Findings

Lagoon:

Nutrient cycling and trophic relationships

We continue to focus much of our research in Hog Island Bay on the influence of benthic algae on nutrient cycling processes and their influence on the fate and transport of watershed nutrient inputs. In the absence of large seagrass populations, macroalgae and benthic macroalgae are the dominant primary producers in the system. This year we discovered using molecular techniques that the dominant taxa, *Gracilaria*, which comprises up to 90% of the macroalgal biomass in the lagoon is an alien species, *G. vermiculophylla*, not the native species, *G. verrucosa*, we previously thought. In light of this discovery we are refocusing our work on *Gracilaria* to understand why this species is such a successful invader, compared to the less successful alien, *Codium fragile*. Our work shows that the widespread dominance of *G. vermiculophylla* in Hog Island Bay can be attributed to traits that make it resistant to stresses that normally occur in coastal lagoons, including desiccation, burial, grazing and low light conditions due to sediment resuspension. We have found that the abundant polycheate, *D. cuprea,* facilitates algal persistence, particularly that of the alien *Gracilaria*, by providing a stable substrate retaining algae against hydrodynamic forces such as tidal flushing and storm surge. We plan to investigate the distribution of *G. vermiculophylla* throughout the VCR lagoons. (McGlathery and students)

In general, macroalgae serve as a large, although temporary, sink for nutrients entering the lagoon from the coastal watershed. Knowing the fate of these plant-bound nutrients is key to understanding how nutrients are retained and transformed as the pass through the lagoon to the coastal ocean. This information also serves as a baseline as the system undergoes a state change to a seagrass-vegetated lagoon. Our results indicate that water quality and sediment characteristics reflect seasonal changes in macroalgal abundance. As macroalgal senesce, nutrient and chlorophyll concentrations in the water column increase and dissolve oxygen concentrations decrease. This suggests that the macroalgae are important in regulating nutrient availability in the lagoon, and likely outcompete phytoplankton during the summer growing season. (Anderson and McGlathery, graduate student Amber Hardison)

Our continuing studies on sediment resuspension show that at high densities macroalgae prevent advective exchange of nutrients and limit sediment resuspension. These ongoing studies will address the effects of state change within the lagoon to compare the effects of macroalgae, benthic microalgae, and seagrass on sediment resuspension and advective fluxes of nutrients from the sediment to the water column. Differences in sediment characteristics and susceptibility to resuspension suggest that there will be different mechanisms of advective nutrient exchange between the sediment and water column at different sites in the lagoon, either desorption from suspended particles or porewater exchange. (Wiberg, McGlathery; graduate student Sarah Lawson)

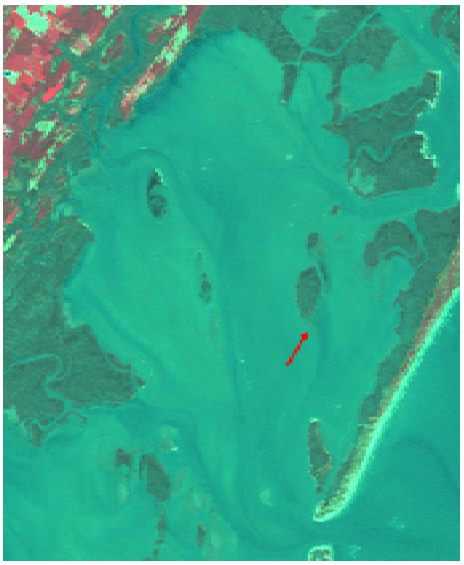
Seagrass recolonization

The seagrass, *Zostera marina*, declined precipitously in the coastal lagoons of the VCR in the 1930s due to the pandemic wasting disease and a destructive hurricane in 1933. Natural recovery occurred in coastal bays north of the VCR, with over 7300 ha vegetated by 2004. However, no natural recovery occurred in the VCR lagoons, until a small isolated plot was found several years ago, presumably due to the distance of the lagoons from potential donor beds and/or restricted exchange with ocean currents that could bring rafting reproductive shoots carrying viable seeds. We have been working with our colleague Bob Orth (Virginia Institute of Marine Sciences) to understand the trophic consequences of newly recolonized seagrass beds in South Bay in the VCR, and are intiating a large-scale restoration effort in our main study lagoon, Hog Island Bay. This successful recolonization gives us an unprecedented opportunity to understand the key role of *Z. marina* as a 'foundation' species in the coastal lagoons, and the landscape-level consequences of an ecosystem state change from a muddy-bottom to a vegetated lagoon. This state change potentially returns the system to a similar state as occurred at the turn of the century when seagrasses provided key ecosystem services, including providing a habitat and food source for the bay scallop (*Argopecten irradians*) and the brant (*Branta bernicla*), both of which disappeared after the loss of the seagrass in the 1930s. (McGlathery)

