

Final Report for Period: 11/2006 - 10/2007**Submitted on:** 01/30/2008**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: Interrelated 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 Coastal 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, *Orchelimum 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, Jaelyn

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 invasive populations of fennel (*Foeniculum vulgare*) and Japanese honeysuckle (*Lonicera japonica*) in a 100-acre old field. Invasive 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. They are involved in developing a management plan 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 conditions.) The consortium is coordinated by Penn State (Rob Brooks, PI) and includes other institutions such as Virginia Institute of Marine Science, Smithsonian Environmental 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 invasive 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 invasion 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 Meteorological 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 emissions 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.vcr.lter.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 preservation of soil organic matter in wetlands. This also involved scientists from the LTER network 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. They are involved in developing a management plan 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, pyrolysis 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 Witwatersrand, South Africa; Robert Swap, PI, SAFARI 2000 (Southern Africa Regional Science Initiative), Department of Environmental Sciences, University of Virginia; Hank Shugart, Leader, Global Climate Change Program, Department of Environmental Sciences, University of Virginia and participating 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 Witwatersrand; 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 Siteo 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:

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

-- 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. (Anderson, McGlathery)

-- Steve Novak (Boise State University) and Greg Plunkett (VCU) on an integrated project (genetics, population biology, and physiological ecology) to assess the invasion potential of *Phragmites australis* on the Eastern Shore of Virginia. (Young)

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

-- Carl Friedrichs, Virginia Institute of Marine Sciences. Collaboration on development and testing of hydrodynamic model for Hog Island Bay, including modeling of particle transport and residence times in Hog Island Bay (McGlathery, Anderson)

-- 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)

-- Raymond Dueser (Utah State University), Barry Truit (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)

-- 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 through our 'Schoolyard LTER' program (see 'Contributions to Education and Human Resources' below) in the area of field measurements using state-of-the-art equipment. This involves classroom teaching on the part of VCR scientists, field demonstrations and WWW-based communications.

The VCR/LTER continues its efforts in the area of graduate education. During 2000-2006 nine Ph.D and twenty M.S. students completed their thesis work at the VCR/LTER.

Some specific training and development activities:

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 methodologies used in U.S. LTER Information Management.

Outreach Activities:

The Schoolyard LTER program continues to be a meaningful way of increasing future public understanding, and now serves elementary, middle and high schools in Northampton County, VA. This program involved over 1,790 students across all educational levels during the period of this grant.

During the past years 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.

PI Stephen Macko continues to be active in African ILTER efforts. He, and PIs Porter, Shugart, Zieman, 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. They 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 12,000 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 biodiversity database, or extensive graphical output, such as our meteorological 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 650,000 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>.

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>.

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 community dynamics and biogeochemical cycling in coastal barrier systems (island uplands, intertidal marshes, subtidal bays), nutrient transport via groundwater in coastal watersheds, and determinants of faunal biogeography in an island system.

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; and 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 were performed jointly by Iris Anderson, VIMS, and Karen McGlathery, University of Virginia.

Our 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.

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 accretion 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 among 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 prescribed 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 our 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 maritime forest.

Nineteen 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 parasitism and disease in overall vertebrate population dynamics.

At the global scale, PI's Hayden and Fuentes worked, 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 of network ecology. Social scientists have also used network analysis, and one of our accomplishments 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 modeling. (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 2000-2006, we have brought LTER research activities into the classroom had extensive contact with more than 950 students in grades 9-12, 600 students in grades 6-9 and 240 students in grades K-6.

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 used distributional data collected from the multi-island surveys in a Teacher Re-Certification class that she teaches at 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 were 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 distributed it through Teacher Recertification courses and workshops.

PI John Porter contributed to training efforts in the area of Ecoinformatics. He participated 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, 2003, 2004, 2005 and 2006. 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. During the period March 2001 through December 2006, our web site has distributed 847 gigabytes of information to over 668,000 different client computers. The site averaged 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, between 10/1/2000 and 12/31/2006. Of the 121 requests in 2006, 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, we were able to provide and upgrade water quality and soil testing kits, and 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.(McGlathery, 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)

