20 kg/ha. The winter quarter accounted for 50% of TN and 60% of TP annual export, concurrent with 64.6% of annual outflow. Over 80% of the TN and TP exported from the site were in organic forms.

Using Decision Tree Models to Target Wetland Restoration Sites for Watershed-level Water Quality Improvement

Neal E. Flanagan and Curtis J. Richardson
Duke University Wetland Center, Durham, North Carolina, USA

Targeting potential sites for wetland restoration requires an understanding of the relationship between wetlands associated watershed characteristics and non-point water pollution. We have developed graphical decision trees that relate water quality to watershed land-use/land-cover patterns, wetland attributes, and physical properties such as soils, topography, etc. To create statistically valid decisions trees we utilized Classification and Regression Tree (CART) modeling techniques. Our initial CART model was developed using water quality data from 14 watersheds that are part of the United States Geological Surveys National Water Assessment Program. The land-use and land-cover characteristics of the watersheds were assessed using the ArcView© GIS system and publicly available spatial data from the United States Geological Survey, the USDA Natural Resource Conservation Service, and the United States Fish and Wildlife Service. The response variable (ortho-phosphorus concentration) was modeled against 35 potential explanatory watershed variables, of which 7 were selected for their ability to reduce the variance. These included basin-wide area in ditched agriculture, transitional land-use, emergent wetlands, wetland area in buffers along second and third order streams, deciduous forest in stream buffers, and transportation in stream buffers. Critical thresholds were also identified.

Effects of Agriculture and Wetland Restoration on Hydrology, Soils, and Water Quality of a Carolina Bay Complex

Gregory L. Bruland, Matthew F. Hanchey, and Curtis J. Richardson
Duke University Wetland Center, Durham, North Carolina, USA

We compared the hydrology, soils, and water quality of an agricultural (AG), a two-year-old restored wetland (RW), and two reference (REF) wetlands located at the Barra Farms Regional Wetland Mitigation Bank, a Carolina bay complex in North Carolina. Our three main objectives were as follows: 1) to determine if the RW exhibited hydrology comparable to a REF wetland, 2) to characterize and compare the soils of the AG, RW, and REF ecosystems, and 3) to assess the differences in water quality in the outflow from the AG, RW, and REF ecosystems. Water table data indicated that the hydrology of the RW has been successfully re-established as the mean water table in the RW was within 30 cm of the surface for 40% of the growing season in 1998, and 37% in 1999, compared to 37% and 40% for the BAY over the same period. In terms of soil properties, bulk density (D_b), total phosphorus (P_t) exchangeable cations (Ca_{ex}, Mg_{ex}) and pH were significantly elevated in the AG and RW in comparison to the REF. The only significant difference between the AG and RW soils was that the AG had significantly higher water extractable phosphate (PO_{4w}) in the upper 0-40 cm. Water quality monitoring revealed that outflow concentrations of soluble reactive phosphorus (SRP), total phosphorus (TP), nitrate+nitrite (NOX), and total nitrogen (TN) were 27, 30, 97, and 19 % lower respectively, in the outflow of the RW as compared to the AG. The REF had the highest outflow concentrations of TN, but lowest TP and SRP. This study revealed that while restoration of wetland hydrology has been highly successful over a short period, the alteration of wetland soil properties by agricultural land-use was so intense that it may take many years for the effects of restoration to be observed on D_b, P_t, Ca_{ex}, Mg_{ex}, and pH. Although major changes in soil properties following restoration were not evident, restoration has provided water quality benefits at Barra Farms.

Modeling of Biogeochemical Processes in Subsurface Flow Constructed Wetlands

Guenter Langergraber and Raimund Haberl
IWGA-SIG, University of Agricultural Sciences, Vienna, Austria

Although there is a lot of experience of constructing and operating constructed wetlands for wastewater treatment their design is still based mostly on 'rules of thumb', providing a specific area requirement per person.

For a better understanding of the processes within the black box 'constructed wetland' and to optimize their design a simulation model for subsurface flow constructed wetlands was developed. The multi-component reactive transport model CW2D (**C**onstructed **W**etlands **2 D**imensional) is able to model the transformation and elimination processes of the main constituents of wastewater (organic matter, nitrogen, and phosphorus) in subsurface flow constructed wetlands. CW2D is implemented into the simulation tool HYDRUS-2D.

Simulation results are presented for three constructed wetlands, two indoor pilot-scale constructed wetlands for wastewater and surface water treatment respectively, and a full-scale two-stage constructed wetland for wastewater treatment.

In general the simulation results show a good match to the measured data when the hydraulic behavior of the constructed wetland under consideration can be modeled successfully. The multi-component reactive transport model CW2D shows to be a promising tool for a better understanding of the transformation processes inside the black box “constructed wetland”.

Concurrent Session 4
Tuesday, June 19, 2001 9:30 A.M.
Classroom B

Nitrogen Dynamics and Cycling, Part I

Moderator: *R. Kelman Wieder*
Department of Biology, Villanova University

Delta ^{15}N as an Indicator of N_2-fixation by Cyanobacterial Mats

Eliska Rejmánková
Department of Environmental Science and Policy, University of California, Davis, California, USA

Jaroslava Komárková
Department of Hydrobiology, University of South Bohemia, Ceske Budejovice, Czech Republic

Cyanobacterial mats (CBM) are important components of wetlands in limestone-based regions of the Caribbean. They contribute to the primary production of these ecosystems, are crucial in marl formation, and some mats fix di-nitrogen. Nitrogen fixation by CBM ranges from < 5 to 20 nmol C_2H_4 cm^{-2} h^{-1}. Differences are best explained by the proportion of heterocyst-forming cyanobacteria showing a linear increase of nitrogenase activity with increasing amounts of Stigonematales. N_2-fixation is accompanied by relatively little isotopic fractionation and as a result, nitrogen-fixing cyanobacteria have delta ^{15}N signature close to 0 ppt. Our main question was: Can delta ^{15}N serve as a reliable indicator of N_2-fixation by CBM? During three sampling periods we measured N_2-fixation at 12 – 16 different locations parallel with measurements of relevant environmental characteristics. Samples of CBM were evaluated for proportions of five groups: (1) *Leptolyngbya*, (2) *Phormidium*, (3) *Oscillatoria*, (4) Chroococales, and (5) Stigonematales. Stable isotopes of N were measured by continuous flow isotope ratio mass spectrometry. Path analysis of the dependence of delta ^{15}N on N_2-fixation, NO_3-N, and NH_4-N in water indicated that the effect of N_2-fixation was more important than the effect of nitrogen amount/form in water. The evidence we present suggests that delta ^{15}N can be used as an indicator of the level of N_2-fixation by CBM.

Nitrate Removal and Denitrification in a Stream Riparian Zone

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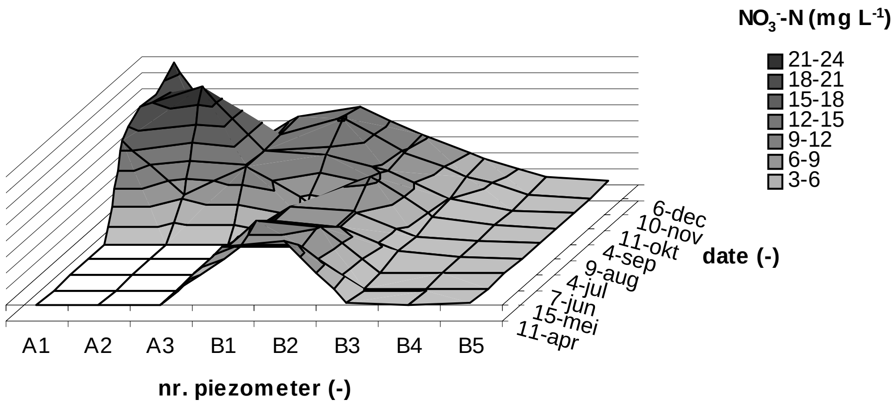
Riparian zones have been proven to be very effective in reducing non-point source pollution (especially NO_3^-) from the groundwater discharges of adjacent uphill croplands. Nitrate removal and the contribution of denitrification activity in nitrate removal was evaluated in a riparian buffer strip in Velzeke-Ruddershove (Belgium).

In this study groundwater samples were collected from piezometers installed on several transects parallel to the slope of the topography of the riparian buffer strip. Monthly shallow groundwater surveys show that practically all NO_3^- was lost in a short distance (< 10 m) from the upper edge of the buffer zone (between piezometer B1-B3 Fig. 1). Measurements of NO_3^-/Cl^- ratios indicate that the decline in NO_3^- concentrations was not caused by dilution effects.

High importance of denitrification in the removal of nitrate could be inferred from favourable environmental conditions in the riparian zone such as high amount of organic carbon, high pH, low redox potentials and a waterlogged soil during most part of the year. In winter time (November-December) lower temperatures causing decreased denitrification rates and higher leaching forced the nitrate plume to infiltrate deeper into the buffer strip (B3-B4 Fig. 1). Denitrification potential in the organic topsoil (0-10 cm) of the riparian zone was 444 µg N kg^{-1} soil d^{-1}. Future *in situ* measurements will provide information on denitrification removals based on $\delta^{15}N$ measurements.

Fig. 1. Monthly NO_3^--N concentrations along a transect of piezometers from the agricultural land (A1-A3) through the riparian buffer zone (B1-B5). White fields indicate that there were no data available.



Regulation of Surface Water Quality in a Chalk Catchment, UK: An Assessment of the Relative Importance of Instream and Wetland Processes

Hannah Prior
The University of Reading, Reading, Berkshire, United Kingdom

To investigate the relative importance of instream nutrient spiralling and wetland transformation processes on surface water quality, total nitrogen (TN) and total phosphorus (TP) concentrations in a 200m reach of the River Lambourn in the south-east of England were monitored over a two-year period. In addition, the soil pore water nutrient dynamics in a riparian ecosystem adjacent to the river were investigated. Analysis of variance indicated that TN, TP and suspended sediment concentrations recorded upstream of the wetland were statistically significantly lower ($p =< 0.05$) than those downstream of the site. Such results suggest that the wetland was performing a nutrient retention function. Indeed, analysis of soil pore waters within the site show that up to 85% of TN and 70% of TP was removed from water flowing through the wetland during baseflow conditions. Thus supporting the theory that the wetland played an important role in the regulation of surface water quality at the site. However, the small variations observed (0.034 mg TN l^{-1} and 0.031 mg P l^{-1}) are consistent with the theory of nutrient spiralling suggesting that both instream and wetland retention processes have a causal effect on surface water quality.

