Annual Report for Period: 11/2005 - 10/2006
Submitted on: 02/25/2007
Principal Investigator: McGlathery, Karen .
Award ID: 0080381
Organization: University of Virginia
Title:
LTER IV: Long-Term Ecological Research on Disturbance, Succession, and Ecosystem State Change at the Virginia Coast Reserve

Project Participants

Senior Personnel

Name: Hayden, Bruce
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Porter, John
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: McGlathery, Karen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Zieman, Joseph
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Blum, Linda
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Shugart, Herman
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Anderson, Iris
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract through VIMS

Name: Moncrief, Nancy
Worked for more than 160 Hours: Yes
Contribution to Project:
support from Virginia Museum of Natural History

Name: Mills, Aaron
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Brinson, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract through East Carolina University

Name: Christian, Robert
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract through East Carolina University

Name: Erwin, R
Worked for more than 160 Hours: Yes
Contribution to Project:
Salary support by USGS/BRD as part of field station at UVA. USGS/BRD employee

Name: Day, Frank
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract to Old Dominion University

Name: Galloway, James
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Macko, Stephen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Young, Donald
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract to Virginia Commonwealth University

Name: Oertel, George
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract to Old Dominion University

Name: Wiberg, Patricia
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Smith, David
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Albertson, John
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Fuentes, Jose
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Smith, David
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: McGlathery, Karen
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Schwarzschild, Arthur
Worked for more than 160 Hours: Yes
Contribution to Project:
Site manager. 2003-

Graduate Student

Name: Tyler, Anna
Worked for more than 160 Hours: Yes
Contribution to Project:
2000-2002 Advisor: McGlathery. Dissertation: Impact of benthic algae on dissolved organic nitrogen in a temperate, coastal lagoon.

Name: Richardson, David
Worked for more than 160 Hours: Yes
Contribution to Project:
2000-2002. Advisor: Shugart.

Name: Knoff, Amanda
Worked for more than 160 Hours: Yes
Contribution to Project:
2000-2004. Advisor: Macko. Dissertation: Bottlenose dolphin (Tursiops truncatus) population structure along the Atlantic coast of the United States : a stable isotope approach.

Name: Wu, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:
VIMS: 2000-2003. Advisor: Anderson. M.S. Thesis: Relationships between watershed characteristics and base flow nutrient discharges to Eastern Shore coastal lagoons, Virginia

Name: May, Mindi
Worked for more than 160 Hours: Yes
Contribution to Project:
Completed M.S. in 2002. Advisor: Brinson. Thesis: Pattern and process of headward erosion in salt marsh tidal creeks

Name: Morrison, Sandra
Worked for more than 160 Hours: Yes
Contribution to Project:
ECU 2001-2002.

Name: Lawson, Sarah
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000- . Advisor: Wiberg. M.S. Thesis 2003: Sediment suspension as a control on light availability in a temperate coastal lagoon.
Continuing work as Ph.D student

Name: White, Jessica
Worked for more than 160 Hours: Yes

Contribution to Project:
VCU 2004-2006. Advisor: Young. Thesis: Interrelatted factors affecting expansion of Phragmites australis in coastal environments of Virginia, USA

Name: Rounds, Rachel
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000-2003. Advisor: Erwin. M.S. Thesis: Nest-site selection and hatching success of four waterbird species in coastal Virginia.

Name: Parker, Frank
Worked for more than 160 Hours: Yes
Contribution to Project:
VIMS 2003-2005. Advisor: Anderson

Name: Dame, James
Worked for more than 160 Hours: Yes
Contribution to Project:
2000-2005. Advisor: Christian. Dissertation: Evaluation of Ecological Network Analysis for Ecosystem-based Management

Name: Keusenkothen, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:
ECU: 2001-2002. Advisor: Brinson. M.S. Thesis: The effects of deer trampling in a salt marsh

Name: Barr, Jordan
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000-2004. Advisor: Fuentes

Name: Rosinski, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000-2002. Advisor: Blum. M.S. Thesis: Controls on benthic biodiversity and trophic interactions in a temperate coastal lagoon

Name: Russell, Kristina
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA: 2000-2002. Advisor: Galloway. Dissertation: Characterization and Deposition of Atmospheric Nitrogen at the Mid-Atlantic U.S. Coast

Name: Chauhan, Meetan
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000-2002 (deceased). Advisor: Mills

Name: Herod, Devon
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000-2003. Advisor: David Smith

Name: Turaski, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA: 2000-2002. Advisor: Wiburg. Thesis: Spatial and temporal controls on saturated overland flow in a regularly flooded salt marsh

Name: Dusterhoff, Scott

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA 2000-2001. Thesis: Controls on Near-Surface Soil Moisture Dynamics within a Tidal Marsh-Forested Upland Costal Environment

Name: Lunsford, Tami

Worked for more than 160 Hours: Yes

Contribution to Project:

VIMS 2000-2002. Advisor: Anderson. Thesis: Comparison of the fate of dissolved organic matter in two coastal systems : Hog Island Bay, VA (USA) and Plum Island Sound, MA (USA)

Name: Holinka, Allison

Worked for more than 160 Hours: No

Contribution to Project:

Worked on mudflat project

Name: Lowit, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA: 2002-2006. Advisor: Blum. Dissertation: Spatial and temporal variation of bacterial community structure and ecosystem properties in two temperate estuaries

Name: Thomas, Cassondra

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA: 2000-2003. Supervised by PI Blum. Dissertation: Salt Marsh Biogeochemistry and Sediment Organic Matter Accumulation

Name: Willis, Patricia

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA: 2002- . Advisor: Blum

Name: Dame, James

Worked for more than 160 Hours: Yes

Contribution to Project:

Supervised by PI Christian

Name: McMillan, Brett

Worked for more than 160 Hours: Yes

Contribution to Project:

ODU: 2002- Advisor: Day

Name: Barnes, Diane

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA 2001-2004. Supervised by PI McGlathery. Thesis: Spatial and temporal variations in dune vegetation, Orthopteran abundance, and herbivory damage on a Virginia barrier island

Name: Thomsen, Mads

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA 2000-2003. Advisor: McGlathery. Dissertation: Macroalgal distribution patterns and ecological performances in a tidal coastal lagoon, with emphasis on the non-indigenous Codium fragile ssp. tomentosoides

Name: Battistelli, Joseph

Worked for more than 160 Hours: Yes

Contribution to Project:
UVA: 2003- . Supervised by PI Mills

Name: Franklin, Rima
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2000-2004. Advisor: Mills. Dissertation: Spatial patterns in microbial communities

Name: Galavotti, Holly
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2001-2004. Supervised by PI Mills. Thesis: Spatial profiles of sediment denitrification at the ground water - surface water interface in Cobb Mill Creek on the Eastern Shore of Virginia

Name: Vandever, Jeffrey
Worked for more than 160 Hours: Yes
Contribution to Project:
ODU: 2003- . Supervised by PI Oertel

Name: McGoff, Nicola
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2001-2004. Advisor:Zieman. Thesis: The influence of the marsh grasshopper, Orchelium fidicinium, on nutrient cycling and productivity of Spartina alterniflora in a salt marsh environment

Name: Michaels, Rachel
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA: 2000- . Advisor: Zieman. M.S. Thesis 2003: Nest-site selection and hatching success of four waterbird species in coastal Virginia. Continuing as Ph.D student

Name: Mozdzer, Thomas
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA: 2002- Advisor: Zieman. M.S. Thesis 2005: Utilization of dissolved organic nitrogen by the macrophytes Spartina alterniflora and Phragmites australis. Continuing as Ph.D student.

Name: O'Connell, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA: 2002- . Advisor: Shugart.

Name: Kozak, Amber
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Floyd, Amanda
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA 2003- . Advisor Blum.

Name: Holzer, Kimberly
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA:2004-2005. Advisor: McGlathery. Moved to another project 2005.

Name: Flewelling, Samuel

Worked for more than 160 Hours: Yes

Contribution to Project:
UVA: 2000-2003. Advisor: Mills

Name: Naumann, Julie

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU: 2002-2004. Advisor: Young. Thesis: Quantifying successional dynamics within the context of a restoration plan for a maritime forest

Name: Long, Matthew

Worked for more than 160 Hours: No

Contribution to Project:
UVA 2004- . Advisor McGlathery

Name: Brantley, Steven

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU: 2003-2005. Major professor: Donald Young. Thesis: Seasonal and spatial variation in leaf area index, litter production and light levels in Myrica cerifera shrub thickets across a barrier island chronosequence

Name: Fuest, Jaime

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU 2002-2005. Advisor: Donald Young. M.S. Thesis: Spatial and temporal variations in dune vegetation, Orthopteran abundance, and herbivory damage on a Virginia barrier island

Name: Fennell, Jeremy

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU: 2005- Advisor: Young

Name: Casciano, Gina

Worked for more than 160 Hours: Yes

Contribution to Project:
UVA 2004- . Advisor: Linda Blum

Name: Cole, Luke

Worked for more than 160 Hours: Yes

Contribution to Project:
UVA 2005- . Advisor: McGlathery.

Name: Conroy, Patrick

Worked for more than 160 Hours: Yes

Contribution to Project:
UVA 2005- . Advisor: David Smith.

Name: Hume, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:
UVA 2005- . Advisor: McGlathery.

Name: Vick, Jaclyn

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU: 2004-. Advisor: Young

Name: O'connell, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:
Advisor: Shugart

Name: Aguiar, Amie
Worked for more than 160 Hours: Yes
Contribution to Project:
2003-2005. Advisor Erwin. M.S. Thesis on foraging of wading birds.

Undergraduate Student

Name: Skane, Elizabeth
Worked for more than 160 Hours: No
Contribution to Project:

Name: Burton, Jessica
Worked for more than 160 Hours: No
Contribution to Project:

Name: Jiron-Murphy, Claudia
Worked for more than 160 Hours: No
Contribution to Project:

Technician, Programmer

Name: Carlson, Charles
Worked for more than 160 Hours: Yes
Contribution to Project:
Site Manager through 2004

Name: Spitler, James
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician through 2001

Name: Smith, Phillip
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician 2001-2003

Name: Overman, Kathleen
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician 2001-

Name: Restein, Jason
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician 2002-2004

Name: Patrick, Brannon
Worked for more than 160 Hours: No
Contribution to Project:

Supported by the Virginia Museum of Natural History for work on the fauna of the islands and mainland

Name: Reynolds, Rene
Worked for more than 160 Hours: Yes
Contribution to Project:
Fiscal Tech 2002-2005

Name: Mace, Joshua
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician 2004-2005

Name: Fauber, Donna
Worked for more than 160 Hours: Yes
Contribution to Project:
Fiscal Tech 2005-

Name: Boyd, David
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician 2006-

Other Participant

Research Experience for Undergraduates

Name: Veloza, Adriana
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: Stroudsburg University
Home Institution Highest Degree Granted(in fields supported by NSF): Master's Degree
Fiscal year(s) REU Participant supported: 2000
REU Funding: REU supplement

Name: Diaz, Samuel
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: University of Puerto Rico
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2000
REU Funding: REU supplement

Name: Robinson, Jaime
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Same as Research Site

Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

Name: Quigley, Katherine
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

Name: Woodworth, Laurel
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2002
REU Funding: REU supplement

Name: van Montfrans, Schuyler
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Kim Holzer/McGlathery

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004
REU Funding: REU supplement

Name: Conroy, Patrick
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Kim Holzer/McGlathery

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004
REU Funding: REU supplement

Name: Snyder, John
Worked for more than 160 Hours: Yes
Contribution to Project:

working with Tom Mozdzer/Zieman

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004
REU Funding: REU supplement

Name: Turner, Jason
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Sarah Lawson/McGlathery and Pat Willis/Blum

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004
REU Funding: REU supplement

Organizational Partners

NASA, Kennedy Space Flight Center
Collaborative comparative studies between the Virginia Coast and the Merritt Island National Wildlife Refuge

USFWS- US Fish and Wildlife Service
Merritt Island: Collaborative, comparative project between the Virginia Coast and the Merritt Island National Wildlife Refuge in Florida.