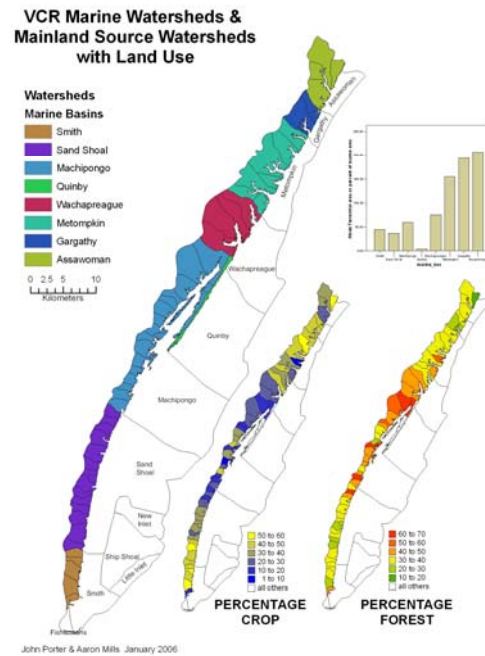
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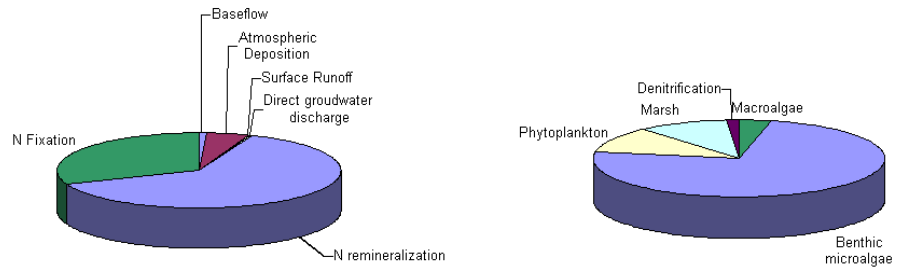
Lagoons:

Our research in this area focuses on the linkage between watershed land use and the impact of nutrient loading on the lagoons, and on the return of the seagrass, *Zostera marina* (eelgrass) as the “foundation” species (sensu Bruno and Bertness 2001). We study the groundwater free surface, which delivers nutrients to the lagoons, and the parallel land (lagoon bottom) and sea level free surfaces, which determine water depth and the tidally-driven exchange with the coastal ocean. Our studies relate nutrient inputs to processing by primary producers and consumers and to physical transport within the lagoon. Our models of hydrodynamics and sediment resuspension set the stage for the planned large-scale recolonization of eelgrass in Hog Island Bay.

Watershed nutrient inputs: Since there are no large rivers that feed into VCR coastal lagoons, nutrient inputs from the watersheds are largely via groundwater and atmospheric deposition. Groundwater enters the VCR lagoons either through small tidal creeks that drain each of the watersheds or directly through or under fringing marshes. We delineated the landscape into 54 small watersheds (0.2 – 19.7 km²), and monitored 15 of the tidal creeks to calculate baseflow nutrient loading. We found that land cover (forest, developed land) in the watershed explained 86% of the baseflow NO₃⁻ loading rate, and that poultry operations in the northern region of the VCR may impact lagoonal water quality (Stanhope 2003). We were surprised to find that overall baseflow nutrient loading rates to the VCR lagoons were low compared to other lagoons, despite large variations in agricultural land use (Chauhan and Mills 2002; Mills et al. 2002; Stanhope 2003). This is in part due to very high removal of NO₃⁻ from groundwater discharging to the streams by denitrification in a narrow band of sediments and bank materials (Flewelling et al. in prep).



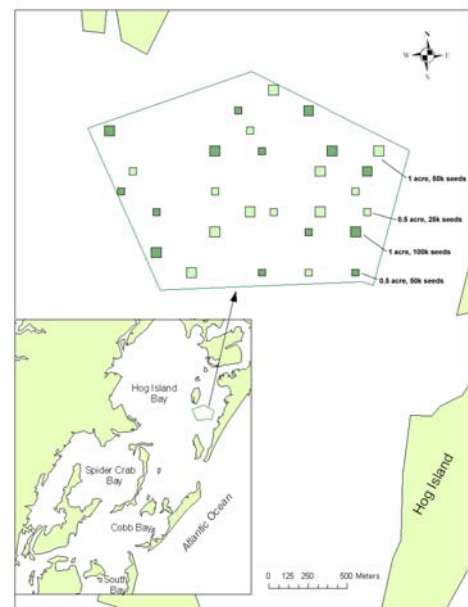
Lagoon nutrient dynamics: We constructed a nitrogen budget for Hog Island Bay, which indicated that sources of groundwater and atmospheric deposition accounted for a small percentage of the total nitrogen demand of the primary producers in the lagoon. The most



important nitrogen source was remineralization in the sediments (Anderson et al., in prep.), indicating that high rates of production were supported mostly by efficient internal nutrient cycling. In the absence of seagrass, benthic algae (micro and macro) are the dominant primary producers (McGlathery et al. 2001), and control benthic-pelagic nutrient coupling (Anderson et al. 2003). In particular, nitrogen uptake by benthic algae suppresses denitrification to negligible rates and prevents the efflux of mineralized nitrogen from the sediment to the water column (Havens et al., 2001; Tyler et al. 2001, 2003; Anderson et al. 2003).`

Hydrodynamics: With additional funding from USDA, we developed a finite element hydrodynamic model for Hog Island Bay (Fugate et al. 2006). The model uses wind and tidal forcing to calculate circulation and transport in the lagoon. It shows that local water residence time can vary at least an order of magnitude in different parts of the system, from 1 day near the inlet to as much as 24 days near the mainland (median 16 days).