Tidal Simulation Chambers for the Investigation of Nutrient Transformation Processes and Gaseous Emissions in Intertidal Zones.

Martin S.A. Blackwell and Edward Maltby
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University of London, Egham, Surrey, United Kingdom

To date, studies of biogeochemical processes in intertidal zones have focussed mainly on measurement of rates under either flooded or non-flooded conditions, with little attention paid to variations that may arise during transitional periods or as a result of variations in patterns of tidal inundation. Incubation chambers that allow the simulation of tidal flooding on intact soil and sediment cores have been developed, enabling the measurement of various nutrient transformation process rates, including denitrification, nitrification, N- and P-mineralization, metal dynamics and gaseous emissions such as N_2O and CH_4. Natural tidal flooding patterns are simulated automatically using a gravity-based system incorporating an adjustable platform on which floodwater reservoirs are raised and lowered to control flooding. The design of the chambers is presented, along with preliminary results of N-transformation rates measured using the new equipment.

Modeling Organic Nitrogen Uptake by Plant and Microbial Communities in Temperate Wetlands

Virginia L. Jin and Rebecca R. Sharitz
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We developed a model (CNWET) for carbon and nitrogen cycling in temperate wetlands to predict the potential impact of plant and microbial organic nitrogen (N_o) uptake on wetland communities. Annual aboveground primary production, microbial biomass dynamics, and uptake of mineral and organic forms of both carbon and nitrogen were incorporated into CNWET. Initial input values are derived or extrapolated from field studies of temperate wetlands in the southeastern U.S. The percents of daily nitrogen uptake as N_o were calculated from one-year simulations, and relative frequency distributions for N_o uptake were determined for plant and microbial compartments. Within the 10^{th} and 90^{th} percentiles, plants showed a wider range of percent daily N uptake as N_o (0-33%) with a median value of 22.0%. In the same percentile interval, the percent of daily microbial uptake as AA occurred in a much narrower range (3-13%) with a median value of 4.8%. For simulations incorporating N_o uptake, mean residence times for nitrogen and carbon were shorter in both plant and microbial pools compared to simulations excluding N_o. Our model results based on wetland parameterization, therefore, suggest that N_o plays an important role in plant and microbial nutrition as well as ecosystem production and N cycling.

Nutrient Cycling Dynamics after Hydrological Disturbance in Boreal Peatlands

Raija Laiho, Harri Vasander, and Jukka Laine
University of Helsinki, Helsinki, Finland

Tapani Sallantaus
Pirkanmaa Regional Environment Centre, Tampere, Finland

Carbon and nutrient cycling was investigated in undisturbed and disturbed fens in southern Finland. In a pristine state, these fens are characterized by the abundance of sedges, and have a sparse stand of pine (*Pinus sylvestris*) growing on low hummocks. Moss layer consists of a thick carpet of *Sphagnum*. Nutrient cycling is characterized by annual cycling of biomass and nutrients through the ground vegetation. The accumulating peat forms a longterm nutrient sink.

Following drainage, peat-forming plant species rapidly decline. After a stress period of 20-30 years, ground vegetation biomass reaches the original level, but the species composition, and thus litter quality, has changed. The growing tree stand is the main carbon binding body, and litter source, in the drained ecosystem, and forms a considerable nutrient sink. The N and P pools in tree stand biomass increase tenfold in 30 years. Simultaneously, the aboveground litterfall from the stand increases from 40 g m^{-2} to 300 g m^{-2} annually. The N and P pools in litterfall also increase tenfold. The composition of tree stand litterfall changes gradually: the proportions of slowly decomposing fine and coarse woody debris increase, which has an effect on the time scale of carbon and nutrient cycling in the soil.

Special Symposium 3
Tuesday, June 19, 2001 2:30 P.M.
Geneen Auditorium

Biogeochemical Indicators of Change in Wetlands

Moderator: *K. Ramesh Reddy*

Institute of Food and Agricultural Sciences, Soil and Water Science Department, The University of Florida

Biogeochemical Fingerprinting of Wetland Sites as a Basis for Assessment of Nutrient-related Functions

J.T.A. Verhoeven
Dept. Of Geobiology, Utrecht University, Utrecht, The Netherlands

Although most wetland functional assessment techniques give a comprehensive assessment of the most important wetland functions, they clearly have their limitations. They give only qualitative assessments in only a limited range of wetland types (i.e. riverine, lakeshore and estuarine wetlands) for a limited geographical area. In order to enable more quantitative assessments of biogeochemical functions in a larger range of wetland types, an international collaborative project (SERC-NIES-Utrecht University) is building up a data base with large geographic coverage. The project works with measurements of process rates and variables in vegetation and soil during 6-week field period in a full range of wetland types in the USA, W. and E. Europe, Japan and Australia. Some first results indicate that it is possible to predict the order of magnitude (4-5 quantitative categories) of decomposition and denitrification rates from a relatively limited set of indicator parameters. Nitrogen and phosphorus cycling rates are, however, much less predictable in quantitative terms.

Biogeochemical Indicators of Nutrient Responses across the Everglades Landscape

Susan Newman
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K. Ramesh Reddy
Soil and Water Science Department, University of Florida, Gainesville, Florida, USA.

Anthropogenic eutrophication and hydrologic manipulation have caused extensive damage to the Everglades. As a result, billions of dollars are being spent to restore the structure and function of this unique habitat. Recovery is a long-term process and to adaptively manage this system during restoration it is essential to assess progress along the way. While water quality criteria will be established to prevent further P enrichment, only biological parameters can be used to both assess impacts and monitor recovery. Therefore, it is important to develop indicators of biological change that can be used to prevent further degradation during the restoration process, as well as provide a quantitative assessment for adaptive management. Microbial communities mediate the majority of nutrient cycling processes in the soil and water column and are sensitive to environmental change. Measurements of microbial processes may therefore provide an indicator of recovery. We measured numerous candidate microbial processes and indicators along nutrient gradients and in experimental P enrichment studies throughout the Everglades. Preliminary analyses suggest these indicators show regional differences, which is probably a function of the varying levels of anthropogenic impact, as well as site specific characteristics, e.g., vegetation community, soil type.

Direct and Indirect Effects of Vegetation Patterns on Biogeochemical Processes in Emergent Wetlands

William G. Crumpton
Botany Department, Iowa State University, Ames, Iowa, USA

Regardless of the dominant vegetation, horizontal zonation is a common feature of most wetlands and many wetlands display dramatic vegetation shifts in response to changing hydrology. As a result, wetlands can be viewed as shifting temporal and spatial mosaics with respect to structural and functional characteristics, including biogeochemical processes. In addition to serving as a principal source of organic carbon, wetland vegetation can exert significant physical control over biogeochemical transformations. This presentation will discuss the influence of vegetation dynamics on biogeochemical processes in prairie pothole wetlands. These wetlands undergo dramatic, cyclic vegetation changes in response to a variety of environmental factors including water level fluctuations and grazing. Through a combination of direct and indirect effects, vegetation dynamics are likely to control major aspects of carbon and nitrogen transformations in these systems, including the balance between aerobic and anaerobic processes. If we are to understand and interpret biogeochemical process dynamics in these systems, it is important to recognize the temporal and spatial context within which these processes operate.

Indicators of Biogeochemical Functioning – Progress in Development of Procedures for European Wetland Ecosystems

Edward Maltby
Royal Holloway Institute for Environmental Research, Huntersdale, Callow Hill, Virginia Water, Surrey, United Kingdom

Considerable research effort over the last 30 years has been directed towards the understanding of biogeochemical processes in wetlands. Such processes are significant for ecosystem functioning. They also contribute to important goods and services for direct or indirect human use, wildlife and environmental quality. The role of processes such as denitrification, phosphorus adsorption and desorption and decomposition in determination of water quality, carbon emissions and biodiversity is increasingly recognized by decision-makers. However, the spatial patterns and degree of performance of processes vary significantly within and between wetlands. Indicators of processes have been incorporated into innovative techniques of functional assessment which will (a) assist in improved management and protection of wetlands and (b) can be applied by non-experts.

Such procedures have been under development in Europe for the last ten years with support from the European Commission. This paper will trace the research and development of the rationale which underlines the procedures and explains the newest phase of the program embodied in EVALUWET (European Valuation and Assessment Tools Supporting Wetland Ecosystem Legislation).

The presentation will focus on indicators of biogeochemical functioning, how they might be used to assess change in wetlands and the relevance of this approach to the rapidly evolving policy environment.

A Comparison of Physiological Bioindicators of Sublethal Stress in Wetland Plants

Irving A. Mendelssohn*†, Karen L. McKee♦, Tao Kong*, and **James W. Pahl***†
Wetland Biogeochemistry Institute* and Department of Oceanography and Coastal Sciences†, Louisiana State University, Baton Rouge, Louisiana, USA
U.S. Geological Survey, National Wetlands Research Center♦, Lafayette, Louisiana, USA

We evaluated various physiological indices of stress, including photosynthesis, chlorophyll fluorescence, adenylate energy charge ratio (AEC), and leaf spectral reflectance, to increasing concentrations of Cd in the fresh marsh plant *Typha domingensis* and the salt marsh grass *Spartina alterniflora*. The physiological indices were compared to growth response to evaluate their ability to assess plant stress. Leaf elongation rate, live/total biomass ratio, and vegetative regrowth rate of both species were significantly reduced by increasing Cd concentration in the growth medium. Of the measured physiological indices, photosynthesis and AEC responded to Cd treatment before visible damage occurred. These indices were also significantly correlated with leaf expansion rate and live/total biomass ratio. Except at the termination of the experiment, when plant mortality occurred at the highest Cd levels, leaf fluorescence (Fv/Fm ratio) was not significantly affected by the Cd treatment. Leaf spectral reflectance showed no significant response to the Cd treatment. Photosynthesis and AEC were the indices most correlated with plant growth, and thus, they appear to best identify Cd stress in these two wetland plant species.

