Annual Report for Period: 08/1998 - 07/1999 **Submitted on:** 08/23/1999

Principal Investigator: Porter, John H. **Award ID:** 9411974

Organization: University of Virginia

LTER: Disturbance Succession and Ecosystem State Change at the Virginia Coast Reserve: LTER III

Participant Individuals

Senior Personnel

Name: Hayden, Bruce
Worked for more than 160 Hours: Yes
Contribution to Project:
On leave from VCR/LTER project 1997-1999 during term at NSF

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

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

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

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

Name: Erwin, R
Worked for more than 160 Hours: No
Contribution to Project:
Salary support by USGS/BRD as part of field station at UVA. USGS/BRD employee.

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

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

Name: Christian, Robert

Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract to East Carolina University

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

Name: Dueser, Raymond
Worked for more than 160 Hours: Yes
Contribution to Project:
Logistical support provided

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

Name: Kochel, Craig
Worked for more than 160 Hours: Yes
Contribution to Project:
Subcontract to Bucknell Univ.

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

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

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

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

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

Name: Berg, Peter
Worked for more than 160 Hours: No
Contribution to Project:

Post-doc

Name: Wohl, Debra
Worked for more than 160 Hours: Yes
Contribution to Project:

Graduate Student

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

Name: Tyler, Anna
Worked for more than 160 Hours: Yes
Contribution to Project:

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

Name: Silliman, Brian
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Layman, Craig
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Lowit, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Rosinski, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:

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

Name: Turaski, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Knoff, Amanda
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Murray, Laura
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Giannotti, Amy

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Thomsen, Mads
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Buffam, Ishi
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Appolone, Eileen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ricker, Lisa
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Buck, Tracy
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Roberts, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Dusterhoff, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Christiansen, Trine
Worked for more than 160 Hours: Yes
Contribution to Project:

Undergraduate Student

Name: Fisher, Mary Beth
Worked for more than 160 Hours: No
Contribution to Project:

Name: Kerkering, Heather
Worked for more than 160 Hours: No
Contribution to Project:

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

Name: Ngy, Diu
Worked for more than 160 Hours: No
Contribution to Project:

Name: Fleer, Charles
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Jacobson, Wayne
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Parris, Adam
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Mastronicola, Tracie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: McCombe, Alison
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Shapard, Corrina
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Skane, Elizabeth
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Winz, Ryan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Truitt, Morgan
Worked for more than 160 Hours: Yes
Contribution to Project:

Partner Organizations

The Nature Conservancy
The Nature Conservancy owns most of the land on which our research is conducted.

NASA Goddard Space Flight Center
NASA Aeronet Sun Photometer (CIMEL)

Virginia Museum of Natural History
Help provide long term archive for research specimens

U.S. Geological Survey
Patuxent Wildlife Research Center, Laurel, MD, Investigator R.M. Erwin

Global Terrestrial Observing System-GTOS
Investigator R. Christian serves as its representative to support Coastal-Global Oceanographic System development.

State of North Carolina
R. Christian works with Modeling and Monitoring of the Neuse River Estuary, NC (ModMon); a program sponsored by the State of North Carolina to assess the consequences of reducing nitrogen loading to that system. Other institutions involved are University of North Carolina-Chapel Hill, North Carolina State Univ., Duke Univ., and UNC-Charlotte. This program helps provide comparative information for our work in Virginia.

NOAA
In conjunction with International LTER research, R. Christian participates in the Northern Adriatic Initiative, an international program currently supported by NOAA to develop a long-term program to evaluate the environmental health of that system. Scientists come from Univ. of Maryland; NC State Univ.; Scripps Inst. of Oceanography; Center for Marine Research, Rovinj, Croatia; Marine Biological station, Piran, Slovenia; Laboratory of Marine Biology, Trieste, Italy.

Merritt Island National Wildlife Refuge
Under EPA Funded project, L. Blum is conducting comparative studies with VCR/LTER ecosystems

Czechoslovak Academy Science
Investigator Iris Anderson has been working with Hydrobiological Institute, Czech Academy of Sciences, Ceske Budejovice, CR

USDA Forest Service
Investigator Iris Anderson collaborated with USDA Forest Service Research, Riverside CA

Other Collaborators

We have many individual collaborators and contacts. They are listed below by investigator:

---John Porter ----
Matt Jones and Rudolf Nottrott (National Center for Ecological Analysis and Synthesis) and James Brunt (LTER Network Office, UNM) on development of Ecological Metadata

---Don Young ----
Currently working with Dr. Greg Plunkett and Dr. John Anderson to document genetic variation within and between populations, as well as the spread of, the invasive grass Phragmites australis. Both Plunkett and Anderson are Assistant Professors of Biology at VCU.

--Iris Anderson---
Jarda Vrba, Jiri Kopacek, Vera Straskrabova, Hydrobiological Institute, Czech Academy of Sciences, Ceske Budejovice, CR
Mark Poth, USDA Forest Service Research, Riverside CA

--- Mark Brinson ---
Donald Cahoon of USGS Biological Resources Division - Collaboration on sediment elevation data.

Dr. Donald Cahoon, US Geological Survey, National Wetlands Research Center, Lafayette, Louisiana.

--- Bob Christian ----
Daniel Baird, University of Port Elizabeth, Port Elizabeth, South Africa. Collaborate on network analysis and co-conveners of session on that topic at ERF 99

Graciella Ramirez, Inter Amercan University of Puerto Rico.

---Linda Blum ---
Currently collaborating with a variety of scientist including Donald Cahoon (USGS), Ron Brockmeyer (St. John's River Water Management District), William Knott (NASA), Ross Hinkle (Dynamac Corp.), Marc Epstein (USFWS), and Douglas Scheidt (Dynamac Corp.) on comparative study between the VCR LTER and Merritt Island National Wildlife Refuge, FL.

Activities and Findings

Research Activities: (See PDF version submitted by PI at the end of the report)
See the attached 'Activities' PDF file for a description of our activities.

See an additional PDF file for a list of our publications.

Research Findings: (See PDF version submitted by PI at the end of the report)
See the attached 'Findings' PDF file for a description of our findings

Research Training:
The VCR/LTER is engaged in training activities at a variety of levels. All Ph.D students are required to submit their dissertation for publication and most of our masters degree students also publish the results of their research. . Students are trained in research techniques and (more importantly) the scientific method.

In addition to university-level studies, the VCR/LTER is a participant in LTER network-wide activities to promote a partnership between LTER sites and K-12 education. Using supplemental support from NSF, PIs David Smith and Karen McGlathery are working with teachers at the Northampton County High School to create new learning opportunities for students. In addition, through a supplement to support LTER and SLTER networking, we were able to help the Northampton Co. school system upgrade and replace outdated and failing network infrastructure that was posing a bottleneck for effective use of network resources, both at the VCR/LTER and elsewhere.

Two graduate students participated in an ILTER trip to view research sites in Japan.

VCR/LTER graduate student A. Christy Tyler plays a leadership role in the LTER Network student group. She has arranged several meetings of LTER students at national scientific meetings and helped to facilitate improved electronic networking. This 'student-to-student' networking provides an important form of informal training.

Additional specific training activities are detailed below by PI:

----Frank Day --
Five graduate students have completed theses or dissertations or are currently working on them in conjunction with my portion of the study. Also about 12 undergraduate students have participated in the research on Hog Island. Every Fall, I conduct a field trip to Hog Island for my Ecosystems Ecology graduate class at ODU. The entire course is oriented to and heavily uses the LTER program as a guide.

----Iris Anderson----
During 1999 two students have graduated, one with an MA and one with a Ph.D. During summer a REU student from Mary Baldwin College worked in the lagoon (Hog Island Bay). She will continue her study as a senior honors thesis. One new master's student has just started a study of microbial metabolism of organic matter in Hog Island Bay.

