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Wetlands and Global Climate Change

by Leah Stetson

Seas rise and reshape barrier islands, coastal shorelines and estuaries. Wetlands store a significant amount of carbon. In response to global climate change, wetland scientists and decision-makers have posed the questions: How do we manage wetlands with added understanding about climate change and its direct, indirect and long-range effects? Are there ways to mitigate the effects of greenhouse gases in our atmosphere in order to protect wetlands? What are the effects of rising sea levels on coastal wetlands? What other climate change factors will have an impact on wetlands? Who is studying these effects and impacts to wetlands?

Why ask *'why'* the sea is rising? The fact is, the sea level is rising.

Regardless of *why* sea levels are rising—whether it is a factor of *el niño* warming trend, the release of carbon, methane and other "greenhouse" gases into the atmosphere, or part of a natural cycle, it is important to turn the focus toward the *what* and *how* of wetlands management. In a paper by EPA, the authors, James Titus and Michael Barth, point out that, "although preventing a global warming would require a worldwide consensus, responding to its consequences would not. Communities can construct barriers or issue zoning regulations; companies and individuals can build on higher ground; and environmental agencies can take measures to reserve dry lands for eventual use as biologically productive wetlands." (*Sea Level Rise: Overview of Causes and Effects*, by James Titus and Michael Barth, et. al., EPA, 1985). For a direct link to read *Sea Level Rise: Overview of Causes and Effects*, go to: http://www.epa.gov/climatechange/effects/downloads/greenhouse.pdf

In response to observations of Louisiana's coastal wetlands inundated by the Gulf of Mexico, Denise Reed, PhD., Professor of Environmental Studies and the 2006 Aldo Leopold Leadership Fellow at the University of New Orleans, has been conducting research on coastal subsistence in Louisiana. According to a recent report on wetland restoration in Louisiana, *Coast 2050: A New Approach to Restoration of Louisiana Coastal Wetlands,* the rapid rate of land loss is due in part to natural landscape dynamics and in part to massive human alterations to deltaic and wetland hydrology, (Reed & Wilson, 2004); to view this report, go to: http://www.ees.uno.edu/restoration/Reed%20and%20Wilson%202050.pdf To learn more about the work being done at the University of New Orleans on wetland restoration, sea level rise, etc., visit: http://www.ees.uno.edu/restoration/index.htm

What are some of the effects of sea level rise on wetlands?

The top three factors affecting wetlands among the effects of sea level rise are shoreline retreat, salt intrusion and increased flooding. These happen through erosion and increase of salinity in certain areas and lead to drowned vegetation, respectively. In coastal marine wetlands, for example, "intertidal habitat area may be reduced by 20–70% over the next 100 years in ecologically important North American bays, where steep topography and anthropogenic structures (e.g. sea walls) prevent the inland migration of mudflats and sandy beaches," (Galbraith *et al.* 2002).

One recent study in Maine projects a two foot rise in sea level over the next 100 years and presents data that can be used in the preparation and planning for the inundation of beaches, salt marshes, estuaries, lowlands and forested uplands in a selected area within the Rachel Carson National Wildlife Reserve. Two coastal marine geologists, Peter Slovinsky and Stephen Dickson, conducted the study using documented data collected from Portland, Maine tidal gauges from 1912-2002, in addition to projected rise data based on a climate change panel (Intergovernmental Panel on Climate Change, 2001).

The study examines three scenarios—1, 2 and 3 foot rises in sea level and the subsequent effects on the selected portion of the Reserve. A major finding is that substantial loss—50 to 100% of high and low marsh areas, respectively, were projected as a result of a one foot rise in sea level. Slovinsky and Dickson also argue that, "the assumption that marshes would be able to keep up with sea level rise through increased sedimentation rates may not be correct. It is quite possible that increasing open water areas (which increase by 33% under a 2 ft rise in sea level scenario) would substantially alter channel morphology," which would change tidal current patterns and lead to increased erosion of the marsh. (*Impacts of Future Sea Level Rise on the Coastal Floodplain* by Peter A. Slovinsky and Stephen M. Dickson, Maine Planning Office/Maine Geological Survey, p. 6, 2006) The Maine Geological Survey also expects that results from this project could be used as leverage for expanded light detected and ranging (LIDAR) surveys in Maine for wetlands protection and efforts to adapt to higher sea levels induced by climate change. For a direct link to this study, visit: http://www.maine.gov/doc/nrimc/mgs/explore/marine/sea-level/mgs-open-file-06-14.pdf

