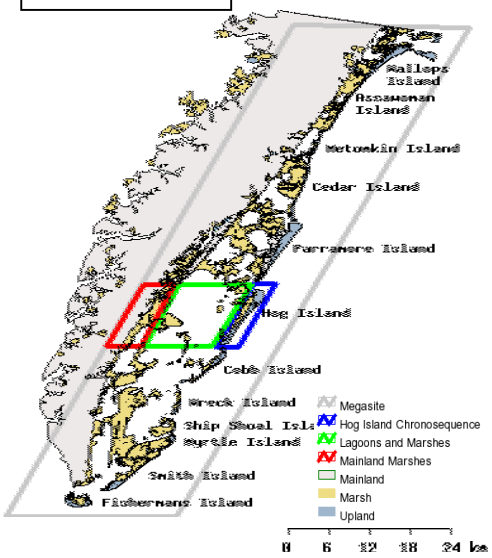
Research by Virginia Coast Reserve Long-term Ecological Research project (VCR/LTER) scientists continues to focus on our core hypothesis that ecosystem, landscape and land use patterns within terrestrial-marine watersheds are controlled by the vertical positions of the land, sea and freshwater groundwater table surfaces. Coastal storms, climate change, long-term eustatic sea-level rise and land subsidence cause variations in the elevations of these surfaces that drive ecosystem dynamics. Ecological processes, including organic matter production, 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 and land and and groundwater surfaces give rise to variations in nutrient availability, primary productivity, organic matter accumulation and trophic interactions.

In VCR/LTER I (1997-1992) we focused on geophysical controls (e.g., storms) on coastal ecosystems. In VCR/LTER II (1992-1994) we introduced the concept of ecological state change, which was linked in VCR/LTER III (1994-2000) to relationships between free surfaces (land, sea, freshwater table). Under the current VCR/LTER grant (VCR/LTER IV 2000-2006), we have added a hypsometric perspective, which provides an alternate way of examining ecological patterns on the coastal landscape.

Continuing research focuses on collection of long-term data sets and maintenance of long-term experiments started during VCR/LTER I-III (1987-2000). Since 2000 we initiated additional monitoring and experimental work in the uplands, lagoons, marshes of the Virginia Coast Reserve. These activities and our findings are outlined below.

VCR/LTER Study Areas



Activities:

Upland:

Our activities in the upland have focused on better understanding the relationship between ground-water and land-surface free surfaces, and how this relationship affects ecological processes including productivity, decomposition. A special effort, intiated in 2002 and continued this year is an attempt to integrate data on meteorology with our records of primary productivity. We have also been engaged in studying the trophic structures related to gulls and colonial waterbirds. With external funding and collaborators (notably Raymond Dueser), we have been examining the relationship between introduced and native predators and productivity of nesting colonial and beach nesting waterbirds and have been using stable isotope analyses to better understand bird feeding patterns. Additionally, we improved our monitoring capabilities by installing a wireless network out to our Hog Island research site. Specific activities include:

1. Intrasite (VCR) synthesis activities continued to examine interannual productivity patterns in relation to meteorological and climatological variables. (Christian, Day, Blum, Young, Brinson, Mills, McGlathery, Zieman, Hayden and Porter). This ongoing effort started with developing a database of meteorological and climatological data that combines LTER meteorological station data with external data that predates the initiation of the VCR/LTER site. Data on productivity and indicators of productivity (e.g., biomass, stem counts) were compiled for *Myrica cerifera*, *Spartina patens*, *Spartina alternaflora*, and *Distichlus spicata*. The research group held meetings in July 2002, October 2002 and May 2003 to work on analyses of this data, focusing on within-site and within-species relationships between production and climatological variables.

