

**Context:**

Research by the Virginia Coast Reserve (VCR) LTER project scientists continues to focus on our core hypothesis that ecosystem, landscape and land use patterns within terrestrial-marine watersheds are controlled by the vertical positions of the land, sea, and freshwater groundwater table surfaces. Coastal storms, climate change, long-term eustatic sea-level rise and land subsidence cause variations in elevations of these surfaces that drive ecosystem dynamics. Biotic feedbacks within ecosystem states also influence the responses to external stressors. Ecological processes, including organic matter production and species extinction and colonization, alter the rates of erosion and sediment deposition and thereby alter land and water table surface elevations. Short-term episodic events and long-term systematic trends in sea level, land and groundwater surfaces give rise to variations in nutrient availability, primary productivity, organic matter accumulation and trophic interactions.

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

**Activities:**

Continuation and augmentation of long-term experiments and core monitoring activities have comprised a large part of our activities for the year. These core activities include tracking of changes in ecological states in relation, collection of groundwater, meteorological, and tidal data, monitoring watershed nutrient inputs into coastal lagoons via tidal streams, monitoring transects in the coastal lagoons for water quality, primary production, and benthic biodiversity, monitoring terrestrial vertebrate populations (birds and mammals), measuring the effect of manipulation of sea level on marsh communities, modeling hydrodynamics and transport in coastal lagoons.

**Lagoon:**

Our research for the VCR coastal lagoons continues to be on the linkages between watershed land use and the impacts of nutrient loading on the lagoon ecosystem, and on the return of the foundation species, *Zostera marina* (eelgrass). In order to assess the fate and transport of nutrients across the landscape, our studies relate nutrient inputs to processing by primary producers and consumers and physical transport within the lagoon. Our models of hydrodynamics and sediment resuspension set the state for the planned large-scale recolonization of seagrass in Hog Island Bay and other lagoons in the VCR.

### *Continuing Activities*

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

We continue to monitor the two long-term water quality transects in the VCR lagoons, one of which was added last year. The transects represent the gradient from mainland – lagoon – barrier island – ocean inlet in two bays that represent different water land use and nutrient loading rates. We couple measurements of water quality (nutrient concentrations, light availability, suspended solids) to estimates of primary producer (benthic algae, phytoplankton) at each site. This year we have added measurements of invertebrate biomass and diversity to the lagoon survey (see below in *New Activities*). (Blum, McGlathery, Christian)

To estimate groundwater nutrient loading during baseflow to the coastal lagoons, we are monitoring 14 tributaries that drain watersheds of differing land use across the VCR landscape. (Mills, Anderson). This year we have added stilling wells to 3 sites to capture storm flow nutrient inputs (see below in *New Activities*). (Anderson)

### *New Activities*

To augment our long-term monitoring program of the effects of watershed land use on water quality in the VCR coastal lagoons, we have instrumented 3 tidal streams that represent different levels of nutrient loading with stilling wells. Continuous monitoring of these wells along with rainfall measurements provide the data input for a hypsometric model to separate baseflow from surface water runoff into the streams. Nutrient samples are also being taken simultaneously to estimate nutrient flux during episodic rainfall events. (Anderson)

We have added sampling of benthic and pelagic invertebrates to our quality sampling along the 2 mainland-ocean transects. For both sediment infauna, and pelagic epifauna, we will be recording abundance and species diversity of the major taxonomic groups. We are particularly interested in the relationship between benthic fauna and the biomass of bloom-forming macroalgae. These data will serve as a baseline for changes in faunal abundance and diversity as the system undergoes a state change to a seagrass-vegetated lagoon. (McGlathery, Smith)

We are continuing our investigations of macroalgal communities in Hog Island Bay, in particular their role in nutrient cycling and trophic dynamics within the bay. We have focused on the role of the abundant polychaete, *Diopatra cuprea*, as a ‘foundation’ species, facilitating macroalgal distribution in Hog Island Bay, particularly the invasive species *Gracilaria vermiculophylla*.