Analysis of the Composition of Microbial Communities along Nutrient Gradients in Impacted Wetlands

Andrew Ogram
University of Florida, Gainesville, Florida, USA

The compositions and activities of microbial assemblages controlling biogeochemical cycling are likely to depend in part on their position along nutrient gradients in nutrient-impacted wetlands. An understanding of the relationships between community composition, nutrient status, and biogeochemical cycling may yield sensitive indicators of environmental impacts. Bacteria respond to environmental change much more rapidly than do higher organisms such as plants, and characterization of shifts in the composition of bacterial assemblages as a response to changes in nutrient concentrations may provide very sensitive early warning indicators of ecosystem change. These indicators could be useful in identifying ecologically sensitive concentrations of nutrients, and conversely, may be used to determine appropriate restoration endpoints.

We are currently using molecular genetic approaches to characterize components of microbial communities at selected sites along nutrient gradients in wetlands in Florida. Our approach is to analyze the composition of assemblages of bacteria involved in carbon cycling by analyzing specific ribosomal RNA gene (rDNA) sequences, and by using a rapid fingerprinting method, Terminal Restriction Fragment Polymorphism (T-RFLP). Preliminary data suggests that these methods show promise in developing indicators of differences in microbial community composition along nutrient gradients.

Concurrent Session 5
Tuesday, June 19, 2001   2:30 P.M.
Classroom A

Metals and Pollutants

Moderator: *Jan Vymazal*
Ecology and Use of Wetlands, Czech Republic

Wetland Plant and Fertilization Effects on the Sediment Chemistry of Lead-zinc Mine Tailings

Donna Jacob and Marinus Otte
University College Dublin, Republic of Ireland

Underwater storage of mine tailings, the fine-grained, heavy metal-rich waste product of ore processing, utilizes anoxic conditions to immobilize heavy metals through reduction processes. Wetland plants may become established on these sediments, whether through volunteer growth or through planting strategies, perhaps for the intent of phytoremediation. The presence of wetland plants can directly and indirectly influence several major sediment chemistry factors including potentially creating localized aerobic microenvironments via radial oxygen loss (ROL). This ROL could reverse the anaerobic processes responsible for toxicant immobilization, leading to the release of metals through metal-sulfide dissolution. An experiment designed to examine the effects of plants (*Typha latifolia* L.) and initial fertilization treatment (to enhance plant growth) on lead-zinc tailings is underway. The sediment redox potential is measured and the interstitial water is extracted and analyzed for pH, alkalinity and concentrations of iron, zinc, arsenic, and sulfide. Results, currently undergoing analysis, based on the first year of sampling will be presented including metal interactions within the experimental treatments. These results may enhance the understanding of the plant-soil interactions that exist in these specific environmental conditions

Biogeochemical Dynamics of Trace-metals in Wetland Sediments: Simulations and Measurements

Peter R. Jaffe, Jung-Hyun Choi, and Shangping Xu
Princeton University, Princeton, New Jersey, USA

Mobility of trace metals in wetland sediments is controlled by the vertical redox profile that develops in these sediments. The transport and reaction of different electron acceptors in the sediments determine this profile. Our objective is to obtain a mechanistically-based understanding of the dynamics of trace metals in wetland sediments, in order to assess how changes in either water quality or vegetation affect the sequestration or release of trace metals in wetland sediments. For this purpose we have developed a numerical model and are conducting laboratory and field measurements to relate the many processes that affect the redox profile in wetland sediments to the fate of contaminant metals in these sediments. The model consists of a set of mass balance equations, accounting for advection, diffusion, bioturbation and reaction of an organic substrate, electron acceptors, corresponding reduced species, and contaminant metals of interest. Effects of plants such as oxygen release, nitrogen uptake, evapotranspiration are taken into account. Model outputs will be compared to measured concentration profiles. These concentration profiles are being measured, using microelectrode techniques in a red maple riparian wetland, as well as in microcosms constructed in the greenhouses in which red maple seedlings were planted at different densities.

Distribution of Heavy Metals in a Constructed Wetland Receiving Municipal Sewage

Jan Vymazal
Ecology and Use of Wetlands, Prague, Czech Republic

Constructed wetland with sub-surface horizontal flow at Nucice near Prague, Czech Republic, is designed to treat sewage from 650 PE and the total area of the beds planted with *Phalaris arundinacea* and *Phragmites australis* is 3224 m^2 (two beds 62 x 26 m each). Pea gravel (8/16 mm) was used as a filtration material. During the period 1998-1999, distribution of Mn, Fe, Cd, Ni, Zn, Pb, Cu and Al was studied in three vertical profiles (0-15, 15-30 and 30-60 cm) and four points along the longitudinal profile of the bed (5, 16, 32, 48 m from the inlet). In addition, heavy metal content in different parts of *Phalaris arundinacea* was determined. The results showed that the retention of metals is high (up to 96%) with the major decrease in metal concentrations within the first 5 meters of the bed. For none of the studied metals a significant difference between depth profiles was found. The highest concentrations of metals in the sediments were found in the beginning of the bed, however, some metals exhibited only slight difference in concentration along the longitudinal profile of the bed. Concentrations of heavy metals in plant biomass decreased in the order roots/rhizomes >> stems > leaves but statistical difference varied among studied metals.

Wheal Jane: Modelling Bioremediation of Acid Mine Drainage in Constructed Ecosystems

Paul Whitehead and Hannah Prior
The University of Reading, Reading, Berkshire, United Kingdom

Jack Cosby
University of Virginia, Charlottesville, Virginia, USA

Acid mine drainage (AMD) is a widespread environmental problem associated with both working and abandoned mining operations. As part of an overall strategy to determine a long-term treatment option for AMD, a pilot passive treatment plant was constructed in 1994 at Wheal Jane in Cornwall, UK. The plant consists of three separate systems; each containing aerobic reed beds, anaerobic cell and rock filters, and represents the largest European experimental facility of its kind. The systems only differ by the type of pre-treatment utilized to increase the pH of the influent minewater (pH <4): lime-dosed (LD), anoxic limestone drain (ALD) and lime free (LF), which receives no form of pre-treatment. Historical data (1994 –1997) indicate median Fe reduction between 55-92%, sulfate removal in the range of 3-38%, and removal of target metals (cadmium, copper and zinc) below detection limits, depending on pre-treatment and flow rates through the system. This paper presents an update of the performance of the pilot plant since it was re-started in March 2000, in addition, preliminary results of a dynamic model developed to assist in optimization of plant performance and the creation of design criteria for future passive schemes.

Oxygen Constraints on Phenol Oxidase: Implications for Peatland Nutrient Cycling

Chris Freeman, Hojeong Kang and Nick Ostle
University of Wales, Bangor, United Kingdom

The vast accumulation of peat (partially decayed plant remains) within the worlds wetlands attest to an ecosystem with exceptionally low rates of decomposition. The poor decomposition rates are often attributed to the low oxygen availability in waterlogged soils. But while some degradative enzymes, such as the oxidase phenol oxidase, are highly dependent on oxygen, others such as the hydrolase enzymes β-glucosidase, phosphatase and sulphatase, should be far less constrained in this respect. It is perhaps therefore surprising that all four enzymes have been found to exhibit unusually low activities in peatlands. We propose that the low hydrolase activities found in wetland soils may be an indirect consequence of oxygen limitation of phenol oxidase. Without oxygen, phenol oxidase activity is impaired and phenolic materials are likely to accumulate in wetland soils. And since phenolic materials are highly inhibitory to enzymes, the activity of other enzymes are likely to fall as a consequence with serious implications for wetland nutrient cycling. Support for this hypothesis was found in a series of experiments involving the manipulation of phenol oxidase activity, phenolic material concentrations and aeration of peat soil monoliths.

Concurrent Session 6

Tuesday, June 19, 2001   2:30 P.M.

Classroom B

Nitrogen Dynamics and Cycling, Part II

Moderator: *Christopher Craft*

School of Public and Environmental Affairs, Indiana University

Effects of Drawdowns on Water and Soil Chemistry in a Managed Wetland

M.M. Fisher, K. J. Ponzio, L.W. Keenan, and K. Snyder
St. Johns River Water Management District, Palatka, Florida, USA

S.V. Rockwood and J. Albury
Florida Fish and Wildlife Conservation Commission, Fellsmere, Florida, USA

Wetland management practices, such as drawdowns, have the potential to impact downstream ecosystems by mobilizing soil nutrients. To test this effect, a marsh drawdown was conducted in a managed wetland of the Upper St. Johns River Basin, Florida (USA). Experimental conditions consisted of 0-, 75-, and 110-day drawdowns in hydrologically manipulated impoundments.

Water samples taken before and after drawdown showed little difference with respect to water column concentrations of nitrogen and phosphorus. However, after drawdown, TP concentration was significantly greater in the 110-d drawdown (0.193 ± 0.156), as compared to the 75-d drawdown (0.143 ± 0.109) treatment ($p = 0.034$). Water column TKN was significantly higher after the drawdown for all the impoundments, including the control ($p < 0.0001$), increasing from 2.1 to 3.6 mg L^{-1}, on average. The cause for the increase in TKN is unclear and may have been caused by factors unrelated to the experimental treatments imposed. In this system, brief periods of soil exposure did not appear to provide sufficient time to mineralize significant quantities of soil nutrients.

The Role of Wetland Substrate in Maximizing Nitrate Removal from Swine Wastewater

Michael R. Burchell II, R.W. Skaggs, and S. Broome
North Carolina State University, Raleigh, North Carolina, USA

C.R. Lee
USACE –Engineering Research and Development Center, Vicksburg, Mississippi, USA

Wastewater from swine production facilities is primarily treated by land application; a method, which in some cases, may result in excessive nutrient losses, threatening water quality in streams and estuaries. Secondary treatment of runoff from these facilities in surface – flow constructed wetlands (SFCWs) may help decrease nutrient losses. This research focuses on determining the feasibility of using SFCWs at these facilities and methods to optimize their effectiveness. Twenty-one mesocosms consisting of six different substrate blends and one control in triplicate were mixed and planted with a monoculture of *Scirpis validus* in April of 2000 at the NCDA – Tidewater Research Station in Plymouth, NC. The engineered substrates vary by type and percentage of silt (indigenous soil vs. USACE Wilmington District dredged material) and cellulose (straw vs. *Phragmites*), and also contain biosolids. Drainage water collected beneath land application fields will be introduced to the wetlands in early 2001 in a series of batch studies, with various nitrogen loading rates and hydraulic retention times. Nitrogen enters the wetland mesocosms primarily as nitrate, as the ammonium in the lagoon effluent nitrifies soon after land application. Engineered wetland substrates are being evaluated on their ability provide conditions that maximize plant growth and denitrification.