2. Measured the nitrate removal from groundwater by riparian wetlands and continued stream flow monitoring (Mills)

3. Investigated the biogeography of microbial decay communities. (Mills, Blum)

4. Continued monitoring of permanent vegetation plots and groundwater wells on Hog Island. Brett McMillan, a doctoral student is focusing his dissertation work on vegetation dynamics on "pimples" (small dunes with highly zonated vegetation found in marshes). (Day)

5. Continued development of our wireless network link over 25 km between our laboratory in Oyster VA and our field research sites on Hog Island. Our goals for the VCR/LTER wireless project are ambitious and threefold: 1) to allow transmission of meteorological and other digital data sources from our island study sites back to our researchers, 2) to provide access to real-time weather radar an other web-based information sources for researchers and technicians in our study areas and 3) to support video- teleconferencing for use with classes and real-time interactions between researchers, students and technicians located at both island and mainland locations. With the help of David Hughes and Tom Williams of the NSF-funded Wireless Networks for Biology project (http://www.oldcolo.com) we have established the network and are now exploiting it. During May 2002 we installed a pan-tilt-zoom webcam on the southern end of Hog Island. This has now been supplemented by 5 additional webcams focusing on Fiddler Crab (*Uca* sp.) habitats and on bird colonies on Chimney Pole Marsh.

6. The Virginia barrier islands historically have been among the most important nesting areas for colonial and beach-nesting waterbirds in the entire mid-Atlantic region. The apparent spread of the raccoon (*Procyon lotor*) and the introduced red fox (*Vulpes vulpes*) on these islands has significantly reduced habitat suitability for these avian species. Collaborator Raymond Dueser and PI Nancy Moncrief are conducting studies designed to produce a strategic plan for restoring avian habitat through predation management. This has included periodic track surveys to estimate densities, radiotracking of individual predators to determine movement patterns (especially inter-island movements) and nest predation experiments using real and simulated (clay) eggs. (Moncrief, Dueser, Porter)

7. We are continuing to study the complex relationships between barrier island morphology and disturbance and the distribution and abundance of mammal populations. In addition to conducting traditional trapping surveys to determine presence/absence and estimate abundances, we are developing molecular markers useful in exploring ecological processes such as colonization and extinction and evolutionary processes such as gene flow in the highly fragmented landscape of the VCR. (Moncrief, Dueser, Porter)

8. Declassified satellite imagery was used to examine landscape change since 1963 on Hog Island and Phillips Creek research sites (Porter, Hayden, Young). Change analyses have been used to document shrinking of marsh surfaces on Hog Island and to determine the topographic ranges colonized by shrubs. This imagery was obtained with the help of John Vande Castle at the LTER Network Office and Scott Collins at the National Science Foundation. It has been supplemented with Thematic Mapper and IKONOS imagery from collaborators Chris Justice (UMD) and Chip Bachmann (NRL).

9. In the area of cross site studies, we have continued work at the Florida Coastal Everglades and Sevilleta LTER sites aimed at understanding the relationship between vegetation hydrocarbon emissions and climate controls (Hayden)

10. Continued long term measurements of shrub and herbaceous productivity on fertilized and unfertilized plots on Hog Island. (Day, Young)

11. Initiated studies examining the effects of wildfire on Parramore Island (Young)

12. Routine weekly sampling of precipitation chemistry continues. All precipitation samples received by the laboratory to date (recovered though 7 March 03) have been analyzed and are currently undergoing standard QA evaluations. Final data will be posted to the LTER data archive within a few weeks. (Galloway)

13. Continued monitoring of bird populations as a member of the Virginia Barrier Island Avian Partnership. Monitoring of gull-billed tern populations in conjunction with U.S.G.S./B.R.D. (Erwin)

Lagoon:

The lagoons within the VCR constitute the ecological bridge between our mainland and island research sites, linking mainland watersheds with the coastal ocean. Activities of primary producers and heterotrophs influence the degree to which lagoons retain or remove watershed nutrients and organic matter during transport from the mainland to the coastal ocean. We are gaining increased understanding of the drivers of water movements within the lagoon (tidally vs wind driven). We are also facing the prospect of a dramatic state change for the entire lagoon over the next several decades. Efforts to return eelgrass (*Zostra marina*) to the lagoon system (where it has been absent since the 1930s) are beginning to bear fruit in lagoons south our principal study area in Hog Island Bay. Our research is paving the way for reintroduction of this species to Hog Island Bay. If

successful, a transition from a relatively unproductive mud-bottomed bay to a highly productive seagrass dominated bay may occur. Specific research activities in the lagoon include:

1. Deployed a profiling Doppler current meter and wave height measurement system to assess current flows behind Hog Island. This data will be used to improve hydrodynamic models of the lagoon system (see below) (Wiburg)

