The Virginia Coast Reserve LTER
1997-1998 Annual Report

1 August 1998

Highlights of VCR/LTER Research

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. The VCR/LTER project has been able to take advantage of the unusually high rates of shoreline change and sea level rise to achieve new understandings of the dynamics of coastal systems. Some recent research findings include: new theories on how marsh and lagoon systems evolve and operate, the discovery that trends in coastal erosion undergo reversals and that these reversals are roughly synchronous along the entire Atlantic Coast (due to changes in storm climates), a more detailed understanding of successional processes on barrier islands (including microbial influences on shrub succession), whether salt marshes are able to accumulate enough new material to keep up with current rates of sea level rise, and patterns of colonization and extinction for mammals and birds on barrier islands. We have listed specific highlights by LTER core area.

Disturbance

SOUTH PARRAMORE OVERWASH SITE -- Major winter storms in early 1998 (Jan-Feb) caused more than 50 m of shoreline retreat in the vicinity of our long-term overwash monitoring site near the UVa pimple project location. Erosion in 1998 resulted in the total removal of one entire pimple that was instrumented with more approximately 18 wells tracking changes in groundwater elevation and salinity. The storm overwash removed major dunes and dune ridges from this location and produced a low-relief barrier island environment. Ongoing GPS resurveys are being processed to determine the details of the changes. When processed later this summer, these GPS data will be used to provide detailed estimates of the volumetric changes of geomorphic subenvironments in the region. We also will be able to use the 1997 mapping data to track the storm's impact on island hydrology and vegetation. Because we had completed a detailed GPS survey of the site in 1997, along with a vegetative and hydrological survey, we will be able to provide one of the best-detailed assessments of island response to coastal storms ever possible.

GPS SURVEY MAPPING -- Significant effort has been put into assessing the utility of GPS technology in sub-cm scale geomorphic mapping of barrier island environments during the past year. This has been a cooperative effort coordinated by Randy Carlson. The results of the first year indicate that GPS mapping provides a favorable platform for monitoring geomorphic and

vegetative changes on barrier islands a scale useful in tracking annual changes and changes due to major storm events.

MYRTLE ISLAND LANDSCAPE CHANGE -- Repeated GPS surveys since 1996 have documented major island-scale geomorphic adjustments along the northern half of Myrtle Island. These changes are measured on the order of 100's of m of shoreline retreat and 100's of square m of destruction of major dune environments. Much of these adjustments began prior to the major storms of early 1998 and must be attributed to changes in geomorphic processes operating at high frequency. Studies are currently underway to determine if these island adjustments are influenced by hydrographic adjustments in adjacent tidal inlets or inlet delta platforms.

Nutrient Movements

NETWORK ANALYSIS OF NITROGEN CYCLING -- It is hard to impossible to measure how nutrients cycle within an ecosystem. The cycling involves many different processes and the ecosystem integrates them all. Nitrogen is a nutrient that has a particularly complex cycle. We have begun to assess how marshes cycle nitrogen as a whole (not just through adding the different parts) by way of network analysis. Network analysis applies different mathematical calculations to box and arrow diagrams of systems. We have made such diagrams of the nitrogen cycles from marshes at Great Sippewissett, Mass.; Sapelo Island, GA; and the VCR. Within each marsh separate analyses were done for 3 zones of the marsh. Patterns can be seen in the ways the marshes process nitrogen. An important controlling feature is the distance from tidal flooding. As sea level rises it can be seen to alter the way the marshes process nitrogen.

NITROGEN CYCLING IN THE BARRIER ISLAND LAGOON SYSTEM -- A study on nitrogen dynamics in Hog Island Bay was initiated. Our main objective is determining the extent to which biological transformations in the lagoon act to remove or retard reactive nitrogen during transport across the land-sea margin. We are particularly interested in the role of benthic autotrophs – microalgae and macroalgae – in these biological transformations. Studies performed during October 1997 and May 1998 suggest that the Hog Island Bay is net autotrophic and a sink for dissolved inorganic nitrogen. However, during July when macroalgae undergo a period of mortality and decomposition, the lagoon becomes net heterotrophic and sediments are a source of nitrogen, especially dissolved organic nitrogen, to the lagoon.

