Annual Report for Period: 12/2011 - 11/2012
Submitted on: 10/23/2012
Principal Investigator: McGlathery, Karen .
Award ID: 0621014
Organization: University of Virginia
Submitted By:
Porter, John - Co-Principal Investigator
Title:
Long-Term Drivers, State Change and Disturbance on the Virginia Coast Reserve: LTER V

Project Participants

Senior Personnel

Name: McGlathery, Karen
Worked for more than 160 Hours: Yes
Contribution to Project:
Lead PI; research focuses on lagoon biogeochemistry and metabolism, seagrass restoration, and changes in marsh coverage in response to climate change (sea-level rise, storms)

Name: Wiberg, Patricia
Worked for more than 160 Hours: Yes
Contribution to Project:
Signatory PI; research focuses on lagoon hydrodynamics, sediment suspension and transport, and changes in marsh coverage in response to climate change (sea-level rise, storms)

Name: Porter, John
Worked for more than 160 Hours: Yes
Contribution to Project:
Signatory PI and Information Manager, research focuses on mammal population dynamics on barrier islands and GIS analysis.

Name: Anderson, Iris
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI, Subcontract to Virginia Institute of Marine Sciences; research focuses on lagoon biogeochemistry and metabolism

Name: Bachmann, Charles
Worked for more than 160 Hours: No
Contribution to Project:
Co-PI, Naval Research Laboratory; research focuses on hyperspectral remote sensing of mainland, barrier island, marsh and lagoon systems

Name: Berg, Peter
Worked for more than 160 Hours: No
Contribution to Project:
Co-PI, University of Virginia; research focuses on application of novel eddy correlation technique to subtidal systems to investigate benthic metabolism and groundwater fluxes

Name: Blum, Linda
Worked for more than 160 Hours: No
Contribution to Project:
Co-PI, University of Virginia; research focuses on the effects of sea-level rise on marsh accretion, and bacterial community structure and intertidal and subtidal systems

Name: Brinson, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI - Subcontract to East Carolina University; research focuses on state change in marsh ecosystems in response to sea-level rise

and disturbance

Name: Christian, Robert

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI - Subcontract to East Carolina University; research focuses on state change in marsh ecosystems in response to sea-level rise and disturbance

Name: D'Odorico, Paolo

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; research focuses on modeling of alternate stable states in coastal lagoons

Name: Day, Frank

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI, Subcontract to Old Dominion University; research focuses on plant community dynamics on barrier islands

Name: Dueser, Raymond

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI, Subcontract to Utah State University; research focuses on small mammal genetics, population dynamics and predator-prey interactions on barrier islands

Name: Erwin, Russell

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia and U.S. Geological Survey, Biological Resources Division; research focuses on population dynamics of waterbirds

Name: Fagherazzi, Sergio

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI, Subcontract to Boston University; research focuses on model lagoon hydrodynamics, coastal geomorphology, and marsh accretion/erosion in response to climate change (sea-level rise, storms)

Name: Fuentes, Jose

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; research focuses on land-atmosphere carbon dioxide fluxes in marshes using tower-based eddy covariance technique

Name: Galloway, James

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; research focuses on atmospheric nitrogen deposition, and nitrogen cycling between land, water, and atmosphere

Name: Macko, Stephen

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; research focuses on using isotope geochemistry to understand trophic dynamics in subtidal systems, specifically in relation to state change to seagrass system. On leave working at NSF 2008-2009.

Name: Mills, Aaron

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; research focuses on groundwater hydrology and nutrient fluxes via tidal streams into lagoons, in particular on importance of denitrification in the riparian zone and stream sediments

Name: Moncrief, Nancy

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, Virginia Museum of Natural History, collaborates with Co-PI Dueser; research focuses on small mammal genetics, population dynamics and predator-prey interactions on barrier islands

Name: Oertel, George

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI, Subcontract to Old Dominion University; coastal oceanographer whose research focuses on reconstructing antecedent landscape of the VCR, hypsometry, and water residence times of lagoons

Name: Reyes, Enrique

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI, Subcontract to East Carolina University; research involves creating a landscape model of state change for the VCR marsh-lagoon-barrier island system in response to climate and land-use change

Name: Scanlon, Todd

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; uses eddy covariance and laser techniques to study nitrous oxide and carbon dioxide fluxes from at the marsh-upland interface

Name: Shugart, Herman

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; terrestrial ecosystem modeling of the barrier islands

Name: Smith, David

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; leads SLTER program with Arthur Schwarzschild, research focuses on invertebrate and fish communities in the coastal lagoons

Name: Young, Donald

Worked for more than 160 Hours: Yes

Contribution to Project:

Co-PI, Subcontract to Virginia Commonwealth University; research focuses on plan community dynamics on barrier islands, specifically on shrub expansion, invasive species and birds as agents of seed dispersal among islands

Name: Zieman, Joseph

Worked for more than 160 Hours: No

Contribution to Project:

Co-PI, University of Virginia; research focuses on salt marsh chronosequence on barrier island and on nitrogen dynamics in salt marshes

Name: Schwarzschild, Arthur

Worked for more than 160 Hours: Yes

Contribution to Project:

Research Site Manager, Co-PI, University of Virginia; leads SLTER program with David Smith

Name: Reidenbach, Matthew

Worked for more than 160 Hours: No

Contribution to Project:
Co-PI, University of Virginia; research focuses on sediment movements in the lagoon. Started 2008.

Name: Moore, Laura
Worked for more than 160 Hours: No
Contribution to Project:
Co-PI, University of Virginia; research on coastal geology and ecology using remote sensing. Started 2008.

Name: Challard, Margaret
Worked for more than 160 Hours: No
Contribution to Project:
Ph.D student working 2010-2015 with PI Mills on stream nitrogen loading and denitrification. Supported by a UVA fellowship 2010.

Name: Kirwan, Matthew
Worked for more than 160 Hours: No
Contribution to Project:
Modeling of marsh and lagoon systems (2010-2012). USGS/BRD employee stationed at UVA.

Name: Mariner, Charlie
Worked for more than 160 Hours: Yes
Contribution to Project:
Northampton HS, 2011 worked with graduate student Gulbranson on her project looking at impacts of the invasive macroalgae

Post-doc

Name: Safak, Ilgar
Worked for more than 160 Hours: No
Contribution to Project:
2010-2012. Post-Doc for PI Wiberg, working on sedimentary geology in Hog Island Bay. Supported by UVA funding.

Graduate Student

Name: Battistelli, Joseph
Worked for more than 160 Hours: Yes
Contribution to Project:
Ph.D student (2004-2009). Advisor: Mills; working on the effects of physical arrangement of nitrifiers in spaces at the scale of the organism on nitrificaiton rates.

Name: Bissett, Spencer
Worked for more than 160 Hours: Yes
Contribution to Project:
MS & Ph.D Student (2005-2009). MS thesis (2005-2009): Avian dispersal of Frankia for successful nodulation of Myrica seedlings. Ph.D student (2009-2014); Working with PI Young, focusing on the physiological ecology of Myrica shrub expansion in coastal environments.

