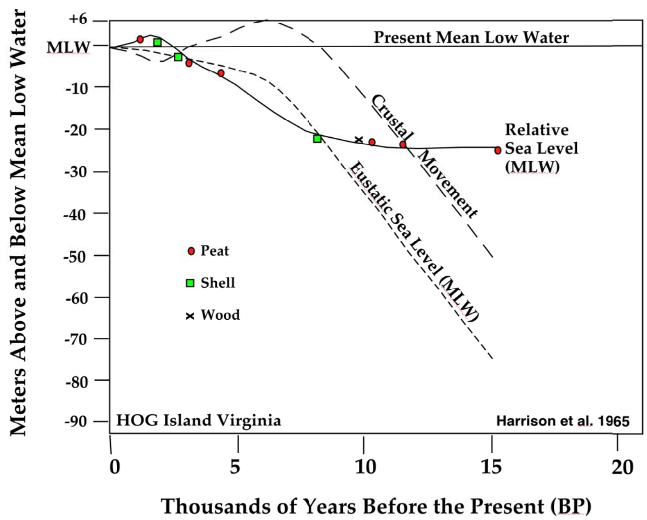
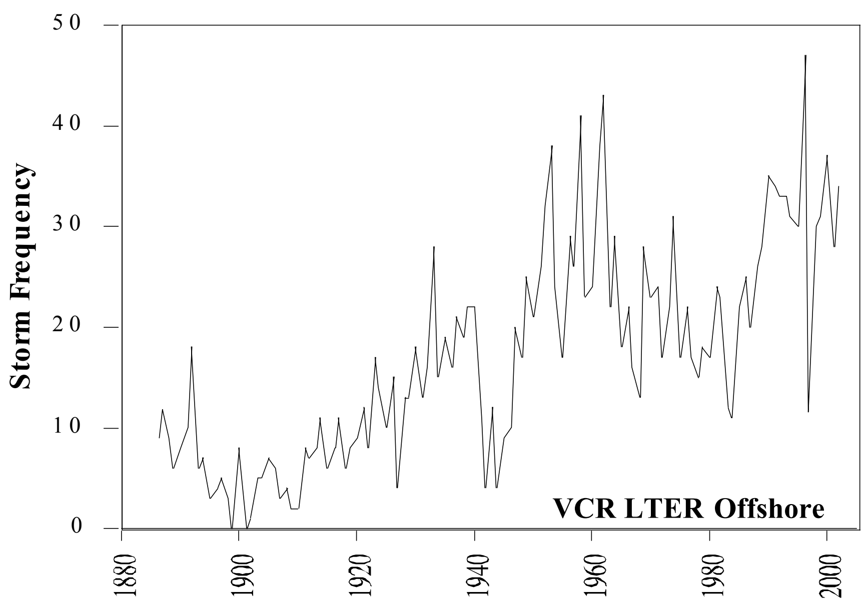
Findings

Since physical drivers, particularly sea level rise play such an important role in our system, we have been working to place the current day system into a historical context. PI Bruce Hayden has compiled literature estimates of eustatic sea level rise and land surface uplift and subsidence over the last 20,000 years. The time sequence shows that up until roughly 8,000 years ago, crustal uplift and eustatic sea level rise were at similar rates – resulting in a stable relative sea level during that period. Since then, there has been a net rise in relative sea level, although for a brief period in the last 2000 years, the relative sea level actually declined. Current rates of relative sea level rise for the VCR/LTER are 3.5 mm per year – one of the highest rates found on the east coast of the US.