Maine recently adjusted its Coastal Sand Dune Rule (Chapter 355 of the Natural Resources Protection Act) in response to a growing body of knowledge on sea level rise's effect on coastal wetlands such as beaches and salt marshes. Based on the revised rule, 38 M.R.S.A. § 480-A, "In order to protect valuable coastal sand dune systems, the department will evaluate proposed developments with consideration given to future sea level rise and will impose restrictions on the density and location of development and on the size of structures," (38 M.R.S.A. § 480-A). The revised rule can be found at: http://www.maine.gov/dep/blwq/topic/dunes/CH355_4-20-06_revised_%20w_leg_chgs_on%203_30.pdf

This rulemaking change resulted in part from a collaborative dialogue among the Beaches Stakeholders Group, who produced an article, *Protecting Maine's Beaches for the Future: A Proposal to Create an Integrated Beach Management Program* (2006), which can be found at: http://www.maine.gov/spo/mcp/downloads/beaches%20future/Protecting%20Maines%20Beaches_Feb06.pdf.

Bluff erosion and gravel beach formation at Fletcher Neck in Biddeford. Maine Geological Survey photo by J. T. Kelley.

Peter Slovinsky and Stephen Dickson with Maine Geological Survey are currently working on a more extensive, follow-up study that looks at similar issues for a wider area along the coast up to 1000 meters inland, which includes the majority of the coastal marsh system. For an abstract of *Simulating Sea Level Rise in Maine*, go to: http://www.aswm.org/pdf_lib/simulating_sea_level_rise_in_maine.pdf

From a geologist's point of view, sea level rise has been an on-going issue for over fifty thousand years—long before it became a hot topic for wetlands and other areas of scientific enquiry. Dr. Graham Giese with the Provincetown Center for Coastal Studies in Massachusetts has been studying sedimentary movement, shoreline change and sea level rise on Cape Cod for fifty years. Dr. Giese's findings in his research on passive submergence of coastlines point to a theory that wetlands maintain themselves between the buffer zone and low tide line in response to sea level rise—that wetlands physically move

through active erosion and submergence at their lower boundary and through growth by upland submergence at their upper boundary. “If, however, the rate of sea level rise were to exceed the rate of vertical growth of the marsh surface through deposition, the area of wetlands loss by submergence would greatly exceed the area of wetlands gained through upland submergence,” (pers. comm.) According to Dr. Giese, “a major potential for wetland loss in response to relative sea level rise lies in the many impediments to upland submergence that surround wetlands in the Commonwealth. These impediments include dikes, seawalls, roads and other forms of upland development. Thoughtful buffer zoning would go a long way toward alleviating this potential loss,” (pers. comm.) To read a short report describing the 1987 study on *Potential Impacts of Sea Level Rise in Massachusetts,* go to: http://www.necci.sr.unh.edu/necci-report/giese.pdf. For those interested in his current research, visit: http://coastalstudies.org/what-we-do/land-sea/index.htm

The Coastal and Hydraulics Laboratory with the Army Corps of Engineers has been working to apply the results of basic research, along with extensive field and laboratory data, to the behavior of inlets and channels, beaches and dunes, and estuaries and wetlands. Kevin Knuuti, a research hydraulic engineer at the U.S. Army Coastal and Hydraulics Laboratory, Waterways Experiment Station, in Vicksburg, Mississippi, is currently conducting research on tidal wetlands in coastal and estuarine environments. Knuuti’s work is primarily focused on physical processes in tidal wetlands but he is also looking at improved remote sensing techniques for dealing with wetland data; these remote sensing techniques include airborne laser (“Lidar”) and hyperspectral imaging, a passive, sun-dependent technique. For his work in remote sensing, Knuuti is working “to develop improved methods for creating Lidar bare-earth models (actual ground elevation) in densely vegetated environments,” (pers. comm..) In addition to Lidar-based models, he utilizes hyperspectral imagery to identify individual wetland plant species and to map vegetation zones for large areas. By combining the Lidar and hyperspectral data through a data-fusion approach, the lab hopes to improve upon the results that can be obtained from analyzing only Lidar or hyperspectral data, says Knuuti. To learn more about the collaborative research happening at the Joint Airborne Lidar Bathymetry Technical Center of Expertise, visit: http://shoals.sam.usace.army.mil/

Among Kuuuti’s projects, he is researching the effects of sea-level rise on tidal wetland geomorphology and physical processes. Knuuti is part of the Army Corps of Engineers group working in collaboration with USGS and NOAA to develop guidance on how to include sea-level change in coastal planning, design and management. According to Knuuti, “while the obvious effect of sea-level rise on tidal wetlands is that habitat zones will change due to increased frequency and duration of inundation, the effects of sea-level rise on erosion and deposition patterns within tidal wetlands is not as clear,” (pers. comm..) Knuuti uses detailed computer modeling techniques, along with results from his current research on physical processes and geomorphic relationships, to predict the effect of sea-level rise on tidal wetland morphology.