Name: Blecha, Staci
Worked for more than 160 Hours: Yes
Contribution to Project:
M.S. Student. (2006-2010) Advisor: Day; Thesis: Interisland variability in above and belowground plant biomass in interior marshes on the Virginia barrier islands

Name: Brantley, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:
Ph.D student (2005-2009). Advisor: Young. Dissertation: Consequences of shrub encroachment: linking changes in canopy

structure to shifts in the resource environment.

Name: Cole, Luke

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. Student (2005-2011), Advisor: McGlathery; worked on the effects of seagrass restoration on nitrogen cycling and retention in coastal lagoons.Dissertation: Inputs and fluxes of nitrogen in the Virginia coastal bays: Effects of newly-restored seagrasses on the nitrogen cycle.

Name: Conroy, Patrick

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2005-2007), Advisor: D. Smith; worked on the effects of macrophytes on invetebrate density and diversity in coastal lagoons

Name: Fennell, Jeremy

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2005-2007). Advisor: Young; Thesis: Phragmites australis patch characteristics in relation to watershed landcover patterns on the Eastern Shore of Virginia

Name: Flewelling, Samuel

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2003-2008), Advisor: Mills; Dissertation: The hydrological control of nitrate fluxes from groundwater to streams on the Eastern Shore of Virginia.

Name: Harbeson, Stephanie

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D Student (2003-2010). Advisor: Macko; Ph.D Dissertation: An investigation of nutrient transfer in a restored eelgrass, Zostera marina, meadow

Name: Hardison, Amber

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. Student (2004-2009). Advisor: Anderson; working on the influence of macroalgal blooms on biogeochemical processes in coastal lagoons using a dual isotope tracer and biomarker approach

Name: Haywood, John

Worked for more than 160 Hours: Yes

Contribution to Project:

MS Student; (2007-2009) working with Mark Brinson on effects of disturbance and stressors on ecological state change in tidal marshes at the VCR.

Name: Hume, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2004-2007). Advisors: Berg & McGlathery; Thesis: Dissolved oxygen fluxes and ecosystem metabolism in an eelgrass (Zostera marina) meadow measured with the novel eddy correlation technique

Name: Kathilankal, James

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2004-2008). Advisor: Fuentes. Dissertation: Carbon and Energy Flow Dynamics in a Coastal Salt Marsh.

Name: Koopmans, Dirk

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2006-2011). Advisor: Berg; working on using the eddy correlation technique to measure groundwater fluxes into coastal waters

Name: Kunz, David

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2006-2008). Advisor:Brinson. Examining shorezone concept with respect to rising sea level. Includes comparisons of NC and Virginia.

Name: Lawson, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2002-2008), Advisor: McGlathery & Wiberg; Dissertation: Physical and biological controls on sediment and nutrient fluxes in a temperate lagoon

Name: Marsh, Amanda

Worked for more than 160 Hours: Yes

Contribution to Project:

M. S. Student (2005 ? 2007), Advisor: Christian. Thesis: Effects on a salt marsh ecosystem following a brown marsh event

Name: McMillan, Brett

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2003-2008), Advisor: Day. Dissertation: Plant assemblage structure on 'pimple' dunes at the Virginia Coast Reserve Long-Term Ecological Research site.

Name: Michaels, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2003-2009). Advisor: Zieman; working on the effects of Uca pugnax on pore water biogeochemistry and salt marsh productivity and stability in the context of sea-level rise

Name: Mozdzer, Thomas

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2004-2009), Advisors: Zieman & McGlathery; Dissertation: Variation in the availability and utilization of dissolved organic nitrogen by the smooth cordgrass, Spartina alterniflora.

Name: Naumann, Julie

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2002-2008). Advisor: Young. Dissertation: Linking physiological responses, chlorophyll fluorescence and hyperspectral imagery to detect environmental stress in coastal plants.

Name: O'Connell, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. student (2003-2009), Advisor: Shugart; Dissertation: Ecohydrology of Delmarva Peninsula barrier island forests and the application of lidar to measure and monitor forest structure.

Name: Poleto, Juliette

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2007-2009). Advisor: Anderson; Thesis: Nutrient Loading and System Response in the Coastal Lagoons of the Delmarva Peninsula.

Name: Reynolds, Laura

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. student (2006-2011). Advisors: McGlathery & Zieman; working on genetic basis of seagrass restoration success in coastal lagoons

Name: Robertson, Travis

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2006-2009). Advisors: Blum, McGlathery & Wiberg; Spatial patterns of bacterial abundance in a seagrass restoration site on the Eastern Shore of Virginia (USA). MA thesis. University of Virginia, Charlottesville, VA.

Name: Sahu, Parameswar

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2005-2007). Advisor: Scanlon; worked on nitrous oxide fluxes from marsh-upland ecosystems

Name: Vick, Jackie

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2005-2007). Advisor: Young. Thesis: Corticular photosynthetic dynamics for a coastal evergreen shrub: Myrica cerifera.

Name: Voss, Christine

Worked for more than 160 Hours: No

Contribution to Project:

M.S. student (2005-2007). Advisor: Christian; worked on network analysis of nitrogen cycling in coastal lagoons

Name: Weinmann, Richard

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2003-2008). Advisor: Shugart; worked on water budgets of coastal watersheds.

Name: Shafer, Justin

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2006-2010). Advisor: Day; Thesis: Interisland variability of dune plant community structure on Virginia's barrier islands

Name: Shiflett, Sheri

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2006-2008). Advisor: Young. Thesis: Avian seed dispersal on Virginia barrier islands: potential influence on vegetation community structure and patch dynamics.

Name: Mcleod, George

Worked for more than 160 Hours: No

Contribution to Project:

M.S. student (2006-2009) Advisor: Oertel; working on data interpolation for DEM's and comparing lagoon hypsometry and repletion in Hog Island Bay, Chincoteague Bay and Magothy Bay

Name: Gomez, Loreto

Worked for more than 160 Hours: No

Contribution to Project:

M. S. student (2006-2008) Advisor: Oertel; Thesis: Spatial analyses and repletion of Gargathy coastal lagoon.

Name: Clarkson, Charles

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D Student (2007-2012). Advisor: Erwin; worked on waterbird population dynamics. Dissertation: Applicability of ptilochronology as a conservation tool in waterbird studies, University of Virginia

Name: Priestas, Anthony

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. student (2007-2011), Advisor: Fagherazzi; working on marsh erosion and modeling feedbacks with vegetation

Name: Harrington, Christine

Worked for more than 160 Hours: No

Contribution to Project:

M.S. student (2007-2009), Advisor: Fagherazzi; working on field measurements of marsh erosion

Name: Mariotti, Giulio

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. student (2008-2012), Advisor: Fagherazzi; modeling tide and wave dynamics in the coastal lagoons

Name: McLoughlin, Sean

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2008-2010). Advisors:Wiberg/McGlathery; M.S. Thesis: Erosional processes along salt marsh edges on the Eastern Shore of Virginia.