Seagrass recolonization: We used the hydrodynamic model together with wave and resuspension models to determine the spatial and temporal patterns of sediment resuspension and light availability in Hog Island Bay (Lawson 2004; Lawson et al., in review). High turbidity events were episodic and wind driven. Based on the modeled average light availability at the sediment surface, 65-87% of the lagoon bottom is suitable for seagrass recolonization (Lawson 2004; Lawson et al., in review). These data were used to justify a 509-acre “set-aside” for seagrass restoration in collaboration with colleagues at the Virginia Institute of Marine Sciences. In fall 2006, 1.5 million seagrass seeds were broadcast into this set-aside in a 2 x 2 factorial design with 2 densities of seeds (50,000 and 100,000 seeds per acre) and two plot sizes (0.5 and 1.0 acre). There were 7 replicates of each treatment combination. Approximately 7-12% of the seeds germinated, which is typical of a ‘successful’ year using this hand-broadcast technique.

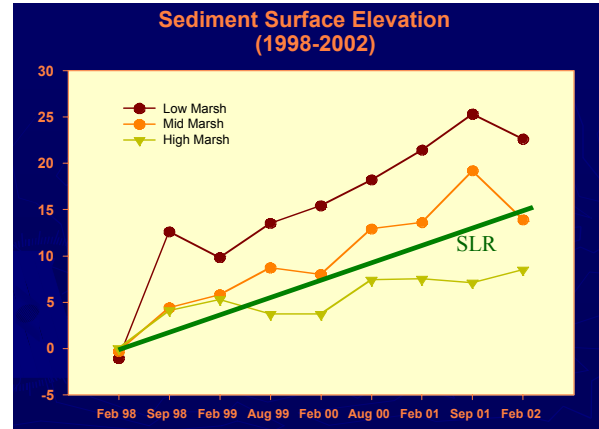


Tidal Marshes:

Research in the VCR tidal marshes focuses on the oscillatory free surface of sea level and its intersection with the sloping land and groundwater free surfaces, and on how the interactions of these surfaces results in ecological state change. We also examine the interplay between the biological and physical processes and the geomorphology within states. We continue to focus our efforts 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 (Silliman et al. 2005).

Marsh accretion and sea-level rise:

Surface elevation tables (SET) have been used to measure the land free surface in mainland marshes since 1997 and in lagoon marshes since 1999. Rates of 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 (3.5 - 3.9 mm yr⁻¹, Erwin et al. 2004; in press) than mainland marshes (Blum and Christian 2004). Also, the processes that contribute to the land surface change are variable within a given marsh. For example, accretion (measured as accumulation of materials over a feldspar marker horizon) is not correlated with changes in land surface elevation in either mainland or lagoon marshes. In our primary mainland marsh site, Phillips Creek, the land surface elevation changes 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.



With sea-level rise, salt marshes along the mainland edge have the potential to transgress inland, while eroding seaward for lack of adequate sediment supply (Christian et al. 2000). The actual changes and the rates of change depend on the frequency and types of disturbances in the various ecosystem states (Keusenkothen and Christian 2004). As transgression occurs, forest is replaced with high marsh, high marsh with low marsh, and low marsh with open water. 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).

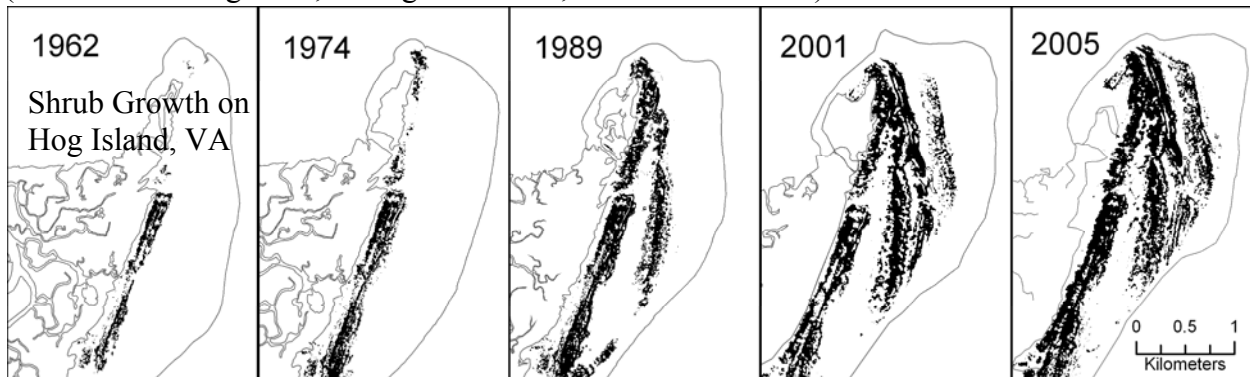
Mechanisms of state change: We have focused on the responses of vegetation to disturbance in the context of ecogeomorphology at the Phillips Creek marsh (Keusenkothen and Christian 2004). Specifically, we have tested inundation-disturbance interactions, and have shown that high marsh plants have considerable 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).