----- Karen McGlathery -----
One graduate student completed a MS thesis on grazing-macroalgal interactions. She is now a biology/environmental sciences instructor at the Fuqua School of Longwood College. Currently 4 Ph.D. students are working with me on various aspects of the ecologyand biogeochemistry of the lagoon. Three of these students have received fellowships: two have STAR fellowships from EPA, and one has a fellowship from the National Science Foundation in Denmark. In addition, 4 undergraduates, including 1 REU student, participated in research in Hog Island Bay. Two of these students work closely with a graduate student in a departmental mentorship program. In fall 98, I designed a new course on Methods in Aquatic Ecology that included 12 undergraduates and focused on processes in the lagoon through lab and field exercises.

----- Don Young ----
I have graduate two MS students this year. One is now a high school biology teacher in the Manassas, VA school district. The other student is an instructor for lower level undergraduate courses within the Dept. of Biology at VCU.

----- Mark Brinson -------

Two theses have been produced recently:

Stasavich, L.E. 1998. Quantitatively defining hydroperiod with ecological significance to wetland functions.

Ricker, L. 1999. Resistance to state change by coastal ecosystems under conditions of rising sea level.

----- Mike Erwin --------

Sea level rise This projects lends itself to training, in that a large network of SET platforms is developing along many coastal areas, both in the US and elsewhere (D. Cahoon, pers. comm.). By training other wetland biologists in the installation of these low-cost marsh monitoring platforms, a larger dataset will develop that will assist in better modeling of marsh changes relative to coastal sea level rise, subsidence, and other processes.

--- Bob Christian ------

Many of the studies are done through master's thesis research with students from ECU. Currently, there are 2 students working in this way, Tracy Buck and Steven Roberts.

One REU student this summer, Alsion Mc Combe, helped with the marsh studies and learned aspects of rapid assessment of ecosystems, GPS skills and several laboratory methods for characterizing soils.

My Microbial Ecology class from ECU used the VCR for its major field experience in spring 1999.

In September 1999, Ph.D. students in Coastal Resources Management will go to the VCR and help in harvesting biomass and will learn about the program.

--- Linda Blum ---
Students supported by LTER: 1. Mike Lowit, Ph.D. candidate

Undergraduates involved with research at VCR LTER: 1. Diu Ngy, 'Distribution of Phargmities on Virginia's Eastern Shore'

2. Elizabeth Wilkensen, 'Contribution of below ground organic matter accumulation to sediment surface accretion in Phillips Creek marsh'

3. Heather Kerkering, 'Organic matter distributions at the VCR LTER'

4. Mary Beth Fisher, 'Organic matter decay at SET sites'

--- Ray Dueser ---

Undergraduate research assistants: 1. Charles Fleer (1998). Virginia Commonwealth University. Changes in insular habitat structure under a regime of El Nino winter storms.

High school research assistants: 1. Charles Brady (1998). 2. Jacob Jolly (1998). Abundance of insular mammal populations.

Education and Outreach:
A two day media workshop was conducted by the VCR/LTER in conjunction with the University of Virginia Media Office during late May 1999. VCR/LTER investigators L.K. Blum, R.M. Erwin, B.P. Hayden, J. H. Porter, and J.C. Zieman, along with collaborators B. Truitt and M. Luckenbach provided both overviews of the ecological forces that dominate barrier island systems and detailed research results that result directly from VCR/LTER research. The press also participated in a tour of the VCR/LTER's Hog Island Chronosequence study site was lead by Bruce Hayden and John Porter. Thus far, the media workshop has resulted in a 1/2-hour Virginia Public Radio program ('With Good Reason') based on the trip across Hog Island, and an article in the Washington Times on the changes Hog Island has undergone in the last 100 years. We understand that an additional radio program on the lagoon system is in production and that an article in the Chronicle of Higher Education is in being written.

Additional activities are listed by investigator (international outreach activities are in a separate section below):

---- Mike Erwin -----

Sea level rise - Posters have been presented at an ERF meeting, and at the annual Chesapeake Bay science meeting in Laurel MD in Feb. 1999 for federal scientists and managers. 2. Gull billed Terns - A presentation was given to the VIMS marine laboratory in April to lay persons and scientists. Two presentations are being given in 1999 on this species' (and other species') response to mammalian distribution changes. In May, a presentation was given at a Media Day event at the Eastern Shore of Virginia National Wildlife Refuge, Cape Charles VA on waterbird biology within the VCR.

---- Karen McGlathery ----

Served as scientific advisor for two panels involved in evaluating the causes and consequences of eutrophication in coastal ecosystems and in recommending management activities: (1) National Estuarine Research Reserves, and (2) National Research Council.

Four presentations given by myself and students on research in the VCR/LTER lagoon at international conferences.

----Iris Anderson----
Presentations describing the functions of lagoons in coastal ecosystems have recently been made to audiences including both lay persons and scientists at the Eastern Shore Laboratory of Virginia Institute of Marine Science (Wachapreague, VA), the Science Museum of Virginia (Richmond, VA), and the Mariners' Museum (Newport News, VA).
A seminar describing results of research at an ILTER site in the Czech Republic was given at the University of Virginia.

--- Bob Christian ------
I serve on the Greenville City Environmental Advisory Commission where my experiences with the VCR have served well.

I made 5 presentations involving VCR/LTER activities, and my students made another 5.

--- Linda Blum ---
Invited Speaker at Virginia Institute of Marine Sciences, Public Lecture Series, May 1998 - Management implications of differences in water quality between Chesapeake Bay and the Coastal Lagoons of Virginia's Eastern Shore.

1. Blum, L. K. and D. M. Scheidt. Impact of marsh impoundment water management on Indian River Lagoon water quality. Sixth Symposium on Biogeochemistry of Wetlands, Ft. Lauderdale, FL, July 11-14.

2. Blum, L. K. 1998. Characterization of impoundment sediments under three types of water management. Fall, Atlantic Estuarine Research Society Meeting, Cape May, N.J.

3. Lowit, M. B. and L.K. Blum. 1998. Pelagic bacterial community response to alterations in estuarine environmental conditions. Eight International Symposium on Microbial Ecology. Halifax, Canada, August 9-14.

4. Buffam, I.D., J. N. Galloway, and L. K. Blum. 1998. A low flow/high flow comparison of dissolved organic matter concentrations and bacterial growth in an Appalachian stream. American Society of Limnology and Oceanography and Ecological Society of America Meeting. June 7-11. St. Louis, MO.

5. Lowit, M.B., L.K. Blum, and A.L. Mills. 1998. Spatial and temporal variability of microbial communities in estuarine ecosystems. American Society for Microbiology Meetings, Atlanta, GA

--- John Porter ---
I have represented the VCR/LTER at a number of national meetings whose discipline is not primarily ecology. This included meetings aimed at developing techniques and standards for the exchange of environmental information (CODATA, IEEE Mass storage, Metadiversity Workshop). In addition I serve on the user working group for the NASA Global Change Master Directory (http://gcmd.nasa.gov).

Additional work involving International LTER activities are listed by PI:

---Bob Christian ---
I have worked to foster the ILTER network and the global observation system. This has included a series of presentations with David Smith at laboratories in Italy, Slovenia and Croatia and meetings with ministry personnel in Croatia and Slovenia to describe the nature of LTER and ILTER.The chapter on the special session onILTER within the proceedings of the Intecol meeting in Italy in July 1998 is in press. I also am involved in developing the Coastal Global Oceanographic Observation System and serve as the respresentative of GTOS for the panel developing the program. These programs are important in assessing global change and in broadening inference in ecology.

---Iris Anderson----

I have been involved with the ILTER network in the Czech Republic both in developing a joint research project with Czech scientists at the Hydrobiological Institute of the Czech Academy of Science in Ceske Budejovice and in presenting results of our research at the International Association of Landscape Ecology, held in Prague.