Monitoring of Denitrification in a Constructed Wetland Receiving Agricultural Runoff

Amy C. Poe, Suzanne P. Thompson, Michael F. Piehler, and Hans W. Paerl
The University of North Carolina at Chapel Hill, Institute of Marine Sciences, Morehead City, North Carolina, USA

In 1999, a wetland was constructed on the Open Grounds Farm (OGF) an 18,210 ha row crop farm located in the lower Neuse River watershed in eastern North Carolina. Approximately 800 ha of cropland drains through the 10 ha site. The wetland was constructed to remove nitrogen, sediment and pathogens from surface water draining to the South River. Within the wetland, sixteen wetland cells are planted with one of the following: *Spartina alterniflora*, *Juncus roemarianus*, *Cladium jamaicense*, or an unplanted control in a randomized block design. Wetland cells alternate with shallow (0.5m) ponds of equal dimensions. Nitrogen removal from the wetland via denitrification is being measured monthly by analyzing dissolved N_2, O_2 and Ar in sediment incubation chambers with a Membrane Inlet Mass Spectrometer (MIMS). Data for the first year of growth show no difference between denitrification rates in the planted and unplanted cells. There was a significant positive correlation between denitrification rates and nitrate concentration in the constructed marsh. Nitrate addition experiments and comparisons with adjacent natural marshes demonstrated nitrate concentration in overlying water limited rates of denitrification in the constructed wetland.

Enhancement of Nitrate Removal in Treatment Wetlands Using an Episediment Layer for Denitrification

Maia S. Fleming-Singer and Alexander J. Horne
University of California, Berkeley, California, USA

Microbial denitrification is the principal removal mechanism for nitrogen in treatment wetlands, with overall rates limited by oxygen, temperature, organic carbon, and nitrate availability. In free surface wetlands, denitrification has been observed to follow first order kinetics with respect to nitrate, a phenomenon that most likely results from a nitrate mass transfer limitation between the bulk water and denitrification sites at or near the sediment-water interface. We have conducted a series of wetland microcosm experiments designed to test the effect of spatial geometry in the denitrification zone on nitrate mass transfer. Two treatments are tested, the first involving a sediment-based denitrification zone, where carbon as cattail (*Typha latifolia*) litter is incorporated into the sediments. The second treatment is an episediment scenario where cattail litter forms a layer atop the sediments. Results show that across nine conditions (3x3 matrix of NO_3^- Influent = 7, 37, 66 mg L^{-1} and t_{res} = 2.5, 5.0, 10.0 day; n=320) episediment-based denitrification is 33± 4% greater than sediment-based denitrification. Vertical profiles of nitrate in both the episediment and sediment layers indicate that 43±6% (n=5) of the nitrate removal occurs in the episediments. The desired application of this research is enhancement of denitrification in treatment wetlands.

Decomposition and N Dynamics in Riparian Buffer Zones along a Climatic Gradient

Mariet Hefting and Jos Verhoeven
Utrecht University, The Netherlands

Piotr Bieñkowski
Polish Academy of Sciences, Poland

Jean-Christophe Clement
Université de Rennes I, France

David Dowrick
University of Durham, United Kingdom

Claire Guenat
Ecole Polytechnique Fédérale de Lausanne, Switzerland

Ester Nin
University of Barcelona, Spain

Sorana Topa
University of Bucharest, Romania.

Riparian buffer zones are known to transform nitrogen compounds from shallow through-flowing groundwater and diminish diffuse pollution of surface waters due to agricultural activities. Plant uptake and denitrification are considered to be the most important among the processes responsible for N retention. Apart from storage in the vegetation, immobilization of N in decaying litter can significantly contribute to the retention of N. We investigated the importance and timing of immobilization of N over a one-year period in a wide range of riparian zones along a climate gradient in Europe. Rates were determined in the field using the litter bag method over an elevation gradient in the riparian buffer zone. Decomposition constants ranged from 3.84 yr^{-1} in the Dutch herbaceous zone to 0.19 yr^{-1} in a Spanish forested zone. The N dynamics of leaf material showed clear immobilization peaks during different periods after incubation. Decaying leaf litter can in specific cases contribute to the retention of N in buffer zones in winter, whereas root litter was found to be insignificant in the retention of N during decomposition.

Tuesday, June 19, 2001   5:45-7:00 P.M.
Concourse, The Fuqua School of Business

Poster Session

Poster presenters will be present at their display during this time.

The Hydrology and Biogeochemistry of Depression Wetlands on the North Carolina Piedmont

Craig J. Allan, Susan Marshal, and Randy Forsythe
Department of Geography and Earth Sciences, UNC Charlotte, Charlotte, North Carolina, USA

Andrew Heyes
Estuarine Research Center, The Academy of Natural Sciences, St. Leonard, Maryland, USA

Seasonally flooded depression wetlands are one of the few wetland types found in upland areas of the southeastern Piedmont region. Such wetlands comprise small but locally important wildlife habitat and are increasingly threatened by continued development. Researchers at UNC Charlotte have been continuously monitoring the micrometeorology, hydrology and biogeochemistry of a depression wetland complex in southeast Charlotte, NC since 1996. The Whitehall Wetlands exhibit a perched water table, overlaying the regional water table by several meters. The wetlands typically fill in January when precipitation exceeds evapotranspiration and dry out during late June as evaporative demands increase. Temporal trends in water quality are characterized by high levels of SO_4^{2-} upon initial rewetting, with subsequent declining SO_4^{2-} concentrations as the anion charge component is increasingly dominated by organic acidity. Wetland pool waters and sediments contain significant concentrations of methylmercury whose concentration varies seasonally.

Carbon, Nitrogen, and Phosphorus Cycling in Upland Wetlands

Hannah Crook*[†], Penny Johnes[†], Bridget Emmett*, and Brian Reynolds*
CEH-Bangor, Bangor, Gwynedd, United Kingdom*
University of Reading, Reading, Berkshire, United Kingdom[†]

This project looks at the dynamics of nutrient cycling in an upland wetland, particularly the fluctuations in dissolved carbon, nitrogen, and phosphorus concentrations, both seasonally and during storm events. Phosphorus has been included as there are few projects looking at carbon, nitrogen, and phosphorus.

The fieldsite is situated in Snowdonia National Park, north Wales. Dissolved carbon, nitrogen, and phosphorus fluxes and gaseous fluxes of CH_4, CO_2, and N_2O have been monitored in the wetland, the adjacent stream, and the surrounding moorland, with particular emphasis on variations between vegetation types and with depth. Results show changing C:N ratios over time in the dissolved organic matter (DOM) and similarities in the patterns of variation in soil water DOC and DON concentrations. There is little variation in soil water chemistry with vegetation type or depth, but significant differences in gaseous fluxes between vegetation types. Relationships exist between the water chemistry and gaseous fluxes, notably between soil water NO_3^- and N_2O patterns.

Future work will look at wetland functioning at the catchment scale, concentrating on DOM, process studies looking into sensitivity to climate change, and possible use of the Decomposition-Denitrification model.

Feasibility of Using Red Mud for Marsh Restoration

Robert P. Gambrell
Wetland Biogeochemistry Institute, Louisiana State University, Baton Rouge, Louisiana, USA

Cale LeBlanc
Walsh Environmental, Inc., Baton Rouge, Louisiana, USA

Red Mud is a soil-like byproduct generated when aluminum is extracted from bauxite ore. Large quantities are produced annually, creating costly disposal problems. In Louisiana where about 50 square kilometers of marshes deteriorate to open water annually, there is interest in the feasibility of the productive use of red mud generated in the state to enhance or restore coastal marshes. The physical and chemical properties of red mud present obstacles to the development of healthy marshes. Plants grow poorly, if at all, in unamended red mud, and the elevated levels of several trace and toxic metals in red mud present an environmental risk.

Laboratory and greenhouse studies suggest that amending red mud with other substrates can result in good plant growth with minimal release of metals to water or plants, and lead to the preliminary conclusion that red mud has potential for restoring or enhancing coastal marshes.

Strong carbon turnover rate differences across forest-peatland edges in Southeast Alaska reflect sharp drainage differences and suggest drainage improvements could greatly accelerate soil organic carbon mineralization rates.

Tony Hartshorn, Caroline Bledsoe, and Randy Southard
University of California, Davis, Davis, California, USA

Because peatlands contain vast stores of potentially mineralizable carbon, peatland edges may be especially vulnerable to accelerated C losses if predicted high-latitude warming improves drainage. Transects were established across 6 forest-peatland ecotones on Mitkof Island to ascertain how soil respiration rates varied and whether belowground carbon cycling rates coincided with aboveground vegetative discontinuities. At our most intensively studied site, we recorded average soil respiration rates ranging from 0.19-0.28 g CO_2 m^{-2} h^{-1} at bog interior, bog edge, and forest edge locations over three growing seasons. These rates were significantly lower than the rates at forest interior stations (0.91 g CO_2 m^{-2} h^{-1}) only meters away. At 8 forest edge sites, 7 were described as poorly drained Cryohemists or Cryofibrists and 1 was described as a well-drained Haplocryod. We found no difference in water table elevations between bog interior and edge sites but sharply lower water tables at the forest interior sites. These discontinuities suggest that any further improvements in drainage at edge locations due to enhanced evapotranspiration or facilitated drainage along root systems could result in the mineralization of ~12 kg C m^{-2}, the difference in carbon contents between the forest edge and forest interior locations.