Eastern Shore: PI Donald Young is working to develop a management plan to control invaisive populations of fennel (Foeniculum vulgare) and Japanese honeysuckle (Lonicera japonica) in a 100-acre old field. Invaisive plant species are an increasing threat to wildlife reserves, especially in coastal environments, and most refuges have no management plans. We have developed a proposal for a three-year experimental study with treatments of fire, herbicide, mowing and shrub plantings. Results from this study will be used to develop a management plan for the entire 100 acres.

USGS Biological Resources Division
USGS scientist R. Michael Erwin holds a joint faculty appointment at the University of Virginia and collaborates extensively on faunal studies on the Virginia Coast.

PI's Blum and Mills have worked on a collaborative, comparative project between the Virginia Coast and the Merritt Island National Wildlife Refuge in Florida that includes USGS as a partner.

Florida St John's Water Management Dist.
PI's Blum and Mills have worked on a collaborative, comparative project between the Virginia Coast and the Merritt Island National Wildlife Refuge in Florida that includes the St. John's Water Management District as a Partner.

University of Buenos Aires
PI Mark Brinson has been working with Dr. Patricia Kandus, University of Buenos Aires, who visited the VCR site. She is part of a wetland ecology group in UBA biology department working on remote sensing of the Parana River Delta in Argentina. The are involved in developing a management plant for a MAB site in the delta, and are interested in ILTER.

Environmental Protection Agency
The Atlantic Slope Consortium, a group funded by an EPA STAR grant, will be working in the connection between watersheds and coastal estuaries. Primary contacts are through Mark Brinson at East Carolina University (ECU is a member of the consortium and will be conducting

evaluations of watershed-estuarine coupling and condtions.) The consortium is coordinated by Penn State (Rob Brooks, PI) and includes other institutions such as Virginia Institute of Marine Science, Smithsonian Environemtal Research Center, and the Environmental Law Institute.

USDA

PI Iris Anderson is working under a USDA -National Research Initiative, Competitive Grants Program with a grant to study physical vs. biological process rates in VCR coastal lagoons

Czechoslovak Academy Science

PI Iris Anderson has been working with the Hydrobiological Institute - Academy of Sciences, Czech Republic on a collaborative study in the Shumava International LTER site.

NASA/Goddard Space Flight Center/Wallops Flight Facility

The VCR/LTER has been designated as a MODIS Validation Site, so NASA has been making available MODIS and other remote sensing data for the site. An Aeronet Sun Photometer has been hosted at the VCR/LTER. It uses changes in solar radiation to quantify atmospheric aerosols.

Participation as a EOS Land Validation core site has provided the VCR/LTER with numerous satellite images (ETM+, IKONOS).

Department of Navy Naval Research Laboratory

PI John Porter has been collaborating with NRL researchers Charles Bachman and Tim Donoto on remote sensing of land cover on the Virginia barrier islands. PI Robert Christian has is working with this research group on identifying areas of marsh die-off.

Nature Conservancy

Many of our research sites are owned by the Virginia Coast Reserve of The Nature Conservancy. We have also collaborated with them on a variety of projects ranging from landscape ecology of colonial waterbirds, to predator populations, to restoration of dredge spoil sites.

US Army Corps of Engineers

Army Corps of Engineers - They have expertise in sensing leaf optical properties which allows us to identify the presence and degree of stress in plants and, hopefully, the cause of the stress. We are evaluating the use of corresponding measurements of leaf reflectance and fluorescence as indicators of leaf/plant physiological responses to stress. We hope to refine the remote sensing technologies to make large-scale generalizations across the landscape. Low diversity coastal communities (i.e., shrub thickets, Spartina marsh) are ideal for scaling-up to the landscape level.

Virginia Dept. of Environmental Quality

They continue to provide support to PI Donald Young for vegetation monitoring on the Swash Bay dredge spoils. The longterm goal of the project is to eradicate or control Phragmites australis at the sites and return the landscape to native flora and fauna.

As part of a NOAA-funded grant to VA DEQ for a Coastal Management Program, PI Donald Young is defining the expansion of the invaisive reed Phragmites australis on the Eastern Shore and on the barrier islands. In addition to mapping we are evaluating spatial variations in Phragmites density, height and flowering. Response to fire on Parramore Island is also included. The results will assist land managers in determining the invaision potential of Phragmites in other coastal habitats.

Northampton Co. VA Public Schools

Through the Schoolyard Long-term Ecological Research supplement we have been interacting intensively with the Northampton County VA public schools. Students have been used to collect water quality and biological data at a number of sites.

Global Terrestrial Observing System

The VCR/LTER is one of the Terrestrial Ecosystem Monitoring Sites participating in GTOS.

City of Greenville, NC

VCR/LTER PI Robert Christian serves as chair of the Environmental Advisory Commission and is a member of the Comprehensive Planning Committee

Global Ocean Observing System

PI Robert Christian works with both GOOS and GTOS on remotely-sensed monitoring of ocean and terrestrial systems, including the Virginia Coast.

Italian International LTER

PI Robert Christian collaborates with a large number of researchers at coastal sites of the Italian Long-Term Ecological Research Network.

American Type Culture Collection

PI Linda Blum has been collaborating with Dave Emerson of ATCC on studies of the microbial communities on the Virginia coast.

Old Colorado City Communications

They have provided wireless networking equipment and expertise to the VCR/LTER, allowing us to link our island research sites with the Internet at high (2 MBS) rates of speed.

NOAA - Climate Research Network

NOAA has established and maintains a Climate Reference Network (CRN) climate monitoring station adjacent to the LTER Meteorlogical Station in Oyster VA. Data from the NOAA station is used to validate LTER meteorological data.

Virginia Marine Resources Commission

Other Collaborators or Contacts

We have collaborated extensively with researchers at other LTER sites. This includes:

-- Meryl Amber at the Georgia Coastal Ecosystems LTER has been collaborating with PI Robert Christian on the topic of areas of high vegetation mortality within salt marshes.

-- James T. Morris and Robert Ulanowicz collaborated with PI Christian on a book chapter on Network Analysis, an outcome of LTER Network workshops associated with the 2003 All Scientists Meeting.

-- James Gosz and Scott Collins of the LTER Network Office and Sevilleta LTER, respectively, have been collaborating with PI Hayden on the role of hydrocarbon emmissions from vegetation and the impact of these gases on local climate. This work was supported by an NSF supplement. This included the deployment of temperature sensors in the spring of 2004.

-- Three Taiwanese scientists (Chau Chin Lin, Sheng-Shan Lu and Meei-ru Jeng) visited the VCR/LTER in January 2004 to collaborate with PI Porter on the development of ecological information systems for international LTER work. In addition, during the spring of 2005 Meei-ru Jeng spent 3 months working with the LTER Information Manager in Charlottesville. During 2006 Chien-Wen Chen, Meei-ru Jeng and Chi-Win Hsiao each spent three additional months at UVA working on aspects ecological information management. Jointly we have run several workshops aimed at the Taiwan Ecological Research Network and the South Asia-Pacific region of the international LTER and produced several publications.

-- Paul Hanson of the University of Wisconsin collaborated with PI Porter on organizing Wireless Networking Workshops at the 2003 and 2006 LTER All Scientists Meeting and the 2004 Ecological Society of America meeting. Presentations from the workshops are available at: http://www.vcrlter.virginia.edu/~jhp7e/wireless.

-- Contacts with Scientists from several countries in Southern Africa, specifically exchanges with LTER sites in southern Africa. Remote teleconferencing instruction was offered during 2002 with participants from Mozambique, Botswana and South Africa (Macko)

-- collaborations through workshops. PI Christian organized 2 workshops on network analysis through LTER (one at Snow Bird and one at ECU) and have received support for another (jointly with Alan Covich at Colorado State U.). More collaborations resulted from a biocomplexity workshop on network analysis. The list of collaborators contacts is extensive. They include individuals from other LTER sites, social scientists, and ecologists from outside the LTER network from the USA and abroad. (Christian)

-- Another collaborative effort from a cross-site LTER workshop focused on preseration of soil organic matter in wetlands. This

alos involved scientists from the LTER netaork and outside. (Christian)

-- Drs. Jiri Kopacek, Vera Straskrabova, and Jarda Vrba, Hydrobiological Institute, Czech Academy of Sciences --collaborative study of nitrogen cycling processes in mountain lakes of the Sumava ILTER (Anderson, Macko)

-- Dr. Hana Santruckova, University of South Bohemia - collaborative study of N-cycling processes in watersheds of the Sumava ILTER (Anderson)

-- Dr. Rudolph Jaffee, Florida International University, Collaborative study of DOM quality in the VCR coastal lagoons and in PIE estuaries (Anderson)

-- Dr. Charles Hopkinson, Marine Biological Laboratory, PIE LTER, intercomparison of dissolved organic nitrogen dynamics in PIE (Anderson)

-- University of Georgia and Georgia Tech, GCE-LTER, intercomparison of groundwater/saltmarsh interactions (Anderson)

-- FCE-LTER, Collaborative study of dissolved organic
matter quality (Anderson)

-- James T. Morris (PIE LTER) co-hosted Organic matter workshop held at Virginia Institute of Marine Science, July 26, 01 (Anderson)

-- Dr. Patricia Kandus, University of Buenos Aires, visited the VCR site. She is part of a wetland ecology group in UBA biology department working on remote sensing of the Parana River Delta in Argentina. The are involved in developing a management plant for a MAB site in the delta, and are interested in ILTER. (Brinson)

-- PI Blum has been an active participant in cross LTER Organic Matter Workshops organized by Jim Morris. The goal of these workshops has been to compare organic matter accumulation in wetland sediments and the mechanisms controlling OM accumulation and to plan a series of experiments that include controlled laboratory incubations and reciprocal transplants of soil cores. Measurements might include CO2 and CH4 flux, O2 consumption, DOC loss, root ingrowth of cores, molecular characterization of microbial communities, pyrolosis GCMS and nutrient characterization of organic matter composition (new
production and old SOM). (Blum)

-- Blum is PI on NSF funded cross-site comparison study to examine the relative importance of local abiotic conditions vs. organic matter on microbial communities associated with decaying marsh grass and mangrove litter. Collaborators include: Gary King, Univ. of Maine Chuck Hopkinson, PIE LTER John Hobbie, PIE LTER Randy Chambers,
College of William and Mary Mike Reiter, Delaware State Univ. Bob Christian, East Carolina Univ. Jim Morris, Univ. South Carolina, NIN Steve Newell, GCE LTER Jay Garland, Dynamac Corp, NASA Mike Roberts, Dynamac Corp, NASA Joy Boyer, FCE LTER

-- Collaborative project with NASA Kennedy, USFWS, USGS,and State of Florida's St. John's Water Management District - working on comparison of the contribution of primary production and decomposition to organic matter accumulation and the effect on salt marsh sediment surface elevation changes between VCR and Merritt Island National Wildlife Refuge. Collaborators include: Ross Hinkle, Dynamac, Corp. Kelly Gorman, NASA Ron Brockmeyer, St. John's Water Management District Don Cahoon, USGS Mark Epstein, USFWS (Blum, Mills)

-- We have also had active contacts with African researchers interested in establishing International LTER sites. With an NSF supplement we hosted a workshop 'SOUTHERN AFRICA VIRGINIA NETWORKS AND ASSOCIATIONS - SAVANA I' Nov. 6-10, 2000. The purpose of the workshop was to explore scientific research topics, to share information about broad institutional collaboration, and to identify demonstration projects that would lay the foundations for a regional environmental research and teaching infrastructure. The workshop participants identified three demonstration projects: (1) a collaborative distance learning project initially including WITS, the University of Eduardo Mondlane, and UVA; (2) an ecology and sustainable resource management station on the Mozambique coast; and (3) a collaborative ecological research station in the eastern Lowveld/Limpopo River basin that joins three existing stations in South Africa and Mozambique. Co-Convenors of the workshop were Harold Annegarn, Atmosphere and Energy Research Group, University of Witswatersrand, South Africa; Robert Swap, PI, SAFARI 2000 (Southern Africa Regional Science Inititative), Department of Environmental Sciences, University of Virginia; Hank Shugart, Leader, Global Climate Change Program, Department of Environmental Sciences, University of Virginia and participanting scientists were Pauline Opha Dube, Department of Environmental Sciences, University of Botswana; Bane Marjanovic, Director, Sasol Centre for Innovative Environmental Engineering, Department of Civil Engineering, University of Witswatersrand; Peter Omara-Ojungu, Dean, School of Science, University of Venda; Lars Ramberg, Director, Harry Oppenheimer Okavango Research Center, University of Botswana,

Maun; Francisco Vieira, Dean, School of Science, Universidade Eduardo Mondlane, Mozambique; 'Diran Makinde, Dean, School of Agriculture, Rural Development, and Forestry, University of Venda; Stephen Macko, Workshop Program Chair, Department of Environmental Sciences, UVA; Paul Desanker, Coordinator, Miombo Network, UVA; and Mike Garstang, Bruce Hayden (Director, Virginia Coastal Reserve NSF LTER), Christelle Hely, Don Clark, Lufafa Abel, and Sam Alleaume, all faculty members in the Department of Environmental Sciences, UVA, and 13 graduate students.