Barrier Islands:

Our activities in the terrestrial portions of the VCR landscape focus on the relationship between the groundwater and land free surfaces, and how this relationship influences plant community structure, and patterns of nutrient cycling and primary production. Storm disturbance, sea-level rise and nitrogen enrichment are all drivers that influence these free surfaces and biotic structure. We are finding emergent patterns between plant community structure, the abundance of predatory mammals, and nesting patterns of colonial waterbirds.

Patch to landscape scale patterns in island vegetation: Processes operating at the scale of the barrier island complex (climate, storm frequency), the island scale (erosion and accretion) and local scale (seed rain, soil development, herbivory) can each play a role in determining the pattern and dynamics of vegetation. *Myrica* shrub thickets are the dominant woody community on most of the VCR barrier islands (Young 1992; Young et al. 1995a). *Myrica* is intolerant of salinity so the thickets represent relatively protected or stable positions on the island landscape (Sande and Young 1992; Young et al. 1992; Tolliver et al 1997). To determine how shrub



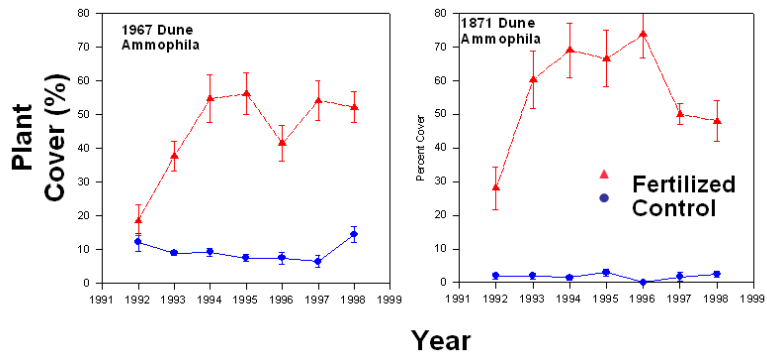
thicket distribution may be responding to the effects of sea-level rise at the scale of the entire barrier island complex, at the island scale and within individual islands, we analyzed aerial photos, maps, and hyperspectral imagery to document spatial changes. At the scale of an individual island, shrub thickets have expanded by more than 500% over the past 50 years on the north end of Hog Island, which continues to accrete at approximately 20 m yr⁻¹. Decadal comparisons indicate that several islands have shown dramatic shrub expansion, often preceded by a lag phase after initial colonization. In contrast, shrub area has decreased on Parramore Island, which has been eroding for nearly a century, and on Smith Island, shrub cover has remained relatively static. Despite general predictions of coastal erosion resulting from climate-driven sea-level rise, the islands within the Virginia barrier complex display a heterogeneous response, and this is reflected in the dynamics of the shrub thicket distribution patterns (Young et al. in prep).

Vegetation patterns and nutrient dynamics: Interactions between the changes in the positions of free surfaces and nitrogen fertilization influence plant community composition on the barrier islands (Day et al. 2004). Our long-term fertilization experiments on the upland

chronosequence indicate that retention of nitrogen within fertilized plots is primarily facilitated by increased biomass, predominantly in roots, and larger pools of plant litter (Heyel and Day, in press). Fertilization alters species dominance patterns and increases density (favoring *Ammophila* sp.), but decreases overall diversity.

Seed dispersal: Positive interactions between the juniper (*Juniperus virginiana*) and woody seedlings may influence succession trends on

the VCR landscape. The effect of *J. virginiana* on the recruitment and distribution of woody seedlings may be passive, through the non-random distribution of fleshy seeds by perching birds, or active, through increased seedling survival due to *J. virginiana* initiated alterations in microclimate and edaphic factors (Joy and Young 2002).