The Chesapeake Bay has adopted a management strategy called “living shorelines,” which are shoreline management options that provide erosion control benefits and at the same time, enhance the natural shoreline habitat. For more information on Living Shorelines, visit: http://shorelines.dnr.state.md.us/living.asp For a brochure on natural approaches to shore erosion control (2005), go to: ftp://ftp-fc.sc.egov.usda.gov/MD/web_documents/programs/rcd/shore_esrcd.pdf

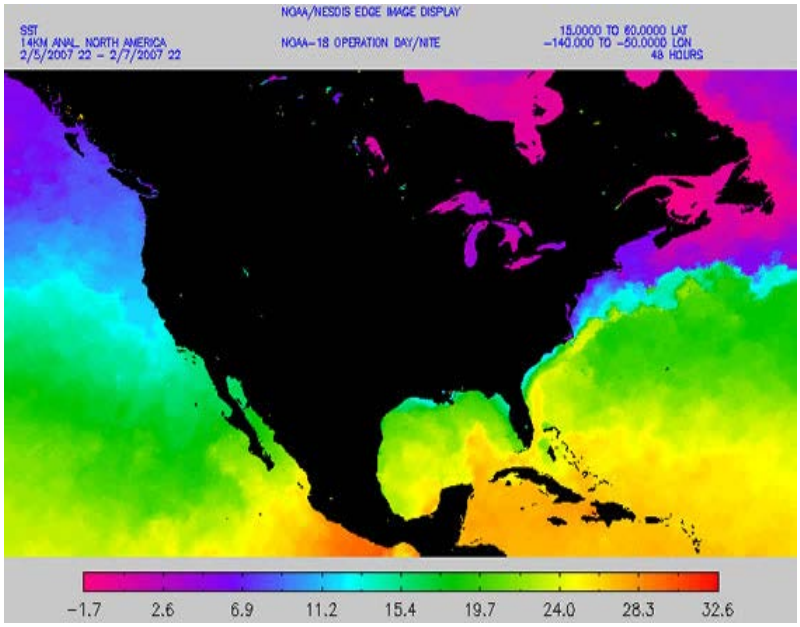
What Climate Change Factors will Affect Wetlands?

Besides sea level rise, several other factors of climate change will affect wetlands. An increase in carbon dioxide (CO_2) will trap heat in the atmosphere causing a rise in air, water and soil temperatures—affecting wetlands, lakes, streams, rivers, estuaries, oceans and ground waters in ways which will challenge even the most adaptive wetland plants and animals, according to a report by Dr. Jon Kusler on Wetland, Climate Change and Carbon Sequestering. Other factors include changes in precipitation, more intense climatological events, such as hurricanes, tornadoes, nor’easters and thunderstorms that affect wetland systems through storm-caused erosion or intense rainfall in historically drier areas. (J. Kusler, 2006)

Furthermore, where biota of wetlands could migrate elsewhere during periods of stress, habitat fragmentation has left no place to go. “Habitat destruction and fragmentation have created ecological islands that species may not be able to escape,” (C. Pyke, 2004) Change in run-off due to climate change has held additional consequences for coastal wetlands, such as marsh browning, or sudden wetland dieback, a phenomenon that scientists have been studying for the past ten years.

ASWM’s Dr. Jon Kusler summarizes the numerous impacts that climate change factors will have on wetlands, which include 1) increased productivity of plants in some areas, 2) changes due to decreased frosts as well as 3) both decreased and increased precipitation, 4) sea level rise and 5) increased carbon storage due to accelerated deposition of carbon rich sediments after storms. To read *Wetland, Climate Change and Carbon Sequestering* by Jon Kusler, go to: http://www.aswm.org/pdf_lib/11_carbon_6_26_06.pdf