-- In May 2001, African scientists Susan Ringrose, Luisa Santos, Rui Brito, and Almeida Sitoe visited the VCR/LTER. They toured the research site and met with VCR/LTER PI's and information specialists to discuss issues surrounding the creation and operation of LTER sites.

-- In July 2002, VCR/LTER PI's Zieman, Macko, Porter and Shugart participated in a series of meetings in Mozambique, South Africa and Botswana. These included participation in the Ecological Long-term Observatories of Southern Africa (ELTOSA) meeting (an International LTER regional group), Information Management training in Maputo, Mozambique, presentations on ecological information management to the staff of Kruger National Park in South Africa and a series of meetings with university administrators at a variety of South African universities.

Non-LTER collaborations include:

-- We have collaborated with Jay Austin (Old Dominion University), Dave Fugate and Karl Friedrichs (Virginia Institute of Marine Sciences) on the development and testing (using automated drifters) of a hydrodynamic model for Hog Island Bay.

-- We are collaborating with Dr. Donald Stillwell of Virginia Tech on the use of autonomous underwater vehicles to measure oxygen concentration in the lagoon. This will give us access to data on ecosystem metabolism that is otherwise difficult to get.

-- Boise State University - Dr. Steve Novak along with Dr. Greg Plunkett (VCU) and PI Don Young are collaborating on an integrated project (genetics, populaton biology, and physiological ecology) to assess the invasion potential of Phragmites australis on the Eastern Shore of Virgina. (Young)

-- Dr. Randy Chambers, Director Keck Laboratory, College of William and Mary - study of nutrient cycling processes in mudflats of the VCR (Anderson)

Dr. Carl Friedrich, Virginia Institute of Marine Sciences. Collaboration with Anderson on modeling studies of particle transport and residence times in Hog Island Bay (Anderson)

-- Dr. Mandy Joye, University of Georgia and Dr. Carolyn Ruppel, Georgia Tech, Groundwater flow at the salt marsh interface (Anderson)

-- Matt Jones, National Center for Ecological Analysis and Synthesis. Collaboration on testing of Ecological Metadata Language. (Porter)

-- Dr. Raymond Dueser, Utah State University, Barry Truitt, The Nature Conservancy. Mammalian predators often have severe negative effects on colonial-nesting waterbirds such as gulls, terns and shorebirds. These effects may vary with predator and prey species and with habitat, but often are extreme for introduced predators on islands. The raccoon (Procyon lotor) and red fox (Vulpes vulpes) are frequently implicated on islands. Based on both long-term anecdotal accounts and 20 years of breeding bird counts, most beach- and dune-nesting colonial waterbird populations have declined in recent decades on the Virginia barrier islands. It has been proposed that much of this decline is attributable to expanding distributions and increasing abundances of raccoons and red foxes. Direct effects such as nest depredation have been observed repeatedly but relatively infrequently over the past 20 years. We have been working to determine more directly the effects of mammalian predators on nesting waterbirds. There appeared to be a real effect of mammalian predators on nesting colonial waterbirds (in the form of reduced bird abundance) even in the absence of apparent effects (in the form of signs of depredation) in a given year. These results support the contention that mammalian predators have had a significant long-term effect on colonial-nesting waterbirds on the Virginia barrier islands despite the infrequency of observed direct effects. This study represents a highly effective partnership among The Nature Conservancy, the Virginia Museum of Natural History, the Virginia Department of Environmental Quality and the VCR-LTER Program.(Moncrief, Porter)

We collaborated in 2002 with Dr. Ronald A. VanDenBussche, Department of Zoology, Oklahoma State University, in an (mtDNA)analysis of the phylogeography of raccoons on the Virginia barrier islands and the adjacent the Delmarva Peninsula (Moncrief).

-- Peter Arzberger of the University of California, San Diego collaborated in 2004 and 2005 with PI Porter on publications and workshops related to wireless networking of ecological research sites.

-- Bob Orth and Elizabeth Canuel(Virginia Institute of Marine Sciences), and Sergio Fahgarazzi (Florida State University have been collaborating on research related to the ecological status of bays, seagrass reintroduction and bay circulation during 2004 and 2005.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

See attached file

Findings: (See PDF version submitted by PI at the end of the report)

See attached file

Training and Development:

We have engaged in training at all levels of education. At the graduate level we have a large number of students who participate in the research conducted at the VCR/LTER. A smaller number of undergraduate student REUs participate in research, while a larger number of undergraduates experience the LTER site through class field trips. In the K-12 area we are engaged in taking hands on science into the classroom in the area of field measurements using state-of-the-art equipment. This involves classroom teaching on the part of VCR scientists, field demonstartions and WWW-based communications.

The VCR/LTER continues its efforts in the area of graduate education. During 2004-2006 six Ph.D and eight M.S. students completed their thesis work at the VCR/LTER.

Some specific training and development activities were:

With additional funding from the Virginia Environmental Endowment we have been developing K-12 class activities using island-based webcams. The web site is at http://ecocam.evsc.virginia.edu.

Our investigations of sea-level rise and its wetland impacts provide many opportunities for visiting scientists all over the world to come and consult on the long-term project and to learn how to install and monitor the SETs. PI Erwin and his USGS colleagues Don Cahoon and J. Lynch have a network of SETs in many US states, and in many other countries at present that have been used for such training.

During 2006, the VCR/LTER hosted for three month periods information managers-in-training from the Taiwan Ecological Research Network. During their stays they worked with the VCR/LTER Information Manager on a variety of tasks from developing wireless sensor networks, to developing automated analysis programs using Ecological Metadata Language. The VCR/LTER Information Manager helped organize additional week-long workshops in Taiwan. One workshop focused on refining the vision for information management being developed by the TERN information management group. The second workshop, in collaboration with TERN, was an international workshop for the East Asia Pacific region, that provided additional training for ILTER information managers. We also hosted 3 short-term (3 week or less) visits by TERN information managers and provided them with an overview of methdologies used in U.S. LTER Information Management.

Outreach Activities:

The Schoolyard LTER program continues to be a meaningful way of increasing future public understanding, now serving elementary, middle and high schools in Northampton County, VA.

During the past year we have worked with The Nature Conservancy on issues of landscape dynamics, surveys of bird populations and on the extent of invasive species.

From 2003-2008, PI Erwin will serve on a seven-member National Science Panel that oversees a large, long-term San Francisco Bay Salt Pond Restoration program. The role is one of oversight over the development of a Science and Monitoring plan, and its implementation.

PI Robert Christian continues to be active with the Italian International LTER program. Christian has served as the Chair of the Expert Panel for development of the Coastal Module of UN's Global Terrestrial Observing System. Relatedly, he has served on the team to write the report for the Coastal Theme of the Integrated Global Observing Strategy. Additionally, he is program co-chair for the 2005 Estuarine Research Federation meeting and President-elect of the Estuarine Research Federation. He also serves on the Scientific and Technical Advisory Committee of the Albemarle Pamlico National Estuaries Program.

While PI Stephen Macko continues to be active in African ILTER efforts. He, Porter, Shugart and student A. Knopf participated in the southern African ELTOSA workshop in Mozambique in July 2002.

Nancy Moncrief used distributional data collected from the multi-island surveys in a Teacher Re-Certification class that she teaches through the University of Virginia at the Roanoke Higher Education Center. She reviewed processes such as extinction and colonization and concepts such as succession, habitat complexity, and carrying capacity. Typically, there are 20-30 K-12 teachers in this course each year. Her work at VCR/LTER was featured in an article about me that appeared in VMNH's popular publication The Virginia Explorer, published in May 2002.

Don Young was appointed to the Governor's Advisory Board of Soil Scientists and Wetlands Professionals. We will be developing guidelines for certifying professionals as wetlands ecologists.

Images from the VCR/LTER WWW site have appeared in a number of publications for the general public. These include Chesapeake Life Magazine, UVA Insights and the Eastern Shore Post.

The VCR/LTER WWW site (http://www.VCRLTER.virginia.edu)is widely used. We average over 12,000 requests for information resulting in over 407 MB of downloads each day. Educational users accounted for 12% of all requests, while commercial users or educational users using a commercial network provider accounted for 54%. A complete web statistics report is available at: http://www.vcrlter.virginia.edu/analog/2006.

Journal Publications

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Web/Internet Site

URL(s):

http://www.VCRLTER.virginia.edu

Description:

This WWW site serves as the "file cabinet" for the VCR/LTER Project - both for researchers within the project and external scientists. It provides access to a wide array of information products derived from the grant including data, searchable bibliographies, full text of proposals and theses and dissertations. The site is heavily used with over 8,500 requests served on the average day.

Other Specific Products

Product Type:

Data or databases

Product Description:

The VCR/LTER provides access to 108 formally documented data sets. They are listed on the WWW at: http://www.vcrlter.virginia.edu/data.html. They include physical, biological, geographical and model data sets. Some data sets also support sophisticated queries, such as our biodiverisity database, or extensive graphical output, such as our meterlogical and tide data sets. In addition to the formal data sets we provide a wealth of textual and graphical material resulting from research at the VCR/LTER.

Sharing Information:

Data is made available via the WWW in conformance with LTER-wide data policies. The data is widely used for research and education, with over half of the data requests coming from researchers, educators and students not associated with the VCR/LTER both within the US and internationally.

Product Type:

Physical collection (samples, etc.)

Product Description:

In collaboration with the Virginia Museum of Natural History, we have established a sample archive for the VCR/LTER. This includes mammalian tissue samples, as well as soil, and water. To date, collections at the Virginia Museum of Natural History include more than one thousand traditional skin and skeletal preparations of 18 species of mammals from more than 40 locations on the Virginia barrier islands and southern Delmarva Peninsula. Ninety-nine percent of these specimens are accompanied by frozen tissue samples (heart, liver, kidney, and skeletal muscle). Also, intensive long-term live-trapping data were collected for 3 island sites and 3 sites on the adjacent mainland for a five-year period. In conjunction with that study, non-invasive tissue samples (earclips) were collected from more than two thousand individuals of three species of rodent.

Sharing Information:

These samples are available through standard loan procedures of the Virginia Museum of Natural History.

Product Type:

Audio or video products

Product Description:

We provide online access to over 350,000 images of ecological research activities and sites at http://www.VCRLTER.virginia.edu/images, http://www.vcrlter.virginia.edu/gallery and an large number of database-accessible webcam images at: http://ecocam.evsc.virginia.edu.
This includes several compressed videos of our site and research procedures on the WWW at http://www.vcrlter.virgina.edu/video. These are not 'production quality' videos, but aid in the orientation researchers who may be interested in conducting research at the VCR/LTER.

Sharing Information:

Images are available in standard Internet formats (.jpg and .gif) at http://www.VCRLTER.virginia.edu/images/ , http://www.vcrlter.virginia.edu/gallery and http://ecocam.evsc.virginia.edu.
They are available in RealPlayer or Windows Media Player formats on the WWW site: http://www.vcrlter.virgina.edu/video

Product Type:

Teaching aids

Product Description:

We provide live Webcams viewing research sites of the Virginia Coast Reserve LTER. These are used by K-12 students to view these remote islands.