Winner of William H. Patrick, Jr. Outstanding Student Poster Award

Denitrification Potential of Sediments in a Future Freshwater Diversion Site on the Mississippi River

Roy R. Iwai, Ronald D. Delaune, Charles W. Lindau, and Robert P. Gambrell
Wetland Biogeochemistry Institute, Louisiana State University, Baton Rouge, Louisiana, USA

The flux of nitrous oxide and dinitrogen gases from submerged aquatic sediment is a major pathway of nitrogen removal from wetlands receiving excess nitrogen loading from anthropogenic sources. Denitrification potential was determined in surface sediment from Lake Cataouatche, the receiving water body for a future Mississippi River diversion located in the northern portion of the Barataria Basin estuary. The capacity and efficiency of sediment to remove nitrate from external nitrogen loading was measured in the laboratory using static sediment microcosms flooded with lake water. Microcosms were amended with excess nitrate to achieve an initial floodwater concentration of 50 mg NO_3-N/l, and denitrification was determined by the acetylene inhibition and the N-15 isotope technique. Denitrification results estimated by both acetylene inhibition and direct N-15 emission were compared to nitrate reduction rates determined from the rate of nitrate removal from the overlying water. Contributions to gas flux by internal cycling of nitrogen were also quantified with N-15 isotope analysis. Results demonstrated that the system has a large potential for denitrification and nitrate assimilation, and thus should significantly decrease the movement of nitrate into the lower estuary and reduce risks for eutrophication.

Sedimentation in Floodplain Forests of Low Order, Perennial Streams: Impacts to Nutrient Cycling and Primary Productivity

Daniel Johns, Graeme Lockaby, and Jack Feminella
Auburn University, Auburn, Alabama, USA

Pat Mulholland
Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

Degradation of wetlands caused by sedimentation is a problem of global concern. Impacts of sedimentation have been well characterized in aquatic systems, but knowledge of sedimentation in riparian zones is limited. This study focuses on the impact of sedimentation on decomposition, nitrogen mineralization, fine root dynamics, and net primary productivity in floodplain forest of perennial streams. These impacts will be studied in relation to upland disturbance that mobilizes the sediment.

The study location will be Ft. Benning, Ga in the Southeastern coastal plain. Sedimentation rates, short term and long term, will be determined using feldspar clay markers and Cs-137 methods, respectively. Decomposition will be evaluated using leaf litter bags, as will nitrogen mineralization. Fine root dynamics will be monitored using root screens, and depth to anaerobic conditions will be determined using redox electrodes. Net primary productivity will be measured by litterfall collection, and aboveground vegetation inventories. Data collection will cover a 5-year period including a restoration component designed to remedy disturbed ephemeral channels.

Nitrification and Denitrification of Biofilms in Two Different Treatment Wetland Basins (Magle, Sweden)

Sofia Kallner and Karin S. Tonderski
University of Linköping, Linköping, Sweden

Peder Eriksson and Lars Leonardson
University of Lund, Lund, Sweden

Irene Martins and João Neto
University of Coimbra, Coimbra, Portugal

The aim of this study was to evaluate the potential denitrification capacity of biofilms of different substrates and to see if the biofilms were affected by different nitrate concentrations in the water. This was investigated in a constructed surface-flow wastewater treatment wetland located in southern Sweden (Magle) during two seasons (July and November) in 1999. Cores of sediment, pieces of Myriophyllum spicatum (only in July) and pieces of wood were incubated and denitrification rates were measured using the acetylene inhibition technique.

Potential denitrification rates were significantly different for the different biofilms during both seasons. However, there was no variation of the potential denitrification rates between the two seasons. The biofilm attached to sediment had the highest potential denitrification rates and the biofilm of wood had higher potential denitrification rates than the biofilm attached to Myriophyllum plants. There were no differences in the denitrification rates between the water treatments of different nitrogen concentrations. This suggests that the denitrifying microorganisms were not limited by nitrate, but by some other factor, *e.g.*, available organic carbon.

C and N dynamics vary based on soil particle size along a 47-year chronosequence of restored freshwater marshes.

Chev H. Kellogg and Scott D. Bridgham
Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana, USA

The historically high rate of wetland destruction and the subsequent losses in functions such as water quality improvement and wildlife habitat have increased the frequency of wetland restoration in the continental United States. Despite the increased frequency of restoration, little is known about successional changes in soils of restored wetlands. We sampled soils of ten restored freshwater marshes in northern Indiana in the saturated and flooded (25 cm standing water) zones. In the saturated zone of sandier sites, linear regression showed that total N increased 3.4 g m^{-2} yr^{-1} ($p=0.02$) while total C increased 62.6 g m^{-2} yr^{-1} ($p=0.01$). Conversely, nitrate availability decreased 0.07 ug NO_3 g-$resin^{-1}$ day^{-1} each year while NH_4 availability showed no change. In the flooded zone, sandier sites had increases in total N of 1.9 g m^{-2} yr^{-1} ($p=0.08$) while total C and available N showed no change over succession. The sites with more clay had no significant changes in total C, total N, or N availability over succession. These differences are likely due to differences in initial adsorption sites and differences in vertical transport of organic matter during succession.

A Pilot Study of Surface Coal Mine Distribution and Land Use in George's Creek Watershed: Implications for Reclamation as Wetlands and Effects on Stream Health

Madhura V. Kulkarni, William S. Currie, and Molly M. Ramsey
Appalachian Laboratory, University of Maryland Center for Environmental Studies, Frostburg, Maryland, USA

George's Creek watershed in western Maryland has been heavily surface mined for coal since World War II. Mines were left as open pits until the passage of the Surface Mining Control and Reclamation Act in 1977. Replacement of mine spoil, regrading of the land surface, and revegetation have been required since then. Both abandoned mines and reclaimed mines in the watershed have developed systems with wetland characteristics. This study identified the placement of such potential wetlands at old mine sites. Agricultural and urban land uses in the catchment areas of these potential wetlands were also examined. The harmful effects of these two land-uses on stream health could possibly be mitigated by deliberately creating wetlands at those mine sites. As the catchment areas of the wet mine sites were very large (83% of the watershed), they encompassed 79% of the agricultural and 86% of the developed areas in the watershed. With a drainage of this magnitude, any wetlands created at these mine sites could, potentially, filter out a very large portion of the sediments, nutrients and other pollutants from agricultural and urban areas, and also dampen the flashiness of floodwaters and regulate water temperature before the runoff reached the stream. Reclaiming mines as wetlands in George's Creek watershed, therefore, could be very beneficial to the health of the watershed's streams.

Comparison of Tracer Studies from Stormwater Treatment Area 1 West (STA-1W) Test Cells and Mesocosm Tanks

Tammy Lynch and Jana Newman
South Florida Water Management District, West Palm Beach, Florida, USA

Chris Keller
CH2M Hill, Tampa, Florida, USA

The Everglades Forever Act (EFA) requires the South Florida Water Management District (District) to construct a series of large treatment wetlands (ca. 42,000 acres) called Stormwater Treatment Areas (STAs) to reduce nutrient loads in runoff to levels that will have no negative impact on the Everglades flora and fauna. The EFA also requires the District to conduct research to develop an operational strategy that maximizes performance of the STAs and to evaluate the ability of advanced treatment technologies to further reduce the phosphorus outflow prior to release into the Everglades. This research has been conducted at many spatial scales, but this poster will focus on experiments in the STA-1W test cells and mesocosm tanks.

Short-circuiting through a wetland may reduce phosphorus removal efficiency of the system. The most effective means to measure this is by conducting tracer studies. Tracer studies were performed on seven test cells with different substrates: four peat-based cells dominated by cattail; two shellrock-based cells dominated by periphyton; and one peat-based cell dominated by periphyton; and also on three shellrock-based, periphyton-dominated mesocosms. Preliminary results indicate that the combined effects of substrate type, vegetative community structure, and vegetation density significantly affect the hydraulics of these systems. Based on the tanks-in-series model (TIS), the shellrock-based systems operated as constantly stirred tank reactors (CSTR) with an N (number of tanks) between 1 and 2, while the peat-based systems approached plug flow with an N between 3 to 7. Hydraulically, the most efficient steady-state flow reactor is plug flow.

Functional Activity of Iron Oxidizing Bacteria: Implications for Rhizosphere Iron Cycling

Scott C. Neubauer and J. Patrick Megonigal
Smithsonian Environmental Research Center, Edgewater, Maryland, USA

David Emerson
American Type Culture Collection, Manassas, Virginia, USA

Johanna V. Weiss
George Mason University, Department of Biology, Fairfax, Virginia, USA

The rhizosphere is a dynamic environment with respect to oxygen supply, carbon and nutrient gradients, and trace metal speciation. Within the rhizosphere, there is competition between microbial and chemical reactions to utilize oxygen released from roots to oxidize methane, iron (Fe(II)), and other reduced compounds. Iron oxyhydroxide precipitates (Fe plaque), which often coat wetland plant roots, are one product of rhizosphere oxidation. At circumneutral pH, Fe kinetics suggest that abiotic oxidation of Fe(II) is responsible for most Fe plaque formation. Recently, Fe-oxidizing bacteria were isolated from wetland plant roots, suggesting a more significant role for microbial Fe oxidation. Using rhizosphere Fe-oxidizers in laboratory batch cultures that mimic *in situ* pH and concentrations of O_2 and Fe(II), we are testing the effects of O_2 and Fe(II) supply on microbial and chemical Fe oxidation rates. Preliminary results at low oxygen concentrations (<4% of air saturation) show that these microbes increase Fe oxidation rates versus uninnoculated controls. Additional experiments will determine if these increased rates are due to bacteria oxidizing Fe(II) for energy or providing coordination sites that enhance chemical oxidation. These data will help determine the microbial contribution to rhizosphere Fe cycling, a process that influences the biogeochemistry of other elements including carbon, phosphorus and sulfur.

Are either nutrient storage in subsiding wetlands or nutrient release from eroding wetlands relevant to coastal eutrophication?

J.A. Nyman
School of Forestry, Wildlife and Fisheries, Louisiana State University, Baton Rouge, Louisiana, USA

Nutrients buried in wetland soils are generally insignificant in aquatic nutrient budgets. In subsiding areas however, burial initially provides a sink and later a source if soils erode. It is unknown if these paths are large enough to be relevant.