We are extending our work on the relationship between sediment resuspension and light availability in Hog Island Bay to understand the effects of different primary producers

(seagrass, macroalgae, benthic microalgae) on sediment resuspension and nutrient release to the water column. The work will be done using Gust erosion chambers that allow us to manipulate shear stress at the sediment surface in sediments vegetated by the different types of benthic plants. (Wiberg, McGlathery)

Macroalgae serve as a large, temporary reservoir for carbon and nitrogen in lagoonal systems, particularly those that are impacted by increased nutrient loading from the coastal watershed. To quantify the various short- and long-term fates of the carbon and nitrogen bound within macroalgal tissue, we are monitoring sediment and water column parameters along a cross-lagoon transect during the macroalgal bloom and crash cycle. In addition, we are tracing the fate of macroalgal carbon and nitrogen during a simulated macroalgal bloom and crash using dual isotope tracer and biomarker techniques in an outdoor mesocosm experiment. (Anderson)

We are applying a numerical model developed for the Venice Lagoon to Hog Island Bay that calculates tidal currents, wind wave heights, bottom shear stresses caused by the waves, and influence of wind stresses on the flow field. The model couples a hydrodynamic finite element module based on the shallow water equations with a finite volume module that accounts for the generation and propagation of wind waves. The wave module solves the wave action conservation on the same triangular mesh used in the hydrodynamic module, thus correctly reproducing the physical relationships between waves and tide propagation. The model is specifically designed for intertidal environments basins with irregular bathymetry characterized by deep channels, emergent salt marshes, and extensive tidal flats. A module specifically computes the transport parameter at the bottom, thus highlighting areas in erosive regime. We hope to build on this framework to develop a more integrated picture of controls on turbidity in Hog Island Bay, the effect of vegetation on the lagoon bottom, residence time and circulation. We also plan to link this model to the biogeochemical measurements made by McGlathery and Anderson to understand the flux of watershed nutrients through the lagoon to the coastal ocean (Wiberg with collaborator Fagherazzi).

In addition, we are combining field data and GIS techniques to develop protocols for understanding flushing characteristics in coastal bays. NWI and hydrographic data are used to develop hydro-hypsographic curves for hydraulic turn-over analysis. Lagrangian data are then used to calibrate depletion patterns of exchange. (Oertel)

We collected approximately 1000 samples of primary producers through higher trophic level fish during the summer of 2004 to examine trophic relationships by stable isotope analyses in seagrass meadows in South Bay that have been restored by seeding within the last 5 years. The dominant invertebrates (crabs, shrimp, amphipods and isopods), plant material (seagrass and algae) and overlying water were sampled for stable isotopes of carbon, nitrogen, and sulfur ( $^{13}\text{C}$ ,  $^{15}\text{N}$ , and  $^{34}\text{S}$ ) to estimate the influence of primary producers in the diet of resident species. Carbon and nitrogen isotopic signatures of gut contents of fish have been analyzed and compared to isotopic signatures of muscle tissue in each respective fish. (Macko)

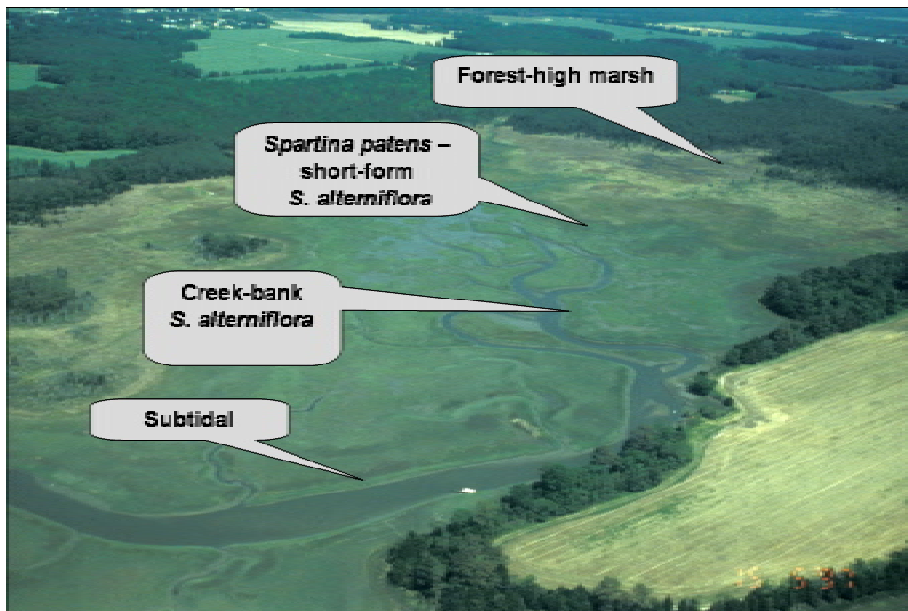
In collaboration with Pier Luigi Viaroli (University of Parma, Italy) we are investigating nutrient cycling and ecosystem metabolism of coastal lagoons using network analysis. We are developing models for Hog Island Bay, which receives relatively low nutrient loading from the agricultural watershed, and the Lagoon of Venice, which is a heavily eutrophic lagoon. (Christian, McGlathery, Anderson)