---John Porter---
I have been involved in the development of information systems to support long-term research at the international level. This included working with latin american information managers within the ILTER network at the regional meeting in Puerto Ordaz, Venezuela. I also made a presentation and conducted a workshop of LTER information management at the International Congress of Ecology in Florence Italy.

Journal Publications

Books or Other One-time Publications

Web/Internet Sites

URL(s):
http://www.vcrlter.virginia.edu
Description:
This is the primary WWW site for the VCR/LTER project.

Other Specific Products

Product Type: Physical collection (samples, etc.)
Product Description:
In addition to providing information on the Internet, the VCR LTER also has an active program aimed at the preservation of physical and biological samples, in partnership with the Virginia Museum of Natural History. Since 1989 Drs. Dueser and Moncrief have collaborated on studies of mammalian island ecology and biogeography at the VCR/LTER. They have supervised graduate student projects that directly examined inter-island movement in rodents (Forys and Dueser, 1993, American Midland Naturalist, 130:408-412). Archived frozen tissue samples allowed examination of gene flow in those same populations (Forys and Moncrief, 1994, Virginia Journal of Science, 45:3-11), as well as gene flow and genetic population structure in two species of rodents with different dispersal abilities (Loxterman et al., 1998, Journal of Mammalogy, 79:66-77). Noninvasive tissue sampling (earclips), initiated in 1995 as part of capture-mark-recapture studies at two island and two mainland sites, has produced frozen tissue samples from more than 2000 individuals representing 5 species of rodents. Preliminary analyses of microsatellite DNA loci in one of those rodent species (Moncrief et al., 1997, Molecular Ecology, 6:299-301) yielded several genetic markers for investigating population substructuring and movement of individuals.

Biogeographic surveys of insular and mainland small mammal populations (primarily rodents) have been conducted by Dr. Dueser in collaboration with other researchers since 1975. Multi-site surveys were conducted during 1988, 1989, 1993, 1994, 1998 and 1999. Since 1989, tissue samples and voucher specimens have been collected from 18 islands and 11 mainland sites and deposited in the mammal collection at VMNH. To date we have archived more than 1500 vials of frozen tissues (heart, liver, kidney, and skeletal muscle) along with vouchers of more than 850 individuals representing 12 species from the Virginia barrier islands and southern Delmarva peninsula. During the past year, Moncrief and Dueser were awarded outside funding to study the distribution and inter-island movement of mammalian predators (raccoons and red foxes) on the Virginia barrier islands. Earclips and hair samples from each animal handled as part of that project are being archived for future genetic and stable-isotope studies.

An archiving committee consisting of PIs Zieman, Erwin, Macko and collaborator Moncrief oversee the archive and make recommendations regarding sample collection and archiving within the VCR/LTER.

Sharing Information:
Specimens are made available following the standard procedures of the Virginia Museum of Natural History, Martinsville, VA

Contributions

Contributions within Discipline:
The VCR/LTER continues to advance our understanding of coastal ecosystems through the application of long-term studies and experiments. The long-term data sets being generated by the VCR/LTER are providing a unique record of longer-term responses not generally observed or recognized in shorter-term studies. The examination of our paradigm of linking ecosystem state change to the relationship between free surfaces continues to motivate interesting and innovative collaborative research. As in the Activities and Findings sections, we have broken our contributions down into sections based on the primary free surfaces involved.

LAND AND FRESH-WATER FREE SURFACES

Our primary goal is to understand the interactions among the three 'free surfaces' and how they affect ecosystem processes across the landscape of the Virginia Coast Reserve. Work by PI Don Young has focused on recently formed swales that are periodically influenced by flooding from sea water and are closely coupled to groundwater reserves. Shrub establishment, a key seral stage in maritime successional models, occurs in these areas. We are beginning to understand how the free surfaces affect or control shrub establishment, leading to thicket formation. More importantly, we are beginning to appreciate the indirect effects of the free surfaces on biotic interactions. These interactions, and their influences on vegetation dynamics are much more important than previously hypothesized for the harsh environment of coastal ecosystems.

LAND AND SALT-WATER FREE SURFACES

Marshes
Salt marshes sit in a unique position within the landscape and across the climate gradient. Their landscape position makes them susceptible to the stress of inundation of salt water, and the pattern of that stress may vary within and among marshes. Furthermore, as they are positioned along the coast they are subject to sea-level change and human activities, such as cultural eutrophication. To add to these stresses are a variety of disturbances that might include wrack (dead plant materials) deposition, severe herbivory by mammals and birds and human manipulations of the landscape. They are both an important ecosystem to be protected and an interesting ecosystem to studied to understand the interactions of ecosystem structure and function with multiple stresses and disturbances.

We are addressing these issues in marshes within a region that has received relatively little study of this kind before.More extensive studies have been made to the north and south. Furthermore, we are concentrating our efforts in the upper and inner parts of the marshes and focusing on transitions from one ecosystem state to another. Juncus roemerianus is near its northern limits, tends to thrive best when inundation is not regular, and appears to exist in relic stands. Understanding the dynamics of these stands is of particular importance to understanding their fate in an environment of rapid sea-level rise and climate warming.

Although much work has been done on plant communities of marshes and their response to disturbance and stress, less has been done on other ecosystem properties. We have focused on other marsh functions and brought them into the context of ecosystem state change.

The waterbird research and monitoring conducted over the past 5-6 years has resulted in some of the first ecological information collected on a species of coastal waterbird (Gull-billed Tern) that appears to be declining in many parts of its range. The research documented unusually slow growth rates of young and unusual diets. Of more broad interest and application is the colony site modeling work. The techniques used in our research could be applied to any animal metapopulation where sites are physically unstable from year to year and discrete habitat types are chosen.

Lagoon
Coastal lagoons are important land-margin ecosystems along the Atlantic coast, and on most continents, yet they have received far less study than deep river-fed estuaries. Given their high surface area relative to water volume, we expect these systems to respond differently to nutrient and organic matter loading than estuaries. One distincitve feature is the dominance of benthic macrophytes as primary producers. We are asking questions about how these macrophytes influence nutrient cycling processes, and we are relating our process measurements to hyrodynamic characteristics of the lagoon to characterize the flow of nutrients across the landscape. We have determined that organic nitrogen is an important reservoir of fixed nitrogen in this system. Few studies have focused on the fate and transport of land-derived nutrients through these important land-margin systems to the coastal ocean.

Megasite
Our work continues to define the mammalian species pool of the Delmarva Peninsula. A 1997 survey of North American museum collections revealed the first specimen of the masked shrew (Sorex cinereus) from the Virginia portion of the Peninsula (Moncrief and Dueser 1999). This species has not yet been reported from the islands. We also are making good progress in developing genetic markers useful in the exploration of ecological processes such as colonization and extinction. Ultimately, this work will allow us to assign (relative) rates to the processes which determine species distributions among the islands, and will reveal the relationship between geographic and genetic distance in this watery, highly fragmented landscape. Finally, our work has begun to explain the role of mammalian predation in the decline of colonial and beach-nesting birds on the islands. This work will provide a basis for an ecologically-realistic predator management strategy for the islands. This work is particularly important in a management sense because of the global extent of the problem of predator impact on ground-nesting birds.

Contributions to Other Disciplines:
Most of our contributions are listed under 'principal discipline' due to the breadth of disciplines that are critical to our understanding of coastal systems. These include ecology, geology and hydrology.

We are developing a more lucid understanding of plant-environment interactions in coastal environments. This is leading to improved management plans and restoration/mitigation projects where disturbed coastal environments are revegetated.