Name: Gulbransen, Dana

Worked for more than 160 Hours: Yes

Contribution to Project:

PhD student (2008-2013). Advisor: McGlathery; working on effects of invasive macroalga, Gracilaria vermiculophylla, in subtidal seagrass and intertidal marsh ecosystems

Name: Funk, Clara

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2008-2010). Advisor: Scanlon; Ph.D Dissertation: Factors contributing to spatial variability of N2O fluxes in a Virginia salt marsh.

Name: Webster, Kirby

Worked for more than 160 Hours: Yes

Contribution to Project:

PhD student (2007-2012). Advisors: Berg & McGlathery; working on measuring benthic metabolism in lagoons using eddy correlation system, with specific focus on state change from benthic algal to seagrass dominance

Name: Robertson, Wendy

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student (2006-2009). Advisors: Mills & UVA colleague Janet Herman; Thesis: Diurnal Variations in Nitrate Concentrations in the Cobb Mill Creek, VA

Name: Probasco, Paul

Worked for more than 160 Hours: Yes

Contribution to Project:
PhD student (2006-2012). Advisors: Herman & Mills; working on dentrification in riparian zones and stream beds in coastal watersheds

Name: Hondula, Kelly

Worked for more than 160 Hours: Yes

Contribution to Project:
2008 worked with PI McGlathery and graduate student Laura Reynolds on seagrass demographics as an REU and subsequently did M.S. degree during 2009-2012 with PI Macko. Thesis: Using multiple stable isotopes including deuterium to trace organic matter in a complex near-shore lagoon. University of Virginia, Charlottesville.

Name: Serebryakova, Alexandra

Worked for more than 160 Hours: Yes

Contribution to Project:
Ph.D student (2007-2008). Advisor: R. Christian; working in Coastal Resource Management at ECU on a long-term data set of vegetation cover in a salt marshes to use in GIS analysis.

Name: Rafferty, Emmett

Worked for more than 160 Hours: Yes

Contribution to Project:
M.S. student (2007-2009); working with G. Oertel on modeling field-generated depth data to create a DEM of Magothy Bay.

Name: Carr, Joel

Worked for more than 160 Hours: Yes

Contribution to Project:
Ph.D student working with PI D'odorico (2007-2011) Dissertation title: Stability and resilience of seagrasses in shallow coastal bays

Name: Wolner, Catherine

Worked for more than 160 Hours: Yes

Contribution to Project:
M.S. Student. University of Virginia. (2008-2011). Advisor: Moore. Thesis: Ecomorphodynamic feedbacks and barrier island evolution, Virginia Coast Reserve, USA

Name: Willis, Patricia

Worked for more than 160 Hours: Yes

Contribution to Project:
M.A. Student 2007-2009; Advisor Blum. Thesis:The effect of hydroperiod on surface elevation and sediment accumulation in Philips Creek Salt Marsh, Virginia, USA

Name: Kost, Elizabeth

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU Biology MS student worked with Don Young on studies on the shrubs on Hog Island 2010-2011. Thesis: Changes in nitrogen, photosynthesis and leaf morphology in Morella cerifera leaves with increased age.

Name: Rubis, Kathryn

Worked for more than 160 Hours: Yes

Contribution to Project:
VCU Biology MS student worked with Don Young on studies on the shrubs on Hog Island 2010-2011. Thesis: Shrubs as sentinels of ordnance contamination: using plant physiology and remote sensing to detect TNT in soils

Name: Greener, Jill

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. student working 2010-2013 with PI McGlathery on carbon cycling in seagrass.

Name: Taube, Sara

Worked for more than 160 Hours: No

Contribution to Project:

MS student working 2010-2013 with PI Wiberg on sediment distribution in salt marshes. Supported by a UVA fellowship 2010.

Name: Graziani, Dominic

Worked for more than 160 Hours: Yes

Contribution to Project:

ODU MS student (2011-2012) Advisor: Day working on island vegetation dynamics.

Name: Hansen, Jennifer

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D student (2009-) Advisor: Reidenbach. Research related to flow and sediment dynamics within seagrasses.

Name: Whitman, Elizabeth

Worked for more than 160 Hours: Yes

Contribution to Project:

UVA M.S. Student (2008-2011). Advisor: Reidenbach. Thesis: Hydrodynamics affecting larval transport and settlement onto intertidal oyster reefs.

Name: Oster, Dana

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2009-2011) working with PI Moore studying beach dynamics on the barrier islands.

Name: McFarland, George

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student at UVA (2011-)working with PI's Mills and Herman on hydrogeochemistry of mainland creeks.

Name: Brenner, Owen

Worked for more than 160 Hours: Yes

Contribution to Project:

M.S. Student (2009-) at UVA working with PI Moore on beach dynamics.

Name: Challand, Maragaret

Worked for more than 160 Hours: No

Contribution to Project:

M.S. Student (2011-) at UVA working with PI Mills on Cobb Mill Creek watershed with support from other grants.

Name: Reid-Black, Kristina

Worked for more than 160 Hours: No

Contribution to Project:

M.S. Student (2008-) at UVA working with PI Mills on Cobb Mill Creek watershed with support from other grants.

Name: McFadden, George

Worked for more than 160 Hours: No

Contribution to Project:

M.S. Student (2009-) at UVA working with PI Mills and Herman on Cobb Mill Creek watershed. Supported by non-LTER funds.

Undergraduate Student

Name: Curtis, Ben

Worked for more than 160 Hours: No

Contribution to Project:

2007 worked with PI Zieman and graduate student Thomas Mozdzer on nitrogen cycling in salt marsh communities.

Name: Hippert, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

2007 worked with PI McGlathery on seagrass restoration.

Name: Long, Bridget

Worked for more than 160 Hours: Yes

Contribution to Project:

2007-2008 worked with PI's Blum, Christian and Brinson on marsh productivity database. BA Thesis 2009: Belowground production of the mixed high marsh plant community Spartina patens and Distichlis spicata. University of Virginia, Charlottesville, VA. Post graduation (2010-2012) worked on Information Management for the project with PI Porter.

Name: Wiles, Cory

Worked for more than 160 Hours: Yes

Contribution to Project:

2009-2010 ECU undergraduate student contributions to Haywood marsh study (faculty advisor, Christian)

Name: Ellis, Stuart

Worked for more than 160 Hours: Yes

Contribution to Project:

2009-2010 ECU undergraduate student contributions to Haywood marsh disturbance study and independent study project on below ground organic matter (faculty advisor, Christian)

Name: Walsh, Kate

Worked for more than 160 Hours: Yes

Contribution to Project:

Worked with PI Reidenbach on seagrass and oyster related research during 2010-2011.

Name: Starling, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Worked with PI Young on studies of barrier island vegetation (2011)

Name: Luckenbach, Patrick

Worked for more than 160 Hours: Yes

Contribution to Project:

In 2011 worked with PI Schwarzschild. Assisted in the synoptic seagrass survey, assisted with pilot study to examine impacts of sediment organic matter on eelgrass morphology and minimum light requirements.