### Marsh:

Research in wetlands at the VCR focuses on the question of how the interaction between the land, freshwater, and sea-level results in state change by examining the way in which biological and physical processes affect the geomorphology within states. We continue to focus our efforts on long-term measurements of marsh biomass and community change, sediment accretion in relation to sea level rise, groundwater levels, and marsh food web dynamics. Of particular interest is the occurrence of marsh die-off in parts of the VCR landscape, a phenomenon that has occurred throughout the eastern seaboard.

### *Continuing Activities*

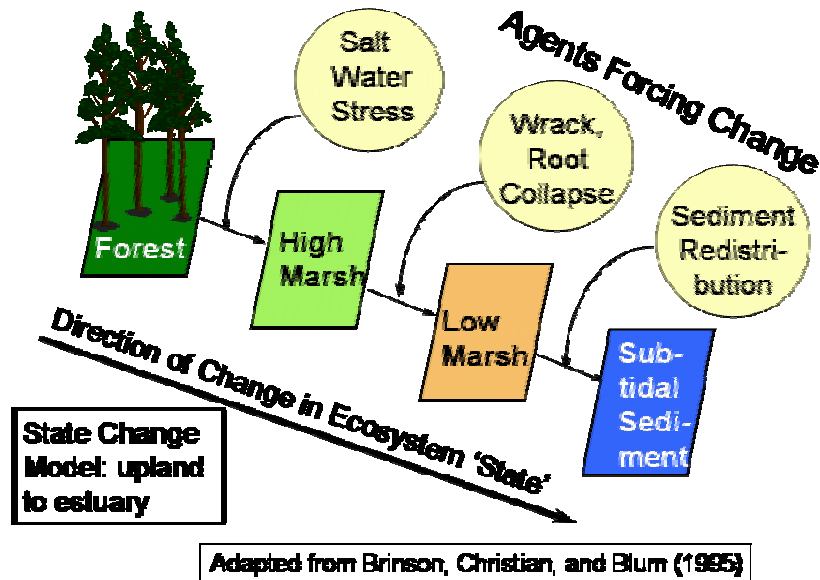
At the landscape scale, we continue our monitoring of peak standing crop of marshes and marsh die-off. This regional study gives us a framework for applying our understanding of the relationship of the free surfaces to state change in the marshes. We are also continuing our more detailed monitoring of marsh biomass and community structure in permanent plots at one marsh site. (Brinson, Christian, Blum)



Habitat/inundation zones in Phillips Creek Marsh, a principal VCR/LTER research site.

We are also continuing our long-term inundation experiment to test the effects of simulated sea-level rise on marsh biomass, community structure and nutrient cycling.

Experimental plots are being used to examine the effect of more frequent tidal inundation on high marsh plant communities. (Christian)



At the Phillips Creek study site, our work on trophic interactions focuses on creating food web networks for high marsh ponds. We are also monitoring changes in groundwater levels in the salt marsh and surrounding uplands at this site, and tracking salt marsh accretion due to root production and sediment accumulation. (Christian, Brinson, Blum)

From these activities, we have established a series of long-term measurements to examine the rates of change in the following parameters (Christian, Blum, Brinson):

- peak salt marsh grass standing stock at a regional scale
- salt marsh surface elevation
- accretion of sediments on the salt marsh
- salt marsh accretion due to root production
- high salt marsh community change
- groundwater levels

We are examining questions about the spatial and temporal distribution of microbial communities in wetland sediments to understand what factors controlling rates of organic matter accumulation and nutrient processing. (Blum)

### *New Activities*

During spring 2004 we observed significant areas of salt marsh grass die-off in a single marsh. Plots were established in 2004 to track the extent of the die-off and to monitor recovery or state change within the die-off areas. We continue to monitor the die-off areas. New die-off was observed in another marsh in spring 2005. Plots to monitor the die-off were established and



are being monitored. Reciprocal transplant experiments were initiated in May 2005.