ROLE OF PRECIPITATION IN HIGH MARSH FLOODING --Coastal fringe salt marshes are often divided into two hydrologic zones based largely on vegetation and flooding frequency. Low marsh vegetation is dominated by *Spartina alterniflora*, depicted as a regularly flooded zone, and a high marsh of mixed species, depicted as an irregularly flooded zone. One interpretation is that tides are a dominant source of flooding in the high marsh, albeit irregular. From a 6-year record of a mainland marsh at the VCR/LTER (upper Phillips Creek), we found that flooding in high marsh zones is due largely to precipitation, and lasts for months without drydown. Depressional storage of high marsh zones is effective in storing water, which contributes to the long hydroperiod and saturation to the surface.

Organic Matter

ORGANIC MATTER ACCUMULATION IN MARSH SEDIMENTS -- Long-term measures of organic matter accumulation continue to show significantly greater rates in the high marsh as compared to creekbank regions. These rates are correlated with differences in root production and with sediment physiochemical differences between high and low marsh. To determine the contribution of organic matter accumulation to sediment surface accretion, a 10-yr experiment has been initiated in conjunction with Don Cahoon (National Wetlands Research Center) by VCR PIs Linda Blum, Mark Brinson, and Bob Christian. Sediment erosion tables and feldspar marker layers are being used to measure sediment surface elevation and sediment deposition in the high marsh, low marsh, and mid marsh, as well as along an actively developing tidal creek. Organic matter accretion is being measured as accumulation of organic materials in litter bags. A similar series of measurements is being initiated at Merritt Island National Wildlife Refuge in impounded wetlands.

SEDIMENT DEPOSITION -- The physical processes that control mineral sediment deposition on a mesotidal salt marsh surface at the VCR have been through a series of measurements of sediment concentration, flow velocity, water surface elevation and local rates of deposition on the marsh surface under tidal conditions ranging from tides barely flooding the marsh surface to spring tides and storm surges. Flow velocities on the marsh surface are low (< 1cm/s) during all tidal conditions measured. Sediment concentrations at the edge of the marsh increase with increased tidal amplitude, whereas in the marsh interior sediment concentration remained low regardless of tidal amplitude. The concentration gradient between creek bank and marsh interior indicates that more sediment is deposited on the creek bank as tidal amplitude increases. Correlation of high sediment transport events with meteorological conditions indicate that all high transport events are associated with strong northeasterly winds. Based on these measurements, it is estimated that 27% of sediment deposited on this mesotidal marsh surface is contributed by storms; the rest is deposited during normal high spring tides.

Trophic Structure

MICROBIAL SYMBIONTS -- Coastal environments are harsh and physical factors (e.g. salinity, flooding, and sand deposition) strongly influence the distribution of plants, but biotic interactions are also very important. Mutualistic interactions with microbial symbionts to fix nitrogen and provide other nutrients enhances the establishment of shrubs. In fact, regardless of how optimal the physical environment is, wax myrtle, *Myrica cerifera*, will not survive unless the bacterium, *Frankia*, is in the soil. *Frankia* infects the root to form nodules that enable nitrogen fixation.

MICROBIAL COMMUNITIES IN HOG ISLAND LAGOON -- The spatial and temporal response of the bacterial communities have been examined for the past two years along the VCR's water quality monitoring transect from tidal marsh creeks to open ocean. Bacterial genetic and physiologic profiles are correlated to one another along the transect and throughout the year. Similar profiles are obtained from locations with similar environmental conditions. At a given location, the community exhibits a predictable pattern of response throughout time. Manipulative experiments along the transect are planned for the coming year.