Dynamics of faunal populations: Several field studies on Hog Island have determined that insect herbivores have a minimal effect on aboveground primary production on the uplands of the VCR barrier islands (Barimo and Young 2002; Fuest 2005; Fuest et al. in prep). Long-term studies of vertebrate populations on the VCR were initiated in 1974 and focus on the interaction of island size and morphology, vegetation cover, and predator-prey interactions (Dueser and Brown 1980; Brannon et al. 2001). At the landscape scale, radiotracking and genetic analyses have been used to identify probable dispersal routes for raccoons (*Procyon lotor*) between islands (Dueser et al., in prep.). The spread of predators (i.e., raccoons, foxes) on the islands has been linked to a dramatic decline in beach nesting birds (Erwin et al. 2001). Also, predator removal experiments showed significant increases in bird breeding success rates (up to 182%) on islands where predators were removed (Dueser et al., in prep.). Loss of marsh habitat associated with sea-level rise also is an important factor causing reduced populations of nesting birds (Erwin et al. 2004). Experimentally manipulating marsh habitats by elevating nesting substrates increased nesting success, but it was primarily social rather than physical factors that influenced nest-site preferences (Rounds et al. 2004).

Synthesis Activities

At the site level, B. Hayden compiled literature estimates of eustatic sea-level rise and land-surface uplift and subsidence over the last 20,000 years. The time sequences show that up until roughly 8,000 years ago, crustal uplift and eustatic sea-level rise were at similar rates, resulting in a stable sea level during that period. Since then, there has been a net rise in relative sea level, although for a brief period in the last 2000 years the relative sea level actually declined. Current rates of relative sea-level rise for the VCR range from 3.5 to 3.9 mm y⁻¹, the highest rates found on the east coast of the U. S. Hayden also compiled a long-term record of storms that shows that we are now in a period of relatively high storm frequencies, comparable to the 1960's. Interestingly, the 1930's had a relatively modest number of storms, even though

several major hurricanes hit the Virginia coast during this period, including the one that decimated the seagrasses in the VCR lagoons.

Six of the VCR PIs have NSF-funded Biocomplexity projects that integrate with, and expand on, VCR LTER research: Nonlinear Feedbacks in Coupled Elemental Cycles During Eutrophication of Shallow Coastal Ecosystems (McGlathery, Berg), Networking the “Invisible Colleges”: Application of Network Theory to Biocomplexity (Christian), and Comparative Stability and Resiliency of Ecosystems: Five centuries of Human Interactions with the Environment on the Eastern Shore of Virginia (Shugart, Porter and Macko). Involvement in these projects extends our VCR research into new geographic regions and into the social science realm. L. Blum and S. Fagherazzi edited a book on the “Ecogeomorphology of Tidal Marshes” (published by the American Geophysical Union). K. McGlathery and I. Anderson wrote several synthesis chapters on nutrient cycling in coastal lagoons and the regulatory role of benthic primary producers (McGlathery 2001; McGlathery et al. 2005; McGlathery and Sundback 2005; McGlathery et al., in review). D. Young contributed a chapter on measuring primary production in shrublands to the LTER synthesis volume “Principles and standards for measuring net primary production.” Based on collaborations begun at the 2003 All-Scientists Meeting (ASM), Porter et al. (2005) (BioScience cover story) detailed how wireless networking technologies are expanding the basis of data collection in ecology, and how use of such technology can increase.

We have been strong participants in LTER network information management (Porter 2000, Porter et al. 2005). J. Porter has helped teach courses on databases, with annual participation in RDIFS/RCN training for field stations since 2002, and at international LTER workshops (Southern Africa, 2002; China, 2005, Taiwan 2006). Additionally, he has been involved in >20 workshops during 2001-2006. During 2005-2006 we hosted three extended visits of 3 months each by information managers from the Taiwan Ecological Research Network, and participated in two international information management workshops for the East Asia Pacific region of International LTER. These intensive interactions with Taiwan led to the production of tools that use Ecological Metadata Language documents to semi-automate analyses.

Activities

During Virginia Coast Reserve Long-Term Ecological Research IV (VCR/LTER IV) we focused activities around our core hypothesis: **that ecosystem, landscape and land use patterns within terrestrial-marine watersheds are controlled by the vertical positions of the land, sea, and of the fresh groundwater table surfaces.** This builds on a progression of ecological research by the VCR/LTER. From 1986 to 1992 we focused primarily on the geophysical controls that underlie the ecology of the barrier island/lagoon system. From 1992 to 2000, our focus was primarily on the role of free surfaces in driving ecological state change. During the 2000-2007 period we added a new emphasis on a hypsometric prospective and on linking the mainland watersheds to the associated lagoon, marsh and island systems.

During the grant period we also observed several “unusual events” that led to additional studies. These included a marsh die-off in a portion of the Phillips Creek Marsh study area in the spring of 2004 and Hurricane Isabel, which passed near the VCR/LTER in September 2003 and caused major flooding on the barrier islands and mainland marshes. In response to the marsh die-off, we established additional plots to determine the extent of the die-off, to track the progress of the die-off, and to monitor recovery or state change within the die-off areas. We responded similarly to a new area of die-off that was detected in 2005.