In the Midwest, namely the prairie pothole region, where more than half of the nation’s ducks and other waterfowl are born, “the well-established sensitivity of prairie wetlands to current climate variability portends a similarly sensitive response to climate change. Weather extremes and climatic fluctuations drive hydrology, which in turn drives key ecological processes in glaciated prairie wetlands. Additional climate variability of the magnitude suggested by global climate change models would profoundly affect wetland hydrology and many other linked processes,” (*Vulnerability of Northern Prairie Wetlands to Climate Change* by W. Carter Johnson, Bruce V. Millett, Tagir Gilmanov, et. al. 2005) For a direct link to this article, visit: http://www.naturalstatecoalition.org/report.pdf



NOAA map shows sea surface temperature in Celsius, February 2007. http://www.osdpd.noaa.gov/PSB/EPS/SST/sst_anal_fields.html

Robert Gleason, Research Biologist with the USGS at the Northern Prairie Wildlife Research Center, in North Dakota, tells ASWM: “During 2005 and 2006 we monitored gas fluxes (methane, nitrous oxide and carbon dioxide) from 120 wetlands in the prairie pothole region. This population of wetlands included wetlands in restored grassland, wetlands actively being farmed, and wetlands in native prairie. The overall goal is to determine how restoration of wetlands alters gas fluxes relative to fluxes in cropland and native prairie (i.e., baselines). We are currently in the process of analyzing the data and hope to get a draft manuscript out this year.” ASWM will post an abstract of this report once it is available. In the meantime, for those interested in a study by Dr. Ned Euliss, Jr. and Dr. Robert Gleason, *Impact of U.S. Department of Interior and U.S. Department of Agriculture Programs and Ecological Services Derived from Restored Prairie Wetland and Adjacent Grasslands* (2004), which discusses sequestration, go to: ftp://ftp-fc.sc.egov.usda.gov/NHQ/nri/ceap/studyplanweb14dec06.pdf

Prairie pothole region in North Dakota. USGS Northern Prairie Wildlife Research Center photo

A Northern Perspective: Ontario, Canada

Because Canada is closer—geographically—to the North Pole, it has already begun to experience the effects of global warming and to fuse new understanding about climate change with fresh strategies for biodiversity and natural resource management. In Ontario's 2005 Biodiversity Strategy, climate change is a focal point for management considerations. The Ministry of Natural Resources sets forth a list of examples of what Ontario has observed for global warming effects on biodiversity; among these are insect and/or disease outbreak patterns that may change or become more severe, plant species that will change their distribution, resulting in new types of forest. Furthermore, animal species distributions will continue to change; for example, the white-tailed deer and the Virginia opossum now survive hundreds of kilometers north of their historic range. And an increase in the frequency of extreme events such as the ice storm that hit eastern Ontario and Quebec—as well as the Northeastern United States—in 1998, forest fires and droughts may affect habitats, particularly habitats that are localized, i.e. separated from other natural areas which might provide a source for replenishing a species that is extirpated locally. –Ontario Ministry of Natural Resources, Biodiversity Strategy, 2005. For a direct link to Ontario's Biodiversity Strategy 2005 report, go to: http://www.mnr.gov.on.ca/MNR/pubs/biodiversity/OBS_english.pdf

A research project on coastal wetland communities of southwestern James Bay, which focused on plants and soils, elevation changes over thirty years, was undertaken in 2003-2005, according to one of the leads on the project, Dr. Kenneth Abraham, a wetlands scientist with Ontario Ministry of Natural Resources, which is currently working on the analysis and publication. "Preliminary results include major shifts in plant species dominance, some new species with southern affinities, succession along a gradient of elevation as predicted but with notable exceptions to development of communities at the sea edge. The factors impacting change include, in addition to climate change directly, the interactions with isostatic uplift of the James Bay shore, sea level rise and high populations of geese impacting the coastal vegetation," Abraham explains. (pers. comm.) ASWM will post the abstract and link to this when it becomes available.

Carbon Sequestering

Wetlands store significant amounts of carbon—up to 35% of the carbon stored in the U.S. is found in wetlands, more specifically, peatlands (Alaska, Minnesota, Maine, Michigan) prairie potholes, bogs, river and lake wetlands as well as coastal wetlands.

California Governor Arnold Schwarzenegger signed an executive order January 9, 2007 to reduce carbon emissions from transportation fuels, part of a plan intended to broaden the development and use of alternative fuels in the Golden State; other states, including a few in New England, have begun joint efforts in designing similar programs, such as the Greenhouse Gas Initiative in Maine. Country-western musician Willie Nelson developed a biodiesel blend called "Bio-Willie" that significantly reduces carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions. The U.S. Department of Energy has said that switchgrass, a tough, fast-growing, native prairie grass, could be grown for use of creating biofuels to run cars and trucks—thereby reducing America's dependence on oils that emit greenhouse gases such as carbon. In addition to these initiatives, wetland professionals look to carbon sequestering as an option to mitigate the effects of global warming or "greenhouse gases" on the environment and in particular, wetlands.