Name: Bruno, Gavin

Worked for more than 160 Hours: Yes

Contribution to Project:

In 2011 worked with PI Schwarzschild. Assisted in the synoptic seagrass survey, assisted with pilot study to examine impacts of sediment organic matter on eelgrass morphology and minimum light requirements.

Name: Anutaliya, Waen

Worked for more than 160 Hours: No

Contribution to Project:

Student at UVA working with PI Mills on Cobb Mill Creek watershed with support from other grants (2011).

Name: Hounschell, Alexandria
Worked for more than 160 Hours: No
Contribution to Project:
Student at UVA working with PI Mills on Cobb Mill Creek watershed with support from other grants (2011).

Technician, Programmer

Name: Overman, Kathleen
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician, Laboratory Manager, assists with long-term monitoring

Name: Boyd, David
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician, responsible for boat logistics and assists with long-term monitoring

Name: Buck, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
Technician, assists with long-term monitoring

Name: Fauber, Donna
Worked for more than 160 Hours: Yes
Contribution to Project:
Fiscal Technician

Name: Betancourt, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
2010-. Lead programmer for PI Reyes VCR Landscape Model.

Name: Rodgers, Brooke
Worked for more than 160 Hours: Yes
Contribution to Project:
Collect data, maintain and operate monitoring equipment and boats at the Anheuser-Busch Coastal Research Center. (2011-2012)

Other Participant

Research Experience for Undergraduates

Name: Richards, Joshua
Worked for more than 160 Hours: Yes
Contribution to Project:
Worked with graduate student Andrew Hume and PIs Berg and McGlathery on benthic metabolism in lagoons during 2007.

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: REU supplement

Name: Smith, Chris
Worked for more than 160 Hours: Yes

Contribution to Project:
2007 Worked with Iris Anderson on lagoon nitrogen studies.

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other: Virginia Institute of Marine Sciences/ William & Mary
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: REU supplement

Name: Barry, Savannah
Worked for more than 160 Hours: Yes
Contribution to Project:
2008 REU worked with PI Reidenbach and graduate student Jenny Romanowich
on clam filtration and seagrass studies

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2008
REU Funding: REU supplement

Name: Pendergrass, Jessica
Worked for more than 160 Hours: Yes
Contribution to Project:
2008 REU, worked with PIs Christian & Blum on genetics of salt marsh cordgrass, Spartina alerniflora

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: East Carolina University
Home Institution Highest Degree Granted(in fields supported by NSF): Master's Degree
Fiscal year(s) REU Participant supported: 2008
REU Funding: REU supplement

Name: Deemy, James
Worked for more than 160 Hours: Yes
Contribution to Project:
VCU undergraduate, worked with Don Young on shrub-related projects in 2010.

Name: Austin, Jared
Worked for more than 160 Hours: Yes
Contribution to Project:
VCU undergraduate, worked with Don Young on shrub-related projects in 2010.

Years of schooling completed: Freshman
Home Institution: Other than Research Site
Home Institution if Other: Virginia Commonwealth University
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2010
REU Funding: REU supplement

Name: Hoffman, Ava
Worked for more than 160 Hours: Yes
Contribution to Project:
UVA undergraduate, worked with Don Young on shrub-related projects in 2010.

Name: Mische, Paige

Worked for more than 160 Hours: Yes

Contribution to Project:

In 2010 worked with PI McGlathery and graduate student Dana Gulbransen on a project studying the ecological impacts of the invasive macroalage Gracillaria

Name: Olcott, Chris

Worked for more than 160 Hours: Yes

Contribution to Project:

In 2010 worked with PI Linda Blum in studies of the effects of fertilizer additions to below ground growth in saltmarshes

Name: Weakley, Meredith

Worked for more than 160 Hours: Yes

Contribution to Project:

In 2010 worked with PI Wiberg and graduate student Wolner on a sediment survey of Hog Island

Name: Peterson, Nancy

Worked for more than 160 Hours: Yes

Contribution to Project:

Worked in 2011 with graduate student Dana Gulbransen under Karen McGlathery on Potential Ecological Impacts of invasion by a non-native macroalgae

Name: Emery, Kyle

Worked for more than 160 Hours: Yes

Contribution to Project:

In 2011 worked with graduate student Jill Griener under the supervision of PI's McGlathery and Wiberg. Topic: Carbon sequestration in sediments of restored seagrass meadows in the coastal bays

Name: Sherman, Arianna

Worked for more than 160 Hours: Yes

Contribution to Project:

Summer of 2012, worked on Seagrass project with PI Karen McGlathery and graduate student Laura Reynolds

Name: Combs, Kendall

Worked for more than 160 Hours: Yes

Contribution to Project:

Summer of 2012, worked on Seagrass project with PI Karen McGlathery and graduate student Laura Reynolds

Name: McIntyre, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

Summer of 2012 worked with PI Don Young on the vegetation dynamics of barrier islands

Organizational Partners

USGS Biological Resources Division

Co-PIs R. Michael Erwin and Matthew Kirwan are supported by USGS/BRD and are stationed at UVA.

Department of Navy Naval Research Laboratory

Co-PI Charles Bachmann is supported by, and works at, NRL.

The Nature Conservancy

The Virginia Coast Reserve of the Virginia Chapter of The Nature Conservancy provides access to study sites and field research facilities. They are frequent collaborators on research projects. In 2010 they provided $75K to assist us in a joint purchase of LiDAR data for the Eastern Shore of Virginia.

NOAA National Environmental Satellite Data Information Service
NOAA installed an operates a Climate Reference Network station at our laboratory in Oyster, VA. The resulting data provides a valuable adjunct to LTER meteorological data.

Coastal Zone Management - Virginia
In 2007 a monthly public seminar series on environmental issues and research activities at the VCR-LTER was established with support by the Coastal Zone Management and Seaside Heritage Program of the Commonwealth of Virginia.

Virginia Museum of Natural History
Collaboration on GIS databases of predator locations involving PI's Dueser (USU), Moncrief (VMNH) and Porter (UVA)

Department of Army, U.S. Army Corp of Engineers
LiDAR expert John Anderson is supported during a sabbatical at UVA (2011-2012) and collaborates on studies of barrier island vegetation.

Other Collaborators or Contacts

Dr. Robert Orth of the Virginia Institute of Marine Sciences has collaborated with us extensively on the seeding of seagrass beds at our research sites.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
See attached PDF file

Findings: (See PDF version submitted by PI at the end of the report)
See attached PDF file

Training and Development:
EDUCATION AND OUTREACH ACTIVITIES

The Virginia County (Northampton) that houses the VCR program is one of poorest counties in the Commonwealth. It has been our experience that the majority of primary and secondary school students on Virginia's Eastern Shore have never spent significant time on the water, and few have ever ventured into the marshes or mudflats. Consequently, our involvement with this audience is very important. We involve about 200 students each year in our Schoolyard LTER program, more than half of whom are representative of women and minority groups. The VCR Program has helped outfit the science faculty at the county high school with badly needed computers, specialized software (e.g., GIS software), portable GPS units, supplies, reference material, etc.