To guide our efforts for recolonization in Hog Island Bay, we have used a model that predicts light availability at the sediment surface and indicates areas in the bay that are suitable habitat for seagrasses (PIs Wiberg and McGlathery, graduate student Sarah Lawson). The model predicts sediment suspension and light availability from waves and currents. In Hog Island Bay, and likely in similar shallow coastal lagoons especially those lacking sediment stabilization by benthic vegetation, wind-driven sediment suspension is the dominant control on light availability. Waves and currents in the bay responded strongly to wind forcing, with bottom stresses from wind driven waves dominant for 88% of the modeled area for the late fall period and 56% of the modeled area for the summer period when wind speeds were lower. The influence of wind events, through both waves and wind-driven currents, was greatest on the shallow flats that are potentially suitable habitat for seagrass. Based on the modeled average light availability at the sediment surface, 22% more of the modeled area was suitable habitat for seagrass in summer (87%) than in late fall (65%) when wind speeds were higher. This study shows that because of the episodic nature of wind events and the spatially variable nature of sediment suspension, conventional methods of examining light availability, such as fair-weather monitoring or single in-situ recorders do not adequately represent light conditions for benthic plants.

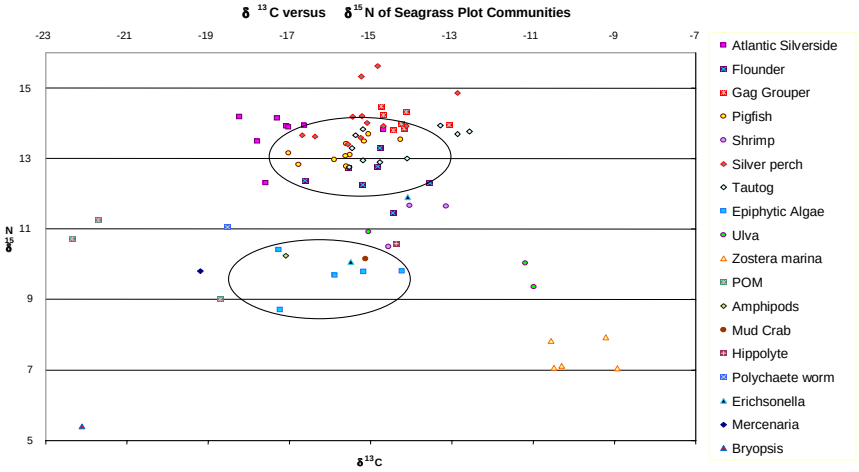
We used the model of light attenuation based on sediment resuspension to identify potential sites in Hog Island Bay for seagrass recolonization experiments. In Fall 2004, we surveyed these sites, and much to our surprise we found a small patch of naturally-occurring seagrass that we estimated to be about 1 year old. This is excellent validation of our model. At this site and one additional site nearby, we set out test plots with seagrass seeds. These seeds germinated and the seedlings have survived through the first

growth season. We have recently negotiated with the Virginia Marine Resource Commission to set aside 400 acres in Hog Island Bay for the seagrass recolonization experiments. We will set out another set of test plots in the seagrass conservation set-aside, and assuming these too are successful, we will begin large-scale recolonization experiments in Fall 2006.



Location of naturally-occurring seagrass found in the fall of 2004. A 162 ha conservation set-aside will be located nearby.

We have also examined trophic relationships by stable isotope analyses in seagrass meadows in South Bay that have been restored by seeding within the last 5 years (PI Steve Macko, graduate student Stephanie Harbeson). Isotopic signatures from prey and predators associated with the two habitats provide an important basis for tracking changes through time as seagrass habitats expand and become more dominant components of VCR lagoons. The primary producers *Z. marina*, epiphytic algae and macroalgae were found to be isotopically distinct, thus allowing for source differentiation. The bulk isotopic values indicate that the isopod *Erichsonella sp.*, amphipods and mud crabs from the seagrass meadows are possible dietary sources for many of the fish captured at these sites. The tissues of nearly all were isotopically enriched compared to their gut contents, indicating probable linkages to the nutritional base of the restored meadows. The effect of plot age on carbon isotopic signature of fish is also being analyzed. The $\delta^{13}C$ varied between fish captured in plots restored in 2001 versus those restored in 2002. Variation in isotopic signature is inconsistent among different species, however, indicating that plot age does not have a simple relationship to the $\delta^{13}C$ of animals in the restored seagrass community. The influence of the habitat on the potential prey species is likely variable, with some being highly dependent on the seagrass, while others appear to be less influenced. As the system undergoes a state change to a seagrass-vegeated bottom, it is likely that seagrass primary production will become an important source of nutrition for a variety of species, including those that are commercially or recreationally harvested such as blue crabs and various fish species.