The PEW Center on Global Climate Change defines sequestration as, "opportunities to remove atmospheric CO_2, either through biological processes (e.g. plants and trees), or geological processes through storage of CO_2 in underground reservoirs."

During a workshop on wetlands and carbon sequestration held at the Oak Hammock Marsh in Winnipeg, sponsored by Ducks Unlimited Canada, Wetlands International and the International Institute for Sustainable Development (1999), some ideas and suggestions for wetland carbon sequestration projects emerged and

culminated in a summary, *Prairie wetlands and carbon sequestration-- Assessing sinks under the Kyoto Protocol*, edited by David Wylynko; the summary discusses the possible inclusion of wetlands as carbon sinks and policy advancements since Kyoto. To view this summary, go to: http://www.iisd.org/wetlands/wrkshp_summ.pdf

Along with research that seeks to identify the effects of climate change on prairie wetlands, scientists Dr. Robert Gleason and Dr. Ned "Chip" Euliss have also sought to analyze the potential for wetlands as carbon stores, or sinks. One of their papers, entitled, *Northern American Prairie Wetlands are Important Nonforested Land-based Carbon Storage Sites,* can be found at: http://www.aswm.org/pdf_lib/north_american_prairie.pdf

Dr. Merritt Turetsky's lab at Michigan State University is currently working on wetland and peatland carbon sequestration, particularly in high latitudes where climate change is occurring rapidly. For a link to this lab's current research projects, go to: http://www.plantbiology.msu.edu/turetsky/research.htm. For another look at recent carbon sequestration research, "The Carbon Balance of North American Wetlands," by scientists Scott Bridgham, Patrick Megonigal, et. al. in the December 2006 issue of *Wetlands,* from the Society of Wetland Scientists, go to: http://www.aswm.org/pdf_lib/carbon_balance_of_north_american_wetlands.pdf

ASWM has prepared several papers on carbon sequestration and has been at the forefront of research on its application in wetlands. Links to these articles are provided below for background and reference.

Research Areas / Priorities

Additional research is needed to better understand complex wetland processes in response to global climate change. Further research is needed to understand the effect of temperature/precipitation, changes on fire frequency, flood frequency, droughts; the response of c3 versus c4 plants to increased CO_2; long range studies that examine carbon and methane sequestration over 100-500 years, as opposed to the currently common 30-50 year range studies. Dr. Jon Kusler has suggested that sequestration data becomes more and more important over a greater time period. It seems, explains Dr. Kusler, that sequestration becomes more important after 100 years and increasingly important after 500 years.

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Useful Links & References

Wetland, Climate Change and Carbon Sequestering
By Jon Kusler, Esq. PhD., Association of State Wetland Managers (2006)
http://www.aswm.org/pdf_lib/11_carbon_6_26_06.pdf

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by W. Carter Johnson, Bruce V. Millett, Tagir Gilmanov, et. al. October 2005 / Vol. 55 No. 10, BioScience
http://www.naturalstatecoalition.org/report.pdf

Climate Change in Wetland Areas Part I: Potential Wetland Impacts and Interactions By Jon Kusler, Esq. PhD., Association of State Wetland Managers, and Virginia Burkett, National Wetlands Research Center, USGS (1999)
http://www.usgcrp.gov/usgcrp/Library/nationalassessment/newsletter/1999.06/wet.html

Climate Change in Wetland Areas Part II: Carbon Cycle Implications
By Jon Kusler, Esq. PhD., Association of State Wetland Managers (1999)
http://www.usgcrp.gov/usgcrp/Library/nationalassessment/newsletter/1999.08/Wet.html

Sea Level Rise: Overview of Causes and Effects
by James Titus and Michael Barth, EPA paper 1985
http://www.epa.gov/climatechange/effects/downloads/greenhouse.pdf

Land Sea Interaction Research at Provincetown Center for Coastal Studies
Includes Dr. Graham Giese's research on shoreline change on Cape Cod
http://coastalstudies.org/what-we-do/land-sea/index.htm

Alaska Center for Climate Assessment and Policy, University of Alaska, Fairbanks
http://www.uaf.edu/accap/