EDUCATION

The goals of our education program are to: 1) involve and excite local school kids and teachers in marine science in general, and specifically about their local coastal barrier island system; 2) reach a broader audience of students through web-based resources; and 3) train undergraduate and graduate students through VCR

research and involvement in national and internal collaborations. Our site director, A. Schwarzschild, is our current Education and Outreach Coordinator and works closely with local teachers and students. He also has forged new education collaborations with our partners at The Nature Conservancy and colleagues at Chesapeake Experience. Schoolyard LTER ? Our Schoolyard LTER program is focused on local high schools in Northampton County and contains 3 main components: 1) curriculum development, 2) teacher training, and 3) high school student summer research internships.

1) Curriculum - We continue to work with science faculty at Northampton High School with the successful and popular Environmental Science II class. This class is built around water quality monitoring at 23 locations along the VCR, analogous to the water quality monitoring done as part of the VCR LTER data collection. Students learn basic laboratory techniques and are engaged in local environmental issues including: land use change and coastal eutrophication, sediment runoff, climate change and sea-level rise. SLTER support was used to purchase and maintain secchi tubes, thermometers, DO probes, refractometers, conductivity meters, and Smart Colorimeters used by the students to measure water quality parameters including: turbidity, temperature (water and air), dissolved oxygen, salinity, nitrate/nitrite, ammonia and dissolved phosphorus. Using digital cameras and hand held gps units, also purchased for the school with SLTER support, the students take pictures of the area surrounding their monitoring sites and collect latitude and longitude positional data. They use this information along with GIS software and computers supplied with SLTER funding to create GIS maps of their study sites in order to characterize the potential impacts of varying land use patterns (i.e. agriculture, development, nature preserve, etc.) on the water quality parameters being monitored. After quality control screening of the student data, it is entered into a long-term database so that the students can see how the data they collected compares to data collected by previous students. Students use these data to analyze long-term trends in water quality criteria along the VCR. At the end of each semester the students describe their methods and results in a PowerPoint presentation.

LTER staff and science faculty at Northampton High School also have developed a new high school science class on Coastal Ecology. This class is focused on the locally relevant human activities impacting the health, productivity and sustainability of coastal ecosystems along the VCR. We also make routine visits to Northampton High School to present guest lectures and assist in classroom instruction on such topics as gps technology, seagrass ecology and water quality in Earth Science, Chemistry and Marine Biology classes. Finally, we host field trips for a variety of visiting middle and high school classes and science groups ranging in size from 10-60 students. On average, 10 school groups visit the VCR each year from the VA Eastern Shore, Virginia Beach, Norfolk, Richmond and Charlottesville.

2) Teacher training - Through our ongoing partnership with Chesapeake Experience, the VCR LTER offers 2 professional development classes for area teachers each year (Fall Migration

Ecology and Coastal Bay Ecology May), with a combined enrollment of 28 teachers. These short courses provided instruction in ecology and environmental science topics centered around the Eastern Shore Barrier islands, but applicable to other VA ecosystems. The VCR LTER has also hosted a new workshop for Art Teachers that linked instruction in Plein Aire painting techniques with our place-based research on salt marsh ecology. Nine teachers (4 from Northampton County) participated in the workshop, and an exhibit of the artwork and ecology essays they produced will be on display at the Barrier Islands Center Museum on the Eastern Shore and the Brown Science and Engineering Library at UVA . The success of this program has resulted in a grant awarded by the Buckner W. Clay Endowment for the Humanities, which will support 2 additional Art and Ecology workshops for public school Art teachers (Observational Drawing scheduled for October 2012 and Plein Aire painting scheduled for April 2013).

Two additional new programs were initiated in 2011-2012. In September 2011, we recruited and trained 6 local teachers (at least one teacher from every public and private school in Northampton County) to participate in the VA Oyster Gardening program. Field trips were run for 3 schools, involving over 40 local school children, to release the oysters they had grown onto local oyster reef sanctuaries. Groups from 2 other schools forged partnerships with the Chesapeake Bay Foundation to release their oysters at sanctuaries in the Chesapeake Bay.

3) High School Research Internships ? Over the last 4 years we have involved 16 high school students in 8-week summer research internships. The program partners qualified high school students with graduate students conducting summer fieldwork at the VCR-LTER, and was initially motivated by a REHS (Research Experience for High School Students) supplement in 2007. Participation in this program is merit based and determined through a competitive application process. A. Schwarzschild provides program oversight and project coordination on site. Graduate students wishing to participate in the program are required to submit a proposal detailing their summer research objectives and indicating the role a high school intern would fill as a research assistant, along with a letter of support from their faculty advisor. All high school students wishing to apply are required to attend an orientation meeting in which they are introduced to the graduate students selected as mentors and presented brief summaries of the available research positions. The high school students then submit applications including: a prioritized list of the projects they would like to work on, a copy of their high school transcript, a letter of recommendation from at least one science teacher, and a an essay detailing why they wish to participate in the REHS program and what they hope to gain from the experience. They work under the direct supervision of their graduate student advisor on assigned tasks, and are also expected to conduct a related project of their own design. All participants gather for informal dinner meetings several times throughout the summer to discuss the progress of their projects. At the end of the summer each intern is required to make a public presentation of the results of their activities.

The Nature Conservancy and Volgenau Foundation leverage LTER funding for up to 2 of the internships. Student projects this summer included an investigation of the ecological impacts of the invasive macroalgae G. vermiculophylla, assisting with our annual survey of seagrass restoration sites that examines the ecological implications of restoring eelgrass to the VA coastal bays, and a continuation of the SLTER water quality monitoring program to obtain summer time values to supplement academic year data taken by the Environmental Science II classes. The quality of the student involvement has been very high ? 2 students from last year were very motivated by their experiences, applied to and were accepted to UVA, joining a student from the summer of 2008 who is now a major in Environmental Sciences at UVA.

4) Undergraduate Training ? Each year the VCR LTER supports at 3-4 undergraduate students with supplemental funding. Each student is partnered with a PI and graduate student as mentors for a 10- week field season. Students are based at the VCR site and assist with the ongoing research activities of their mentors, plus conduct a research project of their own. We expect students to present their work as a poster at the annual VCR LTER All Scientists meeting; UVA undergraduate students also typically make poster presentations at the annual Department of Environmental Sciences annual Graduate Student Symposium.

In addition to REU interns, we provide some support for undergraduate assistants in PI laboratories during the academic year. This allows students to continue their involvement in the LTER program and to get more deeply involved in research projects than a single summer allows. Undergraduate students have also been successful in obtaining their own funding for LTER research. For example, two students in McGlathery's lab applied with their graduate student mentors and received $5000 research grants from UVA to continue their LTER work. One of these students is now a graduate student in Pace's lab.

The VCR site serves as a platform for field classes that have been run by LTER PIs at the field site. Table 5 below includes a list of undergraduate and graduate courses that are taught everyone 1-2 years at the LTER site.