Sharing Information:

Cameras and time series of images can be viewed at: http://www.VCRLTER.virginia.edu/wwwcam/ and at http://ecocam.evsc.virginia.edu/

Contributions

Contributions within Discipline:

We have continued to contribute to the understanding of coastal systems through our efforts in studying the effects of sea level rise (which involves developing detailed understandings of the processes that effect accretion in marshes - both physical and biotic, and encroachment into uplands), coastal eutrophication, controls on plant production, and determinants of faunal biogeography in an island system.

LAGOON

Coastal eutrophication has been recognized as an increasing problem in areas such as the East and Gulf coasts of the U.S. Symptoms of eutrophication include blooms of phytoplankton, which when they decompose may reduce available oxygen in the water; blooms of harmful algae that are toxic to fish, shellfish, and occasionally humans; blooms of macroalgae that cause die-backs of sea grasses which are vital to maintaining populations of many fish and crabs. Eutrophication generally results from export of excess nutrients from land, in particular nitrogen. Sources of nitrogen include agriculture, septic tanks, waste water treatment plants, industry, and atmospheric deposition of nitrogen derived from automobiles, power plants, and other industrial sources. Nitrogen from these sources is most often transported to coastal waters in shallow groundwater and in surface water runoff.

Coastal lagoons are common features of the land margin, especially along the East and Gulf coasts. We have hypothesized that these lagoons play an important role in retarding and transforming nitrogen during transport from land to the sea. Our study of the Virginia Coast Reserve lagoonal system has been designed to: (1) measure groundwater sources of nutrients to the lagoon; (2) measure rates of biological processes that remove or transform nitrogen in the waters and sediments of the lagoon; (3) compare rates of nitrogen cycling processes to physical transport across and out of the lagoon in order to determine whether the nitrogen remains in the lagoon for a sufficient length of time to allow biological processing to occur. The biological studies described in this report are being performed jointly by Iris Anderson, VIMS, and Karen

McGlathery, University of Virginia.

Our preliminary results support our hypotheses that: (1) nitrogen entering the lagoon is rapidly removed by both benthic macro- and microalgae. The bloom of macroalgae that results in early summer crashes during mid-summer, releasing much of the nitrogen as dissolved inorganic and organic nitrogen. The sediments act to rapidly remove the nitrogen released to the water column by a combination of mechanisms including immobilization by benthic microalgae and coupled nitrification - denitrification. We are currently attempting to determine how the nitrogen released during decomposition of the macroalgal bloom is partitioned between the various potential consumptive mechanisms.

Our conclusions regarding the importance of macroalgae in influencing the dynamics of nutrient movements within the lagoon helps to explain the role of the lagoon as an active mediator between mainland nutrient sources (e.g., agricultural fields) and the coastal ocean. The recent discovery that the dominant macroalga in the lagoon is an exotic (rather than its native congener), will be important to understanding long-term changes in the lagoon's characteristics.

MARSH

Surface Elevation Tables (SETs) are used at numerous VCR/LTER research sites to quantify subtle changes in sedimentation that ultimately will determine the fate of marshes in the face of sea level rise. These baseline measurements at different marshes are then used in association with process-based studies focusing on the processes such as transport of material through tidal flooding, burial of organic matter and its decomposition, marsh plant production (both above and below ground), bioturbation by crabs and even herbivory by insects to develop models aimed at predicting changes in marshes over the coming decades. Our preliminary results indicate that the rate of acretion are position dependent, with the upper marsh receiving less input.

Recent work on microbial communities in the marshes and tidal creeks at the VCR (as well as 9 other coastal systems as part of a cross-site comparison study) contribute to our understanding of what abiotic and biotic factors determine microbial community structure and the scales over which microbial communities vary. Linking information about variation in microbial community structure and microbially controlled processes (e.g., nitrogen-fixation), will allow prediction of how critical ecosystem processes will be affected by disturbance. (Blum)

We have continued to work with a small group to compare the ways in which salt marshes, mangroves and coral reefs respond to sea-level change and are perceived to respond to sea-level change. This synthesis promises to be valuable. (Christian)

The work culminating in the masters theses of Scott Dusterhoff (under supervision of Albertson and Wiberg) and Steven Turaski (supervised by PI Wiberg) has applied instrumentation and models most commonly used in studies of fields and forests to marshlands. Measurements of soil moisture (using TDR), water table elevation, soil texture and topography were used to characterize near surface soil moisture dynamics and runoff potential across a marsh-upland transect at Phillips Creek Marsh, VCR-LTER. Models of soil moisture (Richards equation) and evapotranspiration were successfully used to investigate controls on soil moisture and water table level, including soil texture, elevation, root density in addition to precipitation, tidal inundation and etc.

One of PI Robert Christian's major commitments for the last couple of years has been to encourage and promote the use of network analysis within ecology. Network analysis is a modeling tool (really an accounting tool for data. These data must be organized in a network form of interactions aomong system compartments) These efforts have come to some fruition via publications and workshops sponsored by NSF biocomplexity and the LTER network. Now several groups within and beyond the LTER network have begun using the tools. Jim Morris at U. South Carolina and PI Christian have collaborated on large number (>1,000) compartment networks, randomly generated but following perscribed rules. We have found some distribution dependent and independent attributes of food webs. This work was continued at a workshop on Network Analysis at the LTER All Scientists Meeting in Sept. 2003.

UPLAND

The results of this work to date have increased our understanding of dynamic vegetation changes and their causes in coastal barrier island ecosystems. New cross site and cross species analyses are linking meteorological and climatological drivers to plant production. This analysis is revealing complex patterns showing that all species and sites do not respond similarly to meteorological drivers.

To date, one of our most significant contributions has been to demonstrate that biotic interactions are very important in the coastal environment of the VCR, which we often define as being dominated by physical parameters. Most importantly PI Donald Young, demonstrated the importance of the presence for a soil actinomycete, Frankia, for the successful establishment of Myrica cerifera. Myrica usually is usually the first woody species to establish in these environments. Once established, Myrica rapidly forms extensive thickets in coastal environments. These thickets are excellent indicators of island stability and may be precursors to the establishment of maritme forest.

Fourteen years of research in shrub thicket ecology has provided excellent background and experience for studying the potential for invasive species in coastal environments. This is especially true for the weedy grass, Phragmites australis. Populations of Phragmites are establishing and rapidly expanding throughout the VCR as well as in coastal environments of the mid-Atlantic region. Phragmites often establishes in habitats similar to those of shrub thickets. The detailed understanding of the ecology of P. australis with respect to nutrient uptake and competitive relationships provide a basis for predictions regarding its ultimate distribution.

Studies of island-dwelling organisms, such as those underway at VCR, have long played an important role in testing ecological and evolutionary theory about patterns and processes related to distribution and abundance of species and genetic variation within and among natural populations. The Virginia coast is a highly dynamic, frequently disturbed landscape, and the Virginia barrier islands are the only undeveloped barrier system on the Eastern seaboard. As such, this system affords a unique opportunity to study phenomena associated with island systems, including fragmentation of habitats and populations, local extinction, dispersal, and colonization, which are also important issues in conservation biology. The relative isolation of the islands also provides an excellent opportunity for assessing the roles of paracitism and disease in overall vertebrate population dynamics.

At the global scale, PI's Hayden and Fuentes have continued work, in collaboration with the Sevilleta LTER site, on the gaseous and particulate emissions from vegetation and its role in the dynamics of the lower atmosphere. Information about these non-CO2 emissions has increased the awareness of the ecological community as to the diversity of feedbacks from the biosphere to the atmosphere. Our topographically stratified measurements of annual temperature show a coincidence of vegetation zonation with abrupt temperature gradients.

Contributions to Other Disciplines:

The studies conducted by the VCR/LTER are inherently interdisciplinary or multidisciplinary. Our studies are being performed by an interdisciplinary team of ecologists, hydrologists, biologists, and physical oceanographers. When such collaborations take place, it is not unusual that each each group of scientists will gain greater insight into problems that may not be recognized within their own discipline.

Additionally, our workshops on network analysis have exposed a broad group of scientists to the field or network ecology. Social scientists have also used network analysis, and one of our accomplishements has been to bring awareness of the different approaches to the broader group. (Christian)

Research on ecological information management has included computer scientists. The challenges posed by ecological data provide opportunities for innovation in computer science. Our work with development of wireless sensor networks, and processing of the massive data flows they can generate, contributes to better defining the cyberinfrastructure challenges that will confront us in coming decades. During 2006 the VCR Information Manager participated in the Cyberinfrastructure-Core group and we hosted a modeling workshop that focused on the cyberinfrastructure needs of advanced ecological modleling. (Porter)

In association with educators (and with additional support from the Virginia Environmental Endowment) we have been exploring the use of wireless web cameras for use in K-12 science education. (Smith, Porter)

Connections between storminess at the Virginia Coast Reserve LTER and variations at the El Nino frequency have proved negative. In addition, General Circulation Models (The Hadley Model) indicate no changes in storminess at the VCR out as far as 2085 (Hayden).

Contributions to Human Resource Development:

As can be seen from the number of graduate and undergraduate students listed on our participant list, this project provides abundant opportunities for training. Moreover, the inter- and multi-disciplinary nature of the research teaches the students how to operate in a collaborative environment.

We have, in our Schoolyard LTER program provided instruction and assistance to local teachers as well as graduate courses in assistance of their recertification. During 2006, we have brought LTER research activities into the classroom had extensive contact with more than 200 students in grades 9-12.

From Jan 1, 2003 through 2006, the LTER laboratory has been used by six college classes totaling more than 90 undergraduate students.

PI Nancy Moncrief continues to use distributional data collected from the multi-island surveys in a Teacher Re-Certification class that she teaches through the University of Virginia at the Roanoke Higher Education Center. She reviews processes such as extinction and colonization and concepts such as succession, habitat complexity, and carrying capacity. Typically, there are 20-30 K-12 teachers in this course each year. Additionally, she has developed a K-12-level activity that illustrates various island biogeography principles. She distribute it through Teacher

Recertification courses and workshops.

PI John Porter continues to contribute to training efforts in the area of Ecoinformatics. He participates annually in the training efforts of the Resource Development Initiative for Field Stations (RDIFS), which trains information managers at biological field stations. He co-taught a one week short course on ecological databases for participants from the Organization of Biological Field Stations in October 2002. Internationally, he co-taught a two day course on ecological information management in Maputo Mozambique in July 2002. He taught a session on site information management and Ecological Metadata Language (EML) at the East Asia Pacific LTER meeting in Beijing in July 2005. He co-organized two workshops on information management with the Taiwan Ecological Research Network (TERN) in 2006, and also taught sessions at the RDIFS training session in Costa Rica.

Contributions to Resources for Research and Education:

Our WWW site (http://www.vcrlter.virginia.edu) provides access to a wide variety of information in text, graphical and video forms. Data are frequently downloaded for use by classes and researchers at institutions not associated with the VCR/LTER. Since March 2001, our web site has distributed 847 gigabytes of information to over 668,000 different client computers. The site averages over 12,000 'hits' per day throughout that period. A detailed summary can be found at: http://www.vcrlter.virginia.edu/analog/2006/index.html

Through the web server, we have provided data for 892 formal requests, since 10/1/2000, with 121 requests in the last year. 22% were by VCR/LTER associated researchers, but 78% were from individuals not associated with the VCR/LTER. 70% of the total requests were for research use and an additional 30% were for classroom use. Many requests were from outside the US including the United Kingdom, India, Canada, China, Indonesia, Chile, France, Australia, Germany, Mexico and Pakistan, and the Netherlands, among others.

Through our Schoolyard LTER supplement, we have been able to provide equipment such as global positioning system, taxonomic guides and water chemistry analysis kits and equipment to the Northampton Co. VA Public Schools. This program now extends from grades K-12 through the Northampton Co. elementary, middle and high schools.