The biotic feedback of fiddler crab (*Uca* spp.) burrowing activity may influence the state change in marsh ecosystems in response to sea-level rise. We are studying how changes in tidal inundation due to an increase in relative sea-level will affect the pathways of organic matter oxidation and the overall pore water chemistry of salt marsh sediments with the presence of fiddler crab burrows. These processes will have an impact on *Spartina alterniflora* production and organic matter buildup, in response to sea-level rise. (Zieman)

The distribution of the non-native grass *Phragmites australis* has increased significantly in VCR marshes in recent years. We investigated the physiological mechanisms that might be responsible for *P. australis* expansion, including higher photosynthetic efficiency and the direct uptake of dissolved organic nitrogen. (Zieman)

We have begun a new collaboration with Chip Bachman (Naval Research Lab) and Elijah Ramsey (USGS) to use aerial photography to measure marsh community change and estimate regional marsh plant biomass at broad scales than our current ground-based measurements allow. Long-term measurements and experiments will continue and serve as ground-truth measurements for remote sensing measurements. This effort addresses the core area of primary productivity, in addition to providing information about within state biological process rates and state change.

Another new collaboration is with Gene Turner (LSU) to examine the effect of temperature and nutrients on rates of organic matter accumulation began in May 2005. Experimental sites are located in Louisiana, South Carolina (NIN), Virginia (VCR), and Massachusetts (PIE). The results of these experiments contribute to understanding the core of primary production (belowground), organic matter accumulation and nutrient dynamics at broad geographic scales in salt marshes.

#### Terrestrial:

Our activities in the terrestrial portions of the VCR landscape continue to focus on increasing our understanding of the relationship between the groundwater and land free surfaces, and how this relationship influences patterns of nutrient cycling and primary production. We have also continue to study the effects of Hurricane Isabel, which occurred in September 2003, on small mammal populations as a result of flooding and habitat loss, and on the invasion of the marsh grass *Phragmites australis* on some of the islands.

#### *Continuing Activities*

Monitoring of long-term plots, sites, transects and groundwater wells continues annually on Hog Island. PI Frank Day has quantified spatial/temporal variations in fertilized and unfertilized plots on the grass dominated dunes across the Hog Island chronosequence.

These are related to fluctuations in groundwater wells. PI Don Young has compared spatial variations in *Myrica cerifera* shrub thicket annual shoot growth at four locations representing a variation in thicket age and exposure. We have continued the monitoring of small mammals with live traps along Hog Island transects and have developed a digital photographic record of habitats and disturbances on Hog Island (PI Porter in collaboration with Ray Dueser, Utah State University).

During 2004-2005 we have also done a major rebuilding of VCR/LTER meteorological and tide stations. The Phillips Creek meteorological station was completely destroyed by flooding caused by Hurricane Isabel in late 2003. It has now been rebuilt using a new tower and instruments and new documentation created. We are continuing our 15-year record of monitoring deposition of atmospheric nitrogen via wet deposition at the new meteorological site. Precipitation samples are collected weekly and analyzed for the major chemical constituents (including  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ , and  $\text{H}^+$ ). A new tide station was installed in early 2005 on the dock of the Anheuser Busch Coastal Research Center (ABCRC).

### *New Activities*

On a shorter-term basis, numerous projects have been either completed or initiated in support of the long-term activities. Brett McMillan, an ODU doctoral student working with Frank Day, is focusing his dissertation work on vegetation dynamics on "pimples" (small dunes with highly zoned vegetation). Attempts to utilize ground-penetrating radar to map groundwater levels and root architecture and biomass will be attempted this summer. Steven Brantley, VCU doctoral student with Don Young, continues to quantify spatial variations in litter production and leaf area index for *Myrica* shrub thickets on Hog Island. In conjunction with the annual shoot growth measurements, the results will be used to estimate ANPP variations. Jaime Fuest, a VCU MS student working with Don Young, completed a comparison of variations in insect herbivores abundance, herbivory damage, and plant abundance on dunes across the Hog Island chronosequence. Stable isotope analyses, linked individual grasshopper species to preferred diets and locations on the island.