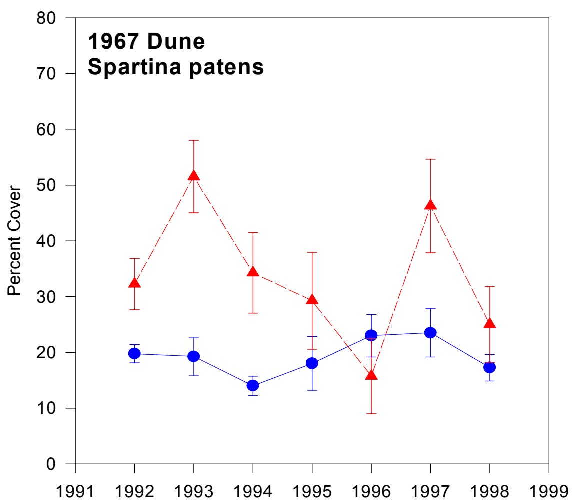
He has also compilied a long-term record storms that allow us to place our research efforts in a longer context. We are now in a period of relatively high storm frequencies, comparable to the 1960s. Interestingly the 1930s which featured several major hurricanes that hit the Virginia coast had a relatively modest number of storms.

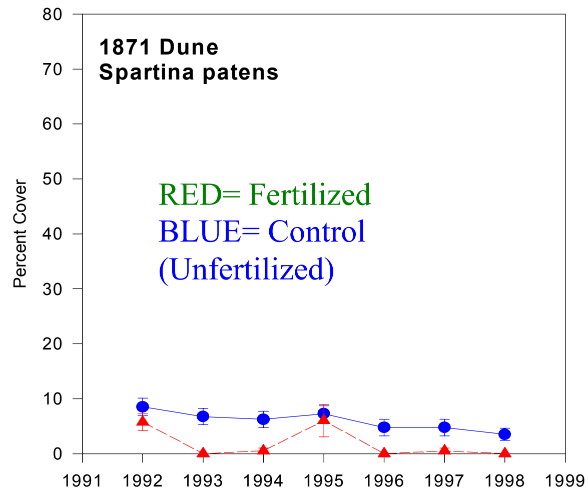


Upland:

In the upland areas of the islands and the mainland, our attempt to integrate primary productivity and climatic variables is ongoing. Univariate and multivariate analyses of productivity are revealing complex relationships between climate and productivity that indicate species and site dependencies (Christian, Day, Blum, Young, Brinson, Mills, McGlathery, Zieman, Hayden and Porter).

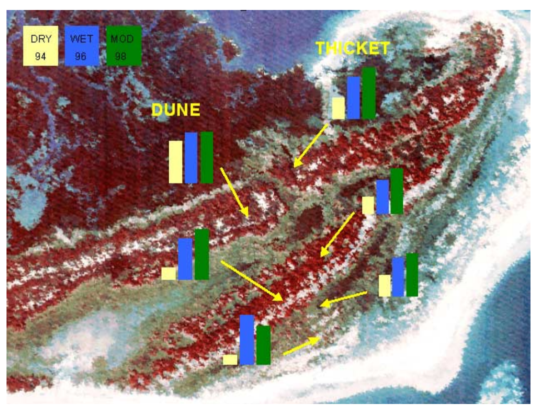
The results from the integrated cross-species study are echoed in the results for individual species. Long-term fertilization experiments show that nitrogen plays important roles in some habitats, but is less important in others. For example, in older dunes fertilization has



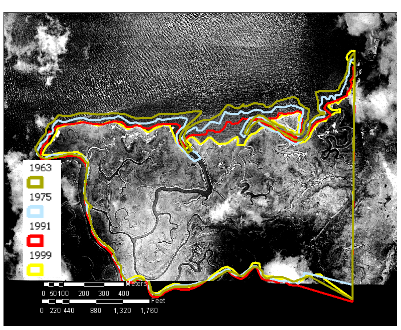


no positive effects on *Spartina patens* cover, but more recently deposited dunes show a pronounced fertilization effect for the same species. The decline in *Spartina* density may be at least partially attributed to development of drier conditions on the older dunes.