Work that we are currently doing at the VCR is of much interest to the Department of Environmental Quality of the State of Virginia, and in particular to the Water Conservation Districts located on the Eastern Shore. The major source of nitrogen to VCR coastal lagoons is agriculture. Proper management of agricultural activities and fertilization practices requires an improved understanding of nitrogen losses to the coastal lagoons via groundwater and surface water runoff.

During 2004-2006 high school students monitored water quality at 21 sites on a bi-weekly basis. They also did quarterly testing of soil characteristics at the same sites. Through the SLTER supplement, this year we were able to upgrade water quality and soil testing kits, provide up-to-date global positioning system units (incorporating WAAS technology).

Contributions Beyond Science and Engineering:

We have engaged in studies designed aid the conservation of avian fauna and better understanding of the extent and change in exotic plant species in the coastal zone in conjunction with The Nature Conservancy. (Erwin, Moncrief, Porter, Hayden, Blum, Young)

Knowledge of the relationship between land use, nutrient contamination of groundwater, groundwater export of nutrients to coastal lagoons, and the fate of nutrients within lagoons will be of benefit to state and federal agencies charged with managing coastal resources. This knowledge will be especially important given the probable return of seagrasses to large areas of the coastal bays, from which they have been absent for over 70 years.(Anderson, McGlathery)

Linking information about variation in microbial and fungal community structure and fungal and microbially controlled processes (e.g., nitrogen-fixation, decomposition), will allow prediction of how critical ecosystem processes will be affected by disturbances due to human activities in the coastal zone. (Blum)

Activities with the UN programs on observing global change along coastal ecosystems have significance for broad aspects of public welfare and environmental protection. One of the greatest potential contributions from PI Christian's work at the VCR LTER are to the global observing systems and the ability to detect and assess global change in coastal ecosystems. The Coastal Module of GTOS is being developed to complement the Coastal GOOS program and highlights terrestrial, wetland, freshwater, and transitional ecosystems. Further and importantly it explicitly includes socio-economic components of global change in the coastal zone. This is the first significant introduction of the human dimension into the global observing systems. (Christian)

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None
Unobligated funds: less than 20 percent of current funds
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

VIRGINIA COAST RESERVE LTER 2006 ANNUAL REPORT

CONTEXT

The goal of the Virginia Coast Reserve (VCR) LTER program is to understand and predict long-term ecological change in the context of slow, progressive changes in climate, land use, and sea level, and short-term disturbance events such as storms in coastal barrier systems. Biotic feedbacks at the local scale interact with these broad-scale drivers to influence long-term ecological change on the landscape. In VCR IV, our central hypothesis was that ecosystem, landscape and land use patterns within terrestrial-marine watersheds are controlled by the vertical positions of the land, sea and groundwater free surfaces. The hypsometric framework developed in VCR IV provides the synthetic framework to link the ecosystems (mainland, tidal marsh, lagoon, barrier island) on the landscape.

In LTER I (1987-1992), we began with the hypothesis that ecosystem dynamics in the VCR are driven by large-scale events and processes such as coastal storms and sea level rise. The concept of abrupt ecosystem change (state change) and slow progressive change (succession) as emergent properties driven by these large-scale events and processes was added in LTER II (1992-1994). In LTER III (1994-2000), we developed the concept that changes in the relative elevations of the free surfaces (land, sea, groundwater table) controlled state change and ecosystem dynamics. LTER IV (2000-2006) focused on hypsometry as a synthetic framework for integrating research on marine watersheds, intertidal wetlands, subtidal lagoons, and barrier islands in the VCR landscape.

ACTIVITIES

Our long-term experiments and core monitoring activities include tracking of changes in ecological states in relation to changes in geomorphology, groundwater and sea levels; collection of groundwater, meteorological, and tidal data; monitoring watershed nutrient inputs into coastal lagoons; monitoring transects in the coastal lagoons for water quality, primary production, and benthic biodiversity; monitoring terrestrial vertebrate populations (birds and mammals); measuring the effect of manipulation of sea level on marsh communities; and modeling hydrodynamics and transport in coastal lagoons. In addition, we have directed research projects that address specific mechanisms by which long-term changes in climate, land use and sea level and short-term disturbance events cause change in the structure and functions of the major landscape units of the VCR: watersheds, lagoons, intertidal marshes and mudflats, and barrier islands. We outline our continuing and new activities associated with both monitoring and experiments below.

Watersheds and Lagoons

Our research on the land-sea connection between coastal watersheds and adjacent lagoons continues to focus on the relationship between watershed land use and the impacts of nutrient loading on the lagoon ecosystem, and on the return of the foundation species, *Zostera marina*

(eelgrass) as the "foundation" species. We study groundwater discharge into the lagoons and relate nutrient inputs to processing by primary producers and consumers and physical transport within the lagoon to determine the fate and transport of watershed nutrients. Our models of hydrodynamics, sediment resuspension, and sediment-water column nutrient fluxes set the stage for the large-scale recolonization of seagrass in Hog Island Bay and other lagoons in the VCR.

Continuing Activities

The specific research activities that we are continuing to do to characterize patterns and processes in the watersheds and lagoon are detailed below.

We continue to monitor the two long-term water quality transects in the VCR lagoons, one of which was added in 2004; sampling on the other transect began in 1992. The transects represent the gradient from mainland – lagoon – barrier island – ocean inlet in two bays that represent different water land use and nutrient loading rates. We couple measurements of water quality (nutrient concentrations, light availability, suspended solids) to estimates of primary producer (benthic algae, phytoplankton) at each site. (McGlathery, Blum, Christian)

To estimate groundwater nutrient loading during baseflow to the coastal lagoons, we are monitoring 14 tributaries that drain watersheds of differing land use across the VCR landscape. (Mills, Anderson)

At the Cobb Mill Creek site adjacent to the new ABCRC, we continue our studies of the role of denitrification in coastal stream sediments in removing NO_3^- from discharging groundwater that will enter the lagoons. We continue to generate continuous discharge data for Cobb Mill Creek (with some gaps due to equipment failure) and we continue to examine other creeks on the Eastern Shore to determine the degree to which they behave like Cobb Mill Creek, and the extent to which they deliver NO_3^- to the lagoons. (Mills, student Sam Flewelling)

We are continuing our comparative study of nutrient cycling and ecosystem metabolism in coastal lagoons using network analysis. This work is being done in collaboration with Pier Luigi Viaroli (University of Parma, Italy) and his colleagues, and Christy Tyler (Rochester Institute of Technology, former LTER graduate student). We are developing models for Hog Island Bay, which receives relatively low nutrient loading from the agricultural watershed, and the Lagoon of Venice, which is a heavily eutrophic lagoon. Our efforts are focused on the effects of primary producer growth form and eutrophication on N cycling. (Christian, Anderson, McGlathery, student Chris Voss)

Successful restoration of seagrass beds in South Bay by our colleagues at the Virginia Institute of Marine Sciences provide an excellent opportunity to study the effects of seagrass restoration on energy transfer through the marine food web using compound-specific isotopes. Approximately 1000 samples from South Bay restored *Zostera marina* plots were collected from the summer of 2004 to the summer of 2006. The samples consisted of primary producers through higher trophic level fish. Carbon, nitrogen, and sulfur bulk isotopic values ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$, respectively) of primary producers verify that *Z. marina*, epiphytes and macroalgae are isotopically distinct, thus allowing for source differentiation. (Macko, student Stephanie Harbeson)

New Activities

We are extending our studies on the relationship between sediment resuspension and light availability in Hog Island Bay to understand the effects of different primary producers (seagrass, macroalgae, benthic microalgae) on sediment resuspension and nutrient release to the water column. This work examines the influence of increased hydrodynamic activity on benthic-pelagic exchange of nutrients, microalgae and sediment using a Gust erosion microcosm and controlled experiments to determine both the mechanisms of exchange and the potential control of primary producers on these fluxes. The significance of the diffusive nutrient flux between the sediment and water column has been demonstrated in laboratory mesocosms and field experiments, but hydrodynamically forced nutrient fluxes from the sediment have not been thoroughly examined. This is particularly important because shallow coastal lagoons are characterized by shallow depth, a well-mixed water column and low freshwater input, all of which increase the significance of benthic-pelagic coupling. (Wiberg, McGlathery, student Sarah Lawson)

We are also extending our investigations of macroalgal communities in Hog Island Bay, in particular their role in nutrient cycling and trophic dynamics within the bay. We have focused on the role of the abundant polychaete, *Diopatra cuprea*, as a 'foundation' species, facilitating the growth and distribution of the invasive species *Gracilaria vermiculophylla* in Hog Island Bay. (McGlathery, Thomsen (former LTER student), students Kim Holzer and Luke Cole)

In collaboration with our colleague Robert Orth from the Virginia Institute of Marine Sciences, in October 2006 approximately 1.5 million seagrass seeds were hand-broadcast in the 509-acre 'set-aside' designated for seagrass restoration by the Virginia Marine Resources Commission. The seeds were broadcast in a full factorial design with 2 seed densities (50,000 and 100,000 per acre) and 2 plot sizes (0.5 and 1.0 acre), with 7 replicates per treatment (Fig 1). This is the start of a large-scale experiment on the ecosystem-level effects on restoring this 'foundation' species to the Virginia Coastal lagoons. Prior to the seeding, we collected background data on sediment characteristics (grain size, organic and nutrient content, bulk density), benthic chlorophyll concentrations, and benthic invertebrate species composition and abundance to serve as baseline data against which to monitor changes with

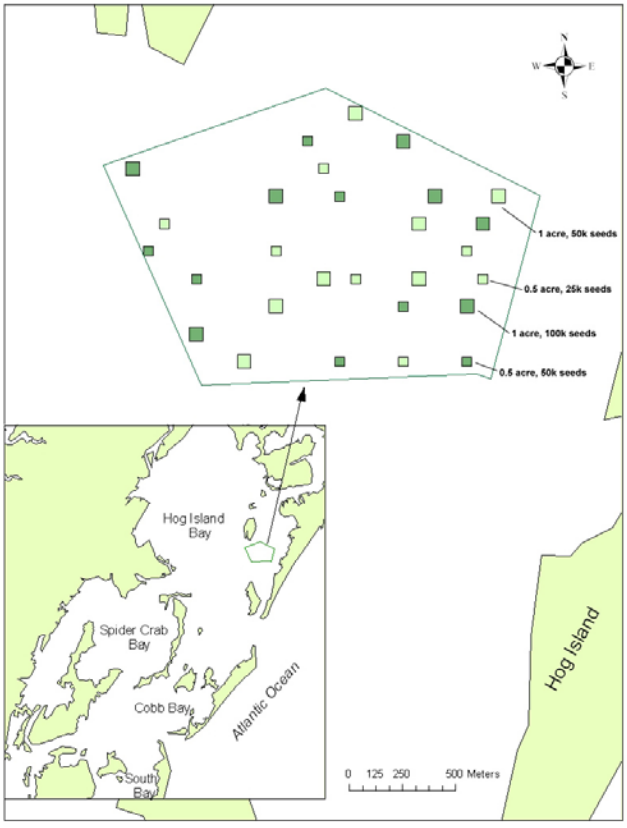

Fig. 1. Seagrass restoration plots in the 509 acre 'set aside' in Hog Island Bay.

seagrass recolonization. (McGlathery, student Luke Cole and Andrew Hume)

We have initiated a collaborative project with colleagues Liz Canuel (VIMS), Craig Tobias (UNC Wilmington), and Joe Vallino (MBL) to quantify the pathways, rates and time scales of nitrogen and carbon turnover in two coastal lagoons that differ in terms of eutrophication status. Two mesocosm experiments were conducted using dual stable 13C and 15N enrichments to investigate C and N dynamics among the sediment, water column, and the major benthic primary producers (macroalgae, and benthic microalgae). The first experiment simulated the deposition of macroalgal organic matter following summer bloom conditions under different physical energy regimes. A 3-way factorial design was used to examine the fate of macroalgal C and N within the mesocosms: sample site (low vs. high nutrient loading), resuspension (presence/absence), and macroalgae (presence/absence). The second experiment manipulated nutrient and light levels (ambient vs. dark) to which sandy sediment from the low nutrient bay (Hog Island Bay) were exposed. The light treatments simulated ambient conditions that would promote autotrophic activity of benthic microalgae, and the dark treatment highlighted bacterial activity. Time series sampling was done for two weeks after isotope addition to determine patterns in water column and sediment nutrients, chlorophyll, lipid biomarkers for C sources (algal and bacterial), bacterial cell wall biomarkers, water column particulate matter, and the processes of N mineralization and coupled nitrification-denitrification. Collectively, these measurements provided the information for calculating the total mass flux of labeled N and C through each of the ecosystem components. In addition to the mesocosm experiments, field monitoring of factors influencing benthic microalgal production (nutrients, light), macroalgal biomass and sediment characterization were conducted during the summer in the high-nutrient Isle of Wight Bay and low-nutrient Hog Island Bay. (Anderson, student Amber Hardison)

Intertidal marshes and mudflats

Research in the VCR tidal marshes continues to focus on long-term measurements of marsh biomass and community change, sediment accretion in relation to sea-level rise, groundwater levels, and marsh food web dynamics. Of particular interest is the occurrence of marsh die-off in parts of the VCR landscape, a phenomenon that has occurred throughout the eastern seaboard.