We have also been active in the development of computer-based information systems suitable for ecological information. The diverse array of data types used by ecologists, geologists and hydrologists confound most conventional database software designed for commercial applications. To this end, we have collaborated on the development of biological metadata standards with others who face the same challenges.

Contributions to Education and Human Resources:
Many of our activites in the development of human resources are listed in the training section of this report. The VCR-LTER project has provided an invaluable training opportunity for numerous undergraduate and graduate students. In addition, during the course of the tern research, PI Mike Erwin was able to use volunteers who were college students, high school teachers, interns with the U.S. Fish and Wildlife Service and with The Nature Conservancy. We also worked with state and other federal agency personnel in the field.
Contributions to Science and Technology Infrastructure:
As detailed in the Project Management section of our 'Activities,' we have made substantial strides in acquiring resources to improve the scientific infrastructure for research on the Virginia Coast Reserve. $2.5 million have been raised from University and private sources to support development of improved laboratory facilities for the VCR/LTER at the University of Virginia Coastal Research Center. We have also received approximately 140 thousand dollars of supplemental funding to support the expansion of computer network facilities devoted to the project.

As listed in the Internet Products section, we operate an extremely active WWW server that provides resources to all researchers interested in the Virginia Coast, as well as the general public.

Also as detailed in the 'Activities' section, we have made substantial progress on developing a strong relationship with the Virginia Museum of Natural History (VMNH) for the management of VCR/LTER physical specimens.

We have also greatly expanded our topographic surveys of a number of research sites using survey-quality Global Positioning System (GPS) technology. Site Manager C. Randy Carlson works with students and PIs on the design and analysis of kinematic GPS data, which is then posted on the VCR/LTER WWW page. This detailed topographic data is freely available to all interested researchers.

Beyond Science and Engineering:
VCR/LTER research products, although aimed at fundamental scientific questions, are also applicable to management questions. VCR researchers have helped to make their results available in the following ways (listed by investigator):

---Bob Christian ----
Functional assessment and hydrogeomorphology are central to the US mitigation programs for wetlands. We have continued to place our work into these contexts. This has aided our understanding of marshes and made our findings applicable to management.

ELOISE (European Land-Ocean Interaction Studies), 2 October 1998. Applications of network analysis to field studies and environmental management.

European Association for Environmental Management Workshop, 15 March 1999. Separating functions and values of wetlands and the need for reference (with M. M. Brinson)

Marine Station, Piran, Slovenia, 22 March 1999. Bacteria to fish and one ecosystem to another (with David Smith of U. VA)

Center for Marine Research, Rovinj, Croatia, 23 March 1999. Bacteria to fish and one ecosystem to another (with David Smith of U. VA)

Laboratory of Marine Biology, Trieste, Italy. 26 March 1999. Bacteria to fish and one ecosystem to another (with David Smith of U. VA)

--- Linda Blum ---
Eastern Shore Water Quality Consortium - Scientific advisor

Lake Monticello Water Quality Monitoring Committee - Assist with interpretation of water quality data and the potential impact on Chesapeake

Bay

---Raymond Dueser---
Information from predator surveys and tracking will be used by The Nature Conservancy and USFWS to develop strategies for preserving viable nesting habitats for waterbirds.

---John Porter---
Our study of the landscape ecology of colonial waterbirds will be used the The Nature Conservancy in the design and implementation of use policies for their extensive insular land holdings.

Special Requirements

Special reporting requirements:

Change in Objectives or Scope:

Unobligated Funds:

Animal, Human Subjects, Biohazards:

Categories for which nothing is reported:

Any Journal
Any Book
Change in Objectives or Scope: None
Special Requirements for Annual Progress Report: None
Change in Objectives or Scope: None
Unobligated funds: None
Animal, human subjects, biohazards: None

Publications of the Virginia Coast Reserve Long-Term Ecological Research Project

Most Recent Year

Journal Publications

Bailey, N., Kochel, R.C., and Carlson, C.R. 1998. Barrier Island Landform and Vegetation Response to Coastal Process Variables on the Virginia Coast Reserve. Geological Society of America Abstracts with Programs 30, n.4:2.

Brinson, M. M., and R. R. Christian. 1999. Stability and response of Juncus roemerianus patches in a salt marsh. Wetlands. 19: 65-70.

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Activities - 9411974 - 1998-1999

The Virginia Coast Reserve (VCR) is a dynamic, frequently disturbed landscape with elements that differ in degrees normally associated with biome-level differences. The types of ecosystem changes that normally occur across large distances (continents, biomes) and over long periods of time (e.g. glacial and interglacial periods) happen on decadal time-scales. As a result, ecosystem state changes are frequent. The central research theme of the Virginia Coast Reserve Long-Term Ecological Research project is the understanding of the dynamics of ecosystem state change, both the transitions among ecosystem states and succession within these states. Our core hypothesis is that changes in ecological states are dictated by changes in the relationship of three "free surfaces" - the surface of the ocean, the land surface and the surface of the fresh water table. In order to relate activities to findings and contributions, in this report, we have provided separate sections that focus on pairs of free surfaces and within those sections we have structured our report by habitat/study area. We have also tagged our activity paragraphs with the LTER Core Areas to which they are applicable (DS=Disturbance, PP=Primary Productivity, NM=Nutrient Movements, OM=Organic Matter, TS=Trophic Structure). At the conclusion of our description of scientific activities, we also discuss activities related to the coordination and prioritization of research within the VCR/LTER project.

Activities

RELATIONSHIP BETWEEN LAND AND FRESH-WATER TABLE

The Hog Island Chronosequence provides an ideal field laboratory to study the relationship between the land and fresh-water table. The chronosequence includes a set of dated landscapes (reflecting the times they were deposited by waves on Hog Island). Our efforts this year have concentrated on ongoing manipulations (fertilization, exclosures) and long-term observations aimed at evaluating the role of biotic influences operating within the physical context provided by the land and fresh water table free surfaces.

PI Don Young and his students concentrated on field and laboratory experiments focused on the interaction among physical and biotic factors that affect shrub establishment on barrier islands. These activities include maintenance of shrub establishment plots, fertilization experiments and manipulation of herbivores. In collaboration with PI's Ray Dueser and John Porter a series of exclosures were established on southern Hog Island to test the effects of mammalian herbivores on shrub establishment. (TS, PP, DS)

PI Frank Day also conducted research on Hog Island. The long-term nitrogen fertilized plots were fertilized again in July 1998 and 1999 and all control and fertilized plots were inventoried. Plant density and cover were quantified by species. We now have eight years of data from these permanent plots. (PP, NM)

This summer aboveground vegetation on the dunes will be harvested in 15 1-m2 plots and biomass determined by species. Along with the harvests we obtained in 1993 and 1996, this represents the beginning of a long-term data set on dune biomass with

observations at least at three-year intervals. These data will be correlated with long-term climatic data and fluctuations in groundwater elevations (one of the free surfaces of interest at VCR). (PP)

Observations of root growth continue to be recorded in the minirhizotron tubes every May and October. We now have eight growing seasons of data from these tubes. Rett Weber's dissertation project is addressing questions related to differential responses of root systems in different nutrient regimes to additional nutrient inputs and includes LTER cross site research with a portion of his work conducted at Konza Prairie in cooperation with John Blair. John Hutton conducted a more intensive study utilizing the Hog Island tubes during June 1998. He is quantifying short-term fine root dynamics (elongation and mortality) and evaluating the effect of temporal scale on the characterization of root dynamics. (PP, OM)

The ground water wells continue to be maintained monthly. We now have nine years of continuous data on ground water levels across the chronosequence. These data have been analyzed and will be correlated with other measured parameters on the chronosequence during the coming year. GPS coordinates have been obtained for the wells and all sample plots to facilitate relating the groundwater free surface to ecosystem processes. (DS, PP)

PI John Porter has continued our long-term data on small mammal abundance on Hog Island, now continuous since 1989. (TS, DS)

RELATIONSHIP BETWEEN THE LAND AND SALT-WATER FREE SURFACE

Marshes

Research in VCR salt marsh areas focuses primarily on the relationship of the land and salt water free surfaces near where they intersect. Groundwater is influential on ecosystem dynamics under limited conditions. Activities in the past year focused (1) on obtaining better measures of marsh erosion and accretion, (2) on characterizing a range of marshes along the megasite and beyond for assessing the effects of sea-level rise and for future considerations, and (3) on evaluating the effects of changes in the salt water surface on vegetation, organic matter storage, and avian components of the VCR/LTER ecosystem.