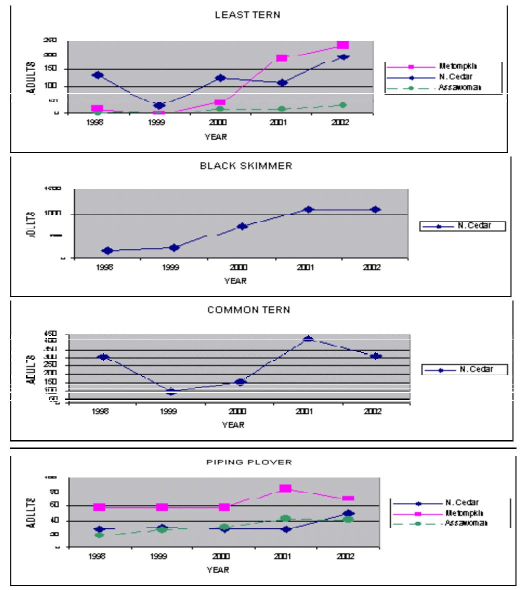
There are also contrasts in the ways shrub production responds to wet, dry and moderate precipitation years, depending on where they are located on the island. Long term studies by PI Don Young found that shrubs on the more recently deposited seaside parts of the island are more sensitive to changes in precipitation than are shrubs in dune communities on the older, bayside portion of the island.



John Porter and Bruce Hayden used declassified satellite imagery to examine the amount of erosion of a marsh on the bay side of Hog Island. They found a loss of over 200 m of marsh in some areas but that the erosion was highly variable, with marshes running east to west having the highest degree of erosion, while marsh boundaries in protected tidal creeks were relatively stable.



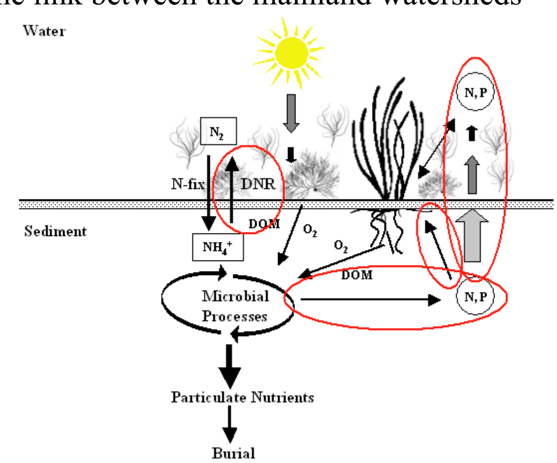
Faunal studies in collaboration with Raymond Dueser and Barry Truitt with PIs Nancy Moncrief and John Porter on the island system continue to support the hypothesis that predators play an important role controlling the locations of breeding bird colonies on the Virginia coast. Removal experiments have show significant increases in bird breeding success rates on islands where predators were removed. Preliminary results from an egg removal experiment are showing strong differences between both the amount of predation and the type of predator (avian vs mammalian) across islands.

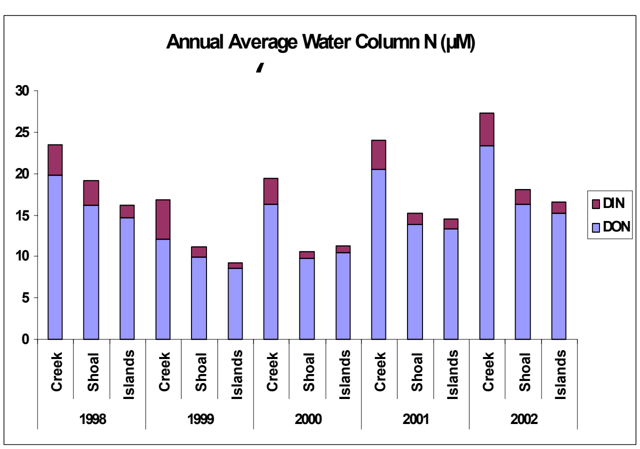


Physical factors effecting bird nesting have been explored. M.S. student Rachel Rounds working with PI Mike Erwin showed that the relationship between site elevation and probability of utilization as a nest site is complex. Despite the advantages nest elevation could potentially provide in an environment where washing away by storm driven waves is a frequent cause of nest failure, birds did not strongly select experimentally elevated plots.