Continuing activities

We have continued our long-term observations and experimentation of the interplay between ecosystem state and hydroperiod. This involves measurements of marsh biomass and community change in our inundation experiment and end-of-year biomass survey (annually), sediment accretion at our SET and marker horizon sites in relation to sea-level rise (biannually), groundwater levels (every seven minutes to monthly in wells without recorders), and marsh food web dynamics (frequency determined by the type of organisms). Surface elevation tables (SET) have been used to measure the land free surface and accretion (measured as accumulation of materials over a feldspar marker horizon) in mainland marshes since 1997 and in lagoon marshes since 1999. These results are combined with information about hydroperiod and depth to groundwater to evaluate marsh susceptibility to the current rate of relative sea-level rise (3.5 - 3.9 mm yr^{-1}, Erwin et al. 2004; in press). We also focus on the responses of vegetation to

disturbance in the context of ecogeomorphology at the Phillips Creek marsh (Keusenkothen and Christian 2004). Specifically, we have explored inundation-disturbance interactions associated with varying hydroperiod and wrack deposition, deer trails, and hypoxia and drought (Brinson, Christian, Blum)

New activities

In 2004, an area of a few hectares of low marsh at our intensively studied UPC site demonstrated symptoms similar to sudden die-back found recently in other salt marshes along the coasts of the Gulf of Mexico and Atlantic Ocean. We began observations of the site in 2004, and continued them through 2006. *In situ* observations of plant growth and condition, ground cover, microbial abundance and edaphic factors were done on site (Marsh 2007). Elijah Ramsey and his colleagues from the USGS National Wetland Research Center conducted further *in situ* work on plant reflectance patterns. Remote sensing was done by Charles Bachmann with hyperspectral imagery. The intent is to improve the capability of detecting and assessing die-back remotely. (Christian, Brinson, Blum)

We have observed that fungal hyphae are abundant in salt marsh sediments, which is unexpected given the broadly accepted idea that they are absent from anaerobic environments. We have examined the spatial distribution of fungal hyphae and communities in the soil as a prelude to understanding the function of fungi in salt marsh sediments. In this work, we asked three questions: How are fungal hyphae and communities distributed with respect to their position between marsh creeks and upland forests, what proportion of the fungal hyphae are living, and how does the distribution of fungi compare with the distribution of bacteria? (Blum)

As part of the work to compile comparative data for all LTER sites in the LTER TRENDS volume, we compared relative sea-level data for several stations along the Atlantic seaboard that would be representative for the VCR. (Wiberg, Erwin)

We have continued our work on wading bird foraging and habitat use in two areas of the Virginia Coast, a semi-urbanized setting near Chincoteague VA and the relatively pristine barrier island site at Hog Island VA. (Erwin, student Amie Aquiar)

We initiated a project to investigate latitudinal gradients in the availability and utilization of dissolved organic nitrogen by *Spartina alterniflora* in temperate Atlantic salt marshes at 8 sites from Maine to Florida. Field work included mesocosm experiments at three sites in MA, VA, and SC along with bimonthly monitoring at all 8 sites. (Zieman, student Tom Mozdzer)

We conducted a large-scale salt marsh mesocosm experiment to test the effects of the presence and absence of fiddler crab burrows on pore water chemical profiles within the marsh sediment. The mesocosms were set up with semi-diurnal tides that inundated the sediment with bottom-up flooding, as is common in tidal marshes. The experiment consisted of two sediment types typical of the VCR-LTER site, sandy low organic matter overwash sediment from south Hog Island and muddy high organic matter creek bank sediment from Phillips Creek. Cores containing *Spartina alterniflora* rhizomes and new shoots were transplanted into mesocosms in the spring. Two different flood regimes were utilized and half of each of the sediment treatments

experienced either well-drained or poorly drained as their low tide scenario. Artificially maintained fiddler crab burrows were maintained in half of the mesocosms, creating a matrix of eight distinct treatments with three replicates each. Monthly *S. alterniflora* production was measured in each mesocosm as well as a suite of pore water characteristics at five sediment depths. Sediment characteristics and sulfate reduction rates and belowground *S. alterniflora* production were also determined. To corroborate our experimental data with field data, six sites within the Machipongo Box Transect were chosen to represent both island and mainland sites and creek and bay shore sites. These six sites were monitored for above and belowground water level during the growing, as well as *S. alterniflora* end of season production and fiddler crab burrow density. Additionally, pore water and sediment characteristics were measured. (Zieman, student Rachel Michaels)

Barrier Islands

Research on the terrestrial habitats of the VCR represents an array of studies from within island habitats to the landscape level. Frank Day and Don Young have focused on grass-covered dunes and shrub thicket dominated swales, respectively, along the Hog Island chronosequence. John Porter continued with small mammal trapping efforts across the VCR islands. Ray Dueser and Nancy Moncrief have initiated experiments to reduce raccoon predation of ground nesting birds. Chip Bachmann's team at the Naval research lab handles an array of hyperspectral imagery to examine ecological processes at the landscape level. Synthetic cross-scale studies have also been initiated.

Continuing Activities

We continue to monitor permanent vegetation plots (fertilized and unfertilized) and groundwater wells annually on Hog Island. In addition, we are continuing our studies on vegetation dynamics on the 'pimples' (small dunes with distinctly zoned vegetation). (Day, student Brett McMillian)

We also continue to examine *Myrica cerifera* shrub thicket dynamics and the mechanisms of shrub expansion on Hog Island. Data on new shot growth has been collected annually since 1990. We hope to extend this research effort through collaborations with Chip Bachmann's lab. We are planning to derive an HSI-based retrieval of the spatial variability of shrub thicket LAI, building on our previous efforts to measure shrub canopy light (PAR) penetration in situ to look at spatial variability in the past several years. Linking the ground-based results to remote sensing imagery will provide landscape level variations in LAI and light attenuation. These relationships, when developed, will enhance future landscape-level modeling efforts planned for the VCR. In addition, we are collaborating with John Porter and Leo Selavo on studies of spatial variations in light pattern. Our project, LUSTER (Light Under Shrub Thickets Environmental Research), involves the development, implementation and testing a wireless light sensor arrays within barrier island shrub thickets. (Young and students)

Our work is continuing to examine the potential for sensing plant stress with leaf reflectance and fluorescence characteristics. Working with *Myrica cerifera, Phragmites australis*, and *Spartina alterniflora*, we have determined that physiological changes due to stress from drought, salinity or flooding are detectable by changes in leaf optical properties well before visual signs of stress

are apparent. All three species form monospecific patches in coastal environments and we are working with John Anderson, Army Corps of Engineers ERDC laboratory, and Greg Carter, Gulf Coast Research Laboratory, to link the leaf level data with landscape-level hyperspectral imagery so that we may scale up to landscape-level patterns. (Young, student Julie Naumann)

The dynamics of small mammal populations and communities continue to be investigated across the VCR landscape. Intensive tissue collection efforts on Ship Shoal and Myrtle Islands collected materials for genetic analysis of disease and parasite status among small mammals. Stanford Feldman, Director of the Center for Comparative Medicine at UVA, continued studies of *Litomosoides scotti*, a newly described species of nematode found in previous sampling. His focus is to determine whether microfilaria would be found in one or more species of mites that might act as the intermediate host for this parasite. (Moncrief, Dueser, Porter)

New Activities

Don Young has collaborated with John Porter and Chip Bachmann in a cross-scale study to interpret broad-scale erosion and accretion patterns and the expansion and contraction of shrub thickets in response to sea level rise at the VCR. We examined the fine-scale processes of shrub recruitment and mortality within the context of the influence of ocean current and sediment transport processes on variations in island size and location. *Myrica cerifera*, a salt-intolerant species, is increasing in cover throughout the Virginia barrier islands, yet rising sea level in response to climate change is increasing erosion and reducing island area. The objective was to explain this apparent paradox using pattern-process relationships across a range of scales with a focus on ocean currents and sediment transport interacting with island characteristics at intermediate scales. The response of the Virginia barrier system to climate change and resultant sea level rise and increased storm frequency was spatially dependent. There was an overall decrease in total upland area for the Virginia barrier islands over nearly three decades, but shrub/woody area expanded. Smaller scale analyses did revealed that there was no clear pattern of change among the islands with regard to changes in island size or shrub/woody cover. These variations at the intermediate scale were a function of the interactions of island size with differences in sediment transport among the islands. However, the fine-scale process of shrub establishment, thicket development, and shrub mortality were uniform across the Virginia barrier system. A summary of this collaborative work is currently in review for a Special Feature Section on Cross-scale Interactions in the journal, *Ecosystems.*

The local scale research of Frank Day and Don Young may be extrapolated across the VCR through links with Chip Bachmann's research. Chip's Naval Research Laboratory primary effort is to investigate ecological processes at the landscape level. His team has continued to image the Virginia Coast Reserve with airborne hyperspectral imaging (HSI) sensors once or twice a year in the last three years. This extends a time series originally begun by us back in May 2000 with a commercial shot taken over just Smith Island. Since that time, we have covered the Virginia Coast Reserve islands between Smith and Parramore Islands anywhere from 1 to three times a year, whenever possible sampling across the beginning, middle, and end of the growing season. Beginning in 2004, imagery collections were expanded to include seaside mainland marsh systems extending from Fisherman's islands up to the vicinity of Wachapreague, as well as significant coverage of the shallow water lagoons bounded by the barrier islands on one side and the mainland on the other. In a few instances, imagery has also been acquired over the northern

islands in the VCR chain between Cedar and Metomkin, including adjacent lagoonal marsh systems.