Isopods (*Ericsonella attenuata, Idotea sp.*) Amphipods, mud crabs, and epiphytic algae are prey for fish. Several fish species are encompassed within one level of trophic enrichment for carbon and nitrogen.

Hydrodynamics

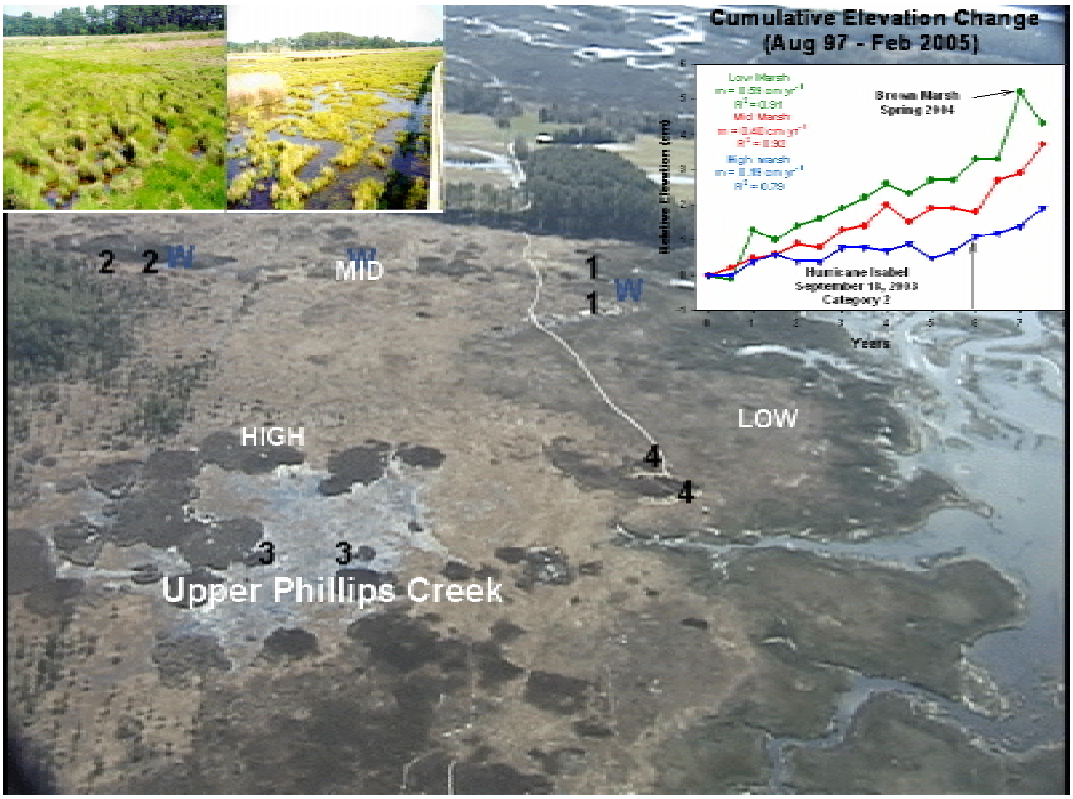
We have found that a strong relationship exists between hierarchies of antecedent topography, hydrohypsography and the flushing of coastal bays. Bays can be categorized by using a combination of hydraulic turn over and percent of repletion penetration.

Marsh:

Blum and students are finding out more on the significant role that fungi play in decomposition of standing dead marsh plants. Fungi have been recognized as having a significant role in decomposition of standing dead marsh grass and in trophic dynamics on stand dead marsh plants. They also form a mycorrhizal association with some marsh grasses and as such may be important in marsh plant growth. Generally, conditions in salt marsh sediments have been viewed as unfavorable for the growth of filamentous higher fungi. However, our recent studies in marsh surface sediments indicate an abundance of filamentous higher fungi at levels similar to those in terrestrial soils. Abundances are higher in monotypic stands of *Juncus roemerianus* than in the mixed *Spartina patens* community and differences are also found depending on flooding frequency. Such differences belie the simplicity in community composition of higher plants, and suggest that fungi may play important roles in other ecosystem functions such as plant decomposition, nutrient cycling, and trophic dynamics that has been thus far overlooked by salt marsh ecologists.

Our results from the inundation experiment of the high marsh show surprisingly little effect of flooding over 6 years in two sites. In the third site there was an effect from the disturbance of having a border around the plots. This third site is developing hollows and hummocks and a replicate site is also showing differentiation from other sites.

The Sediment Elevation Table measurements, now in their 7^{th} year, show evidence of insufficient accretion in the high marsh to match the rate of rising sea level.



Locations of Sediment Elevation Tables in Phillips Creek Marsh. Photographs in the upper left show changes in marsh cover. The graph in the upper right shows the cumulative elevation change at different locations.