2. Continued measurements of sediment resuspension and light attenuation in Hog Island Bay. A model of sediment resuspension and its relationship to light attenuation is being constructed that will allow us to predict where eelgrass colonization is most likely to be successful. (Wiberg, McGlathery)

3. Continued intensive monitoring program for Hog Island Bay and its tributaries (McGlathery, Anderson, Blum, Christian)

4. Continued study of the role of land use in affecting groundwater quality (base flow) in 14 tributaries to coastal lagoons in the VCR (Anderson, McGlathery)

5. Continued study of nitrogen transformations (nitrogen fixation, mineralization, nitrification, denitrification in the water column and sediments of Hog Island Bay (Anderson, McGlathery)

6. Continued studies of lagoonal surface circulation using sequential global positioning system locations of "drifters". This work is being supplemented using GPS equipped sub-surface drifters in collaboration with Jay Austin (ODU) (Oertel, Carlson, McGlathery)

7.Continued development of hydrodynamic model to determine variable residence times in and water transport in shallow subtidal areas of Hog Island Bay (McGlathery, Anderson with collaborator Friedrichs)

8. Wet- and dry-deposition fluxes of N were quantified and were used to assess their contribution to the nutrition of primary producers in Hog Island Bay. In shallow coastal lagoons where fluxes from fluvial sources are small, the role of atmospheric nitrogen may be significant. From 1990 through the present, wet-only precipitation was sampled weekly with an automatic, solar-powered device and analyzed for NO_3^- and NH_4^+ concentrations. Between February 1990 and November 1995 the collector was deployed on Hog Island. Thereafter, it was moved to the nearby (15 km S) Eastern Shore of Virginia National Wildlife Preserve. (Galloway)

9. Continued analysis of the distribution, abundance and performance of macroalgae in Hog Island Bay in relation to the ambient water motion regime. Hog Island Bay is dominated by free-floating and attached macroalgae, but was previously dominated by sediment-binding rooted eelgrass. Recent observations indicate that eelgrass is slowly returning to Hog Island Bay, potentially reversing to the clear water ecosystem state within the next 2-3 decades. (McGlathery)

10. Evaluated the trophic interactions between macroalgae and benthic fauna. Determined seasonal changes in the macrofauna present within the algal mats and within the sediment immediately under the algal mats and the effects of macroalgal density on the macrofauna were. The grazing impact by amphipods and snails on macroalgal abundance is also being evaluated to assess the role of grazers in mediating N transformations in the lagoon. (McGlathery)

11. Determined the effect of ultraviolet radiation on the production of inorganic nitrogen, urea and amino acids from aquatic dissolved organic matter in Hog Island Bay. Waters representing distinct sources of dissolved organic matter to the lagoon were subjected to UV light mimicking the natural solar spectrum. (McGlathery)

12. Quantified benthic-pelagic fluxes of specific dissolved organic and inorganic N compounds along an environmental gradient in Hog Island Bay, and determined how uptake and release by benthic algae impacts nitrogen dynamics. Estimated the turnover rate of the macroalgal N pool to determine the impact of benthic algae on the processing of nitrogen inputs to the lagoon. (McGlathery)

13. Continued research on the use of macroalgae as bioindicators of nutrient enrichment from agricultural watersheds to Hog Island Bay. (McGlathery, Zieman)