Table: Undergraduate and graduate level courses currently run by LTER PIs
at the VCR

COURSE	INSTITUTION	ENROLLMENT
Methods in Aquatic Ecology	University of Virginia	15
Estuarine Ecology	University of Virginia	15
Aquatic Ecology	University of Virginia	15
Marine Invertebrates	University of Virginia	15
Marsh Ecology	East Carolina University	15
Barrier Island Ecology	Old Dominion University	15
Coast Geomorphology	Randolph Macon University	25
Biological and Ecological Conservation in Chesapeake Bay	University of Virginia	20

5) Graduate Training - Graduate student training is an important

part of our education mission. Each year we provide support for 20-30 students who conduct their research at the VCR LTER site; about half of these students work with UVA PIs and the other half work with VCR PIs at partnering institutions. All completed M.S. and Ph.D. theses are uploaded on our website: http://www.vcrlter.virginia.edu/thesis/thesis.html. Thus far during this funding cycling, 30 M.S. and Ph.D. theses have been completed.

6) Public Education and Outreach - The VCR Education and Outreach coordinator serves as an instructor for the Eastern Shore chapter of the VA Master Naturalists program, lecturing on ecology, seagrass ecology, climate change, sea-level rise, and ichthyology. He also coordinates our monthly seminar series focusing on VCR-LTER research for the general public. This seminar series has become popular with the local high school science teachers who regularly offer extra credit to their students who attend seminar and present an oral summary of the information they learned to their science class. Master Naturalists may also receive advanced training credits towards their certification for attending seminars.

The VCR LTER is a member in the Eastern Shore Climate Adaptation Working group, a partnership between TNC, local, regional and federal agencies. He also is part of a regional committee formed to examine current zoning regulations and the potential economic and ecological impacts of developing commercial poultry production.

The VCR LTER has co-hosted a 'listening sessions' to assess local citizen responses to climate change issues with UVA's Institute for Environmental Negotiation (http://ien.arch.virginia.edu/projects-current/virginia-sea-level-rise).

7) Artist-in-Residency Program - The VCR hosted our first Artist in Residence at the VCR. Alice McEnerney Cook, the Plein Aire instructor spent 2 weeks on location, producing 15 landscape paintings of local salt marsh and coastal ecosystems. She presented her work at our monthly public seminar series in June and many of these pieces will be included in an exhibit, 'Ecological Reflections Art and Ecology' will be on display in the Charles L. Brown Science & Engineering Library at UVA starting on October 26th.

Outreach Activities:

The LTER has developed links with conservation organizations, and local, state, and federal agencies through outreach efforts. The LTER has a strong partnership with The Nature Conservancy (TNC), and through this we address the important management and conservation problems that face the region. This puts us in an excellent position to provide a solid, scientific foundation for making decisions related to planning, management, and ecosystem restoration. A good example of this is our collaboration with The Nature Conservancy (and VIMS) on

the seagrass restoration in the VCR coastal lagoons. We provide key data (e.g., lagoon bathymetry) that facilitates the restoration program, and we also provide logistical support for the volunteer-driven TNC efforts on seagrass and oyster restoration.

Our Outreach/Education Coordinator is a member of the Eastern Shore Climate Adaptation Working group, a partnership between TNC, local, regional and federal agencies. He also is part of a regional committee formed to examine current zoning regulations and the potential economic and ecological impacts of developing commercial poultry production. In May 2012, the VCR LTER co-hosted a 'listening sessions' to assess local citizen responses to climate change issues with UVA's Institute for Environmental Negotiation (http://ien.arch.virginia.edu/projects-current/virginia-sea-level-rise).

An important part of outreach to the local community is a public seminar series hosted by the LTER and ABCRC, with monthly presentations by scientists working on the coastal barrier system. A. Schwarzschild runs this series, which began in Fall 2007 supported by a partnership between the NOAA Coastal Zone Management Program/Seaside Heritage Program, the Department of Environmental Sciences and the VCR-LTER. The purpose of the seminar series is to educate the local public about environmental research, management and restoration projects being conducted on the Eastern Shore of Virginia. Past seminar topics covered have included, seagrass ecology, barrier island history, the seaside heritage program, oyster catcher ecology, sea turtle ecology, habitat restoration in support of migratory song birds, the VA natural heritage program, salt marshes and sea level rise, oyster restoration, seagrass restoration, hypoxia and dead zones in the Chesapeake Bay, impacts of climate change on the Eastern Shore, stream and catchment hydrology, and the ecology of barrier island upland communities.

In addition to school classes we have also hosted groups of the UVA Ecology Club, the VA Aquarium Mentoring Young Scientists program, the Eastern Shore chapter of the VA Mater Gardeners and Master Naturalists programs, and the Virginia Association of Biological Sciences. Our Outreach/Education coordinate serves as an instructor for the Eastern Shore chapter of the VA Master Naturalists program, lecturing on ecology, seagrass ecology, climate change, sea-level rise, and ichthyology.

VCR LTER investigators and graduate students frequently give presentations on topics of scientific interest to community groups and at scientific workshops. For example Ray Dueser and Nancy Moncrief made a presentation about predators on the Virginia barrier islands during a Virginia Coastal Zone Management workshop in December 2010 and made a presentation about predation management on the VCR during a meeting of the Virginia Chapter of the Wildlife Society in February 2011; and Matt Reidenbach gave a presentation on 'Following the Scent: Smelling and tracking of odors by animals' as part of the Long Term Ecological Research Public Seminar Series, Oyster VA, March 2011.

Information Management

We continue to fully participate in LTER Network activities, such as Ecotrends, ClimDB, SiteDB, all-site bibliography and personnel directory. All metadata are available as high-quality Ecological Metadata Language documents that are available from the LTERNET Metacat server. Our web server has provided over 5 Terabytes of information and responded positively to formal 860 data requests (See the 'Contributions to Resources for Research and Education' section for detailed statistics on data access and use.).

In addition to formal datasets, the VCR/LTER provides near real-time data in graphical and tabular forms to the scientific and local community. During 2009 and 2010 we upgraded our tide station in Oyster VA to use a more reliable tide sensor using radar to detect changes in tide levels. A new radar sensor was added to the Redbank, VA tide station in 2011 and a replacement meteorological station was added to Hog Island. In August 2007 we completed installation of a network of ten water-level monitoring stations on Hog Island, Virginia. The new stations use 900 MHz serial wireless communications to connect to the Wi-Fi network installed on the island in previous years. This upgrade replaces a mix of mechanical well monitors (using paper chart recorders) and electronic recorders (that required manual monthly dumps). The upgrade has dramatically cut data outages, because problems are identified at UVA, using graphs that are produced three times per day, and fixed before they become serious. Additionally, we have added an additional tide station and a flux tower to our wireless network.