PIs Mark Brinson, Bob Christian, and Linda Blum continue our studies of ecosystem state change in salt marshes, as they are associated with the 3 surfaces, disturbance and sea-level rise.

Activities include:

1. Summarizing 5 years of results from the first inundation experiment. (PP, DS, NM, OM)

2. Continuation of 9 years of study of permanent plots. (DS, OM)

3. Continuation of 2 years of Sediment Erosion Tables and marker horizon studies examining determination of sediment elevation changes in tidal salt marshes. (DS, OM)

4. Continuation in the second year of the second inundation experiment in the high marsh at Brownsville.Began 5-year study to examine the effects of increased inundation frequency on organic matter decay and production in these plots. (DS, PP,OM, NM)

5. Development of a correction of end-of-the-year biomass to net annual aboveground primary production. (PP)

6. Characterize over 15 marshes within the megasite to extend inference. (DS, PP, OM)

7. Monitoring of vegetation change in tidal salt marshes as evidenced by locations of *Juncus roemerianus* patches. (DS, TS)

8. Estimation of the resistance of marsh-forest transition zones to change as a result of rising sea level. (DS)

9. Characterized over 15 marshes within the megasite to extend inference. This was a major new initiative supported in part by a supplemental grant to the VCR/LTER. Zones within marshes and their neighboring uplands were evaluated for plant community structure, edaphic factors and landscape characteristics. These were used to assess (1) the variation in ecosystem states within the megasite, (2) potential for change with respect to sea-level rise, and (3) opportunities to extend our work in Brownsville marshes to a broader conditions. (DS,PP, OM)

10. Instituted a comparative study of marsh surface accretion among marshes at the VCR LTER and Merritt Island National Wildlife Refuge (MINWR), FL. The marsh impoundments at MINWR can be managed to simulate changes in the relationship between the land and salt-water free surface and will allow us to testhypotheses about the impact of altered hydrology and biogeochemical processes contributing to state change. The 3-yr project at MINWR is being supported by a $750,000 grant from EPA. (DS, OM, PP)

PI Iris Anderson and her students, W. David Miller and Scott Neubauer, completed development of a carbon flux model for organic-rich “high” marsh exposed to increased inundation and wrack disturbances at the inundation site developed by R. Christian. Over a two year period changes in community and sediment photosynthesis and respiration were measured as carbon dioxide fluxes in the light and dark at control plots and those treated with wrack and increased inundation. A model estimating annual gross primary production and respiration was developed from these data. Assuming that on an annual basis excess carbon is buried in the high marsh rather than grazed or exported, we

calculated potential organic accretion rates for each of the experimental treatments. (DS,PP,OM)

PI Mike Erwin instituted a new project, in cooperation with the USGS Patuxent Wildlife Research Center, and the National Wetlands Research Center. The project focuses on sea level rise, marsh changes, and waterbird habitats. Research began in spring with installation of Sedimentation Erosion Tables (SETs) in two marsh sites in the VCR. The SETs allow detailed measurements of minute alterations in the surface of marshes.The SETs installed at these two sites will be directly comparable to the 15 SETs installed 2 years ago in other VCR marshes. Observations of waterbird use of habitats in these areas began in May. (TS, DS)

Graduate student Trine Christiansen, working with PI Pat Wiberg, completed her dissertation which used a highly sensitive doppler current meter to assess the potential tidal transport of sediments onto the marsh surface. (DS, OM)

PI Jay Zieman and student Brian Silliman completed an intensive experiment examining the impact of snail herbivory on *Spartina alterniflora*, the dominant marsh grass and completed a survey of populations of the mud crab, *Panopeus herbsti*. (TS, PP)

Lagoon

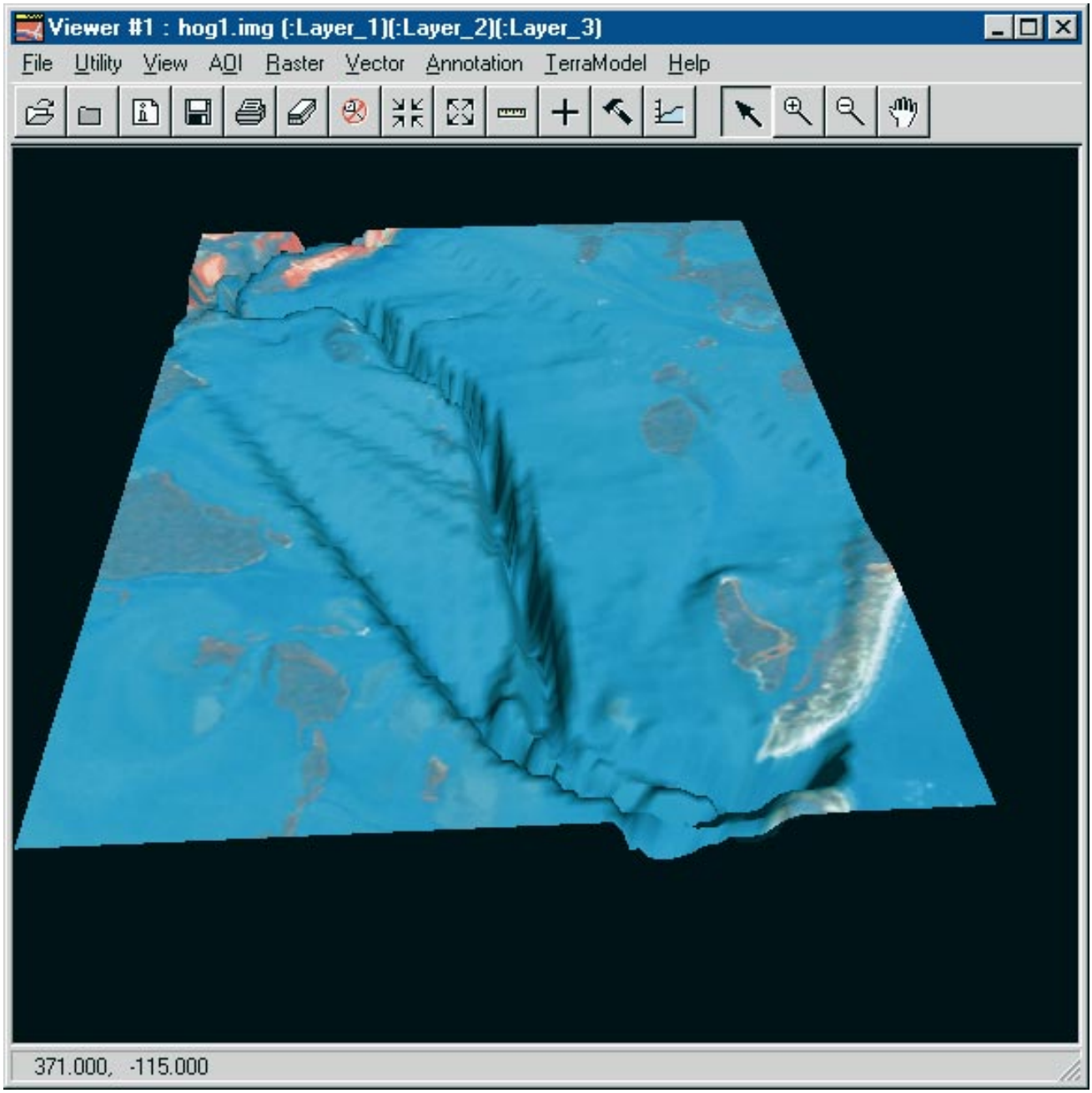
The lagoon of the VCR forms the connection between the mainland and the islands. The primary free surfaces are the surface of the salt water and the surface of the land surface (bottom). However, unlike the Hog Island Chronosequence (where the land is higher than the water) or the Marshes (where the land surface and water surface alternate superposition with the tides), in the lagoon, the water surface is always higher than the land.