I estimated the potential sink in coastal Louisiana from the nutrient content of soil formed since 1963 and from marsh area. The actual sink is probably smaller because plants can translocate nutrients from deeper soil. In 1930, the potential sink was equivalent to 13% of N and 29% of the P discharged by the Mississippi annually. In 1990, the potential N and P sinks were equivalent to 11% of N and 24% of P discharged by the Mississippi River annually.

I estimated the source caused by wetland loss in coastal Louisiana from soil nutrient content, the area lost, and by assuming 0.35 m of erosion following loss. Marsh loss provides 7,314,708 tons/year of C, 400,757 tons/year of N, and 4,389 tons/year of P. The N is equivalent to 22% of N discharged by the Mississippi River, and is also the reduction needed to reduce hypoxia in the Gulf of Mexico. It is unknown if these nutrients actually contribute to hypoxia.

Construction of Wetlands to Treat Agricultural Runoff from Open Grounds Farm, NC USA

Suzanne P. Thompson, Michael F. Piehler, Amy C. Poe, and Hans W. Paerl
The University of North Carolina at Chapel Hill, Institute of Marine Sciences, Morehead City, North Carolina, USA

Stephen W. Broome
North Carolina State University, Raleigh, North Carolina, USA

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Duke University Nicholas School of the Environment and Earth Sciences, Beaufort, North Carolina, USA

Wetlands were constructed in 1999 to treat agricultural runoff from an area draining ~2000 acres of Open Grounds Farm, North Carolina (OGF). Sequential cells of wetlands and ponds were designed to enhance the quality of the surface water leaving OGF to the South River, a tributary of the Neuse River Estuary. Planting treatments included a variety of native wetland plant species and an unplanted control. Loading of nutrients (nitrogen [N] and phosphorus [P]) is monitored at the inlet and outlet of the constructed wetland. Additionally, nutrient levels, total suspended solids, and levels of fecal coliform bacteria are being measured along the wetland transect. The success of the varied plantings is being compared and the role of the plants in the removal of nutrients is being assessed. Microbial removal of N through denitrification is also quantified. Preliminary data indicate the wetland reduces the levels of both N and P leaving the farm by nearly half. Additionally, the rates of removal of both N and P remained high through heavy spring rains and hurricanes. The constructed wetlands appear to be an effective filter for surface water leaving OGF throughout the range of flow conditions.

Methane Oxidation, Production and Emission at Contrasting Sites in a Boreal Bog

Stephen C. Whalen
University of North Carolina, Chapel Hill, North Carolina, USA

Boreal peatlands, an important atmospheric CH_4 source, show a rapidly fluctuating water table and meter-scale variations in relief. I assessed the influence of local hydrology on CH_4 production, oxidation and emission from boreal peatland sites having temporarily (LB1A) and permanently (LB2) water-saturated subsurface peat. Methane cycling dynamics contrasted sharply between sites. LB1A showed low CH_4 concentrations in pore water (<2 μM) and unsaturated peat (<2.6 nM) and consumed atmospheric CH_4. LB2 had pore water CH_4 concentrations >300 μM and emitted 69 mg CH_4 m^{-2} d^{-1}. Roughly 55% of CH_4 diffusing upward from the saturated zone was oxidized. Methane oxidation potentials (V_{ox}) were maximum in the 10 cm zone immediately above the local water table at both sites, but were higher at LB2 (575 ng CH_4 g_{dw}^{-1} h^{-1}) than at LB1A (225 ng CH_4 g_{dw}^{-1} h^{-1}). Methane production potentials (V_p) were low (<2 ng CH_4 g_{dw}^{-1} h^{-1}) at LB1A, but the maximum (139 ng CH_4 g_{dw}^{-1} h^{-1}) at LB2 was spatially coupled with the maximum V_{ox}. Methanogens exposed to O_2 produced no CH_4 in a subsequent 48 h anoxic incubation, while methanotrophs incubated anoxically oxidized CH_4 vigorously on re-exposure to O_2. Methanotrophs contributed 1.4% of gross ecosystem respiration at these sites.

Plenary Session III
Wednesday, June 20, 2001 8:30 A.M.
Geneen Auditorium

"The Hydrology of Wetlands: Factors Affecting Water Table Fluctuations in Hydric Soils"

R. Wayne Skaggs

William Neal Reynolds and Distinguished University Professor
Department of Biological and Agricultural Engineering
North Carolina State University

The Hydrology of Wetlands: Factors Affecting Water Table Fluctuations in Hydric Soils

R. Wayne Skaggs, G.M. Chescheir, and W.F. Hunt, III
Department of Biological and Agricultural Engineering, North Carolina State University
Raleigh, North Carolina, USA

Water table fluctuations in poorly drained soils are dependent on soil physical properties, site conditions and climatological factors. This paper examines the effect of soil properties and site conditions on water table fluctuations in relatively flat hydric soils that are not influenced by flooding from adjacent streams. DRAINMOD simulations and recorded water table data from a range of poorly drained eastern NC soils were analyzed to determine the effects of soil properties and site conditions on water table depth and fluctuations. Results showed that drainable porosity, which is a function of the more basic soil property, the soil water characteristic (or suction release curve), has a big influence on the rate that the water table falls or rises. The other important factor is the relationship between drainage rate and water table elevation. This relationship is a function of the hydraulic conductivity and depth of soil layers, distance to and depth of natural or man made drains, and other factors controlling vertical and lateral seepage. Depth of depressional surface storage also affects water table response to rainfall, evapotranspiration and drainage. Examples are presented to demonstrate how the interaction of these factors affect water table fluctuations in wetlands and poorly drained uplands. Methods for determining whether or not wetland hydrology exists on a site, based on relatively short monitoring records (a few months) are presented and discussed.

Special Symposium 4
Wednesday, June 20, 2001 9:30 A.M.
Geneen Auditorium

Hydric Soils and Biogeochemical Indicators

Moderator: *Michael J. Vepraskas*
Department of Soil Science, North Carolina State University

Applications of Biogeochemistry to Hydric Soil Identification

M.J. Vepraskas
North Carolina State University, Raleigh, North Carolina, USA

Hydric soils are identified in order to protect jurisdictional wetlands in the U.S. Field techniques used for hydric soil identification, both current and those in development, will be reviewed. Most hydric soils are found using *field indicators,* which are signs that a soil was anaerobic or chemically reduced within the upper 30 cm. The indicators form by chemical reduction of dissolved O_2, Fe oxides, or SO_4. Indicators have not been found for all hydric soils and alternative identification methods for the problem soils are being sought. Magnetic susceptibility measurements have been found useful for identifying hydric soils because magnetic minerals dissolve under anaerobic conditions. Redox potential measurements are being recommended for hydric soil identification, but application has been delayed due to difficulty in identifying diagnostic Eh values. Techniques for assessing C abundance in the field need to be developed for certain soils. Chemical tests using dyes that identify ferrous Fe are useful, and more such dyes need to be identified and tested for field use. Field indicators have been related to wetland hydrology using simulation models, and it has been found that the indicators are developing in soils saturated for longer periods than the minimum required.

Kinetics of Nitrous Oxide and Methane Production in Relation to Soil Redox Potential and Mitigation of Their Emissions from Irrigated Rice Fields

Kewei Yu and William H. Patrick, Jr.
Wetland Biogeochemistry Institute, Louisiana State University, Baton Rouge, Louisiana, USA

Guanxiong Chen
Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, China

Irrigated rice fields are an important source of CH_4 and N_2O, two important greenhouse gases in the atmosphere. In the soil suspensions with rice soils from US and China, CH_4 and N_2O emissions occurred at distinctively different redox conditions. Methane productions exhibited an exponential relationship to soil redox potential, but no significant amounts of CH_4 were produced when the soil redox potentials were above -150 mV. Nitrous oxide tended to accumulate in the redox potential range of +120 to +250 mV. Therefore, both CH_4 and N_2O emissions were low in the redox potential range of +120 to -150 mV. The seasonal variations of CH_4 emissions from a flooded rice field of China were consistent with the development of strongly reducing conditions in the soils. Non-flooding irrigation management reduced CH_4 emissions by about 70-80% in the rice growing season, while organic manure application effectively prevented the potential increase of N_2O emissions. With organic manure application, the rice yields were maintained regardless of different irrigation practices during the rice growing season. Irrigation and organic manure management may be a practical approach for mitigation of CH_4 and N_2O emissions in the irrigated rice fields without adverse effects on rice yield.

The Effects of Additions of Available C and P on Eh and pH in an Everglades Histosol

Paul Benzing and Curtis J. Richardson
Duke University Wetland Center, Durham, North Carolina, USA

The effects of additions of available carbon and phosphorus on Eh and pH in an Everglades Histosol from the Everglades Agricultural Area were investigated. Benchtop soil and water microcosms were fitted with platinum Eh electrodes and combination pH electrodes. These electrodes were connected to a data collection system that allowed for continuous automatic data logging by a personal computer. These microcosms were used to perform four experiments. Experiment one indicated that, over a period of thirty days flooding, the Eh of the system remained above approximately 300 mv. Experiment two demonstrated that incubating flooded soil under methane did not produce a more reduced system than flooding alone. Experiment three demonstrated that addition of glucose as an available carbon source resulted in rapid reduction to approximately -200mv. Experiment four demonstrated that that incubating the flooded soil with added available P did not produce a more reduced system than flooding alone.

Winner of William H. Patrick, Jr. Outstanding Student Presentation Award

Enumeration of Fe-oxidizing and Fe-reducing Bacteria in the Wetland Plant Rhizosphere: Implications for a Rhizosphere Fe Cycle

Johanna V. Weiss and Stephanie Backer
Department of Biology, George Mason University, Fairfax, Virginia, USA

J. Patrick Megonigal
Smithsonian Environmental Research Center, Edgewater, Maryland, USA

David Emerson
American Type Culture Collection, Manassas, Virginia, USA

We recently reported that the presence of Fe-oxidizing bacteria in the Fe-plaque on wetland plant roots. In a survey of 13 wetland and aquatic habitats in the Mid-Atlantic region, we found Fe-oxidizing bacteria present on the roots of 92% of the plant specimens collected (n=37). We also determined that roots have a significantly higher percentage of amorphous Fe than the bulk soil (77.4±3.8% vs.33.8±16.8%; n=5 wetlands), suggesting the roots provide a better substrate for iron-reducing bacteria. In this study, we compared the abundance of culturable Fe-oxidizing and Fe-reducing bacteria on wetland plant roots and in the soil. While the soil had significantly more total bacteria (1.44 x10^9cells/g vs. 8.16x10^7cells/g root; $p<0.05$) and Fe-oxidizing bacteria (3.67 x 10^6/g vs. 5.85x10^5/g root) present, no statistical difference was found between the percentage of soil and root Fe-oxidizers (~1% of the total cell number). The roots had significantly higher abundances of Fe-reducers, accounting for 12% of the total microbial community compared to <1% in the soil. This study shows that Fe-oxidizing bacteria are ubiquitous on plant roots and in bulk soil, and Fe-reducers are dominant members of the root microbial community. This supports the hypothesis of a microbially-mediated Fe cycle in the rhizosphere of wetland plants.