Maine DEP's Regional Greenhouse Gas Initiative
http://www.maine.gov/dep/air/rggi.htm

Maine's Climate Action Plan
http://www.maine.gov/dep/air/greenhouse/index.htm

Great Lakes Coastal Wetland Communities: Vulnerabilities to Climate Change
http://www.fes.uwaterloo.ca/research/aird/wetlands/index_files/page0012.htm

Wetlands of Ontario: Wetlands Conservation Action Plan
http://www.on.ec.gc.ca/wildlife/wetlands/glwcap-e.cfm

7th International Conference on Global Change: Connection to the Artic
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http://www.iarc.uaf.edu/workshops/GCCA-7/index.php

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The impacts of climate change in coastal marine systems
Christopher D. G. Harley, A. Randall Hughes, Kristin M. Hultgren, Benjamin G. Miner, Cascade J. B. Sorte, Carol S. Thornber, Laura F. Rodriguez, Lars Tomanek, Susan L. Williams (2006) Ecology Letters 9 (2), 228–241. http://www.blackwell-synergy.com/doi/full/10.1111/j.1461-0248.2005.00871.x?cookieSet=1

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Big Sky Carbon Sequestration Partnership (has good list of recent publications & reports)
http://www.bigskyco2.org/ Reports list: http://www.bigskyco2.org/publications.htm

Chicago Climate Exchange (GHG emission reduction and trading system)
Projects: http://www.chicagoclimateexchange.com/environment/offsets/index.html
Main site: http://www.chicagoclimateexchange.com/

Department of Energy's Voluntary Reporting Carbon Management Tool (COMET-VR)
http://www.cometvr.colostate.edu/

National Carbon Off-set Coalition (7 Montana nonprofit organizations)
http://www.ncoc.us/index.php

Wetlands and Climate Change (International Institute for Sustainable Development)
http://www.iisd.org/wetlands/default.htm

Conservation Fund Carbon Sequestration Program
http://www.conservationfund.org/?article=3127

Professor Kelman Wieder, PhD, Villanova University, carbon sequestration, northern forested wetlands research
http://www13.homepage.villanova.edu/kelman.wieder/CurriculumVitae2.htm#Publications%20in%20Refereed%20Journals

Virginia Burkett, PhD., USGS research on global climate change and wetlands
http://www.nwrc.usgs.gov/about/directorate/burkett.htm

Duck's Unlimited Carbon Sequestration Program
http://www.ducks.org/Conservation/EcoAssets/1306/CarbonSequestration.html

Professor Nigel Roulet at McGill University, Department of Geography, climate change and carbon sequestration research interests and publications
http://www.geog.mcgill.ca/faculty/roulet/

Professor Scott Bridgham, University of Oregon, Center for Ecology and Evolutionary Biology and Environmental Studies Program *Research Interests:* Carbon and nutrient cycling, wetland ecology, trace gas production, climate change, biogeochemistry, microbial ecology, plant community structure, plant-nutrient interactions, restoration
http://evolution.uoregon.edu/bridgham.htm

Global warming in the South – Southern Environmental Law Center
http://www.southernenvironment.org/cases/global_warming/casepage.htm

Intergovernmental Panel on Climate Change
http://www.grida.no/climate/ipcc_tar/wg1/index

PEW Center for Global Climate Change
http://www.pewclimate.org/companies_leading_the_way_belc/company_profiles/cinergy/cinergy_carbon.cfm

NOAA Sea Surface Temperature Analysis (with maps)
http://www.osdpd.noaa.gov/PSB/EPS/SST/sst_anal_fields.html

Global Warming site with info on wetlands: National Environmental Trust
http://www.net.org/warming/state_briefings.vtml

Union of Concerned Scientists
http://www.ucsusa.org/warming/index

Ocean Tracking Network (research on climate change's effect on marine life and seas)
http://www.oceantrackingnetwork.org/index.html

Global Restoration Network: a Project of the Society for Ecological Restoration
http://grn.ser.org/content.asp?CatId=269&ContentType=Degradation

Willie Nelson's Biodiesel Company and "Bio-Willie" blend
http://www.wnbiodiesel.com/index.html

Preliminary review of adaptation options for climate-sensitive ecosystems and resources -- Environmental Protection Agency (EPA)

Case studies will cover a variety of ecosystem types such as coral reefs, wetlands, rivers and streams, forests, and estuaries. http://www.climatescience.gov/Library/sap/sap4-4/sap4-4prospectus-final.htm#Overview