PIs Bob Christian and Linda Blum continued long-term monitoring of water quality along a transect from the mainland across the lagoon system. The monitoring program has evolved to interface better with various projects within the VCR/LTER. Dissolved organic nitrogen concentration was added as a variable to interface better with the work of McGlathery and Anderson. Stations were added to support the work of Zieman. And in characterizing marshes within the megasite, we used sites near water quality monitoring stations. (NM, PP)

A major effort is being made to produce a high-resolution bathymetric mapping of the lagoon by PI George Oertel and VCR/LTER Site Manager Randy Carlson. A Global Positioning System (GPS) unit with links to US Coast Guard differential navigation beacons is linked to a digital depth sounder to provide high-resolution bathymetric information in three dimensions. So far this year over 11,000 individual points have been recorded within the lagoon of Hog Island Bay. The information has been entered into ERDAS remote-sensing and visualization software to create a digital elevation model of the bay (Figure 1). Once the bathymetric information in complete, it will be linked to data from VCR tide stations to allow the production of hypsometric curves that define the

daily "flushing" of the bay by tidal variation. We anticipate that, when linked to our water quality monitoring and to the process measurements of PIs McGlathery and Anderson described below, the completed dataset will give us new insights into the flows of nutrients throughout the VCR system. (DS, NM)

Figure 1 : 1997 Landsat Image of Hog Bay draped over a DEM created from the survey data collected as of Julian Day 197 of 1999. The DEM is at a 1:100 exaggeration to enable an enhanced visibility of subtle changes in the tidal flats. The right side of the channel has been surveyed, the left side has not.



PIs Karen McGlathery and Iris Anderson are continuing their study of nitrogen (N) cycling in the lagoon to determine the extent to which biological processes act to remove or retain N during its transport to the coastal ocean. Three sites have been established along a transect across the lagoon that represents a gradient in organic matter loading. Nitrogen transformation processes are measured seasonally at each site, including benthic nutrient fluxes, macro- and microalgal N uptake, gross and net mineralization in the sediment and water column, and denitrification. A special focus of the study is on the cycling of dissolved organic nitrogen in the lagoon system. Iris Anderson also is measuring diurnal variations of nutrient concentrations and physical/chemical properties of the water column to determine sources of nutrients to the lagoon. Karen McGlathery and her students have established a monitoring program of primary production, macroalgal diversity and tissue nutrient content, and sediment characteristics at 12 stations in the lagoon. Her students are also working on the effects of disturbance and grazing on macroalgal community composition and the trophic implications of the "boom and bust" cycles that characterize macroalgal population dynamics (DS, PP, NM, OM, TS)

PI Linda Blum and Ph.D. student, Mike Lowit, continued their studies of factors controlling microbial community structure and carbon flow through the microbial loop along the gradient from fresh-water at the head of the coastal watershed to open ocean-water. Microbial communities vary in diversity along the salinity gradient. Additionally, annual successional patterns were evident and predictable when examined using a community-level physiological profile technique. (TS, OM, NM)

Megasite

The VCR "megasite" focuses on phenomena occurring over the entire site, such as changes in large-scale landscape structure and the distribution of the biota. The most critical of the free surfaces are the relationship between the land and the salt water table, although fresh water surfaces are also important in some areas. Work this past year concentrated on understanding the influence of biotic and landscape change on the distribution and abundance of mammalian and avian populations, on the fluxes of nitrogen being deposited into the system from elsewhere and on the development of images and GIS data layers of current and past landscapes. Furthermore, as discussed under "Marsh Research Areas", we have begun to broaden our approach to marsh dynamics to encompass the variation of the megasite.

In collaboration with the Nature Conservancy, PIs John Porter and Mike Erwin and collaborators B. Truitt, B. Watts, Bill Williams and Mitchell Byrd are engaged in a study of the landscape ecology of colonial and beach nesting waterbirds on the VCR. Activities during the past year included completing the georeferencing of 20 years of bird survey data, analysis of the relationship between island characteristics and avian diversity and abundance. We have also been engaged in creating GIS data layers based on aerial photos and satellite images. A complete set of georeferenced and rectified images for a 1993

NASA overflight have been completed and work is proceeding on a set of 1974 images. (TS, DS)

PI Mike Erwin - continued to monitor breeding site use and population sizes of Gull-Billed Terns. Four publications from October 1998 to summer 1999 were produced on previous Gull-billed Tern research. (TS, DS)

PI Ray Dueser and collaborator Nancy Moncrief have continued their intensive monitoring of mammalian populations on vulnerable, low-lying barrier islands with the aim of better understanding immigration and extinction. This monitoring includes the collection of small tissue samples for genetic analysis and archiving in the collection of the Virginia Museum of Natural History. (TS, DS)

Mammalian predators have been implicated in the steady, long-term decline of several colonial and beach-nesting birds on the islands. In collaboration with The Nature Conservancy and the Virginia Coastal Resources Management Program, PI Ray Dueser and collaborator Nancy Moncrief have conducted the first comprehensive and systematic survey of predator populations. Systematic surveys of the occurrence of raccoons and the introduced red fox were conducted in 1998 and 1999. Trapping studies of island predator abundance and radiotelemetry studies of inter-island movements of these predators and their interactions with nesting birds were initiated in summer 1999. (TS, DS)

The atmospheric deposition data for both inorganic and organic N collected by PI Galloway and coworkers described in the following section will interface well with the N cycling study of PIs McGlathery and Anderson. Recently, it has been shown that atmospheric inputs of N, along with groundwater nutrients, may be particularly important as a source of N to shallow coastal systems such as the VCR lagoon. This information will be critical to our ultimate goal of understanding the how the lagoon acts functions as "filter" for nutrient inputs in this coastal landscape.

As part of the VCR/LTER, PI Jim Galloway and collaborator Bill Keene are collecting precipitation for chemical analysis at the GATR site of Virginia National Wildlife Refuge in Northampton County, Virginia. Over the period 4/17/98 - 8/12/99, 20 samples have been collected and analyzed. After entry into the LTER precipitation chemistry data base, the sample data are compared with other locations in the eastern United States to determine the representativeness of deposition rates and are also compared with data from remote marine regions (e.g., Indian Ocean, southern Chile, Barbados) and marine regions impacted by long range transport (e.g., Bermuda) to determine the degree of influence of human activities on elemental deposition rates at VCR/LTER.

As part of a NOAA sponsored workshop on assessing atmospheric nitrogen inputs to U.S. coastal waters from the atmosphere, PI J.N. Galloway and graduate student, K.M. Russell used existing long-term data to quantify direct inputs of nitrogen via wet deposition to 42 coastal water bodies around the United States. The average N deposition to the water bodies was calculated and temporal trends were evaluated.

The average wet deposition of ammonium and nitrate to the 42 water bodies of interest were determined by using routine data collected by the National Atmospheric Deposition Program (NADP). The NADP database contains yearly and seasonal ammonium and nitrate deposition data based on weekly collections made at various sites throughout the United States. The organic nitrogen wet deposition was calculated for the assessment using a uniform quantity of 20% of the total inorganic nitrogen wet deposition. Accurate quantification methods for organic nitrogen in the atmosphere are still being developed, and this number is based on average measurements of several recent studies.