Concurrent Session 7
Wednesday, June 20, 2001   9:30 A.M.
Classroom A

Carbon Dynamics and Cycling

Moderator: *R.G. Qualls*
Department of Environmental and Natural Resource Science, University of Nevada

Controls of Organic Matter Characteristics on the Dynamics of CO_2 and CH_4 in a Northern Peatland

Charlotte L. Roehm and Nigel T. Roulet
McGill University, Montréal, Québec, Canada

Peatlands act as net sinks for carbon. Annual accumulation rates have been estimated at 23 g C/m^2. Empirical data and modeling attempts have, however, ignored the C dynamics of the non-growing season. This research study addresses the temporal and spatial dynamics of CO_2 and CH_4 in a Northern peatland

Results have not only shown the non-growing season to contribute a substantial loss of C from these systems (potentially decreasing the strength of the sink), but also that the rate of net ecosystem exchange (NEE) was 3 fold the figures stated in the research to date.

Preliminary laboratory results show that the region of highest production potential lies in the area immediately adjacent to the water table with lower DOC concentrations and higher labile carbohydrate concentrations. Areas of short-term anaerobic consumption correlate with the production of a variety of fatty acids. Both laboratory and field data indicate that there is no seasonal change in the main CO_2 and CH_4 production contributing depth, but rather, a significant change in the amplitude of this contributing region.

These results may provide a better input to modeling efforts, which attempt to predict the impact of changing climatic conditions on the net C turnover in peatlands.

Centimeter-scale Dynamics of Carbon Mineralization in Peatland Soils after Flooding and Drying Events

Christian Blodau and Tim Moore
McGill University, Montréal, Québec, Canada

Functional relationships between atmosphere-soil trace gas exchange and environmental variables are generally weak. The potential contribution of small-scale heterogeneities and transient conditions in peat soils is investigated. To these ends time series of OM decomposition products were recorded after drying and flooding events across a 77-point sampling grid of a peat profile. The production of CO_2 and CH_4 was highly variable both in space and time, with CO_2 being initially consumed by unidentified processes. Time lags for the production of CH_4 and H_2S are on the order of weeks to months. After onset of production transient hotspot developed that were only partly reproducible. No apparent relationship between production patterns and macroscopic features as plant roots existed on the scale of investigation.

Temporal Variation in the Responses of Peatland Carbon Cycling to Temperature

Nathalie Fenner and Christopher Freeman
University of Wales, Bangor, Gwynedd, Wales

Brian Reynolds
Center for Hydrology and Ecology, Bangor, Gwynedd, Wales

Northern peatlands can act as significant sources or sinks for atmospheric and aquatic carbon. It is therefore important to understand how climate change may effect carbon cycling in such regions. This study examines the seasonal response of pore-water dissolved organic carbon from peat incubated over a thermal range (0-20°C) along with enzyme activities (ß-glucosidase and Phenol oxidase) and CO_2 flux. Evidence for dynamic carbon cycling is presented with peaks in DOC enzyme activity and summer CO_2 production being found at a temperature corresponding to external temperature taken in the field. Trends in DOC concentrations are presented for warmer soil temperatures as a result of climate change and the potential for a dramatic change in carbon quality and yields both to atmosphere and draining aquatic systems is highlighted.

Permafrost Thaw Increases Peat Accumulation: The Role of Mosses and Microbes

Merritt R. Turetsky
Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada

365,000 km^2 of Canada's western interior is covered by peat, representing 21% of Alberta, Saskatchewan, and Manitoba. Permafrost underlies 1/3 of these peatlands, and is restricted solely to ombrotrophic peatlands near its southern limit. In response to recent warming across the boreal forest, permafrost in peatlands has been melting to form open, wet *Sphagnum-Carex* fens (internal lawns).

My research seeks to understand how permafrost thaw influences peat accumulation and decomposition. ^{210}Pb-dating shows that internal lawns accumulated 40% and 70% more peat than bogs (no permafrost) and permafrost mounds, respectively, over the past 150 years. Potential CO_2 production, however, was higher in internal lawn peat (mean ± standard error, 47.5 ± 2.3 μmol CO_2 g dry $wt^{-1} \cdot d^{-1}$) compared to bog and permafrost peat (averaging 36 ± 3.2 μmol CO_2 g dry $wt^{-1} \cdot d^{-1}$, respectively). Decomposition also varies among peatland bryophyte species. *Sphagnum riparium*, common to internal lawns, decomposed quickly during *in situ* incubations, losing 26% of its initial mass across a variety of peatland types. *S. fuscum*, alternatively, lost an average of 7.3% of initial mass. Post-melt succession from wet internal lawns to relatively dry bogs is poorly understood, but will be important in western Canada with future climatic warming and permafrost degradation.

Zymogenic bacteria: Are they predictors of CH_4 production potential in flooded rice fields and natural wetlands?

Aixin Hou, William H. Patrick, Jr., and R.J. Portier
Louisiana State University, Baton Rouge, Louisiana, USA

Rice paddies and natural wetlands are major sources for methane (CH_4) in the atmosphere. Methane production in flooded soils is a microbially mediated chain reaction involving zymogenic bacteria, acetic acid and hydrogen-producers, and methanogens. The metabolism of these different microbial groups completes the degradation of organic carbon from large molecules to the most reduced status (i.e., CH_4). There have been many studies dealing with the population of methanogens in rice soils to establish a link between microbial community structures and function (CH_4 production potential) since methanogenesis is the terminal respiratory process in the anaerobic food chain. The results have shown a relatively constant population size of methanogens for changing environmental conditions and for geographically diverse rice fields soils that definitely hampers the prediction of CH_4 production potential using methanogenic community structures. Zymogenic bacteria function at the first step in the anaerobic decomposition of organic matter and release fermentation products which are the catabolic substrates for methanogens, and thereby should have some relationship with CH_4 production. The dynamics of zymogenic population in rice soils in both laboratory and field conditions are discussed in an effort to answer the question: can zymogenic bacteria be used to predict the potential of CH_4 production in flooded rice fields and natural wetlands?

Profiling of Complex Microbial Communities in a Boreal, Continental, Western Canadian Peatland

John A. Navaratnam and R. Kelman Wieder
Department of Biology, Villanova University, Villanova, Pennsylvania, USA

We examined the microbial diversity of three distinct features (continental bog, permafrost mound, and internal lawn) within a peatland complex in the Canadian discontinuous permafrost zone near Patuanak, Saskatchewan, using total genomic DNA extraction of peat, PCR amplification, plasmid cloning and sequence analysis. Eubacterial and fungal diversity was characterized using measures of evenness and the Shannon-Wiener index, which combines components of diversity, species richness and evenness in the peatland features. Preliminary results (0-5 cm of peat) show that the diversity (H) of eubacterial species was highest in the relatively dry permafrost peat (H = 2.80), and lowest in internal lawn peat (H = 2.08) where the water table is at or near the peat surface. For all these peatland features evenness values are high (E # 0.87). Fungal community diversity and evenness was greatest in continental bog peat (H = 1.84, E = 0.85). Both diversity and evenness were substantially lower for fungi than for eubacteria across all peatland features, reflecting dominance of the fungal communities by a single species. Given the complexity and uncertainty concerning predictions of peatland carbon balance responses to global warming, linking investigations of microbial diversity to microbial function regarding carbon processing is vital.

Decomposition of Cattail Litter under Different Water Regimes

Robin L. Miller and Roger Fujii
United States Geological Survey, Sacramento, California, USA

Subsidence of previously flooded peat soils in the Sacramento-San Joaquin Delta, California, has increased the potential for catastrophic levee failure and flooding since they were drained in the late 19th and early 20th centuries. The dominant process currently contributing to subsidence is rapid aerobic degradation of soil organic matter. The effect of wetland reestablishment on the potential storage of new carbon was assessed by studying the decomposition of cattail litter in different hydrologic environments. Litter bags were deployed at a drained site, a permanent shallow flooded site, and a reverse seasonal flooded site. The mass loss, carbon (C) and nitrogen (N) contents, and nuclear magnetic resonance (NMR) spectra of the litter were compared. Results showed that hydrologic conditions significantly affected in situ decomposition. A period of flooding caused the most rapid early loss of litter; and after 1 year, the drained site had more litter remaining than the other sites. However, mass loss of litter was not indicative of its degree of decomposition. C:N and NMR data suggest that litter from the permanent shallow flooded site was least decomposed, and litter from the reverse seasonal flooded site was most decomposed.

Carbon Source Limitation in a Wetland Treating Acid Rock Drainage

James Harrington
Shepherd Miller, Inc, Fort Collins, Colorado, USA

A multistage wetland system was built in the Rocky Mountains near Lincoln, Montana in 1997. The wetland was designed to treat 40 gpm of acidic drainage from a mine adit that contained iron (80 mg/L), manganese (40 mg/L), zinc (40 mg/L), copper (1.3 mg/L), and cadmium (0.3 mg/L). Zinc removal approached 40 percent in the summer months, but after the first year, zinc removal did not occur in the late fall and winter. Investigation into carbon deposition from the sedges in the wetland revealed that plant carbon deposition in the wetland explained the wetland performance with respect to zinc removal. Addition of stoichiometric quantities of an alcohol-based carbon source to the anaerobic cells to stimulate sulfate reduction restored year-round zinc removal, and increased it to 80 percent in the wintertime and up to 99 percent in summer months. Sulfate reduction continued even when water temperature was $0.5^{o}C$. Zinc sulfide (ZnS) precipitates were observed, which matched the sulfate removal in the anaerobic cells. Carbon source addition also stimulated manganese removal in the oxidative cells that received effluent from the anaerobic cells. The results show the importance of managing carbon availability to maintain metal removal in treatment wetlands.