Lagoon:

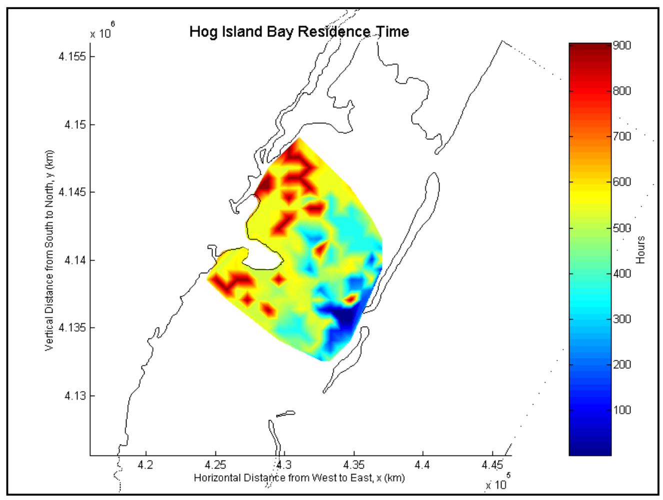
The lagoon system of the VCR/LTER forms the link between the mainland watersheds and the coastal ocean.Our findings show that the lagoon is not a passive transporter between land and sea, but rather an active and complex portion of the coastal ecosystem that leaves its own stamp on nutrient processes. Nutrient loadings from the mainland creeks, through shoal areas out to the inlets between the islands show a gradient in nitrogen loadings that are highest nearest the mainland and declines to seaward.



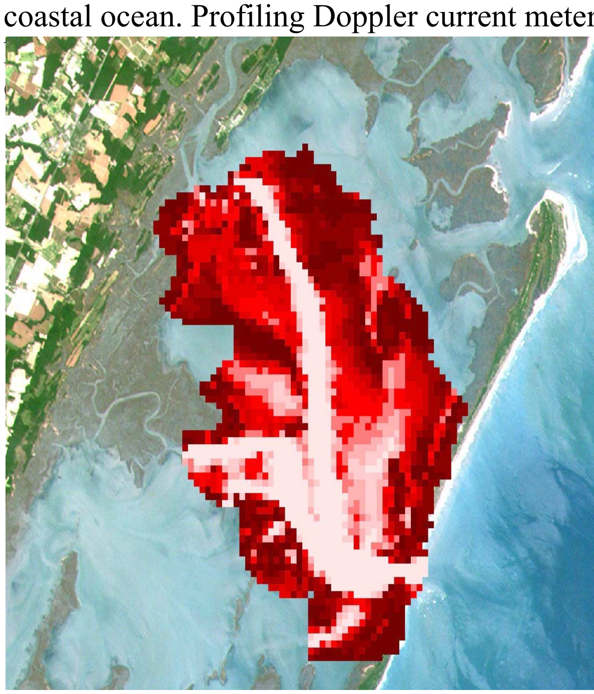


Work by Karen McGlathery, Iris Anderson and their students has found that nitrogen availability is high enough to support macroalgal blooms during some parts of the year, and benthic primary production dominates lagoonal production overall. Benthic algae (micro and macro) influence the exchange of nutrients between the lagoon sediments and the overlying water column. Where microalgal activity made the sediments net autotrophic, total dissolved nitrogen fluxes, mostly dissolved inorganic nitrogen (DIN), urea and dissolved free amino acids, were directed into the sediments. Heterotrophic sediments, particularly beneath macroalgal mats, are a net source of total dissolved nitrogen, mostly DIN. Isolated crashes of dense macroalgal mats led to huge DIN and DON release. When present, living macroalgae dominated benthic-pelagic coupling by intercepting DIN, urea and dissolved free amino acid effluxes and releasing DON, mostly as dissolved combined amino acids. Macroalgae release ~50% of total N uptake. On short time scales, macroalgae act as a conduit whereby both organic and inorganic N are taken up, transformed, and re-released to the water column. This suggests that algal N turnover is higher than previously thought.