Hurricane Isabel prompted renewed surveys of vegetation and fauna to determine the effects of the extensive flooding and salt spray. Deposition caused by the hurricane in marshes was also monitored on Sediment Elevation plots.



Flooding on southern Hog Island during Hurricane Isabel. The first image is from high tide on the previous day. The second image is from near the peak of flooding during Isabel. Web-cameras on both northern and southern Hog Island used our wireless network link to the islands to send live images to researchers at the LTER All-Scientists Meeting in Seattle throughout the storm. The system remained operational throughout the storm, until backup power at the laboratory finally ran out.

The VCR/LTER supported both continuing long-term monitoring, and new long-term monitoring and initiatives aimed at elucidating selected processes. Table 1 lists the continuing monitoring activities and highlights new monitoring efforts that were initiated or significantly enhanced during VCR/LTER IV.

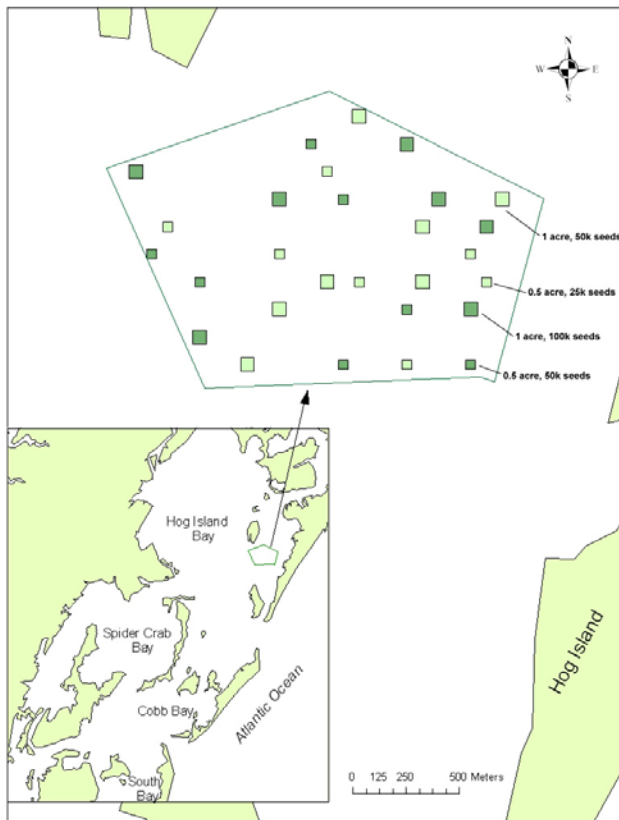
Table 1. VCR LTER core data sets. Measurements are taken in watershed, tidal marsh, lagoon and island locations. LTER core areas: 1) primary production, 2) organic matter, 3) nutrients, 4) disturbance, 5) trophic dynamics. **Highlighted** measurements are new or were significantly enhanced during this grant period.

PARAMETER MEASURED	CORE AREA	FREQUENCY	LOCATION	METHOD
Free Surfaces				
Marsh surface elevation and accretion	2, 4	Semi-annually	Phillips Creek, Fowling Point, lagoon marshes	SET, marker Horizons
Groundwater levels	3, 4 3, 4	1.5 hr-Monthly Continuous	Phillips Creek Hog Island Chronosequence	Wells, YSI Wells
Tides	4	12 min	Redbank, VA Hog Island Oyster Harbor	Tide Guages
Meteorological (Air temperature, wind speed/direction, relative humidity, precipitation)	4	Hourly	Hog Island, Phillips Creek Oyster, VA	Campbell Scientific weather station
Biogeochemistry				
Lagoon Water Quality (Temp, salinity, NH ₄ ⁺ , NO ₃ ⁻ , PO ₄ ³⁻ , DON, PN, PC, PP, TSS, light)	2, 3	Bi-monthly/ Seasonal	9 stations in Hog Island Bay.	Lachat auto-analyzer, persulfate digestion, CHN
Lagoon sediments (PN, (PC, organic content)	2, 3	Yearly	Hog Island Bay	Carlo Erba CHN, high temperature combustion
Lagoon benthic fluxes/ Denitrification, N fixation, mineralization	3	Yearly	Box transect bays and streams	Core incubations
Denitrification	3	Semi-annually	Phillips Creek Chronosequence	Core incubations
Marsh sediments (PN, (PC, organic content)	2, 3	2 years 5 years	Phillips Creek Hog Island Chronosequence Fertilization exper.	Carlo Erba CHN, high temperature combustion
OM accumulation	2, 3	Semi-annually		Root SET
Barrier island soils (PN, organic content)	2, 3	Yearly		Keldahl, high temp combust