Concurrent Session 8

Wednesday, June 20, 2001 9:30 A.M.

Classroom B

Phosphorus Cycling and Transformations

Moderator: *Mark Walbridge*

Environmental Science and Public Policy Program, George Mason University

Phosphorus retention in Forested Riparian Wetlands of the Southeastern United States

Mark R. Walbridge, Arlene K. Darke, Rebecca B. Wright, and Dianna M. Hogan
George Mason University, Fairfax, Virginia, USA

Josephine R. Axt
U.S. Army Corps of Engineers, New York, New York, USA

We examined the P, Al, and Fe chemistries of 20 floodplain and riparian forest soils in TX, GA, NC, VA, and MD, to determine how flooding affects soil chemistry and elucidate relationships between soil Al and Fe chemistry and P retention. Flooding was addressed via an *in situ* field experiment (GA), by comparing changes in soil chemistry with changes in water table elevation and microsite hydroperiod (GA), and by comparing the chemistries of wetland and adjacent upland soils at all sites. Our findings suggest: 1) fundamental differences in the cycling of Al and Fe in these wetland ecosystems that have important implications for P retention; 2) that a key component of P retention and transformation in these forested wetlands may involve reactions of inorganic P with organic matter--metal (Al) complexes; 3) that patterns of P retention and transformation within these wetland ecosystems are spatially explicit; and 4) that soil microorganisms play important roles in P retention. The similarities observed among sites differing in both geographic location and stream order suggest that these trends are fairly ubiquitous for forested riparian wetlands in the southeastern U.S.

Phosphorus Cycling and Partitioning in Oligotrophic and Enriched Everglades Wetland Ecosystems

Gregory Noe, Leonard Scinto, Daniel Childers, and Ronald Jones
Florida International University, Miami, Florida, USA

We examined the cycling and partitioning of ^{32}P radiotracer in oligotrophic and enriched Everglades wetland ecosystems. Carrier-free $^{32}PO_4^{3-}$ was added to replicate mesocosms placed in wet prairie habitat in Everglades National Park. Over the18 day incubations in oligotrophic marsh, ^{32}P moved from water to metaphyton and flocculent detrital matter (floc) to soils, whereas ^{32}P cycled from the water to detritus to soil and roots in the enriched marsh. The rank of $T^{32}P$ activity among ecosystem components after 18 days in the oligotrophic marsh was consumers, epiphyton, metaphyton, dead macrophytes, live macrophytes, surface soil, floc, and water, in decreasing order. The rank of ^{32}P affinity in the enriched marsh was similar: consumers had the highest, followed by dead macrophyte detritus, live macrophytes, soil, water, and floc. At the end of the oligotrophic incubations, water stored the most ^{32}P (38%) on an areal basis, followed by metaphyton (27%), floc (10%), the aquatic macrophyte *Utricularia purpurea* (5%), and soil (5%). Other oligotrophic ecosystem components each stored less than 5% of the total radiotracer activity. In contrast, macrophyte detritus held the largest proportion of ^{32}P (46%) in the enriched sites, followed by belowground roots (28%), water (5%), live macrophytes (5%), and consumers (1%).

Enzymatic Hydrolysis of Organic Phosphorus in the Surface Water of the Everglades Stormwater Treatment Areas

H.K. Pant and K.R. Reddy
University of Florida, Wetland Biogeochemistry Laboratory, Soil and Water Science Department, Institute of Food and Agricultural Sciences, Gainesville, Florida, USA

F.E. Dierberg and T.A. DeBusk
DB Environmental Laboratory, Inc. Rockledge, Florida, USA

The study of bioavailability of organic phosphorus (P) in surface water of submerged aquatic vegetation (SAV) dominated polishing cell of Stormwater Treatment Areas (STAs) could provide vital information required for the maximum removal of organic P as well as for the ecological significance of the released water. To determine the potential hydrolysis of organic P in the inflow and outflow waters of the SAV dominated treatment system of the STA-1 West of the Everglades, fractionated inflow and outflow waters were incubated with alkaline phosphatase and phosphodiesterase. Unlike alkaline phosphatase (≤10%), phosphodiesterase hydrolyzed ≥71% of the organic P in unfiltered water from both inflow and outflow suggesting the domination of bioavailable diester P in the water. A complete hydrolysis of organic P in 0.05 μm retentate and permeate, whereas ≤35% of that hydrolysis in 0.4 μm retentate by phosphodiesterase indicate stable P are mainly associated with particulate (>0.4 μm). These results suggest that though the amount of P leaving SAV dominated treatment system (polishing cell) to the Everglades is low (25 $\mu g\ L^{-1}$), its potential bioavailability could be a matter of concern in achieving P reduction to 10 $\mu g\ L^{-1}$.

Predicting Bioavailability of Phosphorus to Cattail and Sawgrass in Everglades Soils

Matthew F. Hanchey and Curtis J. Richardson
Duke University Wetland Center, Nicholas School of the Environment and Earth Sciences,
Duke University, Durham, North Carolina, USA

Bioavailable soil phosphorus can be estimated by a variety of extraction methods. Choice of method is generally made by determining which extractant is most appropriate to the soil being studied. However, different extractants may be appropriate for use with different plant species as well.

Our first objective was to determine which P extraction method best predicted soil total P in Everglades histosols. Our second objective was to determine the extraction method most appropriate for estimating P availability to two plant species important to the Florida Everglades: *Typha domingensis* (cattail) and *Cladium jamaicense* (sawgrass). We grew individuals of each species in a greenhouse in Everglades soil. We used linear regressions to compare the ability of different extractants to predict soil total P and, for each species, plant tissue P. We considered five extractants: water, Bray 2, Mehlich 3, 0.5 M bicarbonate, and 0.5 M acetic acid.

Three extractants were statistically significant predictors of soil total P: acetic acid (R^2= 0.654), Bray 2 (R^2= 0.567), and Mehlich 3 (R^2= 0.483). For cattail, water extractable P was the only significant predictor of plant P (R^2= 0.372). For sawgrass, Mehlich 3 extractable P was the best predictor of plant P (R^2= 0.616); Bray 2 extractable P was also a significant predictor (R^2= 0.395) of sawgrass P.

While several extractants provided useful indices of soil total P, no extractant predicted the amount of P available to both cattail and sawgrass. The effectiveness of a particular extractant at predicting bioavailable P may depend on the nutrient uptake strategy of the plant species under consideration.

Diatom Species Composition as Predictor of Soil Phosphorus Concentrations in the Everglades - A Bayesian Hierarchical Modeling Approach

Song S. Qian
The Cadmus Group, Inc., Durham, North Carolina, USA

Yangdong Pan
Environmental Sciences and Resources, Portland State University, Portland, Oregon, USA

We present a Bayesian hierarchical modeling approach for inferring environmental conditions using species composition data. The approach requires less restriction on how algae species respond to the change of nutrient concentration. In addition to the traditional bell-shaped "normal" response curve, our method extends the response curve to a smooth unimodal function. The method is presented using data from an Everglades wetland, where soil's total phosphorus concentrations were estimated from diatom species composition data.

Key terms: Bayesian hierarchical model, Everglades, diatom, Gibbs sampling, MCMC, multinomial distribution, species composition, wetland

Preliminary Comparison of Water Quality Trends in Stormwater Treatment Areas (STA-1W and STA-6) with the Everglades Protection Area.

Jana Majer Newman, Tammy Lynch, and Susan Newman
South Florida Water Management District, West Palm Beach, Florida, USA

The Everglades is an oligotrophic ecosystem that is being adversely impacted by hydrologic changes and nutrient-rich runoff generated from urban and agricultural sources. Phosphorus (P) has been identified as the nutrient most responsible for adverse changes in periphyton and plant communities within the Everglades Protection Area (EPA). Historically, major vegetative habitats in the Everglades included sawgrass marshes, wet prairies, and deep-water sloughs.

The Everglades Forever Act (EFA) requires the South Florida Water Management District (District) to construct a series of large treatment wetlands (ca. 17,000 ha) called Stormwater Treatment Areas (STAs) to reduce nutrients in runoff to levels that will have cause no imbalance in the Everglades natural flora or fauna. The STAs were designed to achieve long-term flow-weighted total phosphorus (TP) concentration of 50 µg/L at all points of release. The District has been using the EFA default phosphorus threshold criterion of 10 µg/L as a planning target for research. In 1996 the District completed a comprehensive evaluation of promising advanced treatment technologies that should be researched for meeting the planning goal of 10 µg/L.

This abstract presents a preliminary evaluation of water quality trends from two STAs and several research sites within the EPA. In general, the STA-1W and STA-6 have substantially reduced mean inflow TP concentrations (113.2 and 52.9 µg/L, respectively) to a mean of about 24 µg/L. However, total nitrogen (TN) and calcium (Ca) reductions were less than for TP. Mean TN inflow concentrations were reduced from 2.92 mg/L and 1.89 mg/L to 2.02 and 1.51 mg/L in STA-1W and STA-6, respectively. Mean Ca concentrations in STA-1W and STA-6 were slightly reduced from inflow concentrations of 82.3 and 91.0 mg/L to 60.7 and 84.8 mg/L, respectively.

District research indicates that the mean TP concentrations at interior EPA sites were fairly uniform, while TN and Ca concentrations were more variable. Mean TP concentrations ranged between 9 and 11 µg/L, indicating that these sites are relatively unimpacted. The mean TN concentrations found within the EPA ranged from 1.0 to 2.1 mg/L. However, mean Ca concentrations within the EPA were highly variable and ranged from a low of 13.0 mg/L to 68.7 mg/L.

The STAs are surpassing their design outflow P criteria of 50 μg/L. Currently, they are reducing TP concentrations to a mean of about 24 μg/L. However, this level of performance may be the lowest achievable TP outflow concentrations for STAs without additional treatment technology. Additionally, the STAs are not as efficient at reducing concentrations for other parameters in runoff prior to discharge into the EPA.

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