Development of a preliminary hydrodynamic model in collaboration with Carl Fredrichs and David Fugate shows that water residence time in the lagoon is highly variable depending on where you are in the lagoon. It varies from days in the inlets and along channels to several weeks to a month in the shallow areas closer to the mainland. Median residence time for Hog Island Bay is 534 hours – approximately 22 days. We have found that the driving force for circulation varies across the lagoon. Tides dominate circulation in the inlets and deep channels, while wind-driven currents dominate circulation in the shallower areas of the bay. This is an important information base because it allows us to link our biological models of nitrogen processing to the model of water transport, thus allowing us to estimate how nutrients are being transported into the coastal ocean. Profiling Doppler current meter measurements made by PI Pat Wiburg and



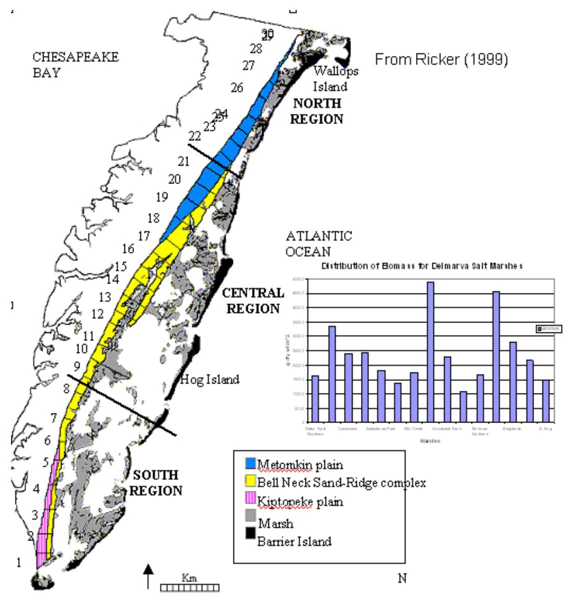
George Oertel, site manager Randy ng to test and refine this hydrodynamic model.



Modeled turbidity for Hog Island Bay.

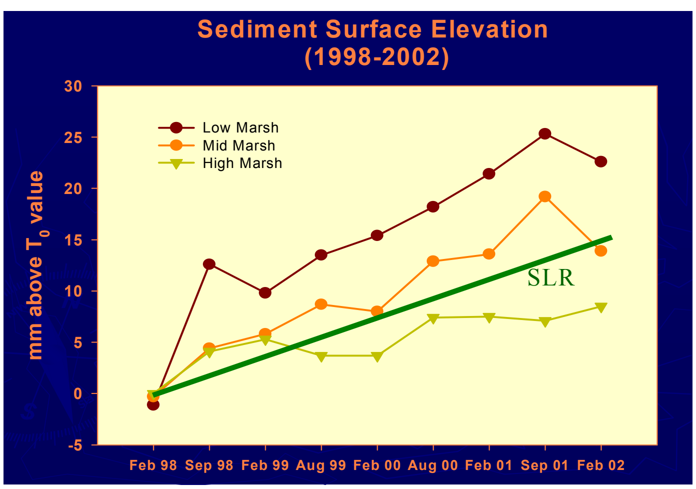
We have also made important progress on understanding the turbidity regime of the lagoon. Return of eelgrass (*Zostra marina*) is contingent upon adequate light reaching the bottom. We have found that high turbidity events are associated with wind rather than tidal forcing and that these events are episodic. We are now completing a model of sediment resuspension and its relationship to light attenuation throughout Hog Island Bay that will allow us to predict where *Zostra* recolonization is likely to be successful. Recolonization efforts, led by collaborator J.J. Orth, in bays to the south of Hog Island Bay are proving successful.

Marsh:

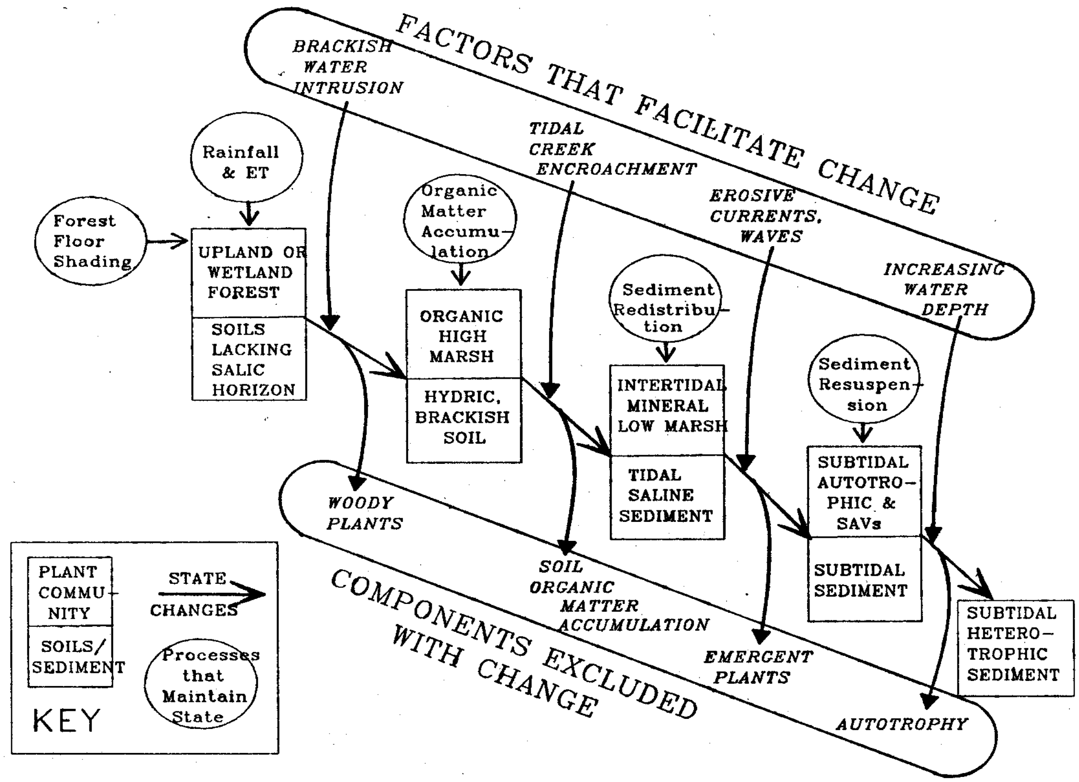


We have also made progress on understanding the spatial trends along the Delmarva Peninsula by identifying and characterizing watersheds and the amount of marsh in the lagoon system. The Virginia portion of the Delmarva Peninsula has differences in soil composition and amount of marsh that make it a useful natural experiment for examining the interactions of marsh, lagoon and upland systems. Principal investigators Blum, Brinson, Christian, Mills and Wiburg are working to exploit this system to understand the processes that drive it.

In the face of high levels of relative sea level rise (3.5 mm/yr), a critical question for marsh studies is whether the marshes will be able to gain enough elevation via accretion to survive in the future. We have established Surface Elevation Tables (SETs) at several locations to track marsh elevation in relationship to sea level rise (SLR). For SETs in Phillips Creek Marsh, there are different responses by the marshes relative to sea level rise depending on the type of marsh. Frequently flooded low marsh has gained in elevation at a rate higher than SLR, whereas the infrequently flooded high marsh has shown only modest increases in elevation – at a rate below that of SLR.



There are numerous mechanisms that can potentially alter the ability of marshes to increase in elevation with sea level rise or to migrate landward into areas that were formerly uplands. A working model for understanding these mechanisms and how they might act was developed by VCR/LTER PIs in the mid 1990s. It has proven invaluable for placing individual processes into a larger context and we are making substantial progress in evaluating the role that each of the processes in the model are actually playing in the marsh context.



We have made substantial progress on understanding the nutrient fluxes that underlie the biological elements of the model and the role of disturbance in driving state change in this system. However, this investigation has not been without surprises. Doctoral student Cassandra Thomas supervised by PI Blum has hypothesized based on her studies of the role of fiddler crabs (*Uca*) in the cycling of materials in a marsh, that they may play an important role in determining the rate of accretion of marshes through altering the rates and modes of decomposition in the marsh sediments. This echos the work of past M.S. student Brian Silliman (supervised by PI Zieman) who found that snails had a hitherto grossly underestimated impact on *Spartina alterniflora* productivity.