PROJECT MANAGEMENT

Coordination and prioritization of research activities is a critical element of successful research by the VCR/LTER. Following our site review in the summer of 1997, we increased to three the annual meetings of investigators to help improve research coordination and collaboration among research groups studying the site. Meetings were held in October 1998, January 1999 and May 1999, each with a different focus. The October meeting was held at the campus of the Virginia Institute of Marine Sciences. Focus of the meeting was research planning, infrastructure development and synthesis activities. The second meeting in January was held at the University of Virginia and focused on exchanging information on research results. To this end, both PI and graduate student sessions were arranged, including poster sessions. Intensive discussions focused on links between hydrologic and tidal forcing of the VCR/LTER ecosystems. The April meeting was held at the research site on the Eastern Shore of Virginia. Topics of discussion were revisiting our core hypotheses and discussion of a hypsometric model, which facilitates expansion of our core hypothesis in space.

To aid in coordinating the ever-increasing demands of VCR/LTER researchers for access to our shared resources (boats, laboratories, personnel), starting in the fall of 1998 we began constructing quarterly Shore Management Plans. These plans lay out our planned activities in a prioritized way that reflects project needs. The plans typically identify high priority activities for the staff at our Eastern Shore laboratory, with highest priority given to logistical and research activities that are critical to achieving the overall goals of the site. The next highest priority goes to activities supporting our program of long-term monitoring through the collection of core data sets. Standard priority activities include those activities that support the specific research tasks of individual PIs and their students. Based on input from the PIs (via a WWW form) on their needs for the upcoming quarter, the lead PI prepares a draft plan that is then reviewed by all the project PIs. After the plan is approved the Site Manager prepares a response that identifies any problems or conflicts and forwards that to the PI group for resolution. Thus far the planning process has proved to be very useful, with many potential research conflicts resolved before they actually conflicted. During the upcoming year we plan to shift from a quarterly system to a seasonal system with plans prepared for fall/early winter, late winter/spring and summer.

Students continue to play an important role in VCR/LTER research. In accordance with the recommendations of the site review team we have continued our efforts to assure that

graduate student projects are published and contribute to the long-term science on the site. This past year yielded 10 new theses and dissertations and 13 journal publications authored, or co-authored by current and former students.

In addition to attempting to manage our resources efficiently, we are pursuing avenues to expand our facilities through external funds. We are in the process of purchasing land on which to build an improved laboratory facility with $320,000 provided by the University of Virginia. We have raised $2.2 million additional dollars for the construction of such a facility. This will allow construction of a modern laboratory and housing facility to replace the badly overcrowded building that we currently rent from The Nature Conservancy.

We have expanded our research infrastructure in other ways. On-site computer support was increased from three to seven computers (including laptops) and a Local Area Network (LAN) was established. A NSF supplement will support expanding our Internet capabilities to a full T1 (1.5 mbs) connection and significant expansion of the LAN to permit better sharing of resources between field and campus facilities. Our GIS has also been expanded and updated through the addition of 5 Sun SparcStation 10 UNIX computers and monitors. These systems had been used by the State Highway Dept., which recently converted to an NT platform and were provided by the University of Virginia at no charge to the VCR/LTER.

We have also increased our infrastructure for the management of physical specimens. A Memorandum of Partnership was negotiated with the Virginia Museum of Natural History (VMNH) for the management of VCR/LTER specimens. The agreement resolves the ownership, control and curatorial issues related to the VCR/LTER sample archive. Equipment purchased using a NSF supplement is expanding facilities available for our samples, both at the VCR/LTER laboratory and at the VMNH.

Other important VCR/LTER activities involve our Schoolyard Long-Term Ecological Research (SLTER) and International LTER activities. These efforts are described in the "training" and "outreach" sections of this report.

The VCR/LTER WWW site (http://www.vcrlter.virginia.edu) continues to provide data and other information on VCR/LTER research. From August 1, 1998 to August 1, 1999 the WWW site transferred 12.4 gigabytes of information to 134,054 different "visitors" from at least 42 different countries. Of the 557,376 different files downloaded, 318,216 (57%) were text or document files while the remaining 43% were graphical. Educational users account for the single largest block of requests (37%), followed by users of commercial Internet systems (30%).

The WWW site provides access to research reports, proposals, publication lists, a personnel directory and calendar of events for the site. In addition it provides access to 51 regular datasets along with 29 "special" datasets, such as our biodiversity and image databases. Our site biodiversity database currently contains information on over 1900 genera. Automated requests for datasets come from researchers both inside and outside

the site. VCR/LTER datasets can also be accessed via the LTER Network Data Catalog (http://www.lternet.edu/DTOC).

Recent enhancements to the WWW site include: a fast navigation bar to facilitate rapid access to site contents, development of an imagery archive, indexing of datasets to LTER core topics, and upgrading of the site personnel directory to reflect projects and datasets for each researcher.

In addition to the main WWW site, several researchers have participated in the creation of WWW resources aimed at particular research areas. PI R.M Erwin created an introduction to the sea level rise research at: http://www.pwrc.usgs.gov/resshow/erwin1rs/erwin1rs.htm. PI's J.H. Porter, R.M.Erwin and collaborators have created a WWW site aimed at the colonial waterbirds of the Virginia Coast at: http://www.vcrlter.virginia.edu/~shorebrd/tnc_bird/

Findings - 9411974 -1998-1999

This "Findings" section of the report parallels the organization of the "Activities" section, with information segmented by free surfaces and study areas.

RELATIONSHIP BETWEEN LAND AND FRESH-WATER TABLE

Hog Island Chronosequence
Experimental and observational results have helped elucidate the role that nutrients play in plant species diversity and root dynamics. Observational and experimental studies also reveal a number of biotic factors that have a direct influence on shrub establishment.

In the fertilization experiment, responses in community composition to fertilization are apparent in addition to previously recognized increases in production. In general, *Ammophila breviligulata* appears to be increasing in importance in fertilized areas of the mid-island dunes; the inverse is apparent for *Spartina patens*. Peaks in cover and density occurred in the fertilized plots one or two years after the start of the experiment and declined after that. This suggests that increased competition within the denser populations is serving as a negative feedback in the system. As predicted by current theories, species diversity decreases in response to fertilization.

The longer term minirhizotron data suggest that there are different classes of roots based on longevity and this probably relates to functional differences. Reported life history responses of roots to fertilization have been varied. In some studies root turnover has increased in response to fertilization, and in others turnover has decreased. The data show that after three years fine roots in the fertilized sites on Hog Island have a mean lifespan (2.1 months) roughly twice that of those in the unfertilized areas (1.2 months). The unfertilized plots tended to have a higher percentage of new roots. Fertilization appears to decrease turnover by increasing the lifespan of individual roots. Root densities reflect the same pattern observed in density of plants in the study described above. This again suggests the effects of increasing competition among increasingly more dense plants in the fertilized plots.

Insect herbivory appears to be an important factor affecting shrub seedling establishment. There are extreme spatial/temporal variations in the importance of insect herbivory.

Shrub establishment and distribution patterns are at least partially controlled by root endosymbionts (i.e. mycorrhizae and nitrogen fixing bacteria). *Myrica cerifera,* the dominant woody species of the Virginia Coast Reserve cannot survive without the nitrogen fixing symbiont, *Frankia*.

The greater seed rain and moderated microclimate beneath eastern red cedar may lead to increased establishment and diversity of woody species. The effect of cedar on the recruitment and distribution of mid-successional woody seedlings in coastal environments may be passive, through the non-random distribution of fleshy seeds by

perching birds, or active, through increased seedling survival due to cedar initiated alterations in microclimate and edaphic factors.

RELATIONSHIP BETWEEN THE LAND AND SALT-WATER FREE SURFACE

Marshes

The infrastructure of ongoing long-term studies is in place that allows coordinated and unique observations of how ecosystem states within marshes and their adjoining uplands respond to changes in sea level and disturbance. This has been brought about through both monitoring at scales from centimeters to the megasite and field experimentation.

Juncus roemerianus is an important saltmarsh plant that is near its northern limits of its range at the VCR. We have studied it extensively to determin its fate during ecosystem state change. Published resultsfrom permanent plots begun in 1990 that show that *Juncus roemerianus* patches in the lowest part of the marsh are undergoing reductions in areal coverage. Those in mid and high marshes are stable or slightly increasing in size.

A limited number of map and field indicators allow one to estimate the resistance of the marsh-forest transition to change as a result of rising sea level.

The long-term response of the salt marsh toexperimental wrack disturbance is dependent on salt marsh plant communities covered. *Juncus roemerianus* did not recover after 5 years post deposition. It was invaded largely by *Distichlis spicata*. Invasion by *Spartina alterniflora* also occurred in a wetter area. On the other hand, *J. roemerianus* may be resistant to other types of disturbance. Stands of this rush continue unchanged, while other high marsh plants develop a hollow and hummock microtopography and depressions and have their peat degrade. The development of depressions may be associated with herbivory, and *J. roemerianus* may resist this.

Confirming findings in other regions, *Spartina patens* appears more susceptible to stress than *D. spicata* in the high marsh.

Work at the megasite scale was used to predict the ecosystem state change from changes in sea level. A limited number of map and field indicators allows one to estimate the resistance of the marsh-forest transition to change as a result of rising sea level.

We used ecological network analysis to evaluate nitrogen cycling. High marshes recycle nitrogen more effectively than low marshes, and the overall nature of cycling by a marsh in response to SLR is dependent on its ability to prograde or transgress.

A fourth surface may be important to the dynamics of state change in salt marshes, the antecedent surface. This will be evaluated more fully through the megasite marsh studies.

Based upon the Carbon Flux Model output, it was determined that in organic-rich high marshes:

1. Increased inundation both reduces respiration and photosynthesis in the macrophyte and sediment communities with an overall decrease in carbon available for burial and accretion compared to control plots.
2. Plots treated with wrack experienced a net loss of carbon with negative potential accretion rates of up to 6 mm per year.
3. Placement of a border around a control plot causes increased rates of carbon accretion due to higher rates of gross primary production in the macrophyte community.

PI Patricia Wiberg and graduate student Trine Christiansen found that the water velocity of flows onto a marsh surface during a rising tide drop off very rapidly as the water proceeds onto the marsh. This means that sediments carried by those flows will be deposited at the border of the marsh and not carried into the marsh interior. This work has important implications for persistence of salt marshes in the face of rising sea level.

PI Jay Zieman and graduate student Brian Silliman found that the mud crab can play an unanticipated role in the salt marsh. The distribution of the omnivorous mud crab, *Panopeus herbstii*, is thought to be limited to intertidal and subtidal oyster reefs. In the past year, however, we have documented its widespread distribution (mean densities = 4.2 m^{-2}) in the vegetated portions of the salt marsh community in both the tall and intermediate stands of *S. alterniflora* throughout the VCR as well as in DE, MD, and NC. Initial observations of its feeding habits suggest that this crab exerts a strong control on the population of salt marsh periwinkles. This information, combined with the results of our snail addition and exclusion experiments, which demonstrated that grazing by periwinkles significantly reduces *S. alterniflora* growth, suggest that *P. herbstii* indirectly controls the growth of *S. alterniflora* by regulating the density of snails. This linkage, between top level predators and *S. alterniflora*, has, to this point, never been documented or suggested in the salt marsh literature. We are currently excluding predators from the marsh to determine their effects on the populations of resident epifauna (i.e. marsh periwinkles mud snails, fiddler crabs, and ribbed mussels).

Gull-billed Tern project - One major finding was that the metapopulation of terns in coastal Virginia seems to be selecting colony sites in a nearly random, and non-Markovian manner over a four-year period. No major habitat effect (beach vs. marsh) was found, nor was previous success at a site an important determinant in selection the following year. A diet study revealed a strong dependence on fiddler crabs, a keystone prey species for many waterbirds. It also documented the significance of insects, and a seasonal shift in diet. The species is unusual in integrating both terrestrial and marine prey in its breeding cycle. Two papers on reproductive success showed very low success for the species in all years, below the levels believed to sustain the population, thus we suspect it is a "sink." Chick growth rates also reveal growth is slower than for most other North American terns when corrected for body size. However, food limitation was not strongly implicated in the 3 years of study.

Lagoon

Some preliminary results from the intensive bathymetric survey using our digital depth sounder coupled to a global positioning system unit is given in figure 1. When completed

late this summer, this survey will form the basis for estimating tidally-driven fluxes of water and nutrients.

The transect of three sites from the mainland across the lagoon to the barrier island represents a gradient in organic matter loading. This is evident in the decrease in sediment organic matter, sediment exchangeable ammonium, and water column nutrient levels as one moves from the mainland to the barrier island. Macroalgae are the dominant primary producers in the lagoon, with peak biomass levels in the mid-lagoon shoal areas among the highest reported for shallow coastal lagoons. Grazing is an imporant control of macroalgal abundance where nutrients are lower at the barrier island site because macroalgal growth can not compensate for grazing losses. Species diversity varies across the transect, and is highest at the mid-lagoon shoal site where the algae also undergo seasonal population crashes. The macroalgae are an important temporary sink for dissolved inorganic N (DIN) during most of the seasons, except immediately following the macroalgal bloom in mid-summer. Dissolved organic N (DON) concentrations in the water column are high, representing 50-95% of total dissolved nitrogen, and fluxes of DON from the sediment to the water column are always higher than those of DIN. Macroalgae take up urea in the dark and may be capable of heterotrophic growth, but overall are a source of DON to the lagoon. Most of the organic nitrogen mineralized from sediment organic matter is rapidly immobilized by bacteria.

MEGASITE

We established permanent live-trapping grids for comparisons of population dynamics and population genetics of rodents on two islands and two mainland sites in 1995. The island sites were chosen in part because populations on one of the islands (Myrtle) appeared to be particularly susceptible to extinction. Island populations of *O. palustris*, the house mouse (*Mus musculus*) and the meadow vole (*Microtus pennsylvanicus*) exhibited neither higher density nor greater stability than the corresponding mainland populations through 1999. Moncrief et al. have determined suitable genetic markers (microsatellite DNA loci) for examining fine-scale population structure in *M. pennsylvanicus*). They analyzed approximately 100 tissue samples during 1998-99. One of the island sites where we established permanent trapping grids (Myrtle) has undergone dramatic changes in area (from 50+ ha in 1995 to < 1 ha in 1999) and habitat structure (extensive grasslands and tall shrub thicket in 1995 to overwash fan in 1999). Three species of rodents went extinct locally on Myrtle during 1998, and only *M. musculus* has recolonized. We are using the dissolution of this island to study the relationship between island area, geomorphological structure and biological diversity.

Analyses of NADP nitrogen revealed that waterbodies receiving the highest inorganic nitrogen loading from the atmosphere over the last several years (and thus the highest organic nitrogen loading based on the assumption above) are those at the mid-Atlantic coast and include New York/New Jersey Harbor, Delaware Bay, and Chesapeake Bay (with atmospheric N inputs of about 7-8 kgN ha-1 yr-1). Similar inputs would be expected for the waters surrounding the Virginia Coast Reserve. Temporal trend analysis showed that inputs to the mid-Atlantic estuaries are not increasing, however. Areas with

significantly increasing wet deposition of N include Mobile Bay watershed and all the estuaries in Florida.