We have begun a move towards Linux from the proprietary UNIX (SunOS) we use for servers. In this context, we worked on the implementation of virtual machines on a variety of low and high-end hardware. On the high end, in spring 2008 we purchased an eight-processor Linux server that has begun to replace the VCR/LTER web server (currently running on a Sun workstation). Currently the main web page and MYSQL database have been moved to the new server, but specialized functions are still provided by the old server. On the low-end, we have used PCs that were discarded due to low speed or lack of memory required to run new versions of Windows to install Linux variants which are much less consumptive of resources. These machines have been used to take over primary electronic data collection tasks using the wireless network at the ABCRC. By using VNC (Virtual Network Console) all the machines can be administered using graphical tools from any place in the world. Graphs and tables, along with updated data from these systems are placed on the public web several times each day.

International Outreach

The VCR/LTER has been active in international outreach, particularly in the East-Asia Pacific region in the area of Information Management and in Italy, focusing on comparisons of coastal systems.

We have continued our work with Taiwan Ecological Research Network (TERN) and participated in an East-Asia Pacific ILTER Urban Forestry and Information Management Workshop in Seoul Korea in the fall of 2007. In 2009 and 2010 we helped lead two workshops aimed at applying advanced ecoinformatics techniques to ecological data. Week-long workshops in Taiwan (2009) and Malaysia (2010) used Ecological Metadata Language and scientific workflow tools (e.g., Kepler) to

analyze data from permanent plots at International LTER sites.

Three presentations were given in Italy in 2008 by Sergio Fagherazzi and Enrique Reyes to researchers working in the Venice lagoon and in the Po River delta, the two areas are part of the Alto Adriatico Italian/European LTER: - Long-Term Environmental Change at the Virginia Coast Reserve, Department of Environmental Sciences, Parma University, Italy June 2008 - Long-Term Environmental Change at the Virginia Coast Reserve, ISMAR-CNR, Venice, Italy, June 2008 - Long-Term Environmental Change at the Virginia Coast Reserve, Department IMAGE, University of Padua, Italy, June 2008

One Ph.D. student from Boston University (Anthony Priestas) spent a month at the University of Padua in the summer 2008 funded by the LTER International Supplement. The student participated in field measurements in the salt marshes of the Venice Lagoon. Another Ph.D. student from Padua (Alberto Canestrelli) spent six months at Boston University working on modeling of intertidal hydrodynamics, and part of the dissertation of Mara Tonelli (PhD, University of Udine Italy) was based on the application of wave models to the VCR marshes.

Mark Brinson represented the VCR LTER at the Man and the Biosphere in the winter 2008. He presented a poster entitled 'Research and Education at the Virginia Coast Reserve Long-Term Ecological Research Project.'

Iris Anderson, Robert Christian and Karen McGlathery have begun a collaboration with Victor Camacho-Ibar on nitrogen cycling and ecosystem functions and hydrogeomorphology in San Quentin Bay, Mexico. Iris Anderson collaborates with colleagues at the University of Padua, Italy, studying the effects of hard-clam aquaculture on shallow coastal ecosystems.

Network Activities

Karen McGlathery is a member of the LTER Network Executive Board (2010-).

Bob Christian has collaborated with the LTER Network Office on a social network analysis project to evaluate the way the LTER network is coalescing as a network. They are using inter- site joint publications as the variable.

John Porter has collaborated with other information managers on the creation of a controlled vocabulary for LTER data sets that was accepted by the LTER Executive Board in 2010. In 2011 he chaired two workshops that organized the controlled vocabulary into a thesaurus and with other members of the Controlled Vocabulary Working Group created web services that allowed the thesaurus to be used to enhance searching using the LTER Metacat server. The controlled vocabulary can be seen and used to search datasets at: http://vocab.lternet.edu

The VCR LTER has also been active in a number of network educational activities. VCR LTER I.M. John Porter participated and made presentations in the SensorNIS and several training workshops aimed at training investigators in advanced I.M. techniques. With Paul Hanson from the NTL LTER and Chau-Chin Lin from the Taiwan Forestry Research

Institute he published a review paper on information management for sensor networks as part of a special issue of Trends in Evolution and Ecology. Continuing work on the LTER Controlled Vocabulary in 2011-2012 took an international turn with participation in an ILTER workshop in Shanghai China focusing on semantic approaches to multilingual data discovery of ILTER data. Web services created for use with the U.S. LTER controlled vocabulary were modified to interface with the RDF-based and multilingual EnvThes thesaurus to create a prototype system for multilingual searching. A poster on this work was presented at the 2012 LTER All-Scientists' Meeting. Porter has been actively working on interfacing VCR LTER data with PASTA and have several exemplar datasets ingested, with many more ready to ingest as PASTA becomes ready to take them. That work has stimulated additional activities in the area of developing web services that facilitate analysis of LTER data by automating the routine programming tasks associated with writing code to ingest LTER data into statistical software. With the PASTAprog web service, one can go from searching for an LTER dataset to having a working R, SAS or Matlab (thanks to Wade Sheldon of GCE) program that has ingested the data and provided a statistical summary in less than one minute (video available).

During 2010- 2011 the VCR/LTER participated in the MIRADA workshop, aimed at providing an environmental context for microbial genetics measurements, providing both microbial samples and associated environmental measurements.

In 2010-2012, Outreach/Education Coordinator, Art Schwarzschild, serves as a member of the LTER Education Executive Committee and co-chair of the Higher Education Working Group.

VCRLTER Researchers are frequently chosen to participate in NSF site visits to other LTER sites. Karen McGlathery participated in the 2011 North Temperate Lakes Review and John Porter participated in 2009 reviews of Harvard Forest and Central Arizona Phoenix LTER sites.

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Web/Internet Site

URL(s):

http://www.vcrlter.virginia.edu

Description:

This is the main web site for the VCR/LTER project and serves as the "file cabinet" for all aspects of the project. The web site provides access to data, interactive maps, images, bibliographic listings and full-text of student theses and dissertations.

Other Specific Products

Product Type:

Data or databases

Product Description:

The VCR/LTER publishes over 160 datasets using standard Ecological Metadata Language metadata. In addition to the VCR/LTER web site they are available through the national LTERnet, KNB, DataOne and the USGS Core Science Metadata Clearinghouse data catalogs.

Sharing Information:

Data is made available to all researchers online. Researchers use the LTER-wide Data Access Server to authenticate and are immediately granted access to the requested data.

Details on this data use can be found in the "Contributions to Resources for Science and Technology" section of this report.

Product Type:

Audio or video products

Product Description:

The VCR/LTER has provided a variety of video products, including interviews of seagrass researchers, field trips, data collection procedures and formal presentations on educational and video sharing sites such as SciVee and COSEE.

Sharing Information:

A compilation of these can be viewed at:
http://amazon.evsc.virginia.edu/video/scivee.html .
Additionally, brief video clips for inclusion in presentations are available at: http://amazon.evsc.virginia.edu/video .

Contributions

Contributions within Discipline:

VCR scientists have contributed to theoretical advances in understanding complex non-linear dynamics of ecosystem change. Our strength is the interdisciplinary approach we take coupling geomorphology with ecological feedbacks. We have built on our long-term observations and experiments to develop quantitative models of these non-linear dynamics that show the emergence of alternative stable states, separated by thresholds, in the intertidal and subtidal parts the landscape.