To assess the relationship between forest aboveground structure and freshwater resources, surveys were completed in 2006 on Parramore Island. Data on forest biophysical structure data, temporally fine-scale freshwater level readings, and survey-grade elevations were collected in five study sites on Parramore Island. These were coupled with surveys at Assateague Island National Seashore, MD. Analyses on the Experimental Advanced Airborne Research LiDAR (EAARL) data were then begun. The raw data were processed to 3 meter horizontal resolution coverages for bare-earth and canopy top. These analyses will continue and will incorporate the coincident CIR (Color Infrared) imagery from the EAARL survey to predict more canopy variables like cover, basal area, and leaf area index. Plot data from the existing long-term upland monitoring network on Parramore will also be included. (Shugart, student Mike O'Connell)

We field-tested the efficacy of an estrogen-induced food aversion to reduce egg depredation by raccoons (*Procyon lotor*) on the Virginia barrier islands. The project goal is to design and test an aversion-based management tool that will reduce predation on the eggs of ground-nesting wildlife species on the Virginia barrier islands. We conducted both a pen trial of the efficacy of estrogen-based aversive conditioning with captive raccoons and a pilot field trial with free-ranging raccoons in summer 2006. (Moncrief, Dueser, student Joel Martin)

Information Management

During 2006 we hosted three extended (90-day) visits from researchers involved in information management in the Tawain Ecological Research Network (TERN) and three shorter visits. Chien-Wen Chen spent March-June learning how to deploy and operate wireless sensor networks. His colleague Meei-ru Jeng spent July-September developing tools to work with Ecological Metadata Lanaguage (EML), and their colleague Chi-Wen Hsiao, who visited from October to December, focused on developing tools to automate the use of EML metadata. Additionally, three other researchers made short-term visits of three weeks each. Fu-ching Yang and Yunyin Yeh, along with Ms. Jeng, made trips to discuss information management with John Walsh of the BES LTER, Emory Boose of the HFR LTER and John Campbell of the HBR LTER, and also participated in the LTER All-Scientists Meeting in Estes Park, CO in September 2006. Wen-Chih Lin also visited during November 2006 for a 2-week long introduction to establishing wireless sensor networks. VCR/LTER Information Manager, J. Porter participated in two workshops held in Taiwan during February, 2006, and served as an instructor in the OBFS information management training held at La Selva biological station in Costa Rica during October 2006

During the summer of 2006, J. Porter installed a system for monitoring the feeding locations of wading birds at Machipongo Station on the northern end of Hog Island. On an hourly or bi-hourly frequency, an automated web camera took 132 images forming a panorama around the station. These images were formed into a large mosaic for detecting where birds were feeding, with the ability to zoom from a small browse image, to a full-resolution image. A sample pan view can be seen at:
http://www.vcrlter.virginia.edu/wwwcam/machipongo/pan/2006/06/birdpan0606281030/index0606281030.html with a

sample detailed image at:
http://www.vcrlter.virginia.edu/wwwcam/machipongo/pan/2006/06/birdpan0606281030/bpanbig_0606281030_02_02.jpg.
Coupled with this system was a more detailed monitoring system that alternated with the pan pictures to focus on specific sites, capturing images at a frequency of ~1 per second for 5 minutes. This system operated in alternating hours with the panning system. An example "burst" image sequence can be viewed with an animation viewer at:
http://www.vcrlter.virginia.edu/wwwcam/machipongo/burst/2006/06/Amie40606281535/index.html . These images will be used to identify intensive study sites for future wading bird researchers and to provide inter-year comparisons of tidal pond use by wading birds.

Network Analysis

We extended an international collaboration with Pierluigi Viaroli from the University of Parma by comparing nitrogen cycling between Hog Island Lagoon and the Sacca di Goro. We focused on the effects of primary producer growth form and eutrophication on N cycling (Voss et al. 2005). In support of previous studies (Christian et al. 1996), the dominance of phytoplankton in primary production was a significant determinant of the amount of internal recycling. Finally, we conducted a preliminary analysis of the social network of the LTER program. This was done in conjunction with Bob Waide, Caleb Hickman and James Brunt at the Network Office and Jeff Johnson at East Carolina University. We began to examine the pattern of connections between sites through joint publishing. This led to a cross-site mini-grant to extend the work.

FINDINGS

Watersheds and Lagoons

Watershed studies

Our work in Cobb Mill Creek indicates that the groundwater-surface water interface (GSI) at streams is a potential barrier for groundwater NO_3^- loading from non-point diffuse sources. To investigate the establishment and migration of redox sequences along the flowpath and the subsequent impact on NO_3^- fate, intact cores of sediments from Cobb Mill Creek, VA, were used to trace the evolution of NO_3^-. A macroscopic multi-species reactive transport model based on multiple Monod kinetics was developed to interpret the experimental results. The carbon source was simulated by first-order kinetic dissolution-adsorption kinetics. Sensitivity analysis and parameter estimation was used to determine a set of parameters that best describe the experimental data for one column. The calibrated model successfully replicated the spatial profiles of nitrate under both steady and transient conditions in the other column operated under different conditions. A dimensionless form of the model was used to examine how coupled processes operative within the GSI could be understood in terms of a Peclet number and Damkohler numbers. (Gu et al. submitted)

The use of small seepage meters in the stream bed has allowed a crude mapping of groundwater discharge into the stream. Seepage into the stream from the groundwater is highly heterogeneous with seepage rates ranging from 1-5 mL hr^{-1} 50 cm^2 to > 50 mL hr^{-1} 50 cm^2. The high seepage rates partially explain the concentrations of NO_3^- in the streamwater, as during rapid flow through the biologically active zone at the groundwater-surface water interface reduces the retention time below that necessary to remove all of the NO_3^-. This finding is supported by the modeling described above in which Damkholer numbers characterize the potential for NO_3^- removal from the discharging groundwater, and the observation that water collected from seepage meters where the discharge was highest contained more NO_3^- than in water from where the discharge was low. (Flewelling et al., in preparation).

It is still unclear, however, what portion of the reduction in nitrate concentration is due to denitrification and what portion is due to mixing of ground water end-members. Using a simple quantitative approach that incorporates the mixing of ground water end members and allows us to separate the effects of ground water travel time and reaction rate coefficients on the magnitude of denitrification, we show that denitrification in streambed sediments removes ~ 50 % of nitrate in ground water before it enters the stream and that denitrification is strongly dependent upon ground water travel time through nitrate reduction zones in the streambed as observed in the seepage meter study. We assert that convergent mixing of ground water in the near-stream zone, denitrification reaction rates, and ground water travel time through active reduction zones in the subsurface are critically important considerations when quantifying nitrate loss to denitrification. A simple end-member mixing model coupled to a first-order kinetic model of denitrification provides a reasonable quantitative description of nitrate loss in the streambed of Cobb Mill Creek. Statistical analysis shows that ground water travel time has a larger effect on nitrate removal than denitrification reaction rates, suggesting that hydrological differences between

catchments could be more important than shifts in the distribution of denitrification rates. (Flewelling et al, in prep)

Our watershed nutrient loading surveys were conducted in watersheds ranging in size from 213 ha to 1971 ha on 7 dates between March 2005 and October 2006. Discharge values varied spatially among streams by as much as a factor of 23 and temporally for a single stream up to a factor of 14. Nitrate concentrations ranged from 0.14 mg/L to 9.4 mg/L. On six dates, the two streams with the lowest nitrate concentrations were those that drained watersheds with the greatest fraction of forested land as compared with cropland and developed land. Estimated annual nitrate loadings to the lagoons based on individual surveys ranged from 5.2×10^4 kg to 2.2×10^5 kg, varying primarily due to seasonal streamflow fluctuations. Comparisons between nitrogen loading predictions made using measured stream nitrate concentration values and spatially-averaged concentration values in individual watersheds differed by less than 9% in all instances, indicating that stream discharge is a better predictor for overall nitrate loading than specific nitrate concentration.

Nutrient cycling and trophic relationships

The results from the Gust erosion chamber studies show an increased nutrient flux from the sediment to the water column under increased shear stress at two sites in Hog Island Bay and increased loss of nitrogen at the site with the highest sediment organic content. Fluxes of nutrients, sediment and microalgae all show seasonal and inter-annual variation as well as site variation. We are now working to link this variation to sediment characteristics, primary productivity and preceding weather conditions. These results will then be used to model these processes in the lagoon.

The mesocosm studies of sediment-water column metabolism and nutrient cycling simulating the high-nutrient Isle of Wight Bay and low-nutrient Hog Island Bay suggest that there are substantial differences between the two types of systems. Metabolism in the eutrophic lagoon was more heterotrophic, and there was greater uptake of ammonium by the sediments, likely due to enhanced coupled nitrification-denitrificaiton rates. Although the addition of macroalgae and sediment resuspension did not have a statistically significant effect on sediment metabolism, the addition of macroalgal organic matter to the sediment resulted in the increased ammonium uptake by the sediments. The mesocosm experiments also showed that benthic microalgae intercepted fluxes of remineralized ammonium from sediments and contributed to the net autotrophic metabolism observed under ambient light conditions. Mesocosms held in the dark showed net heterotrophic metabolism and fluxes of ammonium from the sediment to the water column. Coupled nitrification-denitrification was detected only in mesocosms held continuously in the dark, suggesting that benthic microalgae effectively outcompeted nitrifying and denitrifying bacteria for substrate. We observed high 15N and 13C enrichment in bulk sediment POM in both light and dark treatments, which indicates that bacterial incorporation, cycling, and perhaps immobilization occurred even in the absence of benthic autotrophs. The compound-specific and bacterial biomarker isotope analysis will be done in collaboration with Bart Veuger and Jack Middelburg at the Netherlands Institute of Ecology.

Seagrass recolonization

In restored seagrass beds in South Bay (2-4 years old), bulk isotope analyses of consumers indicate a diminished signal coming from seagrasses. There are no species feeding solely on *Z. marina*. However, a mixture of food sources that includes a small proportion of seagrass is possible. Combinations of primary producers with a range of proportions are seen to contribute a portion of a number of consumer diets. Isotope differences were found between tissues of fish captured in the restored seagrass sites and those from algae sites. Atlantic silversides, silver perch, bay anchovies, and spot collected in late summer in seagrass plots have distinct $\delta^{13}C$ and $\delta^{34}S$ isotope values compared to individuals of the same species collected in algae plots. The carbon isotopic values of fish collected in algae sites were consistently more depleted relative to fish collected in seagrass sites for all four species. The carbon isotope difference is likely indicative of distinctly different dietary carbon source to organisms at these sites. With the exception of the bay anchovy, the sulfur isotope values of the fish were also depleted in algae sites relative to seagrass plots.

Several explanations may account for the diminished contribution from seagrasses to the higher trophic levels of the food web. First, it is likely that seagrasses may be a small but necessary component of consumer diets. Second, tissue isotope compositions turnover slowly, especially for larger animals. Fish captured within the plots had migrated there recently, and insufficient time may have passed for the seagrass signal to show up in bulk tissue samples. Third, a number of fish species may only rely on seagrass primary production for specific time periods owing to changes in feeding strategies over the course of a season or over a lifetime. Fourth, seagrass may enter the food chain through the detrital pathway, and the signal may be altered by bacterial reworking of the tissues. *Zostera marina* detritus may be too refractory for nutrition and may require chemical modification by the microbial community prior to utilization by macrofauna. Some of the data suggest changes in diet preferences with age. A linear correlation was found between bulk tissue $\delta^{13}C$ and fish length for several species during the sampling period. The phenomenon was recorded for Atlantic silversides and spot captured in algae sites, as well as pinfish and pigfish captured in seagrass plots. The larger, presumably older silversides and spot are isotopically depleted relative to smaller, more juvenile fish while the reverse is true for pinfish and pigfish. The isotope distinctions between monthly samples are most clear among the algae sites, although it was also noted in seagrass plots.

Intertidal marshes and mudflats:

Marsh accretion and disturbance

Rates of marsh elevation change are as variable among plant zones within a single marsh (2.1 mm $yr^{-1}$to 7.4 mm yr^{-1}; high and low marsh, respectively) as they are among marshes within similar plant zones (1.4 mm yr^{-1} to 7.4 mm yr^{-1}; lagoon and mainland, respectively). Our observations suggest that lagoon marshes are less sustainable to loss at the current rate of relative sea-level rise. Also, the processes that contribute to the land surface change are variable within a given marsh. For example, accretion is not correlated with changes in land surface elevation in either mainland or lagoon marshes. In our primary mainland marsh site, Phillips Creek, land

surface elevation change in the low marsh is correlated with the depth to the groundwater surface, and in the high and mid marsh is correlated with thickness of the root zone. The high marsh has organic soils and maintains itself by biogenic accretion in the face of rising sea level, whereas accretion in the low marsh, with more mineral soils, is more dependent on sediment deposition (Appolone 2000: Blum and Christian 2004). The transition from high marsh to low marsh involves major changes in species, soil properties and ecosystem functioning (Roberts 2000; Buck 2001), and nitrogen cycling becomes more open during this process (Thomas and Christian 2001).

Tests of inundation-disturbance interactions on Phillips Creek marsh have shown that high marsh plants have considerable resilience to experimentally enhanced inundation, but respond differently to disturbance by wrack deposition (Tolley and Christian 1999; Brinson and Christian 1999; Roberts 2000; Buck 2001; Miller et al. 2001). Wrack disturbance creates habitat heterogeneity over the short term by removing plant cover and altering a number of ecosystem processes (Tolley and Christian 1999), and succession usually results in recovery to the same state. We assume that the resilience to change in plant community structure after disturbance is in part because a threshold of state change was not reached. Deer trails are another agent of disturbance that causes different responses among marsh ecosystem states (Keusenkothen and Christian 2004). Finally, the stresses of hypoxia and drought cause major shifts in the food webs of marsh ponds, as assessed by network analysis models (Dame 2005).