PARAMETER MEASURED	CORE AREA	PROG AREA	FREQUENCY	LOCATION	METHOD
Vegetation Lagoon primary production	1	A, C	Bimonthly/ Seasonally	Hog Island Bay Phillips Creek, 8-15 sites	Algal biomass seagrass growth, pigment analysis P/R by eddy correlation
Marsh primary production	1	A, C	Yearly 5 years	Marsh chronosequence Phillips Creek	Phenometric – End of year biomass
<i>Juncus</i> abundance	1, 4	A	Yearly		Percent cover
Upland primary production	1	A	Yearly	Hog Island Chronosequence, and Fertilization experiment	Peak biomass, new shoot biomass
Upland plant cover/density	1	A	3 years		Percent cover
Fauna Mammals	5	A, B, C	Semi-annually 5 years	3 transects on Hog Island All VCR islands	Trapping
Waterbirds	5	A, C	Bi-weekly in summer	All VCR islands	TNC data base Survey
Lagoon invertebrates and fish	5	A, C	Seasonally	Hog Chronosequence	Core samples, seines
Land-atmosphere fluxes Wet deposition (Conductivity, H ⁺ , SO ₄ ²⁻ , CH ₃ SO ₃ ⁻ , Cl ⁻ , NO ₃ ⁻ , NH ₄ ⁺ Na ⁺ , K ⁺ , Mg ²⁺ , Ca ²⁺)	3	A, C	Weekly	LTERR met station	Electrodes, Ion chroma- tography, flame spectroscopy colorimetry
N ₂ O emissions	3	A, C	Continuous	Cobb Mill Creek Marsh-Upland	Tunable diode laser trace gas analyzer
Carbon/water fluxes	1, 2, 3	A, C	Continuous	Fowling Point, Cobb Mill Creek	Eddy correlation
Watershed fluxes Discharge	3, 4	A, B, C	15 minutes	15 tidal creeks	Marsh-McBirney current meter, ADP
Nutrients (Cl ⁻ , NO ₃ ⁻ , SO ₄ ³⁻ , NH ₄ ⁺ , DON)	3, 4	A, B, C	Monthly	15 tidal creeks	Ion chroma- tography, colorimetry

Lagoon

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 seagrass recolonization.



We extended 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 examined 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 examined thoroughly. 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.

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.

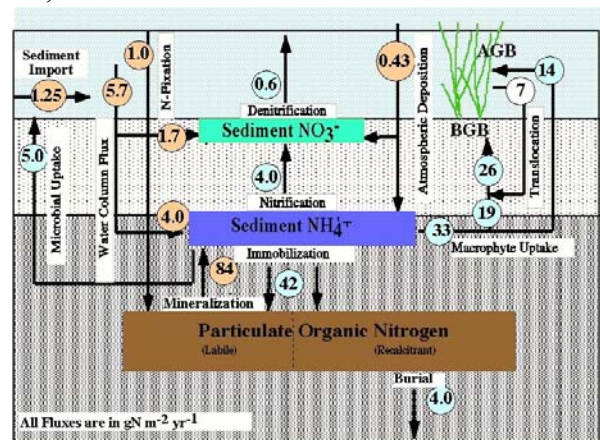
We also made significant improvements in the way automated data is collected. At the beginning of the grant period, all automated measurements were retrieved manually through the retrieval of memory packs. However, by the end of the grant we had established a wireless computer network covering most VCR/LTER research sites, including on the barrier islands. This allows us to retrieve data on an hourly basis, greatly improving our ability to address sensor problems before significant amounts of data are lost. The system allowed us to monitor in real time conditions on Hog Island when Hurricane Isabel struck the Virginia Coast in Sept. 2003.

Marsh

Activities in the marsh focused on determining the factors that promote or oppose state change in these frequently inundated systems, such as the balance between shading and salt-water intrusion at the interface between upland forests and salt marsh, the balance between erosion and

deposition at the marsh edge and surface, and the role of biogenic accretion on that balance.

The high level of local sea level rise poses special risks to salt marshes, which must occupy a narrow vertical zone between upland and tidal flats. For this reason Sediment Elevation Tables (SETs) were used to monitor minute changes in the elevation of marsh surfaces over time, including the response to large storms, such as Hurricane Isabel. To track changes in primary production, we instituted an annual end-of-year biomass survey in marshes widely spread through the VCR/LTER. We also produced and expanded nutrient-based models and budgets with the aim of understanding the role of nitrogen in controlling marsh productivity and dynamics. Experiments that used pumped water to increase the frequency and duration of inundation by salt water were used to examine the impact of inundation on state change. The discovery of a “die-off” of vegetation in part of the Phillips Creek Marsh also provided a focus for more specific studies aimed at understanding this poorly understood phenomenon.