Our work on the non-native grass P. australis showed that this species, as well as the native *Spartina alterniflora*, can take up dissolved organic nitrogen (DON) at directly, at rates that are between 8-20% of ammonium uptake rates. This is the first documentation of DON assimilation in marsh plants, and is similar to the findings that marine algae and tundra plants can utilize DON. *P. australis* had significantly higher photosynthetic rates than the native grasses under similar conditions, and this photosynthetic efficiency provides a possible mechanism that contributes to the invasion success of this species. (Zieman, McGlathery; graduate student Mozdzer)

Terrestrial:

After seven growing seasons, results from the permanent plots suggested more intense negative effects of competition in nitrogen-fertilized plots. Greater cover of *Ammophila* in fertilized plots indicates *Ammophila* is in a better position to compete for light with enhanced aboveground dominance. Diversity was lower in fertilized plots on all but the dune formed in 1967 and diversity decreased most dramatically in fertilized plots on the oldest dune. The increase in total density with fertilization as diversity decreased, coupled with the shifting composition of *Ammophila* and other dominants, appears to

support the interspecific competitive exclusion hypothesis. Changes in the positions of free surfaces (groundwater level in particular) appear to be the primary influence on plant community composition. On the dune pimples, environmental data, such as depth to water table, height above marsh, aspect, soil texture, and total C:N are being used with ordination techniques, primarily canonical correspondence analysis (CCA), to quantify their relationship with species distribution patterns. Preliminary analyses suggest a strong influence of elevation and water availability on species distribution. Addition of more variables, such as nutrients will help explain finer differences in species composition.

After fourteen years of quantifying annual shoot growth in *Myrica cerifera* shrub thickets, several patterns have emerged. Shoot growth decreases as thickets age, with highest growth rates occurring as individual shrubs initial merge to form an enclosed thicket. Similar to the results for the long-term plots on the grass covered dunes, annual growth is strongly influenced by summer precipitation patterns with the lowest values for all sites occurring during years with significant summer drought. Island position is also important. Thickets located in the central portions of Hog Island show less fluctuation in shoot growth over the years of measurement. Presumably these thickets are less exposed to salt spray and wind damage and have greater access to stored groundwater during periods of drought.

Four methods to determine LAI were compared across *Myrica cerifera* shrub thickets. Traditional allometric modeling was considered to provide the best estimates of LAI. Light attenuation and annual litter production estimates of LAI were similar to the allometric estimates. Although measurement with an LI-COR integrating radiometer is rapid and non-destructive, the instrument continually underestimated LAI relative to the other three methods. Depending on position on the island landscape and age of the thicket, shrub LAI may vary from 6 to 11 as estimated with allometric relationships. These values are much higher than previously assumed (e.g. 4). These accurate LAI estimates will increase the predictability of water, carbon, and other nutrient stoichiometric analyses at the landscape level. In addition, as the landscape is changed from grass dominated swale to shrub thicket, LAI at least doubles. The increased LAI, especially when considering physiological differences between grass and *Myrica* shrubs, will significantly increase evapotranspiration. Thus, some landscape units may remain grass dominated because limited groundwater availability will not support the increased demand associated with the higher shrub LAI.

Collaboration with Sandford Feldman at the Center for Comparative Medicine at UVA to examine wildlife disease has been successful. Collection of samples of feces and blood from small mammals on Myrte, Ship Shoal, Mink and Hog Islands indicates the presence of *Salmonella* infections in some individuals. This could have important implications for population dynamics, as *Salmonella* can be fatal in mice and rats, especially at young ages. Tests for *Shigella* (commonly associated with shellfish), parainfluenza viruses, coronaviruses, pathogenic mycoplasmas, reovirus-3 and *Campylobacters* were negative.

Based on collaborations begun at the 2003 LTER All-Scientists Meeting, a cover story in BioScience (Porter et al. 2005) detailed how wireless networking technologies are

expanding the basis of data collection in ecology, and how use of such technology might be expanded. Such technologies are widely used at the VCR/LTER, with network links extending to Hog, and Cobb Islands, over 20 km off the coast. The article included images of extensive flooding at the VCR/LTER captured by digital cameras during a major storm.

Images captured automatically by wirelessly networked cameras.
The first shows southern Hog Island during a non-storm time.
The second shows the same view during Hurricane Isabel,
showing the extensive flooding.

Mike O'Connell's work with remote sensing of barrier island vegetation has some preliminary results. Inspection of the coincident high-resolution CIR digital imagery has shown that much of the *pinus taeda* canopy on Parramore Island was defoliated at the time of the EAARL survey. This is likely the result of decline due to the island-wide fire in August 2002, followed by Hurricane Isabel in September 2003, and the infestation of weakened stands by bark beetles. Mike O'Connell is coordinating with Chip Bachmann of the Naval Research Lab to start looking at available spectral datasets in the last few years to try to determine the progression of mortality.