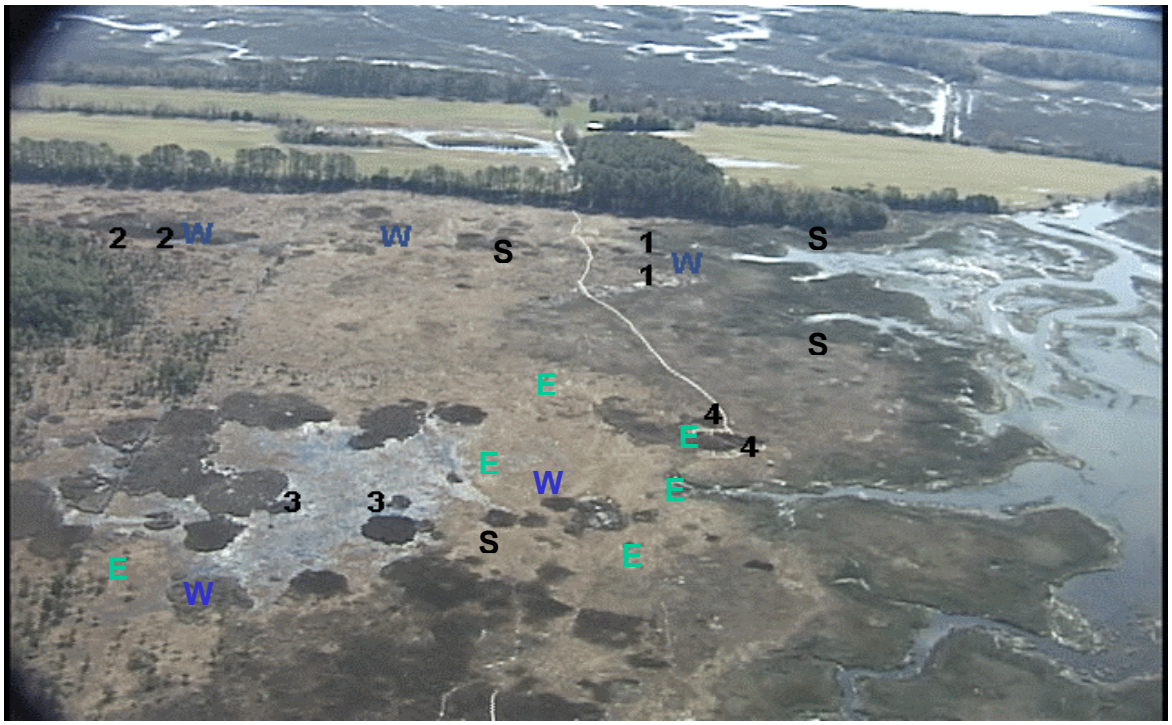
14. Continued measurements using a digital fathometer integrated with global positioning system measurements to extend our bathymetric mapping to include lagoon inland of Smith Island (Oertel, Carlson)

15. In collaboration with U.S.G.S./B.R.D., continued operation of Surface Elevation Tables (SETs) on lagoonal marshes to analyze the effect of sea level rise on the marshes (Erwin)

Marsh:

Marshes represent the biomes most susceptible to state changes driven by changes in sea level. For this reason we have focused on understanding the relationship of marsh surfaces to sea level rise and the role that biology may play in the response of marshes to that rise. Specific research activities this year included:

1. Continued long-term studies of effects of sea-level change and disturbance on salt marshes. This work included continuation of pumping experiment, elevation measurements, plant biomass studies at multiple marshes, and monitoring vegetation in permanent plots. Also continued network analysis studies. (Christian)



Monitoring sites on Phillips Creek Marsh. Numbers: permanent plots W: water level recorders
S: SET/Marker Horizons E: inundation and wrack experiments

2. Development of global scale observing system for land-based activities as part of GTOS. (Christian)

3. Doctoral student Bo Dame is using marsh ponds as focal ecosystems for food web networks and Masters student Mark Keusenkothen recently completed a thesis on deer trails as a disturbance mechanism on salt marsh. (Christian)

5. Continued work on spatial and the temporal variation in bacterial communities in response to environmental gradients, the relative importance of organic material vs. local environmental conditions on microbial decomposer communities - a biographic study, and the contribution of organic matter dynamics to salt marsh landscape patterns. (Blum)

7. Continued studies of the distribution and growth of *Salicornia virginica* in relation to sediment chemistry (NH_4^+, PO_4^{3-}, H_2S, salinity, pH, organic content, Eh, total nitrogen and phosphorus) on mainland and island marshes. (Zieman)

8.Continued studies of the impact of grazing insects on the salt marsh cord grass *Spartina alterniflora* on island and mainland marshes. (Zieman)

9. Continued work on the impact of fiddler crab (*Uca pugnax*) burrows on pore water chemistry of a *Spartina alterniflora* marsh on Hog Island. (Zieman)

10. Continued monitoring and data management of shallow groundwater wells in upland margin of upper Phillips Creek, showing rising trends in specific conductance since the mid 1990's. (Brinson)