Marsh die back

Although the cause of the observed die back could not be determined directly, several interesting patterns emerged from the *in situ* studies. In areas where plants had died, ground cover changed seasonally with dominance of algal mats, purple sulfur bacteria, or bare mud (Fig. 2). In-growth of plants into the area was slow. Pore water sulfide concentrations were often not different in and out of the die-back area, but significantly higher concentrations were found in the die back at times that may have been critical to plant growth.

Fig. 2. Area of die back in Phillips Creek Marsh

One hypothesis is that Hurricane Isabel caused sedimentation at the edge of the marsh (evidenced in SET data) that caused a restriction in water exchange in the low marsh. This seems to have led to increased retention of water in the area and decreased regrowth and death under the altered hydroperiod. There was some evidence of a loss in elevation where plants were absent.

The dieback phenomenon may be an indication of how disturbance can promote state change, or at least instability within the marsh.

The role of fungi in tidal marshes

Analysis of samples, collected in 2004 and 2
component of the decomposer community. I
the structure of the fungal community is correlated with differences in soil organic matter content and the composition of the plant community. The patterns of fungal abundance and community composition observed may reflect differences in fungal community activity. How fungi contribute to soil surface elevation changes through their effect on soil structure and organic matter accumulation are questions that will be addressed in the future.

Sea-level rise

The relative sea level trend at Atlantic City, NJ, and Kiptopeke, VA, based on monthly mean sea level from NOAA's long-term tide gauges is shown in Fig. 3. Tidal elevation is relative to the 1983-2001 mean sea level datum established by the NOAA Center for Operational Oceanographic Products and Services (CO-OPS). The records from Atlantic City and Kiptopeke show similar trends (correlation coefficient r=0.94) with rates of sea level rise of 3.8 - 4.0 mm/y, indicating that this region of the mid-Atlantic coast has experienced comparable and generally synchronous variations in sea level over the last 50 or more years.

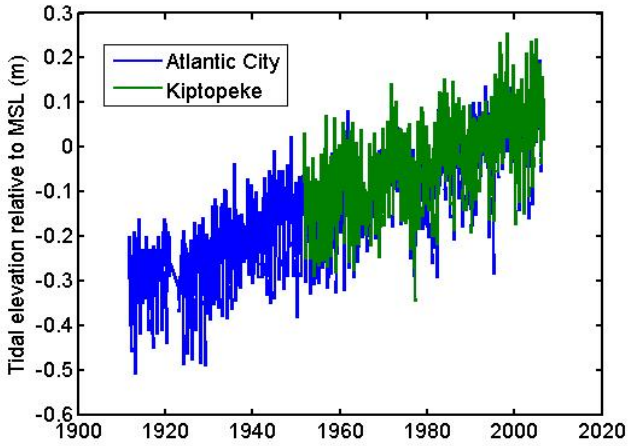

Fig. 3. Relative sea-level rise for mid-Atlantic region.

Non-native Phragmites australis

Results on the *Phragmites australis* eco-physiology study demonstrate that non-native *Phragmites australis* has a greater photosynthetic potential than the native type. Finally, the 3 year study conducted with land managers (Natural Heritage, DCR) at Kipotopeke State Park demonstrated that the newly approved herbicide imazapyr, under the trade name, Habitat, does a significantly better job in eradicating *Phragmites australis.* This information is critical to land managers dealing with *Phragmites australis.*

Wading birds

Our work on wading bird foraging and habitat use in two areas of the LTER, a semi-urbanized setting near Chincoteague VA and the relatively pristine barrier island site at Hog Island VA, has revealed major differences in social tendencies in foraging tactics, habitat specializations, and feeding efficiencies. Snowy Egrets were the most social, and acted as attractors to other species.

As predicted, the more generalized habitat foragers (Great and Snowy Egrets) had lower average feeding efficiencies in particular habitats such as tide pools than did more specialized feeders in those habitats (e.g. Little Blue Herons). The species with the lowest average feeding efficiency, Great Egret, apparently spends longer periods feeding, and takes a much larger range of prey sizes than do the smaller species. We also found significant dependence by all the wading bird species (5 primary species) on the manmade impoundments at the Chincoteague National Wildlife Refuge, especially in late summer when young birds are learning to forage.

Barrier Islands:

Vegetation dynamcs

On the island chronosequence, results from the permanent plots suggested more intense negative effects of competition in nitrogen-fertilized plots. Greater cover of *Ammophila* in fertilized plots indicates *Ammophila* is in a better position to compete for light with enhanced aboveground dominance. Diversity was lower in fertilized plots on all but the dune formed in 1967 and diversity decreased most dramatically in fertilized plots on the oldest dune. The increase in total density with fertilization as diversity decreased, coupled with the shifting composition of *Ammophila* and other dominants, appears to support the interspecific competitive exclusion hypothesis. In addition, aboveground biomass declined significantly in control and fertilized plots from 1991 to 2000, while belowground biomass exhibited a significant increase in both control and fertilized plots. In particular, biomass of standing dead, litter, and live roots, and nitrogen standing crop in all plant components were substantially greater in fertilized plots in 2000. Nitrogen concentrations were higher in the litter in the fertilized plots. These data suggest that the retention of nitrogen within the fertilized plots has been primarily facilitated by increased biomass, predominantly in roots, and increased pools of plant litter.

Environmental data, such as depth to water table, height above marsh, aspect, soil texture, and total C:N are being used with ordination techniques, primarily canonical correspondence analysis (CCA), have been collected on the 'pimples' (small dunes with distinctly zoned vegetation)to quantify their relationship with species distribution patterns. Preliminary analyses suggest a strong influence of elevation and water availability on species distribution. Changes in the positions of the three free surfaces appear to be the primary influence on plant community composition. Addition of more variables, such as nutrients, will help explain finer differences in species composition.

Data on *Myrica cerifera* shrub thicket dynamics and the mechanisms of shrub expansion on Hog Island show significant year-to-year variations dependent primarily on summer precipitation patterns (Fig. 4). There are spatial variations in growth patterns related to proximity to the ocean and the age of the thickets. Doctoral student Steven Brantley quantified spatial variations in shrub leaf area index and litter production. Both LAI and litter production were greatest in shrub leaf area index and litter production. LAI varied from a high of 13 for young, developing thickets behind the ocean side primary dune, to a low of 6 for the oldest thickets near the bayside of the island where the canopy was breaking up. Similarly, litter production varied from 890 g m^{-2} y^{-1} for young thicket to 377 g m^{-2} s^{-1} for the oldest thickets. The LAI and litter production

values are among the first to be reported for shrubs and are exceeded only by tropical forests. Light attenuation via high LAI and a thick litter layer may be mechanisms that contribute to shrub thicket expansion by excluding grasses. A summary report of the LAI shrub data are currently in press for publication in *Ecology*.

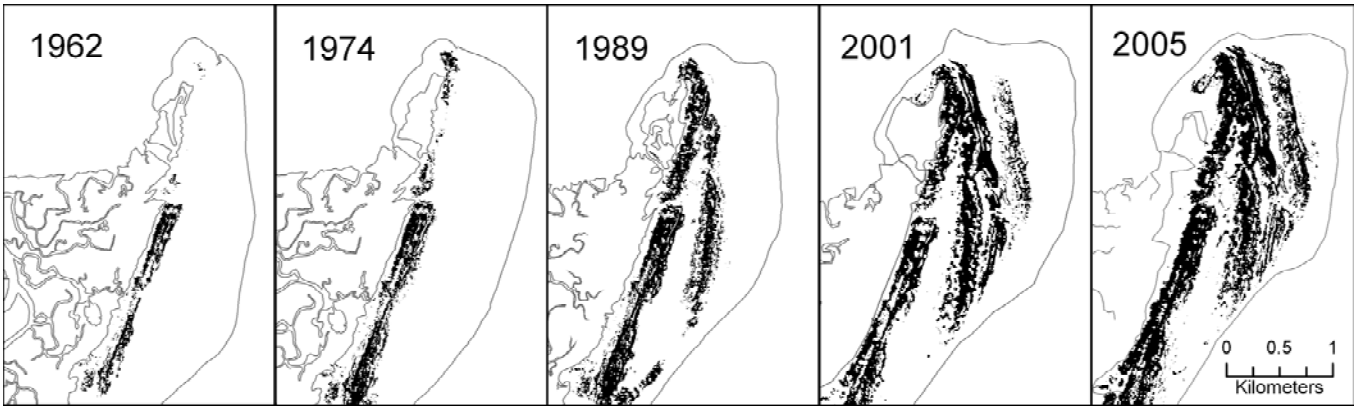

Fig. 4. Change in the extent of shrub cover on the northern third of Hog Island from 1962 to 2005.

Mammal populations

Small mammal trapping on Myrtle and Ship Shoal islands showed that robust populations of rice rats (*Oryzomys palustris*) continue to exist on these small, extremely low-lying islands. A small population of meadow voles (*Microtus pennsylvanicus*) continues to persist on Myrtle Island, despite habitats that have eroded to a large extent. However, the population of house mice (*Mus musculus*), present on Myrtle Island prior to Hurricane Isabel in 2003, has disappeared from Myrtle Island and remained absent during 2006 trapping sessions.

The collaborative work with Stanford Feldman (Director of the Center for Comparative Medicine at UVA) showed the presence of the newly described nematode *Litomosoides scotti* in both species tested, suggesting that they may act as the intermediate host for this parasite. In addition, we did additional screening to determine the specific types of hantaviruses found in these isolated populations. Unfortunately genetic probes successfully used on other species have not yet worked on rice rats (*Oryzomys palustris*), however, there are other alternatives that we are continuing to explore.

From our initial work on the use of an aversion-based management tool to reduce predation on ground-nesting wildlife, it appears that: (1) Control animals fed non-treated eggs have an almost infinite capacity for egg consumption, (2) Raccoons do indeed develop an aversion to egg consumption following ingestion of eggs injected with oral estrogen, and (3) Oral estrogen can be effectively deployed through injection in Japanese Quail eggs. The pilot field trial was run on the bird-free Skidmore Island section of Eastern Shore of Virginia National Wildlife Refuge. Ten mixed-age raccoons were captured on this small (44 ha) island, for a population density of approximately ~1 raccoon per 4 ha overall (~1 per ha upland). Each individual was fitted with a large numbered and color-coded tag in each ear (for photographic identification) and a radio collar. We established six artificial colonies, and monitored depredation events with two automatic cameras per colony. We ran a 13-day treatment period during which estrogen-injected

eggs were deployed in the colonies, and a subsequent 13-day challenge period during which non-treated eggs were deployed in the colonies and treated ("barrier") eggs were placed outside the colonies. All 10 raccoons became averse to egg consumption within 2-4 days. This aversion was persistent for a period of at least 26 days. The treatment effect was significant for all six colonies: the mean number of treated eggs damaged per day during the treatment phase was greater than the mean number of non-treated eggs damaged per day during the challenge phase. Raccoons could not distinguish treated from non-treated eggs: during the challenge phase the mean number of non-treated eggs damaged per day for all colonies combined. Averted raccoons altered their foraging behavior to visit "colony" areas less frequently and to visit fewer colonies, and buffer eggs provided reinforcement of the aversion for the occasional raccoon that chose to sample. The estrogen aversion was real, it influenced the foraging activity of individual raccoons, and it lasted long enough to bridge the avian egg-laying period. This work has set the stage for a field-scale application of estrogen-induced aversive conditioning to reduce raccoon predation on the nests of ground-nesting species.

Network Analysis:

Several advances were made in our studies of networks. Our efforts on promoting the importance of understanding uncertainty in foodweb network studies were advanced by publication of the first paper from James Dame's dissertation (Dame and Christian 2006). The paper was a feature article of the magazine.