N-Mass Balance Model--*Spartina alterniflora*
(Virginia Coast Reserve, Lower Phillips Creek)

Upland

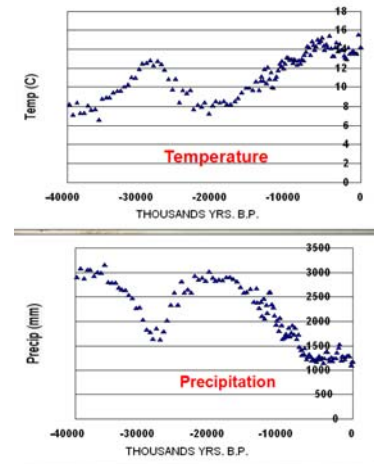
Our research on the barrier-island component of the system continued to be focused on the Hog Island Chronosequence, a series of locations where the age of the underlying landscape can be established by examination of historical maps or aerial photography. Long-term efforts included measurements in permanent plots to examine responses of vegetation to nitrogen limitation, spatial variations in primary productivity, establishment and growth of shrub thickets and inter-annual variability in production. We continued a fertilization experiments aimed at understanding long-term responses of vegetation to nitrogen additions. We also tracked a major expansion in the extent of shrubs on northern Hog Island.

Shorter-term projects focused on examining controlling influences on ecosystem processes including decomposition, fine root dynamics, and responses of vegetation to disturbances (e.g., Hurricane Isabel and a fire on Parramore Island in 2002).

Megasite

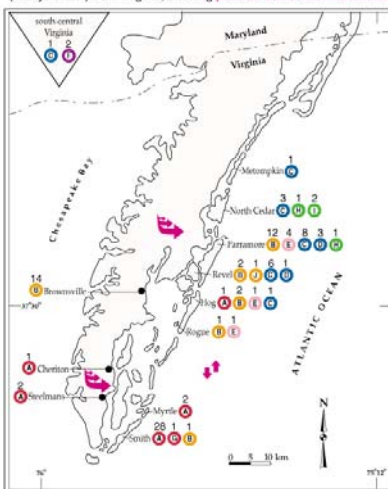
Research activities at the whole system “Megasite” focused on better understanding the spatial and temporal context within which the ecological systems of the Virginia Coast operate. These research efforts included modeling of the past sea level and climate over the last 40,000 years, which indicate that the VCR/LTER is in a period of relative warmth and aridity. Sea levels are in a period of rapid increase, following long periods where crustal uplift matched or exceeded the rate of sea level rise. However, we are now in a period of sea level rise linked to crustal decline, leading to local sea level rise of 3.5-3.9 mm/yr.

Additionally, we collaborated with partners at The Nature Conservancy (TNC) and Utah State University on studying the distribution of vertebrates in the system, particularly beach nesting and colonial waterbirds and their predators, particularly raccoons and foxes. This analysis has



built on a long-term database of TNC-sponsored surveys. Examination of patterns in mitochondrial DNA across raccoon populations on different islands has provided new insights into the paths followed by predators in establishing populations on the barrier islands.

Geographic distribution of mtDNA haplotypes for 104 raccoons (*Procyon lotor*) from Virginia, showing possible corridors of movement.



We also used remote sensing, coupled with geographical information systems (GIS) to characterize the land cover of mainland watersheds, and to link that information to the chemistry of the lagoon into which they drain. This included characterizing the sediments of a series of mainland marshes with respect to their physical and chemical characteristics.

Cross-site, Network and Information Management Activities

VCR scientists have been involved in several cross-site research activities during this funding cycle and have been active in LTER Network governance. K. McGlathery (2004-2005), B. Hayden (2002-2004) and J. Porter (1997-2002) each served on the LTER Network Executive Committee. I. Anderson serves on the GCE Advisory committee. J. Fuentes, and student J. Barr, made the first eddy covariance measurements of carbon exchange in mangroves at FCE. Fuentes, B. Hayden, and students studied climate control on fluxes of volatile organics at SEV.

L. Blum coordinates an intersite comparison of organic matter accumulation in marshes with researchers from PIE (Morris), GCE (Pennings, Newell), and several other long-term sites. She is also planning a cross-site study of fungal diversity with long-term sites in New Hampshire and Florida. D. Young is involved in a cross-site comparison of shrub expansion. And R. Christian gave a series of Network-funded workshops on ecological network analysis, which resulted in collaborative efforts at other sites (MCM, LUQ). At the Network level, K. McGlathery has been involved in Planning Grant activities. She led the workshop on coupled biogeochemical-hydrological cycles at the Fall 2003 ASM meeting, and the biogeochemistry workshop at the Meeting of 100 in November 2004. She also gave a presentation on LTER contributions to understanding the coastal eutrophication problem at the NSF mini-symposium in February 2005. Finally, we hosted the Fall 2005 Coordinating Committee meeting at the VCR.