Small mammal trapping on Ship Shoal and Myrtle islands was conducted in the summer and fall of 2004 and the summer of 2005 to determine changes in the fauna of the island driven by extensive flooding and habitat loss during Hurricane Isabel. Sample collection activities during trapping have been expanded to include fecal and blood samples aimed at identifying wildlife diseases. In addition, VCR PIs (Porter, Erwin) have collaborated with Shawn Padgett of the College of William & Mary on a digital image database that tracks use of a nest tower by Peregrine Falcons. Images are captured every 10 minutes from three cameras located in, or near the box. The images are transferred via a wireless network connection to UVA where they are archived. Thus far over 18,000 individual images have been captured.

A three-year assessment of the invasive grass, *Phragmites australis*, is in the final year. This is a collaborative project between VCU and the Virginia Departments of

Environmental Quality and the Natural Heritage Program. Over 1,400 patches have been mapped on the barrier islands and Eastern Shore of Virginia. Special attention has been given to Parramore Island, where fire and Hurricane Isabel have created increased disturbance that may facilitate *Phragmites* expansion. This summer, a random subset of the patches has been sampled to determine the percentage of native vs. the introduced, invasive genotype. Julie Naumann, VCU doctoral student, has initiated a field based student of variations in plant stress and leaf fluorescence to remotely assess the physiological condition and potential for expansion of individual patches of *Phragmites* the Virginia Coast Reserve. (Young)

Graduate student Michael O'Connell is investigating the effects of site water conditions on barrier island (Assateague Island, MD and Parramore Island, VA) vegetation, and - characterizing ecosystem vulnerabilities to environmental forcing factors such as sea level rise, climate change and geomorphologic change. Measurement of vegetation biophysical properties related to canopy structure and leaf area is accomplished with a unique small-footprint, airborne, scanning *lidar* (Light Detections and Ranging) system. Field sampling documents forest structural components including Plant Area Index (PAI), verifies remotely sensed data, and describes site water availability. Freshwater availability, geomorphic, and vegetation assemblage gradients identified by field observation will be tested for correlation with patterns in PAI and other pertinent vegetation measures like height, basal area, and biomass to assess sensitivities and predict future changes. This novel combination of remotely sensed properties and field environmental data will be developed to investigate fundamental physiological interactions (such as water and foliar area in transpiration) and characterize and monitor effects of environmental change on island vegetation.

Thus far, one EAARL (Experimental Advanced Airborne Research Lidar) survey has been completed of the entire upland portion of Parramore Island on August 26, 2004. Cooperators at the USGS are currently processing these data for basic information like first-return and last-return position layers (approx. 1m horizontal and 11cm vertical resolution) as well as time-resolved intensity waveforms for the eventual analysis of vegetation structure. No further Lidar surveys of Parramore are planned, however, there is a possibility that the Virginia end of Assateague Island will be surveyed this fall.

In May of this year, he installed four automatic water-level recorders (recording water table position points every hour) at critical upland locations that are in or near the established long-term vegetation monitoring plots of Shugart. These data will provide for a characterization of on-site water availability and the development of gradient analyses.

#### Information Management:

The principal activities in the area of Information Management, have been the development of rich Ecological Metadata Language (EML) metadata and a new web site for the VCR/LTER. During late 2004 we developed a program which extracts the information needed to populate and EML document from metadata in our existing database. It includes most of the elements needed to reach "level 5" status in the best



practices guide written by the LTER Information Management Committee. Starting in July 2005, our metadata is available in the KNB Metacat system.

The new web page uses a content management system to facilitate management. In a content management system, page contents are stored in a relational database (MYSQL) and used to populate the pages "on the fly." Our system is a hybrid, with some web pages generated from the database and others in a static form more suitable for archival storage.



The new VCR/LTER Home Page: