Preview of Award 1237733 - Annual Project Report

Cover

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Accomplishments

*** What are the major goals of the project?**

1. Evaluate the existence of alternative stable states and threshold responses to environmental drivers as a unifying dynamic across the coastal barrier landscape, by integrating coordinated long-term observations and experiments that address the mechanisms of nonlinear change with models and new experimental studies. Relate ecosystem state change to key ecosystem processes, services and trophic dynamics.

2. Address how connectivity via transport of sediments and organisms influences alternative stable state dynamics of adjacent ecosystems (e.g., seagrass and oyster connectivity to marshes, island connectivity to backbarrier marshes) and if subsidies via organism fluxes between adjacent habitats influence key ecosystem processes, services and states.

3. Use future scenarios to explore how interacting drivers affect threshold behavior and resilience of ecosystem states at different spatial scales, including climate change and changes in land use and nutrient loading. Relate ecosystem

state change to key ecosystem processes, services and trophic dynamics. Engage a diverse group of stakeholders to incorporate public valuation of ecosystem services and tradeoffs into quantitative models of future scenarios.

SPECIFIC QUESTIONS ADDRESSED

1a. What are the mechanisms of non-linear state change in coastal barrier landscapes in response to environmental drivers?

1b. Are there specific thresholds for ecosystem state change and leading indicators of proximity to that threshold?

2a. To what extent does connectivity of adjacent ecosystems via sediment fluxes affect responses to environmental change?

2b. Is there evidence of subsidies via organism fluxes between adjacent habitats that influence key ecosystem processes, services and states?

3a. How will ecosystem resilience and state dynamics vary in response to climate drivers across the landscape?

3b. How will changes in land use affect subtidal and intertidal ecosystems, and how will these drivers affect the resilience of ecosystems to climate change? How are state changes related to the delivery of to key ecosystem processes, services and trophic dynamics?

3c. How do regional attitudes and motives modify future scenarios?

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities: **Mechanisms of non-linear state change**

For marsh transitions, we are monitoring fluctuations in groundwater, temperature and depth along a marsh-upland forest transect where vegetation dynamics suggest bistable behavior. The goal is determine how microtopography and establishment of small ponds during storms are connected to tree dieback and state transition from forest to marsh. In collaboration with USGS and NRL we are using hyperspectral imagery for a large-scale pre- and post-Sandy analysis of marsh transgression. At the marsh boundary, high-resolution, long-term measurements and cellular automata simulations were used to investigate erosion by wave action.

To assess seagrass feedbacks on sediment suspension in the subtidal, we 1) correlated seasonal water velocity, turbulence, and wave dynamics with in situ turbidity and benthic chlorophyll concentrations, 2) completed a study of large-scale flow and wave attenuation, and 3) assessed the role of benthic microalgae on critical shear stress. Seagrass state change effects on benthic metabolism were determined using the eddy correlation technique, and spatial variation in carbon burial rates were related to meadow age and patch size. Effects on trophic dynamics are being assessed from long-term monitoring of fish populations and analyses of biodiversity of benthic foraminiferal communities.

Feedbacks on shrub-grassland bistability were assessed by 1) establishing permanent plots at known elevations to monitor depth to groundwater, salinity, temperature, light, and density, species composition, 2) conducting greenhouse experiments of grass density effects on shrub establishment, 3) classifying vegetation from airborne data to determine extent of shrub expansion and elevation ranges, and 4) using hyperspectral imagery to detect water stress in shrubs.

To explore barrier island bistability, we assessed the effect of changes in storm frequency and sea-level rise on barrier island state using our coastal dune model. We also analyzed dune elevation from LIDAR profiles to determine the distribution of island elevation and compared with model results. Effects of sea-level rise, shoreline change, and island geomorphology on pobability of nest presence/absence for the threatened piping plover were determined in collaboration with USGS using linked models, and predictions were tested using historical data.

Thresholds for state change

To map marsh-forest boundaries and develop a model for bistable transitions, we used LiDAR data and multispectral aerial imagery and are related boundaries to topographic variables of elevation, distance to tidal channels and slope. In the marshes, we have 1) studied *Spartina alterniflora* production response to the duration/frequency of flooding in marsh organs, 2) examined production responses to disturbance (field experiment, remote sensing) to determine whether “critical slowing down” can be used as an indicator of ecosystem collapse at the boundary between tidal flat and marsh, 3) measured morphometric and spectral characteristics of culms of *S. alterniflora* during sudden marsh dieback and recovery, and 4) examined *S. alterniflora* genetic diversity in an area adjacent to one that experienced sudden marsh dieback.

In the subtidal, a network of light and temperature sensors were monitored along the depth gradient that brackets the current threshold of the seagrass stable-bistable states predicted from our model.

On the barrier islands, we monitored shrub seed dispersal and expansion using seed traps along transects through the shrub-thicket edge, and soil salinity, water content, and root decay. We expanded our model of effects of future sea-level rise, shoreline change, barrier island geomorphology on piping plover nesting probability from modest rates of sea-level rise (3-4 mm yr-1 over for years) to higher, yet realistic rates (7-12 mm yr-1) to test additional future scenarios.

Ecosystem Connectivity

To assess sediment availability for marsh accretion, we quantified sediment flux across the bay-marsh border using wave gauges, current meters and turbidity sensors at eroding marsh-edge sites. Residence times of neutrally buoyant particles and exchange among the bays were examined with Lagrangian particle tracking using the FVCOM hydrodynamic model. We developed a novel method for mapping spatial variations of sediment size fractions in shallow bay bottoms and used it to initialize a hydrodynamic and sediment transport model (Delft3D) to explore spatial variations in turbidity during resuspension events.

We used a 3-point dynamic model to examine potential trajectories, both short (30-100 yr) and long term (1000 yr), of coupled tidal flats and marshes. Synthetic time series were developed based on 30 years of hourly wind data from VCR, PIE, and GCE. The trajectories illustrate nonlinear interactions of sea-level rise, external sediment loading, river sediment supply, and wave modification by the presence of seagrass.

On intertidal oyster reefs, we 1) quantified boundary layer flow and oxygen fluxes, and 2) deployed larval settlement plates on natural and restored reefs and developed a particle-tracking model to quantify larval dispersion and connectivity between reefs and the impact of swimming behavior on settlement. We also

initiated a study to determine how burrowing activity of polychaete worms alters oxygen flux and sediment biogeochemical cycling.

We finalized GEOMBEST+ experiments to assess the impact of 1) overwash deposition on backbarrier-marsh morphology, and 2) marsh morphology and rates of barrier island migration. We added wave erosion to GEOMBEST+ and began to conduct model simulations addressing how erosion of the marsh-edge affects the coupling of island and marsh systems and bistable dynamics. We initiated a field experiment to assess the impacts of overwash on marsh vegetation growth.

Subsidies

To investigate nutrient subsidies from bays to marshes and mudflats from an invasive macroalga, we related N-15 isotope tracer experiments and observations of faunal (invertebrates, shorebirds) abundance and diversity.

Using annual aerial photos from VIMS, we mapped aquaculture clam bed coverage from 2002-2012. Total coverage was calculated for each year and locations mapped in relation to depth and water residence time. Nitrogen fluxes and denitrification were measured seasonally from clam aquaculture beds, oyster reefs and bare sediments.

State change & projected climate/land-use drivers

To determine N loading to coastal bays, we 1) monitored stream stage and N concentrations at fixed stations, 2) measured N removal from sediments and water columns of streams draining watersheds, and 3) examined the production and efflux of N2O from streambed sediments and assessed expected changes based on climate (temperature) and land use (fertilizer use). We determined hydrologic controls of stream metabolism by conventional oxygen flux techniques and eddy correlation.

For 7 islands, we calculated island size and total area of bare, herbaceous, woody, marsh, and water using Landsat imagery (1984, 1998, 2011) and began quantifying NDVI for each vegetation class and change of each cover type between years. Activities linking changes in island geomorphology to vegetation, mammal predators and shorebirds, include 1) data collection on shoreline change and piping plover nesting, 2) camera-trapping of predators, 3) and completion of a 9th spring migration survey of shorebirds and their invertebrate prey.

Socio-ecological drivers

A mail survey was conducted to understand what ecosystem services coastal residents cared about and whether this influenced their preferences for climate change adaptation measures. We began experiments to compare several approaches to for growing the salt-tolerant biofuel crop *K. pentacarpos* in agricultural fields abandoned due to saltwater encroachment.

Specific Objectives:

Mechanisms of non-linear state change

Mainland Forest/Shrub vs. Marsh. The extent of marshland is controlled by changes at its terrestrial boundary, where complex interactions determine its landward-most extent. Our objective is to document transgression of this boundary.

Marsh vs. Tidal Flat**.** Positive feedbacks between vegetation growth and sediment

transport promote the development of two alternative states: salt marshes and tidal flats. Our objective is to understand the ecological and physical connectivity between these two stable systems, and the mechanisms of state change that transform salt marshes in tidal flats and vice versa.

Seagrass vs. Unvegetated Seafloor. To further constrain and validate the stage change model, and to investigate the resilience of seagrass meadows, our objectives are to: 1) continue long-term monitoring of seagrass morphology and meadow characteristics, and 2) evaluate the consequences of the seagrass state change for sediment suspension, biogeochemistry and carbon sequestration.

Barrier Island Grassland vs. Shrub Thicket. Our objective is to evaluate the relative importance of temperature and water-table feedback between grassland and shrubland by investigating: 1) how shrubs modify the local microclimate, particularly in the coldest months, 2) how shrubs lower the water table, 3) the cold sensitivity of shrubs, and 4) the sensitivity of shrubs to shallow water tables using field and remote sensing (spectral/Lidar) measurements.

Barrier Island Geomorphology, "High" vs. "Low" Islands. Our objective is to develop a model of barrier-island dynamics from an existing model of dune growth that includes aeolian sediment transport and vegetation population dynamics. In model runs, forcing parameters (sea-level rise, overwash frequency, sediment-loss rates) is varied to evaluate the effect on island state (high vs. low) using migration rate as an inverse proxy (e.g., low islands have high migration rates and vice versa).

Thresholds for state change

Intertidal Marshes. The ability of marshes to maintain elevation high in the intertidal zone determines if marshland will convert to subtidal mudflats. Our objective is to understand how marsh plant growth responses to duration and frequency of tidal inundation reveal if there are leading indicators of proximity to the threshold of change.

Seagrass. To refine the growth model that estimates the maximum depth threshold of seagrass, our objective is to install a network of light and temperature sensors along the depth gradient that brackets the current threshold of the stable-bistable states predicted from the model.

Barrier Islands. Our objective is to continue monitoring fronts of shrub expansion to identify specific thresholds of change (i.e. introduction of nitrogen-fixer *Frankia* to the soils). We will identify changes in key ecosystem parameters along dune/swale transects and related these to elevation (nearness to groundwater). This will provide a basis for predictions on a larger spatial scale of state transitions with changes in elevation (erosion, accretion, sea-level rise, groundwater fluctuation).

Ecosystem Connectivity

Sediment Redistribution. Our objective is to quantify sediment fluxes from the tidal flat to the marsh at 2 sites in Hog Island Bay.

Seagrass – Marsh. Our objective is to develop a 3-point dynamic model, incorporating ecogeomorphological feedbacks between wind waves, vegetation, sediment loading and sea-level rise, to investigate how internal and external processes affect coupled marsh-mudflat systems.

Oyster – Marsh. Oysters reefs fringing marshes may impact erosion and sediment

supply. Our objective is to perform *a new long-term experiment* in which we construct artificial oyster reefs and measure waves, mean currents, turbulence, suspended sediment concentrations and larval recruitment.

Island – Back-barrier Marsh. To explore couplings between barrier islands and back-barrier marshes, our objective is to merge: 1) a barrier island model, GEOMBEST, that incorporates sediment composition and supply rate to forecast barrier island evolution in response to sea-level rise and 2) a marsh transect model that predicts coupled marsh – tidal flat evolution in response to sea-level rise and storms.

Subsidies

Cross-Habitat Macrophyte Subsidies. Our objective is to assess how the invasion of the macroalgae, *Gracilaria vermiculophylla*, affects nitrogen subsidies and trophic dynamics in adjacent marshes and mudflats.

Subsidy support and expansion of aquaculture. Our objective is to document sources of organic matter supporting clam production and changes in clam aquaculture over time, and to evaluate possible impacts of clams on biogeochemical and ecological processes.

State change & projected climate/land-use drivers

Intertidal Habitats. To determine rates of transgression, our objective is to determine historical rates of marsh expansion at the forest edge from aerial photographs.

Subtidal Habitats. Our objectives are to: 1) address how location affects habitat suitability for restoration and resilience of seagrass meadows by considering variation in physical and chemical parameters and linking these with our model of state dynamics, and 2) understand how meadow patchiness (size and configuration) affects vegetation feedbacks on sediment suspension, light attenuation, and state-change dynamics. Changes in land use will affect nutrient loading to subtidal habitats, and our objectives are to: 1) continue monitoring stream stage and nitrogen concentrations at fixed stations, 2) assess nitrate removal via denitrification from groundwater feeding streams, and 3) quantify nitrate removal from streams.

Island Habitats. To build on our 30-yr historical analysis of vegetative cover change, our objectives are 4-fold: 1) examine fine-scale changes in vegetation as a result of shoreline accretion/erosion, 2) use NDVI as a link between changes in woody cover due to hydrological patterns, 3) use LiDAR to determine the potential range of distribution based on habitat polygons, and 4) quantify changes in island shape and size and corresponding vegetative classes over 40 years using Landsat TM imagery. These remote-sensing analyses will be integrated with long-term data on species distributions and local-scale mechanisms to model bistability and vegetation change in the context of climate change scenarios of shoreline migration and sea-level rise.

Habitat/Vegetation Analysis. Our objective is to develop a temporal sequence of spatially explicit habitat descriptors for the islands based on the NOAA Coastal-Change Analysis Program (C-CAP) land cover data layers for 1984-2005. The layers contain data for 14-22 land-cover classes with 30-m pixel resolution.

Island Faunal Dynamics. Our objectives are to: 1) determine species occupancy to

look for evidence of local extinctions and/or colonizations, 2) collect tissue samples for analysis of genetic relationships among populations, 3) determine species diversity to look for evidence of community-level changes over time, 4) quantify the relationship between species diversity and island attributes such as size, isolation and habitat complexity which can be used to predict future distributions relative to changes in elevation and vegetation cover driven by climate, and 5) assess effectiveness of predator removal as a strategy for conservation management for waterbirds.

Socio-ecological drivers

Our objective is to develop a survey of public valuation of ecosystem services to incorporate input from multiple stakeholder perspectives into future scenario planning related to climate and land-use change. We also are initiating a *new long-term experiment* to explore the ecological and economic benefits of an alternative biofuel crop in agricultural fields abandoned due to sea-level rise.

Significant Results:

Mechanisms of non-linear state change

When waves are weak and the local marsh resistance is strong, non-uniform erosion creates jagged marsh boundaries. High wave energy erodes boundaries uniformly yielding a relatively smooth shoreline. For marshes with sufficient sediment to maintain elevation as RSL rises, increases in volumetric erosion from deeper water and larger waves may be offset by taller marsh scarps so that lateral erosion remains relatively constant.

Seagrass meadows reduce current velocities, dampen wave heights and enhance concentrations of extracellular polymeric substances from microphytobenthos that stabilize sediments. Restored seagrass meadows are net autotrophic on an annual basis, yet sediments are significant stores of “blue carbon”, with sequestration similar to natural meadows after 12 yr.

On the islands, elevation (proxy for depth to groundwater) is important in determining shrub success, and there is a non-linear relationship between groundwater depth and stress. Freshwater/brackish marshes store C at rates comparable to recognized blue carbon systems. Coastal dune model experiments show that barrier islands are bistable and that island response is controlled by storm erosion, RSLR, and aeolian/biological processes that drive dune recovery. This explains our new observation that dune/island elevation in the VCR is bimodal.

Thresholds for state change

A threshold width exists for tidal flats bordering salt marshes, beyond which irreversible marsh erosion takes place, even in the absence of RSLR, due to positive feedbacks among tidal flat widening by wave-induced marsh erosion, tidal flat deepening driven by wave bed shear stress, and local wind waves.

A threshold groundwater level influences stress response in the expanding shrub *Morella cerifera*. Seedling establishment is mediated by several factors (cover type, grass density, salinity) and is dependent on elevation. Seedlings are able to tolerate a range of densities and salinities, but have threshold levels critical for survival.

Our model of effects of future RSLR, shoreline change, barrier island geomorphology on piping plover nesting probability shows that there are threshold dynamics at current RSLR (3-4 mm yr-1 over 100 years).

Ecosystem Connectivity

Comparison of coupled marsh-bay responses to similar rates of RSLR for the 3 Atlantic coastal LTER sites highlight key mechanisms: 1) without seagrass or large river sediment supply (PIE), feedback between increasing fetch and wind leads to marsh retreat, 2) high river sediment supply (GCE) reduces the importance of wind-generated waves, and initial tidal flat size influences marsh infilling or retreat, and 3) seagrass (VCR) reduce near-bed shear stress and wave power, decreasing both sediment supply to the marsh and marsh-edge erosion.

At the marsh-bay interface, natural intertidal oyster reefs increase local turbulence (settlement cue for oyster larvae) more than restored reefs, and changes in swimming behavior result in 50% more recruitment. Greater self-recruitment occurs on reefs in low-flow regions adjacent to the mainland compared to reefs near channels or in outer bays.

Barrier islands backed by marsh platforms transgress more slowly and overwash deposition provides backbarrier marshes with a source of sediment that maintains narrow marshes in areas where they would otherwise not exist. Narrow marshes represent a stable state, though marsh productivity declines with increasing thickness of overwash deposited.

Waves primarily control suspended sediment concentrations in coastal bays, but the impact of wave events on sediment deposition on the marsh is limited because these events typically occur when the marsh is not flooded. Sediment residence times depend on bay geometry, wind, tidal phase and location of particle release. A higher fraction of marsh vs. open water area is associated with longer residence times. Wind forcing acts as a diffuser that shortens particle residence in bays. We found strong correlations between grain size fractions (sand, silt) and residence time and used these relationships to develop a map of grain size distributions in VCR bays, and as input to the Delft3D coastal hydrodynamic and sediment transport model.

Subsidies

Intertidal sediment, marsh cordgrass, and mudflat invertebrates all incorporated N of *Gracilaria vermiculophylla* origin, indicating that the macroalga is an important mediator of nutrient transfers. On mudflats algal presence increased oxic-anoxic heterogeneity in the sediment and coupled nitrification-denitrification, and though there was an increase in invertebrate biomass, this did not translate to increases in shorebird foraging.

Algae from mudflats and marshes subsidize subtidal clam beds, and clams are potentially significant C sinks. Clam aquaculture beds increased 4x and total area doubled from 2002 to 2012. Beds are located in shallow areas of short water residence time, and only a small fraction of potential habitat is in aquaculture. Rates of denitrification in clam beds are low and similar to bare sediments, and dissimilatory nitrate reduction to NH4+ exceeds denitrification, suggesting little N removal and high recycling to NH4+.

State change & projected climate/land-use drivers

'Marsh organ' experiments suggest that the response of *S. alterniflora* productivity to flooding is site specific and that marsh organs are not a good analog for plant sensitivity to flooding. Disturbance experiments and remote sensing of naturally

disturbed patches in VCR and the Netherlands support a consistent phenomenon of "critical slowing down", which may be a more universal indicator of impending state change.

Seagrass-vegetated areas reduce shear stress in a larger area than they footprint, including a sheltered area downstream. This is important to understanding how the patchy structure of meadows affects sediment resuspension and light.

On the barrier islands, total upland area was reduced by 29%, and woody vegetation increased 40%, from 1984-2011. Conversion rates from grassland and shrubland were non-linear and varied among islands. Three patterns emerged from multivariate analysis of land cover: resistant “high islands”, eroding “low islands”, and islands in transition. These data will be related to historical changes in bird and mammal populations.

At current RSLR rates the area of habitat favorable to piping plover nest presence in 2100 will increase compared to baseline predictions for 2008. This the first linkage of RSLR effects on shoreline change at a local level (5 km) to dynamic geomorphological changes, to wildlife habitat selection at the level of an individual nesting pair (5 m2).

The distribution of raccoons has expanded on the islands over the past 30+ years, with islands near the mainland having greater recolonization. The minimum costs of immigration to specific islands vary >3 orders of magnitude, making some islands better targets for predator removal to aid recovery of shorebirds.

Analyses of N input via streams to coastal bays indicate that: 1) higher discharge rates decrease NO3- lost by denitrification and hydrology has a stronger control than temperature; 2) higher stream denitrification is linked to higher stream metabolism; and 3) N2O efflux will be higher as groundwater NO3- increases from fertilizer use or other N inputs.

Socio-ecological drivers

The economic valuation showed that 1) residents prefer a 'living shorelines' approach to sea walls for protecting shorelines, but most respondents chose 'no-action', 2) residents who were more 'conservation-minded', and those who claim membership in a concerned citizen’s group, were more likely to choose a management plan than to take 'no action', 3) a person’s desire to preserve historic culture (“keep things the way they are”) was an indicator of likelihood to choose 'no action', and 4) wildlife preservation, shoreline protection, and marsh persistence were the most valued ecosystem services.

Key outcomes or Other achievements:

Mechanisms of non-linear state change

The dynamics of the marsh boundary is primarily controlled by sediment supply rather than RSLR. The lack of sediment supply, often associated with human activities, is a major driver of marsh loss and is at least comparable to the accelerating RSLR due to global warming. With collaborators, we have pioneered the use of computer-aided-tomography for measuring marsh root and rhizome volume, a parameter that is critical to understanding sediment structural integrity, marsh surface elevation and geomorphic patterns.

“Blue” carbon systems play a large role in global carbon sequestration, which impacts climate change and RSLR. We are the first to show the importance of seagrass restoration in sequestering C as a key ecosystem service, and have

developed the methodology for greenhouse gas benefits of seagrass restoration by the Verified Carbon Standards program. We also show the importance of freshwater/brackish marshes and clam beds to C sequestration.

The coastal dune model continues to provide key insights into dune recovery and barrier island evolution, demonstrating that vegetation plays a more active role in determining coastal vulnerability than previously thought.

Thresholds for state change

The phenomenon of critical slowing down has been proposed as a leading indicator of ecosystem collapse, where recovery to disturbance slows as an ecosystem approaches a critical threshold. Our work suggests critical slowing down is evident in marshes, and that the response is consistent between extremely diverse systems (VCR vs. Dutch Schelde Estuary). This work provides important “real world” support for this ecological theory, which is primarily grounded in numerical models and highly controlled experiments.

Our finding that islands are bistable contributes to a growing literature reporting the existence of alternate stable states in ecosystems and provides the basis for predicting future island state as a function of storm erosion, RSLR, and the aeolian/biological processes involved in dune building.

Our results provide fine-scale evidence of threshold groundwater conditions controlling shrub physiology, which affects growth and distribution. This creates potential for feedbacks with evapotranspiration and local climate, potentially shifting favorable habitat with altered precipitation regimes and RSLR.

Ecosystem connectivity

Across all systems and with current RSLR, retreat is a more likely marsh loss modality than drowning. Marsh retreat increases resilience, allowing the marsh platform to keep pace with elevated RSLR.

Residence time is a master variable that helps to quantify ecosystem connectivity, bed sediment size variations, and spatial temperature distributions. We have developed methods for mapping residence time and grain size across all the bays of the VCR.

Oyster reefs may not be effective as previously thought at dissipating the largest waves that accompany storms with strong winds and storm surge. Oysters increase suspended sediment deposition, decrease turbidity and enhance light availability for benthic primary producers. By enhancing turbulence, oyster reefs also provide cues to larvae that increase settlement. For the oyster metapopulation, the relative success of individual patches depends on larval supply and the distribution of source and sink populations. The connectivity of larvae between reefs is greatest if the source reef is adjacent to high-flow channels or exposed to flows affected by the open ocean.

Sudden shifts in island state (especially from high to low, as initiated by storms once the island is in the bistable regime) have the potential to initiate changes across the broader coastal system through connections to adjacent marsh and bay environments.

Subsidies

Cross-habitat subsidies in the coastal barrier system influence the provision of ecosystem services. Macrophyte subsidies from subtidal to intertidal habitats enhance N supply to primary producers and consumers, increase biodiversity, and stimulate the removal of N via denitrification. The latter effect has implications for the role of lagoons and marshes as a filter for watershed N inputs.

Sustaining the growing clam aquaculture requires analysis of carrying capacity as well as understanding positive and negative impacts on the benthic environment.

State change & projected climate/land-use drivers

Seagrasses are important foundation species in shallow coastal ecosystems that provide critical ecosystem services including stabilizing sediment, sequestering carbon and nutrients, and providing habitat and an energy source for a diverse fauna. Our project represents the world's largest successful seagrass restoration, and demonstrates the reinstatement of key ecosystem services with successful large-scale restoration within a decade.

Marsh expansion driven by sediment supply rarely matches lateral erosion by waves, creating a dynamic landscape. Recent results show that marsh collapse can occur in the absence of RSLR if the rate at which sediment is eroded at marsh boundaries is higher than the input of sediment. In a period of accelerated sea level rise and reduced sediment supply one of the few options for the survival of marshes is migration inland. Our observations show that longer and more frequent flooding events can lead to tree dieback and transformation of forest to salt marsh.

Marsh dieback has affected *S. alterniflora* marshes from the Gulf of Mexico to New England. The cause of dieback is not clear; however, the patterns of the dieback may reflect patch size of *S. alterniflora* clones. Clonal patch size and genetic diversity among clones provides insight into the spatial pattern of salt marsh die-back and re-colonization. Long-term (>25 yr) data on *Juncus roemerianus* patches indicate that distribution is influenced by expansion with climate warming and retraction from storm disturbance and increased flooding frequency.

Our results on the islands show that local scale conversions between ecosystem state (exposed sediment, grassland, shrubland) influence large scale island shape and size and may be used to predict future island trajectory, especially when coupled with elevation data.

Socio-ecological drivers

As sea level rises, Eastern Shore communities face three choices: retreat inland and abandon farmland, harden the shoreline with structures to delay upland submergence that cause negative impacts on adjacent areas, or adopt alternative strategies such as planting salt-tolerant crops to support the local economy.

*** What opportunities for training and professional development has the project provided?**

35 graduate students and about 19 undergraduate students were trained this year through the VCR LTER program. VCR has a formal 'tiered' mentoring program that involves faculty, graduate students, undergraduate students and high school students working together as a team on specific research projects.

Ongoing K-12 activities include: Coastal Bay Ecology and Fall Migration Workshops on the Eastern Shore, professional

development workshops for area K-12 teachers; Oyster Gardening Program which provides training and curriculum materials for local teachers along with classroom materials and field trips for participating classes run in partnership with VA Oyster Reef Keepers; Summer Science Internships for local high school students through our Research Experience for High School Students (REHS) program made possible by levering SLTER Funds with additional support from TNC; and our Water Cycle/Nutrient dynamics field trip at the VCR-LTER run on request for class groups from across VA. VCR researchers and staff work with the science faculty at Northampton High School, giving guest lectures and assisting with curriculum development. Every one of the 200 high school student in the county is exposed to VCR research at least once in their high school career; over 50% of these students are from traditionally under-represented groups.

We held two Art and Ecology workshops (Plein AIre Painting and Observational Drawing) that provide training for ~45 teachers per year. Artwork and essays generated from the workshops are displayed in public exhibitions at the Barrier Islands Center Museum on the Eastern Shore and in the Science and Engineering library at UVa each year. We partnered with the Virginia Institute of Marine Science in a week-long Coastal Ecology PD program for 18 teachers from the Tidewater region.

With the The Nature Conservancy and Chesapeake Experience we ran a week-long Coastal Ecology summer camp for local 3-6 graders. Half of the campers were from "At-Risk" families and received scholarships funded through our SLTER budget. Campers used kayaks to explore different coastal habitats each day and learn about important plant and animal communities including oyster reefs, seagrass meadows, mud flats and salt marshes.

UVa and University of Richmond faculty ran a summer term Marine Biology class in May. In collaboration with faculty from the UVA Engineering Department's Science Technology and Society Program he co-instructed a January term Nature Writing workshop (STS2500: A Sense of Place: Perceptions of Coastal Ecosystems) for undergraduate students. The ABCRC has hosted field trips for Marine Biology and Ecology classes from the University of Richmond.

*** How have the results been disseminated to communities of interest?**

The VCR holds a monthly public seminar series at the Anheuser-Busch Coastal Research Center, which is attended by 20-50 local residents and planners. VCR-LTER PIs and graduate students from UVA and our partner institutions provide lectures to school and public groups in their areas.

VCR scientists are members of 1) the Eastern Shore Climate Adaptation Working group, a partnership between TNC, local, regional and federal agencies, and 2) a regional committee formed to examine current zoning regulations and the potential economic and ecological impacts of developing commercial poultry production. The VCR Citizen Science Program includes colaborations with the VA Oyster Reef Keepers and the VA Master Naturalists. The VCR lab is a demonstration site for local vegetation.

The VCR disseminates research findings and data through the VCR LTER website (www.vcrlter.virginia.edu). Use of the website continues to increase.

'Blue' carbon systems play a large role in global carbon sequestration, which impacts climate change and sea level rise. VCR scientists are the first to show the importance of seagrass restoration in sequestering carbon and as a result have been chosen to develop the methodology for determining greenhouse gas benefits of seagrass restoration by the Verified Carbon Standards VCS program. The VCR seagrass restoration project has been highlight in the public media with a recent Boston Globe article on "blue carbon sequestration" highlighting Lead P.I. McGlathery's research.

*** What do you plan to do during the next reporting period to accomplish the goals?**

Mechanisms of non-linear state change

At the marsh-upland boundary, we will continue to collect data from the two wells established at the boundary between forest and salt marsh to evaluate long-term oscillations in water levels and salinity. Using hyperspectral imagery, we will analyze the shoreward transgression of marsh pre- and post Hurricane Sandy and develop tools to be used to assess patterns following future storms.

We will continue our long-term study of marsh-boundary dynamics to understand the complex feedbacks between marsh erosion, waves, and RSLR. We will continue work on how burrowing mechanics and pumping rates of worms alters oxygen levels in intertidal sediments and influences rates of nutrient turnover and mineralization.

For the subtidal systems, we will continue our long-term monitoring of plant, sediment and faunal parameters in the restored seagrass meadows. We will also quantify spatial variation in carbon sequestration and sources of buried carbon. We will validate our alternative-state change model with data on light, sediment characteristics and temperature, and use these to modify our model of habitat suitability for seagrass restoration in the VCR lagoons. Studies on denitrification will continue in seagrass meadows and in regions where clam beds and seagrass meadows co-occur. Metabolism studies using the eddy correlation approach will be expanded.

On the barrier islands, we will continue measurements of groundwater and temperature in the grassland/shrubland transition zone and will add plots to quantify spatial variations in grassland species composition relative to landscape position. We will test experimentally nitrogen limitation to shrub establishment. We will monitor distribution of *Uniola* across the barrier islands and begin planting of dune-building grasses (*Uniola, Spartina, Ammophila*) in an overwash zone.

Thresholds for state change

We will map areas of tree dieback where transition from forest to salt marsh occurs. We will relate these areas to the local vegetation characteristics and landscape morphology.

In the seagrass system, we will test the theory of slowing down as an indicator of ecosystem resilience by expanding our experimental transplant studies and initiating new studies where meadows are disturbed and the recovery time is followed along a stress gradient (water depth) where resilience is expected to differ based on the alternative stable state model.

On the barrier islands, we will continue monitoring seed dispersal and seedling establishment/growth under various cover types. We will continue monitoring salinity, and will include a gradient of grass density to determine effect on shrub establishment/survival. We will conduct experimental manipulations of salinity and drought on representative grass species to quantify physiological tolerances. Analyses of the fine-scale relationship of root decay to groundwater along a dune/swale transect will be completed. Belowground responses are expected to be sensitive to changes in elevation and nearness to groundwater.

Ecosystem Connectivity

At marsh sites, a 2-3 week late-fall/winter deployment of wave, current and turbidity sensors will be carried out to quantify SSC and transport in response to wave and tidal forcing. We will develop a cellular automata model to address sediment transport and redistribution in the context of marsh vulnerability to RSLR.

We will finalize data analysis of seagrass impacts on wave attenuation and seasonal measurements of total benthic microalgal biomass and extracellular polymeric substances (EPS) to relate these measurements to critical shear stresses necessary for sediment resuspension.

We will add marsh edge erosion due to waves to the coupled barrier island-marsh model (GEOMBEST+) and conduct experiments to determine how this additional complexity affects couplings between the two landscape units. We will continue experiments measuring the impact of overwash on marsh productivity, and examine the results in context of marsh-barrier numerical modeling, and early VCR work on marsh development on overwash fans of different ages.

Subsidies

Our main focus in relation to aquaculture will be to refine potential habitat estimates and evaluate carrying capacity using various modeling approaches. Flux studies and site characterization will also continue. Over the long-term, we envision data on changing coverage as important in evaluating relative bottom habitat used by aquaculture and seagrasses. Eventually, there may be conflicts and trade-offs involved in these two types of benthic habitat.

State change & projected climate/land-use drivers

We will continue to validate the alternative stable state model for seagrass with field data on light attenuation, water temperature, depth of productive meadows. Data will be used in combination with DELFT modeling to assess suitable seagrass habitat. A modified model will be run with future scenarios of eutrophication and climate change, and will incorporate the coupling of seagrass and marsh habitats. This is a novel approach to understanding state change dynamics.

For the barrier islands, we will refine our rules-based cellular automata model that simulates shrub thicket dynamics within the context of bistability at several spatial scales: swale, cross-island, island, and island chain. We will use the model to predict shrub expansion (or contraction) in response to RSLR and to changes in storm frequency, associated variations in shoreline migration, and availability of groundwater from the freshwater lens. We will trap mammals on islands where predators are transient, on islands where they are resident (i.e., source islands), and on islands that might serve as bridges between source and transient islands).

We plan to summarize the National Atmospheric Administration (NOAA) Coastal-Change Analysis Program (C-CAP) land cover information for each island to provide a statistical basis for modeling island occupancy by small mammals. We will do occupancy analysis of the mammal data, and relate them to the habitat/vegetation analysis. We will continue our 24-year semi-annual small mammal sampling in November and April, and will initiate a camera-trap study of predator movement relative to nesting bird colonies on the islands..

We will integrate data on potential shorebird predators into an existing model that links RSLR to shoreline change rates, island geormophology, and the probability of nesting by piping plovers. These models developed using data from Assateague Island National Seashore will be expanded to new sites from North Carolina to Massachusetts, in collaboration with the USGS Sea Level Rise Hazards Project and USFWS, and will include sites in the VCR. We will complete our May field season surveys of migratory shorebirds, their prey, and habitat use.

To assess NO3- loading to lagoons, we will examine the effect of transient events such as flood waves from storms on the flux of NO3- from streambed sediments. Models predict that NO3- flux will decrease during the passage of small waves (i.e., small storms), but will increase as the wave from large storms passes. Field investigations will provide information on the boundary between “small” and “large” storms. We will also begin to examine the effect of RSLR on the areal extent of denitrification in low-relief coastal streams.

We will continue to examine facilitation of high-marsh transgression into low lying agricultural areas planted to *K. pentacarpos.* Current experimental plots will be increased in size and additional fields will be identified for future planting. Collaboration with the VA Tech Agricultural Experiment Station is being explored.

Products

Books

Book Chapters

McBride, R.A. and Anderson, J.B. and Buynevich, I.V. and Cleary, W. and Fenster, M.S. and FitzGerald, D.M. and Harris, M.S. and Hein, C.J. and Klein, A.H.F. and Liu, B. and Menezes, J.T. de and Pejrup, M. and Riggs, S.R. and Short, A.D. and Stone, G.W. and Wallace, D.J. and Wang, P. (2013). Morphodynamics of Barrier Systems: A Synthesis. *Treatise in Geomorphology* Sherman, Douglas J.. Academic Press. San Diego. 166-244.. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Small, Gaston and Baulch, Helen and Bechtold, Heather and Holzer, Kimberly and Newell, Silvia and Vaquer-Sunyer, Raquel (2014). Headwaters to estuaries: Complex responses to cultural eutrophication at the watershed scale. *Eco-DAS IX Symposium Proceedings* Association for the Sciences of Limnology and Ocea. 106-118. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Conference Papers and Presentations

Yue, Ian and Swallow, Stephen (2014). *Identifying Which Ecosystem Services Coastal Residents Actually Value: A*

Choice Experiment Survey of the Eastern Shore of Virginia Regarding Climate Change Adaptation. 2014 Annual Meeting of the Agricultural and Applied Economics Assoc.. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dueser, R. D. and Porter, J. H. and Moncrief, N. D. (2014). *A Proposed Measure of Cost-Effective Predator Movement Through a Fragmented Landscape*. Annual Meeting of the Virginia Chapter of The Wildlife Society. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dibbell, T. and Blum, L.K. and Kirwan, M.L. (2013). *Are Spartina alterniflora Plants from Different Marshes Equally Productive at Similar Elevations?* . Coastal and Estuarine Research Federation Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Gieder, K. and Karpanty, S.M. and Gutierrez, B. and Thieler, E. and Plant, N. and Fraser, J.D. and Catlin, D. (2014). *Assessing the impacts of sea level rise on piping plovers at Assateague Island*. Atlantic Coast Piping Plover and Least Tern Workshop. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Stanhope, JW and Anderson, IC and Brush, MJ and CA, Currin and Piehler, MF. (2013). *Benthic microbial responses to interacting physical-biological drivers in a shallow estuary*. Coastal and Estuarine Research Federation. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Murphy, A, Anderson, IC, Luckenbach, MW. (2013). *Biogeochemical responses to clam aquaculture and environmental conditions: Sacca di Goro, Italy and Cherrystone Inlet, US. .*. Coastal and Estuarine Research Federation. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Adams, E. and Day, F.P. (2014). *Blue carbon in coastal freshwater marshes on the barrier islands of Virginia: aboveground carbon pools*. Association of Southeastern Biologists Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Adams, E. and Day, F.P. (2014). *Blue carbon in coastal freshwater marshes on the barrier islands of Virginia: aboveground carbon pools*. Joint Aquatic Sciences Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sedghi, N. and Day, F.P. (2014). *Blue carbon in coastal freshwater marshes on the barrier islands of Virginia: belowground carbon pools*. Association of Southeastern Biologists Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Sedghi, N. and Day, F.P. (2014). *Blue carbon in coastal freshwater marshes on the barrier islands of Virginia: belowground carbon pools*. Joint Aquatic Sciences Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Pickus, B. and Cosans, C. and Herman, J.S. and Mills, A.L. (2014). *Building rating curves for low-order streams draining small watersheds of the Atlantic coastal plain*. Southeast Regional Meeting, Geological Society of America.. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christian, R. R. (2014). *Coastal issues with terrestrial ECVs*. Terrestrial Observation Panel for Climate – XVI. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Zinnert, JC and Shiflett, SA and Bissett, SN and Dows, BL and Manley, PV and Via, SM (2014). *Cross-island comparison of temporal variations in shrub-grassland bistability at the Virginia Coast Reserve*. Ecological Society of America. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Cosans, C., B. Pickus, J.S. Herman, and A.L. Mills (2014). *Determining nitrogen fluxes in low-relief coastal streams: assessment of projecting localized measurements to regional-scale modeling*. Southeast Regional Meeting, Geological Society of America. Geological Society of America, Abstracts with Prog. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christian, R. R. (2014). *Ecological flows and the complications of being on the coast*. ECU Water Center Seminar Series. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Blum, L.K. and Davey., E. (2013). *Examination of Spartina alterniflora root contributions to salt marsh soil volume by CT-imaging.* . Coastal and Estuarine Research Federation Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McFadden, G.S. and Flewelling, S.A. and Herman, J.S. and Mills, A.L. (2013). *Generality of nitrate removal in streambed sediment on the southern DelMarVa Peninsula*. American Geophysical Union Fall Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Smyth, A.R. and Piehler, M.F. and Grabowski, J.H. (2013). *Habitat setting influences oyster-mediated denitrification*. Coastal and Estuarine Research Federation. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Walters, D.C and Moore, L.J. and Duran, O. and Fagherazzi, S. and Mariotti, G. and Kirwan, M.L. (2014). *How much is too much: The impact of overwash deposition on backbarrier marsh vegetation*. Geological Society of America annual meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Murphy, A, Anderson, IC, Luckenbach MW, Stanhope, JW. (2013). *Impacts of Mercenaria mercenaria aquaculture on benthic metabolism and nutrient fluxes and the role of macroalgae*. Atlantic Estuarine Research Society. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, IC and Murphy, A and Luckenbach, MW (2013). *Impacts of clam aquaculture on benthic microbial processes*. Coastal and Estuarine Research Federation. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dunckel, A.E., and Mills, A.L. (2013). *Influence of environmental factors on N2O emissions from denitrification in streambed sediments of low-relief coastal streams*. American Geophysical Union Fall Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Anderson, IC and Stanhope, JW and Brush, M and Smyth, A and Currin, C and Piehler, M (2014). *Interacting drivers regulating the fate of nitrogen in shallow photic marine systems*. JASM, 2014. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Etheridge, S. and Christian, R. R. and Brinson, M. M. (2013). *Juncus roemerianus patch stability and community shifts across a marsh*. 22nd Biennial Coastal and Estuarine Research Federation Conference: Toward Resilient Coasts and Estuaries, Science for Sustainable Solutions. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Moncrief, N. D. and Dueser, R. D. and Porter, J. H. (2014). *Least-Cost Path Analysis of Movement by Raccoons (Procyon lotor) on the Virginia Barrier Islands*. Annual Meeting of the American Society of Mammalogists. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Moncrief, N. D. and Dueser, R. D. and Porter, J. H. (2014). *Least-Cost Path Analysis of Movement by Raccoons (Procyon lotor) on the Virginia Barrier Islands*. Annual Meeting of the Virginia Academy of Sciences. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Koopmans, D. and Berg, P. (2014). *Oxygen flux in a coastal stream calculated with the open water and eddy correlation techniques*. Joint Aquatic Sciences Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christian, R. R. and Allen, D. M. and Kimmel, D. and Mallinson, D. and Overton, A. and Reyes, Enrique (2014). *Potential future of the Pamlico Sound ecosystem: a space for time analysis*. Biodiversity Responses to Climate Change – Perspectives from the Southeastern US. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dows, BL and Zinnert, JC and Young, DR (2014). *Shrub expansion into coastal grasslands: Seed dispersal and environmental filters determine patterns of invasion*. Ecological Society of America. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

McFadden, G.S. and Herman, J.S. and Mills, A.L. (2013). *Streambed sediments of the Atlantic Coastal Plain as sites for denitrification: The role for sediment carbon content and pore-water composition and velocity*. Geological Society of America, Annual Meeting, October 27-30, 2013 . . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Wiberg, P.L. and Carr, J.A. and Safak, I. (2014). *Suspended sediment concentrations derived from models, measurements and imagery for a system of shallow coastal bays*. Ocean Sciences Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Allen, D. M. and Christian, R. R. (2013). *Trophic and nutrient subsidies by nekton in a southeastern U.S. salt marsh estuary*. 22nd Biennial Coastal and Estuarine Research Federation Conference: Toward Resilient Coasts and Estuaries, Science for Sustainable Solutions. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Gutierrez, B. and Gieder, K. and Karpanty, S.M. and Thieler, E.R. and Plant, N. (2014). *Using Bayesian networks to predict coastal vulnerability to sea level rise*. USGS Climate Change in Urban Settings Workshop. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Koopmans, D. and Berg, P. (2013). *Water velocity as a driver of stream metabolism: A parallel application of the open water and eddy correlation techniques.* . American Geophysical Union Fall Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Yue, Ian and Swallow, Stephen (2014). *What Ecosystem Services Do People Actually Care About? A Choice Experiment Survey of the Eastern Shore of Virginia Concerning Environmental Values and Climate Change Adaptation*. Annual Meeting of the Northeastern Agricultural and Resource Economics Association. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Christian, R. R. & Blum, L. K. (2013). *Why compare hemispheres: a case for salt marsh response to sea-level change*. 22nd Biennial Coastal and Estuarine Research Federation Conference: Toward Resilient Coasts and Estuaries, Science for Sustainable Solutions. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Journals

Bachmann, Charles M and Philpot, William and Abelev, Andrei and Korwan, Dan (2014). Phase angle dependence of sand density observable in hyperspectral reflectance. *Remote Sensing of Environment*. 150 53-65. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.rse.2014.03.024

Bissett, Spencer N and Zinnert, Julie C and Young, Donald R (2014). Linking Habitat with Associations of Woody Vegetation and Vines on Two Mid-Atlantic Barrier Islands. *Journal of Coastal Research*. 30 (4), 843-850. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.2112/JCOASTRES-D-13-00177.1

Brantley, Steven T and Bissett, Spencer N and Young, Donald R and Wolner, Catherine WV and Moore, Laura J (2014). Barrier Island Morphology and Sediment Characteristics Affect the Recovery of Dune Building Grasses following Storm-Induced Overwash. *PloS one*. 9 (8), e104747. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0104747

Durán, Orencio and Moore, Laura J. (2013). Vegetation controls on the maximum size of coastal dunes. *Proceedings of the National Academy of Sciences of the United States of America*. 110 (43), 17217-17222. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fagherazzi, S and Mariotti, G and Banks, AT and Morgan, EJ and Fulweiler, RW (2014). The relationships among hydrodynamics, sediment distribution, and chlorophyll in a mesotidal estuary. *Estuarine, Coastal and Shelf*

Science. 144 54-64. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecss.2014.04.003

Fagherazzi, S and Wiberg, P.L. and Temmerman, S. and Struyf, E. and Zhao, Y. and Raymond, P.A. (2013). Fluxes of water, sediments, and biogeochemical compounds in salt marshes. *Ecological Processes, 2:3*. 2 (3), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fagherazzi, Sergio (2013). The ephemeral life of a salt marsh. *Geology*. 41 (8), 943-944. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1130/focus082013.1

Gieder, Katherina D and Karpanty, Sarah M and Fraser, James D and Catlin, Daniel H and Gutierrez, Benjamin T and Plant, Nathaniel G and Turecek, Aaron M and Robert Thieler, E (2014). A Bayesian network approach to predicting nest presence of the federally-threatened piping plover (< i> Charadrius melodus) using barrier island features. *Ecological Modelling*. 276 (24), 38-50. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecolmodel.2014.01.005

Gonzalez, Dana J and Gonzalez, Raul A and Froelich, Brett A and Oliver, James D and Noble, Rachel T and McGlathery, Karen J (2014). Non-native macroalga may increase concentrations of Vibrio bacteria on intertidal mudflats. *MEPS*. 505 29-36. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3354/meps10771

Hondula, K. L. and Pace, M. L. (2014). Macroalgal support of cultured hard clams in a low nitrogen coastal lagoon. *Mar. Ecol. Prog. Ser.*. 498 187-201. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3354/meps10644

Hondula, K. L. and Pace, M. L. and Cole, J. J. and Batt, R. D. (2014). Hydrogen isotope discrimination in aquatic primary producers: implications for aquatic food web studies. *Aquatic Sciences*. 76 (2), 217-229. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s00027-013-0331-6

Leonardi, Nicoletta and Canestrelli, Alberto and Sun, Tao and Fagherazzi, Sergio (2013). Effect of tides on mouth bar morphology and hydrodynamics. *Journal of Geophysical Research: Oceans*. 118 (9), 4169-4183. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/jgrc.20302

Leonardi, Nicoletta and Sun, Tao and Fagherazzi, Sergio (2014). Modeling Tidal Bedding In Distributary-Mouth Bars. *Journal of Sedimentary Research*. 84 (6), 499-512. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.2110/jsr.2014.42

Mariotti, G and Carr, J (2014). Dual role of salt marsh retreat: Long-term loss and short-term resilience. *Water Resources Research*. 50 (4), 2963-2974. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013WR014676

Mariotti, G and Fagherazzi, S (2013). A two-point dynamic model for the coupled evolution of channels and tidal flats. *Journal of Geophysical Research: Earth Surface*. 118 (3), 1387-1399. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; DOI: 10.1002/jgrf.20070

Mariotti, G and Falcini, F and Geleynse, N and Guala, M and Sun, T and Fagherazzi, S (2013). Sediment eddy diffusivity in meandering turbulent jets: Implications for levee formation at river mouths. *Journal of Geophysical Research: Earth Surface*. 118 (3), 1908-1920. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/jgrf.20134

Mariotti, Giulio and Fagherazzi, Sergio (2013). Wind waves on a mudflat: The influence of fetch and depth on bed shear stresses. *Continental Shelf Research*. 60 S99-S110. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.csr.2012.03.00

McLoughlin, S.M. and Wiberg, P.L. and Safak, I. and McGlathery, K.J. (2014). Rates and forcing of marsh edge erosion in a shallow coastal bay: Virginia. *Estuaries and Coasts*. . Status = PUBLISHED; Acknowledgment of

Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s12237-014-9841-2

Mozdzer, Thomas J and McGlathery, Karen J and Mills, Aaron L and Zieman, Joseph C (2014). Latitudinal variation in the availability and use of dissolved organic nitrogen in Atlantic coast salt marshes. *Ecology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1890/13-1823.1

Reidenbach, M.A. and Berg, P. and Hume, A. and Hansen, J.C.R. and Whitman, E.R. (2013). Hydrodynamics of intertidal oyster reefs: the influence of boundary layer flow processes on sediment and oxygen exchange. *Limnology and Oceanography: Fluids and Environments*. 3 225-239. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Rheuban, Jennie E and Berg, Peter and McGlathery, Karen J (2014). Ecosystem metabolism along a colonization gradient of eelgrass (Zostera marina) measured by eddy correlation. *LIMNOLOGY AND OCEANOGRAPHY*. 59 (4), 1376-1387. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.4319/lo.2014.59.4.1376

Rheuban, Jennie E and Berg, Peter and McGlathery, Karen J (2014). Multiple timescale processes drive ecosystem metabolism in eelgrass (Zostera marina) meadows. *Mar Ecol Prog Ser.*. 507 1-13. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3354/meps10843

Shiflett, Sheri A and Zinnert, Julie C and Young, Donald R (2014). Conservation of functional traits leads to shrub expansion across a chronosequence of shrub thicket development. *Trees*. 28 (3), 849-858. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s00468-014-0997-y

Smyth, A.R. and Geraldi, N.R. and Piehler, M.F. (2013). Quantifying the effects of oysters on nitrogen pools and processes. *Marine Ecology Progress Series*. 493 23-30. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3354/meps10516

Valentine, K and Mariotti, G and Fagherazzi, S (2014). Repeated erosion of cohesive sediments with biofilms. *Advances in Geosciences*. 39 (39), 9-14. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/adgeo-39-9-2014

Licenses

Other Products

Databases.

The VCR/LTER shares 210 online datasets with an aggregate volume of approximately 150 GB. These are published via the VCR/LTER web site, the LTER Data Portal, the LTER Metacat and the DataOne ONEMercury system.

The datasets are frequently downloaded for use by researchers and students. 231 of the data files associated with online datasets (some datasets include multiple data files) were downloaded a total of 5,375 times (4,238 times from the LTER Data Portal and 1,137 times via the LTER Data Access Server) during the period 2013-10-01 to 2014-09-30.

Other Publications

Patents

Technologies or Techniques

The VCR/LTER provides a web service that automates generation of statistical programs based on Ecological Metadata Language-based metadata. Given the identity of a specific dataset in a repository or any web-accessible EML metadata the web service will create R, Matlab (courtesy of GCE LTER), SAS or SPSS programs. The web service is described at http://www.vcrlter.virginia.edu/data/eml2/PASTAprogHelp.html, with detailed information at: http://www.vcrlter.virginia.edu/data/eml2/PASTAprogWebService.pdf. There is also a web-portal for statistical code generation at: http://www.vcrlter.virginia.edu/data/eml2/eml2stat.html.

During 2014 the web service was incorporated into the LTER Data Portal so that links which use the service are available for data from all LTER sites in the "Code Generation" section of each data package that includes one or more data tables. The service is currently being accessed approximately 180,000 times per month (probably a large majority of this access is from search engines hitting the LTER Data Portal).

Thesis/Dissertations

Hokkanen, Molly. *Environmental influences on sex ratio and spatial distribution of dioecious Morella cerifera L. on a Virginia barrier island*. (2013). Virginia Commonwealth University. Acknowledgement of Federal Support = Yes

Thomas, Emily L.. *Influence of Zostera marina on Wave Dynamics, Sediment Suspension, and Bottom Boundary Layer Development within a Shallow Coastal Bay*. (2014). University of Virginia. Acknowledgement of Federal Support = Yes

Rheuban, Jennie E. *Oxygen metabolism in restored eelgrass (Zostera marina L.) meadows measured by eddy correlation*. (2013). University of Virginia. Acknowledgement of Federal Support = Yes

Dows, Benjamin. *Roles of seed dispersal and environmental filters in establishment of the dominant shrubs: Morella cerifera and M. pensylvanica, on an Atlantic barrier island*. (2014). Virginia Commonwealth University. Acknowledgement of Federal Support = Yes

Koopmans, Dirk J.. *Stream metabolism and groundwater discharge to coastal waters: Applications of the eddy correlation technique*. (2013). University of Virginia. Acknowledgement of Federal Support = Yes

McFadden, George S. *Streambed Sediments of Virginia Eastern Shore Streams are Poised for Pore-Water Dentrification*. (2013). University of Virginia. Acknowledgement of Federal Support = Yes

Duvall, Melissa S.. *The Effects of Waves and Tidal Inundation on Sediment Deposition and Flux across a Bay-Marsh Boundary*. (2014). University of Virginia. Acknowledgement of Federal Support = Yes

Websites

Virginia Coast Reserve Long-Term Ecological Research
http://www.vcrlter.virginia.edu

Main web site for the Virginia Coast Reserve Long-Term Ecological Research project. Includes links to personnel, data, research summaries, student theses, online maps and planning resources for fieldwork. During the period Oct 1, 2013-Sep 30, 2014 the primary site had 4,321 users and 22,842 page views. 44% of visitors used the site more than once. Users were primarily from the US (78%), with additional users from Brazil (3%), UK (2%), India, Canada, France and China (1% each).

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support:	REU supplement
How many REU applications were received during this reporting period?	20
How many REU applicants were selected and agreed to participate during this reporting period?	3
REU Comments:	

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked

McGlathery, Karen	PD/PI	2
Porter, John	Co PD/PI	9
Reidenbach, Matthew	Co PD/PI	3
Wiberg, Patricia	Co PD/PI	2
Anderson, Iris	Co-Investigator	1
Bachmann, Charles	Co-Investigator	1
Berg, Peter	Co-Investigator	2
Blum, Linda	Co-Investigator	4
Christian, Robert	Co-Investigator	2
D'Odorico, Paolo	Co-Investigator	1
Day, Frank	Co-Investigator	3
Dueser, Raymond	Co-Investigator	3
Fagherazzi, Sergio	Co-Investigator	2
Fenster, Michael	Co-Investigator	1
Fuentes, Jose	Co-Investigator	1
Galloway, James	Co-Investigator	1
Hayden, Bruce	Co-Investigator	6
Herman, Janet	Co-Investigator	1
Karpanty, Sarah	Co-Investigator	2
Kirwan, Matt	Co-Investigator	1
Lawson, Sarah	Co-Investigator	1
Macko, Stephen	Co-Investigator	1
Mills, Aaron	Co-Investigator	2
Moncrief, Nancy	Co-Investigator	1

Moore, Laura	Co-Investigator	2
Pace, Michael	Co-Investigator	1
Scanlon, Todd	Co-Investigator	0
Schwarzschild, Arthur	Co-Investigator	12
Smith, David	Co-Investigator	1
Swallow, Stephen	Co-Investigator	1
Young, Donald	Co-Investigator	1
Zieman, Joseph	Co-Investigator	1
Zinnert, Julie	Co-Investigator	2
Carr, Joel	Postdoctoral (scholar, fellow or other postdoctoral position)	4
Goldstein, Evan	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Smyth, Ashley	Postdoctoral (scholar, fellow or other postdoctoral position)	6
Boyd, David	Technician	12
Buck, Christopher	Technician	12
Luckenbach, Patrick	Technician	10
Maben, John	Technician	1
Richardson, David	Technician	8
Adams, Emily	Graduate Student (research assistant)	3
Aoki, Lillian	Graduate Student (research assistant)	6
Bissett, Spencer	Graduate Student (research assistant)	1
deVries, Elsemarie	Graduate Student (research assistant)	1
Dows, Benjamin	Graduate Student (research assistant)	3
Dunkel, Anne	Graduate Student (research assistant)	2

Duvall, Melissa	Graduate Student (research assistant)	12
Egge, Noah	Graduate Student (research assistant)	6
Emery, Kyle	Graduate Student (research assistant)	8
Etheridge, Sherer	Graduate Student (research assistant)	8
Jass, Theo	Graduate Student (research assistant)	6
Kearney, William	Graduate Student (research assistant)	6
Koopmans, Dirk	Graduate Student (research assistant)	2
Lauzon, Rebecca	Graduate Student (research assistant)	2
Leonardi, Nicoletta	Graduate Student (research assistant)	2
Lunstrum, Abby	Graduate Student (research assistant)	6
Manley, Paul	Graduate Student (research assistant)	1
Mariotti, Giulio	Graduate Student (research assistant)	2
McFadden, George	Graduate Student (research assistant)	2
Murphy, Anna	Graduate Student (research assistant)	1
Murphy, Elizabeth	Graduate Student (research assistant)	7
Oreska, Matthew	Graduate Student (research assistant)	6
Priestas, Anthony	Graduate Student (research assistant)	4
Raub, Kristin	Graduate Student (research assistant)	1
Ruiz-Plancarte, Jesus	Graduate Student (research assistant)	3
Sedghi, Nathan	Graduate Student (research assistant)	3
Smith, Matt	Graduate Student (research assistant)	3
Thomas, Emily	Graduate Student (research assistant)	2
Thompson, Joseph	Graduate Student (research assistant)	1
Timmerman, Ross	Graduate Student (research assistant)	7

Via, Stephen	Graduate Student (research assistant)	3
Viggato, Tammy	Graduate Student (research assistant)	2
Volaric, Martin	Graduate Student (research assistant)	4
Walters, David	Graduate Student (research assistant)	9
Yue, Ian	Graduate Student (research assistant)	1
Conrad, Brianne	Undergraduate Student	2
Cosans, Cassandra	Undergraduate Student	1
Cruz, Rosa	Undergraduate Student	1
Deaton, Charles	Undergraduate Student	2
Grady, Margaret	Undergraduate Student	3
Jenet, Blair	Undergraduate Student	3
Mahon, Ryan	Undergraduate Student	2
McIntosh, Jessica	Undergraduate Student	2
Parcells, Hales	Undergraduate Student	3
Pickus, Benjamin	Undergraduate Student	1
Ren, Jennifer	Undergraduate Student	1
Rodriguez-Gomez, Juliana	Undergraduate Student	1
Rogers, Laura	Undergraduate Student	1
Valentine, Kendall	Undergraduate Student	6
Weinmann, Ben	Undergraduate Student	1
Kremer, Marnie	Research Experience for Undergraduates (REU) Participant	3
Long, Victoria	Research Experience for Undergraduates (REU) Participant	3
Margolis, Sarah	Research Experience for Undergraduates (REU)	3

	Participant	
Shayka, Bridget	Research Experience for Undergraduates (REU) Participant	3

Full details of individuals who have worked on the project:

Karen McGlathery
Email: kjm4k@virginia.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: Lead investigator, seagrass dynamics

Funding Support: UVA, NSF

International Collaboration: Yes, Australia, Denmark
International Travel: No

John H Porter
Email: jhp7e@virginia.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 9

Contribution to the Project: Information Manager

Funding Support: NSF

International Collaboration: Yes, Taiwan
International Travel: No

Matthew A Reidenbach
Email: reidenbach@virginia.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 3

Contribution to the Project: Studies of hydrodynamics associated with oyster reefs and seagrass

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Patricia L Wiberg
Email: pw3c@virginia.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 2

Contribution to the Project: Studies of lagoon water and sediment dynamics

Funding Support: NSF, UVA

International Collaboration: No

International Travel: No

Iris Anderson
Email: iris@vims.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Studies of nitrogen and phosphorus cycling and clam aquaculture

Funding Support: SeaGrant, VIMS

International Collaboration: Yes, Italy
International Travel: No

Charles Bachmann
Email: bachmann@cis.rit.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Use of hyperspectral remote sensing

Funding Support: Office of Naval Research

International Collaboration: No
International Travel: No

Peter Berg
Email: pb8n@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Aquatic flux measurements

Funding Support: NSF, UVA Dean's office

International Collaboration: No
International Travel: No

Linda Blum
Email: lkb2e@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 4

Contribution to the Project: Study of linkages between ecological and geomorphological process in salt marshes focused primarily on soil organic matter accumulation and thus plant belowground production and decomposition

Funding Support: UVA

International Collaboration: No
International Travel: No

Robert R Christian
Email: CHRISTIANR@ecu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Network analysis, studies of marsh macrophytes

Funding Support: Personal

International Collaboration: Yes, Italy
International Travel: Yes, Italy - 0 years, 0 months, 6 days

Paolo D'Odorico
Email: pd6v@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Modeling of coastal lagoons

Funding Support: UVA

International Collaboration: No
International Travel: No

Frank Day
Email: fday@odu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3

Contribution to the Project: Long-term studies of vegetation dynamics and water relations on barrier islands

Funding Support: ODU

International Collaboration: No
International Travel: No

Raymond D Dueser
Email: ray.dueser@usu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3

Contribution to the Project: Mammalian population and community studies

Funding Support: USU

International Collaboration: No
International Travel: No

Sergio Fagherazzi
Email: sergio@bu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Modeling of coastal lagoon water and sediment dynamics

Funding Support: NSF, USGS

International Collaboration: No
International Travel: No

Michael Fenster
Email: mfenster@rmc.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Monitoring of shoreline change

Funding Support: Randolf Macon College

International Collaboration: No
International Travel: No

Jose Fuentes
Email: jdfuentes@psu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Marsh carbon fluxes

Funding Support: Penn State, NSF

International Collaboration: No
International Travel: No

James N Galloway
Email: jng@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: working on N cycling in coastal systems

Funding Support: UVA

International Collaboration: No
International Travel: No

Bruce Hayden
Email: bph@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 6

Contribution to the Project: Climatology research, work on LTER Climate Ecosystems Dynamics blog and VCR Synthesis volume

Funding Support: UVA

International Collaboration: No
International Travel: No

Janet S Herman
Email: jsh5w@eservices.virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Elucidating processes of groundwater—surface-water exchange and their influence on the environmental fate of nitrogen in Coastal Plain watersheds draining to seaside lagoons.

Funding Support: UVA

International Collaboration: No
International Travel: No

Sarah M. Karpanty
Email: karpanty@vt.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Studies of birds on the Virginia Coast

Funding Support: Virginia Tech

International Collaboration: No
International Travel: No

Matt Kirwan
Email: kirwan@vims.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Modeling marsh formation, marsh-barrier couplings

Funding Support: VIMS, NSF, USGS

International Collaboration: Yes, Belgium, Netherlands
International Travel: No

Sarah Lawson
Email: ssojka@randolphcollege.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Work in collaboration with Karen McGlathery on seagrass research

Funding Support: Randolph College

International Collaboration: No
International Travel: No

Stephen Macko
Email: sam8f@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Research using stable isotopes

Funding Support: UVA

International Collaboration: No
International Travel: No

Aaron Mills
Email: alm7d@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Worked on streambed biogeochemistry

Funding Support: NSF

International Collaboration: No
International Travel: No

Nancy Moncrief
Email: nancy.moncrief@vmnh.virginia.gov
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Predator dynamics on the barrier islands

Funding Support: Virginia Museum of Natural History

International Collaboration: No
International Travel: No

Laura J Moore
Email: moorelj@email.unc.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Leading investigations of barrier island bi-stability and couplings between marsh and barrier

Funding Support: NSF, UNC-CH

International Collaboration: Yes, Germany
International Travel: No

Michael L Pace

Email: mlp5fy@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Studied Role of clam aquaculture in VCR

Funding Support: NSF

International Collaboration: No
International Travel: No

Todd Scanlon
Email: tms2v@Virginia.EDU
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 0

Contribution to the Project: Nitrogen dynamics

Funding Support: UVA

International Collaboration: No
International Travel: No

Arthur C Schwarzschild
Email: arthur@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 12

Contribution to the Project: Educational Coordinator, Site Manager

Funding Support: UVA, W. Buckner Clay Endowment for the Humanities

International Collaboration: No
International Travel: Yes, Korea, Republic Of - 0 years, 0 months, 10 days

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David E Smith
Email: des3e@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Aquatic vertebrates and education

Funding Support: UVA

International Collaboration: No
International Travel: No

Stephen Swallow
Email: stephen.swallow@uconn.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Social science research related to environmental value systems

Funding Support: NSF

International Collaboration: No
International Travel: No

Donald R Young
Email: dryoung@vcu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Investigating the mechanisms relating to shrub expansion across the VCR landscape

Funding Support: NSF, Army Research Office

International Collaboration: Yes, Spain
International Travel: Yes, Spain - 0 years, 0 months, 8 days

Joseph C Zieman
Email: jcz@virginia.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1

Contribution to the Project: Marsh dynamics

Funding Support: UVA

International Collaboration: No
International Travel: No

Julie C Zinnert
Email: jczinnert@vcu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2

Contribution to the Project: Linking remote sensing to environmental and ecological functioning at the VCR island chain scale and spatial-temporal variability in vegetation hyperspectral indices to characterize terrain state

Funding Support: Army Corps of Engineers

International Collaboration: Yes, Spain
International Travel: Yes, Spain - 0 years, 0 months, 8 days

Joel Carr
Email: jac6t@Virginia.EDU
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 4

Contribution to the Project: Modeling of coastal lagoons focusing on the physical conditions associated with seagrass growth

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Evan Goldstein
Email: ebgold@live.unc.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 2

Contribution to the Project: Working with L. Moore on: Contributing to study of biological and physical processes involved in dune building

Funding Support: NSF

International Collaboration: Yes, Germany
International Travel: No

Ashley Smyth
Email: arsmyth@email.unc.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 6

Contribution to the Project: Working with I. Anderson on nitrogen and phosphorus cycling

Funding Support: David H. Smith Conservation Research Fellowship

International Collaboration: No
International Travel: No

David M Boyd
Email: dmb4dd@cms.mail.virginia.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 12

Contribution to the Project: Maintain rain gauge network and boats, transport researchers to field sites by boat

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Christopher R Buck
Email: crb2p@virginia.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 12

Contribution to the Project: Maintain and deploy sensors and boats. Fabricate field equipment. Transport researchers to remote sites by boat.

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Patrick J Luckenbach
Email: pjl2x@virginia.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 10

Contribution to the Project: Water quality analyses, maintain sondes, transport researchers to field sites by boat.

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

John R Maben
Email: jrm@virginia.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 1

Contribution to the Project: Analyze precipitation sampled weekly for major ionic constituents

Funding Support: NSF

International Collaboration: No
International Travel: No

David L Richardson
Email: dlr2n@virginia.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 8

Contribution to the Project: Programming support for LTER Information Management

Funding Support: NSF

International Collaboration: No
International Travel: No

Emily C Adams
Email: eadam016@odu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Works with F. Day on vegetation dynamics on the barrier island dunes

Funding Support: ODU

International Collaboration: No
International Travel: No

Lillian R Aoki
Email: lra5vx@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Working with K. McGlathery on seagrass ecology and biogeochemistry

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Spencer Bissett
Email: bissettsn@vcu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Working with D. Young and J. Zinnert on the ecology of climbing plants in coastal systems

Funding Support: NSF, Graduate fellowship VCU

International Collaboration: No
International Travel: No

Elsemarie deVries
Email: elsemar@live.unc.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Working with PI Moore on coastal dynamics

Funding Support: NSF

International Collaboration: No
International Travel: No

Benjamin Dows
Email: dowsbl@vcu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Working with D. Young and J. Zinnert on landscape scale growth patterns within barrier island vegetation. Completed thesis in 2014.

Funding Support: NSF, Graduate Fellowship

International Collaboration: No
International Travel: No

Anne Dunkel
Email: aed9bw@virginia.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Worked with J. Herman and A. Mills on stream biogeochemistry

Funding Support: NSF

International Collaboration: No
International Travel: No

Melissa Duvall
Email: msd2cr@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Working with P. Wiberg on hydrodynamics and sediment dynamics

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Noah E Egge
Email: nee79@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Working with S. Macko on determining the historic extent of seagrass cover in Virginia's coastal bays using stable isotopes

Funding Support: NSF

International Collaboration: No
International Travel: No

Kyle A Emery
Email: kae2n@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 8

Contribution to the Project: Work with M. Pace on clam aquaculture effects

Funding Support: NSF, UVA TA

International Collaboration: No
International Travel: No

Sherer Etheridge
Email: ETHERIDGES09@students.ecu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 8

Contribution to the Project: Working with R. Christian on extending and analyzing the long-term data set for vegetation cover in Upper Phillips Creek Marsh

Funding Support: NSF, ECU Teaching assistantship

International Collaboration: No
International Travel: No

Theo Jass
Email: theojass@live.unc.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Working with L. Moore on shoreline change and dune building

Funding Support: NSF

International Collaboration: Yes, Germany
International Travel: No

William Kearney
Email: wkearn@bu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Working with S. Fagherazzi on modeling of coastal lagoon water and sediment dynamics

Funding Support: NSF, BU, ACS

International Collaboration: No
International Travel: No

Dirk J Koopmans
Email: djk9v@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Worked with P. Berg on aquatic fluxes in streams.

Funding Support: UVA, NSF

International Collaboration: No
International Travel: No

Rebecca Lauzon
Email: Rebecca.lauzon@duke.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Contributing to investigation of barrier-marsh couplings and assisting with field work with L. Moore

Funding Support: Duke Univ.

International Collaboration: No
International Travel: No

Nicoletta Leonardi
Email: nicoletta_leonardi@hotmail.it
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Working with S. Fagherazzi on modeling of coastal lagoon water and sediment dynamics

Funding Support: NSF, BU, ACS

International Collaboration: No
International Travel: No

Abby M Lunstrum
Email: aml3ra@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Working with K. McGlathery on nitrogen cycling in seagrass beds

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Paul Manley
Email: manleypv@vcu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Working with D. Young and J. Zinnert on barrier island vegetation

Funding Support: NSF

International Collaboration: No
International Travel: No

Giulio Mariotti
Email: giuliom@bu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Worked with S. Fagherazzi on modeling of coastal lagoon water and sediment dynamics

Funding Support: NSF

International Collaboration: No
International Travel: No

George S McFadden
Email: gsm9v@Virginia.EDU
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Worked with Herman and Mills on the roles of hydrological gradients and subsurface residence time in determining the quantitative water and nutrient fluxes from groundwater into stream channels

Funding Support: UVA

International Collaboration: No
International Travel: No

Anna Murphy
Email: annie@vims.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Working with I. Anderson on effects of clam aquaculture, including comparison of the effects of clam aquaculture on sediment biogeochemistry in the Sacca di Goro Italy with those effects in the Virginia Coast Reserve

Funding Support: SeaGrant, College of William & Mary

International Collaboration: Yes, Italy
International Travel: Yes, Italy - 0 years, 0 months, 21 days

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Elizabeth Murphy
Email: eakmurphy@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 7

Contribution to the Project: Working with M. Reidenbach on fluid dynamics in oyster reefs and burrowing biomechanics

Funding Support: NSF

International Collaboration: No
International Travel: No

Matthew P Oreska
Email: mpo4zx@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Working with K. McGlathery on assessing environmental change impacts on ecosystem services

Funding Support: NSF, UVA

International Collaboration: No
International Travel: No

Anthony Michael Priestas
Email: priestas@bu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: Worked with S. Fagherazzi on modeling of coastal lagoon water and sediment dynamics

Funding Support: NSF

International Collaboration: No
International Travel: No

Kristin Raub
Email: kristin.raub@uconn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Worked with PI Swallow on social science research, specifically data coding of a survey and development of her own survey regarding residents' willingness to pay and preferences for supporting management actions that lead more coastal landowners to choose non-conventional adaptations to climate (such as living shorelines or retreat).

Funding Support: NSF

International Collaboration: No
International Travel: No

Jesus Ruiz-Plancarte
Email: jzr201@psu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Working with PI Fuentes on carbon fluxes in salt marshes

Funding Support: NSF

International Collaboration: No
International Travel: No

Nathan Sedghi
Email: nsedg001@odu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Works with F. Day on vegetation dynamics on the barrier island dunes

Funding Support: ODU

International Collaboration: No
International Travel: No

Matt Smith
Email: msmit211@odu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Works with F. Day on vegetation dynamics on the barrier island dunes

Funding Support: NSF

International Collaboration: No
International Travel: No

Emily L Thomas
Email: elt9eb@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Working with M. Reidenbach on the influence of Zostera Marina on wave dynamics and sediment suspension

Funding Support: NSF

International Collaboration: No
International Travel: No

Joseph A Thompson
Email: thompsonja5@mymail.vcu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Working with Don Young and Julie Zinnert on barrier island vegetation dynamics

Funding Support: VCU

International Collaboration: No
International Travel: No

Ross Timmerman
Email: rt6ce@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 7

Contribution to the Project: Working with M. Reidenbach on wave dynamics and benthic fluxes within coastal ecosytems

Funding Support: NSF

International Collaboration: No
International Travel: No

Stephen M Via
Email: viasm@vcu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 3

Contribution to the Project: Works with D. Young and J. Zinnert on barrier island vegetation

Funding Support: NSF

International Collaboration: No
International Travel: No

Tammy Viggato
Email: tammy.viggato@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Worked with S. Fagherazzi on modeling of coastal lagoon water and sediment dynamics

Funding Support: NSF

International Collaboration: No
International Travel: No

Martin P Volaric
Email: mpv3a@virginia.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: Working with PIs McGlathery and Berg on studies of oyster metabolism using eddy correlation techniques

Funding Support: UVA, NSF

International Collaboration: No
International Travel: No

David C Walters
Email: dcwalter@live.unc.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: Working with Matthew Kirwan and Laura Moore on marsh-barrier couplings

Funding Support: VIMS, UNC, NSF

International Collaboration: No
International Travel: No

Ian Yue
Email: ian.yue@uconn.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Worked with S. Swallow on social science research. He worked on a first-round survey of residents' preferences and values for ecosystem services affected by the location of sea walls, living shorelines , or the lack of adaptation for Sea Level Rise, including data analysis and 2 conference presentations listed in publications/presentations.

Funding Support: NSF, USDA National Institute for Food and Agriculture (NIFA), UConn Hatch Grant from the UConn Agricultural Experiment Station

International Collaboration: No
International Travel: No

Brianne Conrad
Email: beconrad@randolphcollege.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Work with Sarah Lawson on seagrass research

Funding Support: Virginia Foundation of Independent Colleges

International Collaboration: No
International Travel: No

Cassandra L Cosans
Email: clc2kh@virginia.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Worked with J. Herman and A. Mills on stream biogeochemistry

Funding Support: UVA

International Collaboration: No
International Travel: No

Rosa C. Cruz
Email: cruzrc@mymail.vcu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Worked with Don Young and Julie Zinnert on an independent study project related to barrier island vegetation dynamics

Funding Support: VCU

International Collaboration: No

International Travel: No

Charles Deaton
Email: ccdeaton@wm.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Senior thesis working with Matt Kirwan on marsh migration

Funding Support: none

International Collaboration: No
International Travel: No

Margaret Julie Grady
Email: mjg9qz@Virginia.EDU
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Worked with PI Schwarzschild on topographic mapping of marsh edges.

Funding Support: USGS

International Collaboration: No
International Travel: No

Blair Sparks Jenet
Email: bsj3nd@Virginia.EDU
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Worked with PI Schwarzschild on surveys of salt marsh edges

Funding Support: USGS

International Collaboration: No
International Travel: No

Ryan Mahon
Email: rmmahon@randolphcollege.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Working with Sarah Lawson on seagrass research

Funding Support: Randolf College Summer Program

International Collaboration: No
International Travel: No

Jessica M. McIntosh

Email: jmmcintosh@randolphcollege.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Worked with Sarah Lawson on seagrass research

Funding Support: Randolf College Summer Program

International Collaboration: No
International Travel: No

Hales Elizabeth Parcells
Email: hep4qd@Virginia.EDU
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 3

Contribution to the Project: Worked with PI Schwarzschild on sediment samping

Funding Support: USGS

International Collaboration: No
International Travel: No

Benjamin Pickus
Email: bap4db@Virginia.EDU
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Worked with J. Herman and A. Mills on streambed biogechemistry

Funding Support: NSF

International Collaboration: No
International Travel: No

Jennifer E Ren
Email: jer5ty@virginia.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Worked with J. Herman and A. Mills on streambed biogechemistry

Funding Support: UVA

International Collaboration: No
International Travel: No

Juliana Rodriguez-Gomez
Email: rodriguezgoj@mymail.vcu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Worked with Don Young and Julie Zinnert on an independent study project related to barrier island vegetation dynamics

Funding Support: VCU

International Collaboration: No
International Travel: No

Laura Rogers
Email: Laurar@live.unc.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Assisted with field work with L. Moore

Funding Support: Volunteer

International Collaboration: No
International Travel: No

Kendall Valentine
Email: kendallv@bu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 6

Contribution to the Project: Worked with PI Fagherazzi on research related to lagoon dynamics and marsh erosion.

Funding Support: NSF, BU

International Collaboration: No
International Travel: No

Ben Weinmann
Email: brw241@email.vccs.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 1

Contribution to the Project: Community College volunteer working with Matt Kirwan on marsh migration

Funding Support: NSF WISE

International Collaboration: No
International Travel: No

Marnie Rachel Kremer
Email: mrk2dt@Virginia.EDU
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 3

Contribution to the Project: Worked with PIs Reidenbach and McGlathery on lagoon and seagrass research

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: University of Virginia
Government fiscal year(s) was this REU participant supported: 2014

Victoria Long
Email: evl5yz@virginia.edu
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 3

Contribution to the Project: Work with L. Blum on technical support for EoYB monitoring. Senior thesis directed towards soil and plant community changes during high marsh transgression into upland agricultural fields

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: University of Virginia
Government fiscal year(s) was this REU participant supported: 2014

Sarah Margolis
Email: Sarahmar608@gmail.com
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 3

Contribution to the Project: Contributing to study of biological and physical processes involved in dune building with L. Moore

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior
Home Institution: Boston University
Government fiscal year(s) was this REU participant supported: 2014

Bridget F Shayka
Email: bfs5he@Virginia.EDU
Most Senior Project Role: Research Experience for Undergraduates (REU) Participant
Nearest Person Month Worked: 3

Contribution to the Project: Worked with PI McGlathery on seagrass-related research, particularly synoptic sampling of seagrass.

Funding Support: NSF

International Collaboration: No
International Travel: No
Year of schooling completed: Junior

Home Institution: University of Virginia
Government fiscal year(s) was this REU participant supported: 2014

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Chesapeake Experience	Other Nonprofits	York County, VA
Dickinson College	Academic Institution	Carlisle, PA
Northampton County Public Schools	School or School Systems	Eastville, VA
Old Dominion University	Academic Institution	Norfolk, VA
Smithsonian Environmental Research Center	State or Local Government	Edgewater, MD
The Nature Conservancy	Other Nonprofits	Nassawadox, VA
University of Bremen	Academic Institution	Germany
Virginia Institute of Marine Sciences	Academic Institution	Gloucester Point, VA

Full details of organizations that have been involved as partners:

Chesapeake Experience

Organization Type: Other Nonprofits
Organization Location: York County, VA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: We collaborate on joint educational programs for K-12 and public groups.

Dickinson College

Organization Type: Academic Institution
Organization Location: Carlisle, PA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Thomas Arnold collaborates on carbon flux studies

Northampton County Public Schools

Organization Type: School or School Systems
Organization Location: Eastville, VA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: We collaborate with the Northampton Public School system on Schoolyard LTER activities for K-12 students.

Old Dominion University

Organization Type: Academic Institution
Organization Location: Norfolk, VA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Richard Zimmerman collaborated on development of bathymetric data layers

Smithsonian Environmental Research Center

Organization Type: State or Local Government
Organization Location: Edgewater, MD

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Whitman Miller collaborates on carbon flux studies

The Nature Conservancy

Organization Type: Other Nonprofits
Organization Location: Nassawadox, VA

Partner's Contribution to the Project:
Facilities

More Detail on Partner and Contribution: The Virginia Coast Reserve of The Nature Conservancy (TNC) is our primary research site. TNC allows us access to the islands for our research.

University of Bremen

Organization Type: Academic Institution
Organization Location: Germany

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: L. Moore has collaborated with Orencio Duran Vinent

Virginia Institute of Marine Sciences

Organization Type: Academic Institution

Organization Location: Gloucester Point, VA

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Collaborate with Robert J. Orth on seagrass restoration and Mark Luckenbach on invertebrate population montoring

Have other collaborators or contacts been involved? No

Impacts

What is the impact on the development of the principal discipline(s) of the project?

We have continued to contribute to the understanding of coastal systems through our efforts in studying the effects of climate and land-use change (sea-level rise, storm disturbance, coastal eutrophication), habitat restoration (seagrass, oyster), expanding aquaculture, invasive species, controls on plant production, determinants of faunal biogeography in an island system, and prediction of future state change.

The VCR is representative of coastal barrier systems that are prominent features of the world's coastlines, occurring on all continents except for Antarctica, and comprising 13% of coastlines globally. We have established that ecological changes in the coastal barrier system are non-linear, with gradual changes punctuated by abrupt transitions to another ecosystem state. The effects of these dynamic relationships influence vegetation patterns and productivity, nutrient cycling and faunal relationships in ecosystems (upland, marsh, tidal flat, coastal bay) on the landscape. We have developed quantitative models and that include threshold responses, which trigger rapid ecosystem state change, for intertidal wetlands, subtidal seagrass meadows and barrier islands. Our models and data shows that dynamic change in the coastal barrier islands is characterized by bistability and the existence of alternative stable states. Our most recent results show the coupling of bistable dynamics in adjacent systems (e.g., mainland upland-marsh, marsh-tidal flat, tidal flat-seagrass, marsh-barrier island upland, grassland-shrubland), which is the first step in addressing bistability and non-linear state change at the landscape scale.

WATERSHEDS AND LAGOONS

In shallow coastal systems, seagrasses provide important ecosystem services including stabilizing sediment, sequestering carbon and nutrients, and providing habitat and an energy source for a diverse fauna. The eelgrass (*Zostera marina*) that once carpeted the seafloor of the VCR coastal bays and supported a thriving economy became locally extinct in the early 1930s as a result of disease and storm disturbance, causing a catastrophic shift to an unvegetated state. We have collaborated with colleagues at the Virginia Institute of Marine Sciences and The Nature Conservancy in a large-scale ecosystem-level experiment to reverse the state change. This has resulted in >17 km2 of restored habitat in a chronosequence of seagrass meadows 0 – 13 years since seeding. We have documented, for the first time, the recovery of key ecosystem functions related to primary productivity, carbon and nitrogen sequestration, increased water column clarity, and sediment stabilization with a state change to seagrass dominance. Our long-term data indicate that at least a decade is required for these functions to be restored fully.

The expansion of seagrass in the coastal bays has altered local hydrodynamics and switched the seafloor from an erosional environment to one that promotes deposition of suspended sediment by reducing near-bottom velocities (70-90%) and wave heights (45-70%). Coupled bay-marsh modeling results indicate that the presence of seagrass can be both beneficial and detrimental to marshes depending on tidal flat extent, either attenuating wave energy that would erode the marsh edge or reducing sediment supply that would help marshes keep pace with RSLR.

Our modeling and process studies have indicated that the VCR coastal bays receive low inputs of nitrogen from the coastal watersheds and serve as a reference site for eutrophied coastal bays both nationally and globally. The expansion of seagrass represents an additional filter for nutrient inputs, with enhanced rates of nitrogen removal through denitrification. Clam aquaculture has little effect on nitrogen loss via denitrification.

Our conclusions regarding the importance of macroalgae and seagrass in influencing the dynamics of nutrient movements within coastal bays helps to explain the role of the bay as an active mediator between mainland nutrient sources (e.g., agricultural fields) and the coastal ocean. The discovery that the dominant macroalga in the bays is an exotic (rather than its native congener), has highlighted the importance of this invasive macroalgae in subisidizing nutrients and habitat in intertidal marshes and mudflats.

WETLANDS

The phenomenon of critical slowing down has been proposed as a leading indicator of ecosystem collapse, where recovery to disturbance slows as an ecosystem approaches a critical threshold. Our work suggests critical slowing down is evident in marshes, and that the response is consistent between extremely diverse systems (VCR vs. Dutch Schelde Estuary). This work provides important “real world” support for this ecological theory, which is primarily grounded in numerical models and highly controlled experiments.

Our Surface Elevation Tables (SETs) indicate that the on mainland marshes, the rate of accretion is generally keeping pace with sea level rise, and that specific rates are position dependent, with the upper marsh receiving less input. Results in the lagoon marshes suggest that sea-level rise may be exceeding the ability of the marshes to keep up. Coupled lagoon marsh modeling results indicate that the presence of seagrass can act both beneficially and detrimentally to the lagoon marshes depending on tidal flat extent.

Our research has shown that salt marshes are highly dynamic systems that generally have kept pace with historic changes in sea level, largely through non-linear feedbacks that influence vertical elevation and landward migration. However, human activities alter the strength of these feedbacks by changes that decrease sediment delivery to estuaries, such as dams or river diversions, or land development and shoreline armoring that prevent upland transgression. The increased human modification of coastal watersheds and shorelines globally has led to widespread concern about salt marsh loss in the face of accelerated rates of SLR

BARRIER ISLANDS

Our long-term data illustrate that barrier island plant communities serve as sentinels to climate change due to a rapid response to shoreline migration and storm related disturbances. Our results have increased understanding of vegetation changes at the local scale, their causes in coastal barrier islands, and the consequences on broad scale barrier island formation. Cross-scale interactions are at the cutting edge of spatial and ecological sciences. We are advancing our fundamental understanding of how barrier systems naturally behave and how they will respond to climate change. Our work is contributing to the global body of research regarding ecosystem state change, stability domains and coupling of biotic and physical phenomena.

We have established that long-term and landscape-scale vegetation patterns on the islands reflect non-linear dynamics and threshold responses to environmental drivers. We have shown that controls on plant community distribution can be explained by two key environmental parameters: distance from the shoreline (and susceptibility to salt spray and overwash disturbance) and elevation above sea level (a surrogate for distance to groundwater). We have documented a dramatic increase in shrub thickets (>400%) as shrubs encroach onto grasslands and shown that increased shrub cover provides refuge for mammalian predators that impact migratory waterbird populations. The ~40% increase in woody vegetation also has substantial effects on biogeochemical cycling. Aboveground net primary productivity (ANPP) results in a 5-fold increase in ANPP, from ~300 g m-2 in grassland to ~1500 g m-2 in woody communities. Large-scale expansion of *Morella cerifera* (N-fixing shrub)results in increased soil organic N, leaf %N, and net N mineralization rates. On islands with high fluctuations in woody vegetation or islands losing woody cover, N may be transferred into adjacent systems.

What is the impact on other disciplines?

The studies conducted by the VCR/LTER are inherently interdisciplinary including ecologists, hydrologists, biologists, geomorphologists and physical oceanographers. When such collaborations take place, it is not unusual that each group of scientists will gain greater insight into problems that may not be recognized within their own discipline.

Research on ecological information management has included computer scientists. The challenges posed by ecological

data provide opportunities for innovation in computer science. Our work with development of wireless sensor networks, and processing of the massive data flows they can generate, contributes to better defining the cyberinfrastructure challenges that will confront us in coming decades.

As part of our collaboration in the LTER sponsored Ecological Reflections program we held two Art and Ecology professional Development workshops for public school Art Teachers. Along with faculty from the Science Technology and Society program in the UVA School of Engineering we hosted a Nature Writing workshop for undergraduate Engineering Students. These workshops introduce participants to the place-based science being conducted at the VCR-LTER. Participants are encouraged to find new ways to incorporate environmental issues/themes in their artwork and classroom projects. Paintings, drawings, essays, poems and short fiction created during the workshops are used to generate public Art and Ecology exhibitions displayed at the local Barrier Islands Center Museum and on the grounds of UVA.

What is the impact on the development of human resources?

As can be seen from the number of graduate and undergraduate students listed on our participant list, this project provides abundant opportunities for training. Moreover, the inter- and multi-disciplinary nature of the research teaches the students how to operate in a collaborative environment. Each year, the VCR LTER supports approximately 25 graduate students who conduct their M.S. and Ph.D. projects at the VCR site and approximately 15 undergraduate students work each year as research assistants in the field and laboratory. Our REU and REHS activities provide graduate students mentorship training as they supervise and support the work of undergraduate and high school student interns.

Our SLTER program, and related activities, have helped introduce scientific concepts to K-12 students. All high school students take an LTER-based course before they graduate, and some take more than one course. More than half of these students are from traditionally underrepresented groups. Our Professional Development workshops help train >45 school teachers/year, introducing them to the key environmental issues impacting our coastal ecosystems.

Day was a member of a diversity working group that received funding from the LTER office and met in Albuquerque to address LTER related diversity issues. That group has now been appointed as an LTER standing committee, and he is developing a diversity plan for the VCR LTER site. These activities were the inspiration for the development of a Diversity Plan for the site (now posted on the VCR web site). This plan can serve as a model for other LTER sites.

What is the impact on physical resources that form infrastructure?

The VCR/LTER is the principal user of the Anheuser-Busch Coastal Research Center (ABCRC) of the University of Virginia and provides, through user fees, resources that allow the center to support a substantial housing, lab and boat infrastructure. The ABCRC provides facilities for a number of smaller, more limited projects and educational programs.

Reidenbach has developed an underwater laser-based velocity measuring system. Particle image velocimetry (PIV) has been used for a number of years in laboratories to measure velocity and turbulence over an area ranging from square millimeters to square meters. This system uses a laser and optics to create a laser light sheet. This light illuminates suspended particles in the flow and, using a digital camera, particle motion is recorded. With the recent development of laser diodes, powerful yet energy efficient lasers can be placed in water tight housings and submersed underwater. The system developed uses a 250 mW laser with a wavelength of 532 nm (green light). A waterproof housing has been designed to hold both the laser and optics used to spread the beam into a narrow, yet wide sheet. Imaging of the illuminated particles is done using a high definition camera to obtain images up to 60 frames per second. The system is attached to a rigid frame and can be deployed in the coastal ocean where suspended sediment particles are tracked. This PIV system has recently been coupled with a planar-optode system that utilizes thin oxygen sensitive foils to quantify oxygen fluxes at the sediment water interface. This coupled system enables researchers to quantify the interactive effects of hydrodynamics and biological activity (such as burrowing) on oxygen exchange across the seafloor.

Berg has pioneered the approach of underwater eddy correlation to measure oxygen fluxes in benthic systems. This technique has the advantage over conventional techniques of measuring dynamic fluxes with a high temporal resolution

(64 hz), and over a large spatial scale (10-100 km2), which captures natural heterogeneity in these systems. Novel results obtained from the application of this technique are the identification of multiple time-scale processes that drive seagrass metabolism and a hysteresis in seagrass metabolism that occurs over the day.

What is the impact on institutional resources that form infrastructure?

LTER researchers form the core of a monthly seminar series offered at the Anheuser-Busch Coastal Research Center (ABCRC) of the University of Virginia. Additionally, ecological science programs in the Northampton County High School are highly dependent on resources and facilities provided through our SLTER program.

Our wireless network provides real-time access to remote monitoring locations in and around Hog Island. Researchers from other universities/programs have access to this data, and our network is also used to support collection of images by other user groups like the Center for Wildlife Conservation at the College of William and Mary, which uses our wireless infrastructure to monitor peregrine flacon nesting activity on Cobb Island. Streaming video is made available to the general public during the nesting/fledging season.

What is the impact on information resources that form infrastructure?

This project provides a wide array of information resources to the larger scientific community through our formal datasets, which are available via our site data catalog (http://www.vcrlter.virginia.edu/cgi-bin/browseData.cgi), LTER Network, and affiliated data centers (e.g., KNB, DataOne).

The VCR/LTER shares 210 online datasets with an aggregate volume of approximately 150 GB. These are published via the VCR/LTER web site, the LTER Data Portal, the LTER Metacat and the DataOne ONEMercury system. The datasets are frequently downloaded for use by researchers and students. 231 of the data files associated with online datasets (some datasets include multiple data files) were downloaded a total of 5,375 times (4,238 times from the LTER Data Portal and 1,137 times via the LTER Data Access Server) during the period 2013-10-01 to 2014-09-30.

Additionally, on our website (http://www.vcrlter.virginia.edu) we provide access to maps, photographs, documents, publication lists and research descriptions.

What is the impact on technology transfer?

The VCR/LTER organized and hosted a workshop in 2013 that enhanced the LTER Controlled Vocabulary, a tool that is used to improve data discoverability. The LTER Controlled Vocabulary has been integrated into other systems, such as the European LTER ENVTHES project.

What is the impact on society beyond science and technology?

The high historic rate of sea-level rise (~4mm/yr) within the Virginia Coast Reserve make it a bell-weather site for assessing the probable impacts of global sea-level changes. Our results concerning the response of salt marshes, upland and lagoon systems can provide insights that extend to other systems that are only now beginning to experience heightened sea level. VCR researchers work with regional planners and decision-makers in the Mid-Atlantic Climate Adaptation Working Group. In addition, VCR researchers are working The Nature Conservancy to develop a web-based decision tool for coastal resilience that includes natural and social science data to visualize future scenarios of climate change and sea-level rise.

Our ability to make fine-scale, site-specific predictions of island geomorphology and Piping Plover habitat suitability in response to SLR and shoreline change is novel and will be useful managers coast-wide as application of the models is expanded geographically. Our findings related to SLR and beach management strategies at Assateague Island, where models were developed and first tested, have relevant implications for policy-makers today. For example, we found that a beach management strategy that involved annual sand nourishment along the sections of Assateague Island would result in vegetation encroachment and reduce the area of habitat suitable for Piping Plovers as compared to a scenario of modest SLR (3 - 4 mm/year) and no sand nourishment. While there is no such identical management strategy currently proposed for Assateague Island, targeted sand placement in order to stabilize barrier islands is a commonly discussed management strategy along the U.S. Atlantic Coast.

The VCR LTER (UVA) has joined a consortium of institutions in the Mid-Atlantic, including NASA - Wallops Island, University of Delaware, University of Maryland, and the Virginia Institute of Marine Sciences to establish the Mid-Atlantic Coastal Resilience Institute, with the purpose of collaborating with respect to data, models and tools to address coastal resilience in response to climate change.

Work that we are currently doing at the VCR is of much interest to the Department of Environmental Quality of the State of Virginia, and in particular to the Water Conservation Districts located on the Eastern Shore. The major source of nitrogen to VCR coastal lagoons is agriculture. Proper management of agricultural activities and fertilization practices requires an improved understanding of nitrogen losses to the coastal lagoons via groundwater and surface water runoff.

We work closely with colleagues at the Virginia Institute of Marine Sciences and The Nature Conservancy to address issues relevant to sustainable restoration of seagrass and oysters in the VCR and in the mid-Atlantic region in general. Our models on bistable dynamics of seagrass meadows and the dependence on water depth provides useful information on regions within the VCR coastal bays that could potentially support seagrass habitats. We also are providing information on how the maximum depth limit for sustainable seagrass meadows could vary as a function of sediment conditions (organic content, grain size, hydrogen sulfide) and this helps managers identify areas that are most likely to support seagrass habitats over the long term. In addition, our work on hydrodynamic influences on oyster feeding and larval settlement is useful to practitioners in understanding how currents and exposure affect oyster growth and the persistence of oyster reefs.

Recent VCR research is the first the importance of restored seagrass meadows in sequestering carbon and highlighted the role of habitat restoration in mitigation of rising atmospheric CO2 levels. Because the scale and success of seagrass restoration, VCR scientists have been chosen to write the international protocol for the Verified Carbon Standards program on to assign carbon credits on international trade markets for seagrass restoration.

In collaboration with the TNC, we have done a retrospective analysis of long-term trends in erosion and accretion of mainland marshes throughout the VCR from the 1950's to the present. This is coupled with information on the presence of oyster reefs as a potential buffer to marsh erosion. Patterns of erosion were also overlain on maps of TNC-conserved lands to identify potential areas to study climate adaptation and the potential for marshes to transgress onto the mainland with predicted scenarios of climate change and sea-level rise.

Knowledge of the relationship between land use, nutrient contamination of groundwater, groundwater export of nutrients to coastal bays, and the fate of nutrients within bays will be of benefit to state and federal agencies charged with managing coastal resources. This knowledge will be especially important given the ongoing return of seagrasses to large areas of the coastal bays, from which they have been absent for over 70 years. In the decade of seagrass restoration, ecosystem services have been reinstated, including increased water quality and clarity (decreased sediment suspension), and increased biodiversity (foraminfera), and faunal abundance (introduced scallops). The VCR coastal bays are also a model system to understand the important role of plants in mediating nutrient export from coastal watersheds to the open ocean.

Barrier islands are heavily developed landforms that are highly vulnerable to changing climate conditions. Concepts such as green and nature-based solutions are gaining attention within the coastal management and engineering community. Our work contributes to understanding how barrier islands will respond to climate change —including the mechanisms influencing and driving future island response—which is a prerequisite to sustainable coastal management.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.