POPULATION STABILITY ON ISLANDS -- Many studies show that populations of mammals exhibit higher densities and greater stability on islands than on adjacent mainlands. We have monitored populations of *Microtus pennsylvanicus*, *Mus musculus*, and *Oryzomys palustris* on two Virginia barrier islands and two nearby sites on the Delmarva Peninsula mainland since October 1995. *Microtus* and *Oryzomys* conform more closely than *Mus* to the expectation of higher abundance and greater stability on the islands. Species differences appear to be more important than site differences in determining population attributes.

ROLE OF SUBSTRATE QUALITY IN NESTING BIRDS -- We have been studying the population dynamics of nesting Gull-billed Terns, in coastal Virginia since 1993. Populations along the Atlantic Coast have been declining, presumably due to loss of habitat, predators, and sea level rise and storm flooding. In 1997, we initiated a study where we added shell material to selected nesting sites to increase elevation (hence, reducing flooding). In spite of this seemingly more attractive habitat alteration, **fewer** terns nested at the experimental sites than at the control sites. We suspect that perhaps using surf clam shell rather than oyster shell (not available to us) may have been one of the factors involved in the surprising result.

Primary Productivity

MACROALGAL BIOMASS AND DIVERSITY -- With support from the REU program, we have established 8 stations along two transects across Hog Island Bay that represent a gradient in organic matter input. At each station we measure macroalgal species composition, biomass, production and elemental tissue content at monthly – bi-monthly intervals. These stations will serve as permanent sites for monitoring.

Other

DEVELOPMENT OF COMPARATIVE SITES -- In response to input from the 1997 site review, we are expanding our efforts to develop collaborations that will allow meaningful cross-site comparisons. Addition of the Plum Island (PIE) LTER to the LTER network has accelerated this process by adding a second coastal site to the network. We have collaborated with PIE LTER on establishing common topographical references using VCR/LTER Global Positioning System units. High-resolution information on relative and absolute elevations of marsh and land surfaces is critical to conducting meaningful comparisons between sites. In addition, VCR/LTER PI's Linda Blum and Aaron Mills are developing replicates of experiments already deployed on the VCR/LTER at NASA sites in Florida.

Applications of VCR/LTER Research

- Our work on the ecosystem state changes within the marshes of the VCR have opened up opportunities to apply them to issues of restoration. This is summarized in our presentation and submitted chapter for the International Conference of Tidal Wetlands last April in Vineland, NJ. Also, we have begun activities with state personnel in North Carolina to apply our work to restoration issues there. (Christian)

- Our work on network analysis has allowed us to participate in a program to assess management actions in the Neuse River estuary, North Carolina. (Christian)
- After nearly ten years of research towards a better understanding of plant distribution patterns on Virginia barrier islands, we have developed an understanding of plant responses (major woody species) to flooding and salinity. These results are currently being used (and tested) in the revegetation efforts of the Swash Bay spoils. The revegetation effort is a cooperative study involving funds and/or support from The Nature Conservancy, NOAA, VA Dept. of Transportation, VA Dept. of Environmental Quality, US Army Corps of Engineers, US Fish and Wildlife Service, and the VA Natural Heritage Program. The treatment protocol, including the eradication of the invasive weed, *Phragmites australis*, may be used to develop similar plans for the many coastal spoils sites around the Tidewater area (Young).
- Results from the shell experiment were used in making decisions about further restoration of salt marshes for nesting waterbirds by the USFWS. A decision was made to use material *in situ* in the future rather than adding materials from off site (Erwin).
- Results from the colony site modeling exercise are being used to persuade coastal park and wildlife refuge managers to develop and/or preserve multiple sites for nesting waterbirds, whether or not the sites have been used in the previous year or two. Many alternative sites appear to be required by the declining Gull-billed Tern and Black Skimmer and 6 other species of nesting waterbirds in coastal Virginia. The uncertainties of predators, storm events, and human activities argue for maintaining numerous alternative sites.(Erwin)
- Software tools developed at the VCR LTER have been used by other LTER sites in coordinating meetings etc. A VCR/LTER system for automatically converting data from WWW forms to online documents has been used at the LUQ LTER for handling surveys, research summaries and meeting registrations. (Porter)

Planned Activities for 1998-1999

Two major new activities are planned for 1998-1999. The first is the establishment of a large scale, long-term inundation experiment. This experiment will use barriers to alter the patterns of marsh flooding by extending the length of flooding in some areas, while decreasing it in others. In some treatments, monthly pumping will also be used to manipulate seawater levels relative to the marsh. These experimental manipulations will build on an information-base developed during a pumping experiment at a smaller scale in 1994-1997. Establishment of the inundation treatments will be accompanied by an intensive survey of the physical and chemical characteristics of a large number of marsh surfaces. It is anticipated that this experiment will increase our insights into the effects of continued sea-level rise and the relationship between vegetation and tidal flooding.

A second activity will increase the number of replicate herbivore exclosures in place on the barrier islands of the Virginia Coast Reserve. The exclosures will be located in areas of Hog Island and other islands that are expected to undergo a shift from grassland to shrubland within the next decade, to help examine the effects of herbivory on this significant successional shift. The exclosures will be linked to monitoring efforts aimed at mammals and small-scale studies of shrub succession.

The VCR LTER is building new Field Station at Oyster, VA. A grant from the University of Virginia (450K) and from a graduate of the University of Virginia ($1M) are being used to purchase and construct phase one of a new field station for research. Negotiations on the land purchase have taken much longer than anticipated (original plans called for construction starting in 1997), however they are now nearly complete. PIs of the VCR LTER have worked over the last 4 years to reach this point and we expect construction to begin in the Fall of 1998 or Spring of 1999.

Several additional activities will involve interactions with other LTER sites, particularly the new Plum Island (PIE) LTER. PI's Karen McGlathery (UVA) and Iris Anderson, (VIMS) will be participating in cross-site activities with the Plum Island LTER. Details are to be worked out in collaboration with Chuck Hopkinson. Their plan is to measure water column gross and net mineralization at both VCR and PIE. Karen McGlathery will also be participating in collaborative work with Pier Luigi Viaroli,(Sacco Di Goro, Italy) and Rutger de Wit (Bassin d'Arachon, France), also including VCR LTER PI Bob Christian (ECU) on DON cycling in shallow lagoonal systems.

New research is being proposed for the VCR that would potentially link the Plum Island LTER and many other coastal wetland sites. We are planning to measure sea level rise, marsh accretion/elevation changes, and couple these with waterbird habitat use to determine whether marsh lagoonal islands are able to keep pace with sea level rise in selected mid Atlantic coastal lagoons where there is a major concentration of federal trust species of waterbirds. These number almost 100 species of wading birds, seabirds, shorebirds, and waterfowl from southern New England to Virginia. Work with Don Cahoon from the National Wetlands Research Center, and J. Allen and C. Roman from URI's Coastal Research Lab (now part of USGS Patuxent Wildlife Research Center) is being coordinated by VCR/LTER PI R. Michael Erwin, and S.E.T. devices will be installed in marshes in summer 1998 in New England. In 1999, the plan is to include the Virginia Coast Reserve as a second site.

Cross-Site & International Activities

Activities for Iris Anderson

- International Activities: Will take part in a field study of the effects of nitrogen saturation on a forested watershed in the Sumava Mountains, an ILTER site. Research will be performed in conjunction with Drs. Vera Straskrabova, Jarda Vrba, and Jiri Kopacek of the Hydrobiological Institute, Academy of Sciences Czech Republic.
- Will present a paper on research results of Sumava study at the IALE Conference, to be held in Prague, September 6 - 13, 1998.
- Took part in a NSF-sponsored workshop, Safari 2000, in the Republic of South Africa. Purpose of the workshop was to develop a research program to study land-atmosphere interactions. In particular we are interested in the relative roles of atmospheric nitrogen deposition relative to in situ nitrogen fixation as a source of new nitrogen to nutrient-poor ecosystems in southern Africa. We are interested in proposing a project to be performed in Kruger National Park, a proposed ILTER site. South African colleagues include: Bob and Mary Scholes (S. Africa, Witts University), Harold Annegarn (S. Africa, Witts University), Susan Ringrose (University of Botswana), Wilferd Versfeld, Etosha Ecological Institute, Namibia.

Activities for Linda K. Blum:

- Samples sent to Jorgen Lissner Institute of Biological Sciences Department of Plant Ecology University of Aarhus Nordlandsvej DK-8240 Risskov DENMARK, Ingrid Burke Colorado State University Dept. of Forest Sciences Fort Collins
- Steve Newell, intersite comparison of fungal dynamics on *Spartina alterniflora*
- Denise Reed, submitted a joint proposal for comparative work between LA and VA
- Ross Hinkle and Ron Brockmeyer, submitted proposal for comparative work between the Indian River Lagoon and VCR marshes
- Currently working with Ross Hinkle and Ron Brockmeyer to establish intersite comparison between Indian River Lagoon and VCR marshes

Activities for Robert R. Christian:
- Helped organize the ILTER symposium and workshop at the Intecol meeting in Florence, Itlay in July 1998.
- Mark Brinson and Robert Christian gave a workshop on network analysis and functional assessment at the Academia Sinica, Taipei City, Taiwan. Robert Christian also met with Drs. Chou and Chiu who have been active with the Taiwanese LTER program.
- Mark Brinson and Robert Christian taught for 1 week in the European Union sponsored European Masters in Environmental Management. Our part of the course was taught at the Univ. of Parma.
- Mark Brinson and Robert Christian gave a 3-part workshop on hydrogeomorphic classification and functional assessment of wetlands in Puerto Rico.
- Participated in the VCR efforts regarding nitrogen inputs from atmospheric deposition.

Activities for Frank P. Day:
- Graduate student, Rett Weber, conducting intersite study at Konza and VCR.

Activities for Karen J. McGlathery
- Involvement in LTER Nitrogen Initiative (organized by Jim Gosz)to use LTER sites as index sites to compare N inputs to N retention and loss.

Activities for John H Porter:
- LTER Executive Committee Member.
- Designed and implemented All-Site Data Catalog. System has now been transferred to LTERNET server.
- Luquillo LTER Advisory Committee. Worked with LUQ information manager on improving system capabilities, particularly in the area of online forms.
- NASA Global Change Master Directory. Member of User Working Group.
- IEEE Metadata Meeting. Speaker.
- U.S. CODATA Meeting. Attended.
- Organization of Tropical Studies Database Workshop, Costa Rica. Participant.
- Latin American ILTER workshop, Puerto Ordaz, Venezuela, information management group
- Presentation on LTER Information Management to Biodiversity and Ecological Informatics group (an interagency group focusing on informatics issues)
- XROOTS Workshop, Davis California. Participant
- Data Task Working Group Meeting (with NET, BNZ, NWT, AND LTER sites)

- International Congress of Ecology, Florence, Italy. Two presentations on LTER Information Management
- ILTER Meeting, Florence Italy. Presentation on Latin American Information Management efforts
- Chair, Long Term Studies Section of the Ecological Society of America
- Ecological Society of America. Committee on Data Sharing and Archiving. Member

Information Management

The VCR LTER Information Management System was extensively revamped during late 1996 and early 1997. A major step was taken to allow PI's to directly input and modify metadata (documentation) using online forms on the WWW. The metadata is maintained in a relational database (MSQL) running on a UNIX platform. Using that system 45 datasets were placed online during 1997-1998. VCR/LTER data can be accessed at: http://www.vcrlter.virginia.edu/data.html.

WWW System Use -- The VCR LTER WWW server transferred 807,458 files during May 1997-May 1998. This included an average of 939 requests per day for WWW pages (not graphics). There were a total of 66,520 different computers accessing the system during that period. Educational users made up the largest single block of users, comprising 46% of overall requests and 47% of all bytes downloaded. 110 different countries were identified among the user-base. Detailed weekly usage logs are available at http://www.vcrlter.virginia.edu/usage/.

With a supplement from NSF we will be strengthening our program for archiving physical samples. This activity will be conducted in partnership with the Virginia Museum of Natural History. We will be cataloging existing and new samples and placing the catalog online via the WWW. Samples will include a variety of tissue samples (suitable for genetic and stable isotope analyses), a herbarium and soil and water samples.

Outreach Activities

- Undergraduate Student Outreach -- The VCR LTER has 2 NSF REU students during the summer of 1998. Out of project funds, we augment these REUs with 2 to 3 undergraduate students. In the Fall of 1997 we offered instruction to 8 students on building a biodiversity information system for the Delmarva Peninsula (Smith and Porter). The biodiversity information system project now contains nearly 6000 species observations, many of them annotated with natural history and graphical information. The system is available for public use at: http://www.vcrlter.virginia.edu/data.html.
- Penrose Conference -- The VCR/LTER hosted a full-day field trip by 80 geologists and ecologists attending the 1998 Penrose Conference. Participants toured four diverse coastal sites and received briefings on VCR/LTER research and LTER research in general.
- Exhibitor, The Coalition for National Science Funding 4th Annual Exhibition and Reception, House Building, May 1998. Representing the Ecological Society of America and LTER Network. (Porter) (note: no LTER funds were used to support this activity).
- Guest, statewide NPR program "With Good Reason" (Young)

- Used LTER Program and VCR site extensively in graduate course in Ecosystems Ecology at Old Dominion University. (Day)
- Seminar at VIMS on Eastern Shore water quality work (Blum)
- Scientific advisor to Eastern Shore Water Quality Consortium (Blum)
- Use examples and information from the VCR-LTER project in several undergraduate classes extensively. (Kochel)
- Depending on weather and logistics, we try to make one trip per year to the VCR-LTER sites with my advanced course in Applied Environmental Geomorphology (Kochel)
- Plans are being made to highlight the VCR-LTER in a Fall series of Freshman Seminars devoted to the study of the Susquehanna River-Chesapeake Bay watershed which will culminate with a trip to the LTER site and visits with professionals and local working on the Bay.(Kochel)

Other Grants at VCR/LTER Site

Frank P. Day -- Atlantic White Cedar Restoration: Monitoring for Ecosystem Services and Self Maintenance EPA (subcontract from Christopher Newport University). $166,317

Frank P. Day -- Belowground plant responses to carbon dioxide enrichment DOE (subcontract from Smithsonian Institution) $131,250

Craig Kochel -- Undergraduate Research Fellowship (support of Nicole Bailey) Bucknell University $2,200

Robert R. Christian -- Contributions to the long-term modeling tier of MODMON State of North Carolina, Div. of Environmental Health and Natural Resources, through UNC WRRI $10,399

Patricia Wiberg -- Generation of non-point source pollution and flood waters: identifying source areas from considerations of soil moisture dynamics U.S. Geological Survey and Virginia Water Resources Research Center

Donald R. Young -- Interacting biotic mechanisms that control shrub establishment on Atlantic Coast barrier islands Jeffress Memorial Trust $9,910

Donald R. Young -- Revegetation of coastal spoils on Swash Bay, Virginia VA Dept. of Environmental Quality $27,018

Donald R. Young -- Monitoring revegetated spoils in Swash Bay, Virginia VA Dept. of Environmental Quality $12,722

Karen J. McGlathery -- Nitrogen Cycling in a Lagoonal Land-Margin Ecosystem: Importance of Dissolved Organic Nitrogen NSF $71,230

John D.Albertson -- Generation of Non-Point Source Pollution and Flood Waters: Identifying Source Areas from Considerations of Soil Moisture Dynamics USGS $24,288

John D. Albertson -- Anthropogenic and Topographic Controls on Transition of Coastal Marshes Virginia Water Resources Research Center $5,000.

John D. Albertson -- Experimental Investigation of Soil Moisture-Runoff Dynamics Virginia Water Resources Center $10,000

R. Michael Erwin -- Habitat Restoration for terns in coastal Virginia US Fish and Wildlife Service $8,000

John H. Porter, R. Michael Erwin, R. Dueser et al. Ecosystem research on the Virginia Coast Reserve: Conservation within Dynamic Landscapes. The Nature Conservancy. $114,968.

Collaborations

Mark M. Brinson -- Donald R. Cahoon Southern Science Center, Biological Resource Division, U.S. Geological Survey

Robert R. Christian -- Christine French NSF and Network Office

R. Michael Erwin -- James D. Nichols Patuxent Wildlife Research Center - USGS

R. Michael Erwin -- Jeff S. Hatfield Patuxent Wildlife Research Center - USGS

R. Michael Erwin -- Barry R. Truitt The Nature Conservancy

R. Michael Erwin -- Laura Mitchell Chesapeake Field Office, US Fish and Wildlife Service

New Publications

Journal Articles

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Conn, C.E. and F.P. Day. 1997. Root decomposition across a barrier island chronosequence: litter quality and environmental controls. Plant and Soil 195:351-364.

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Erwin, R.M., J.D. Nichols, T.B. Eyler, D.B. Stotts, and B.R. Truitt. in press. Modeling colony-site dynamics: A case study of Gull-billed Terns in coastal Virginia. Auk

Erwin, R.M., T.B. Eyler, D. B. Stotts, and J.S. Hatfield. in review. Aspects of chick growth in Gull-billed Terns in coastal Virginia. Colonial Waterbirds

Hayden, B. P. 1998. Ecosystem feedbacks on climate at the landscape scale. Phil. Trans. R. Soc. Lond. B 3553, 5-18.

Michener, W.K., E.R. Blood, K.L. Bildstein, M.M.Brinson, and L.R. Gardner. 1997. Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands. Ecological Applications 7:700-801.

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The Working Group on Sea Level Rise and Wetland Systems (includes Christian and Brinson). 1997. Conserving coastal wetlands despite sea level rise. Eos 78:257, 260-261

Book Chapters

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Christian, R. R., L. Stasavich, C. Thomas, and M. M. Brinson. in review. Reference is a moving target in sea-level controlled wetlands. In M. P. Weinstein and D. A. Kreeger. Proceedings of "Concepts and Controversies in Tidal Marsh Ecology". Kluwer, Dordecht,The Netherlands

Christian, R. R., M. Naldi, P. Viaroli. 1998. Construction and analysis of static, structured models of nitrogen cycling in coastal ecosystems. Mathematical Modeling in Microbial Ecology. Chapman Hall, New York :162-195.

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Theses and Dissertations

Bailey, Nicole. 1998. Hydrogeomorphic Control of Landforms and Vegetation on Southern Parramore Island, Virginia Coast Reserve. Bucknell University, Department of Geology, Honors Thesis, 160pp.

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Elliott, M.T. 1997. Influences of tidal litter (wrack) and microtopography on strand species and on community composition. MS thesis. Virginia Commonwealth University, Richmond, VA

Sullivan, H.J. 1998. Ant distribution patterns and the potential dispersal of root endosymbionts in a strand environment. MS Thesis, Virginia Commonwealth University, Richmond, VA

Other Publications

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Christiansen, T. 1998. Sediment Deposition on a Tidal Salt Marsh. Dissertation. University of Virginia, Charlottesville VA pp. 134.

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