We have developed models describing alternative stable states in the intertidal and subtidal parts of the landscape, and have observed patterns in barrier island vegetation and island morphology that are consistent with bistable dynamics. The dynamics of alternative stable states have been described in inland terrestrial, freshwater, hard-bottom, and off-shore marine ecosystems, but only recently by us in soft-bottom coastal systems.

We have continued to contribute to the understanding of coastal systems through our efforts in studying the effects of sea level rise (which involves developing detailed understandings of the processes that effect accretion in marshes - both physical and biotic, and encroachment into uplands), storm disturbance, coastal eutrophication, seagrass restoration, controls on plant production, determinants of faunal biogeography in an island system, and prediction of future state change.

WATERSHEDS AND LAGOONS

Coastal eutrophication has been recognized as an increasing global problem. Symptoms of eutrophication include blooms of phytoplankton, which when they decompose may reduce available oxygen in the water; blooms of harmful algae that are toxic to fish, shellfish, and occasionally humans; blooms of macroalgae that cause die-backs of seagrasses which are vital to maintaining populations of many fish and crabs; and increasing anoxia. Eutrophication generally results from export of excess nutrients from land, in particular nitrogen. Sources of nitrogen include agriculture, septic tanks, waste-water treatment plants, industry, and atmospheric deposition of nitrogen derived from automobiles, power plants, and other industrial sources. Nitrogen from these sources is most often transported to coastal waters in shallow groundwater and in surface water runoff.

Coastal lagoons are common features of the land margin, especially along the East and Gulf coasts. We have hypothesized that these lagoons play an important role in retarding and transforming nitrogen during transport from land to the sea. Our study of the Virginia Coast Reserve lagoonal system has been designed to: (1) measure groundwater sources of nutrients to the lagoon; (2) measure rates of biological processes that remove or transform nitrogen in the waters and sediments of the lagoon; (3) compare rates of nitrogen cycling processes to physical transport across and out of the lagoon in order to determine whether the nitrogen remains in the lagoon for a sufficient length of time to allow biological processing to occur.

Our modeling and process studies have indicated that the VCR lagoons receive relatively low inputs of nitrogen from the coastal watersheds compared to more eutrophic lagoons in the mid-Atlantic. This is true

in part because population densities are relatively low in the VCR watersheds and there is little point-source agriculture (e.g., chicken farms). Much of the fertilizer nutrients that enter the groundwater is removed by an intact riparian zone and by stream sediments, both of which are active sites of denitrificaiton. Nitrogen that enters the lagoon is rapidly removed by both benthic macro- and microalgae. As a result, there is little flux of nutrients from the sediment to the water column and phytoplankton concentrations are typically low. Blooms of macroalgae that occur in early summer typically crash during mid-summer, releasing much of the nitrogen as dissolved inorganic and organic nitrogen. The sediments act to rapidly remove the nitrogen released to the water column by a combination of mechanisms including immobilization by benthic microalgae and coupled nitrification - denitrification. We are currently attempting to determine how the nitrogen released during decomposition of the macroalgal bloom is partitioned between the various potential consumptive mechanisms. Our most recent research has shown that nitrogen is retained in the sediments for a longer time than would be expected by turnover of plant biomass because nitrogen 'shuttles' back and forth between bacterial and benthic microalgal pools.

Our conclusions regarding the importance of macroalgae in influencing the dynamics of nutrient movements within the lagoon helps to explain the role of the lagoon as an active mediator between mainland nutrient sources (e.g., agricultural fields) and the coastal ocean. The recent discovery that the dominant macroalga in the lagoon is an exotic (rather than its native congener), will be important to understanding long-term changes in the lagoon's characteristics.

Shallow bays in the VCR and elsewhere along the US Atlantic coast experienced a dramatic state change in the 1930's when a single storm decimated seagrass populations already decimated by disease. Until recently, VCR lagoons persisted in an alternate, algal-dominated state. Recent field work and modeling showed that high turbidity events in the VCR were episodic and wind driven and we estimated that average light availability over 65-87% of the lagoon bottom is suitable for seagrass recolonization (Lawson et al., 2007). Beginning in 2007, in collaboration with Robert Orth from the Virginia Institute of Marine Science, we began to restore seagrass in a 509 acre 'set aside' we have obtained from the Virginia Marine Resources Commission in our primary lagoon study site, Hog Island Bay. The set-aside was renewed in 2010. The restoration builds on our 10-year database on patterns and process in Hog Island Bay in the absence of seagrass, and gives us the opportunity to determine experimentally the ecosystem-level effects of a rapid state change back to the original seagrass- vegetated state.

The seagrass restoration project contributes to important theoretical and applied problems related to coastal ecosystems. On a more theoretical level, it directly addresses questions related to ways in which biotic feedbacks modify the response to of the systems to external drivers by maintaining a stable state or facilitating a change to another state. In the lagoons, the biotic feedbacks that influence the success of seagrass establishment and growth include the vegetation effects on reducing sediment resuspension and the potential facilitation of seedling establishment by benthic fauna. In addition, a state change from algae to seagrass will have system-wide impacts

because these benthic primary producers play key roles in determining rates and patterns of primary production and nutrient cycling and in trophic interactions. Variations in the rates and dominance of these processes as primary producer communities change, will ultimately determine the fate and retention of watershed nutrients as they pass through the lagoon 'filter' to the open ocean. As the community shifts to seagrass dominance, we expect the retention time of watershed N in the lagoon to increase. In addition, there may be landscape-level feedbacks where stabilization of the lagoon sediments by seagrass restoration may reduce the availability of sediments for marsh accretion. This may have implications for the ability of marshes to keep pace with increasing rates of sea-level rise.

On a more applied level, the experimental approach we are taking to establishing and monitoring the seagrass plots in Hog Island Bay, a relatively pristine system, will provide important baseline information for restoration projects undertaken in more highly impacted systems. To put our results on the new seagrass beds in context, we have established a chronosequence by augmenting the Hog Island Bay meadows with those recently seeded (1-7 yr old) using the same technique in South and Spider Crab Bays, just south of Hog Island Bay, and a natural meadow in South Bay, which is at least 10 years old.

This long-term state change experiment documents the recovery of key ecosystem functions related to primary productivity, carbon and nitrogen sequestration, increased water column clarity, and sediment stabilization with a change from bare sediments to seagrass dominance. The long-term data indicate that at least a decade is required for these functions to be restored fully.

Our study of the coupling between biotic and abiotic processes controlling the dynamics of seagrass ecosystems has shown that: 1) The positive feedback that exists between seagrass and their light environment is strong enough to induce bistable dynamics within a limited depth range; and 2) Seagrasses within this depth range possess limited resilience, in that disturbances (high temperature events/poor growth conditions) may cause shift to stable bare sediment conditions.

Surface Elevation Tables (SETs) are used at numerous VCR/LTER research sites to quantify changes in sedimentation and subsidence that ultimately will determine the fate of marshes in the face of sea level rise. These baseline measurements at different marshes are then used in association with process-based studies focusing on the processes such as transport of material through tidal flooding, burial of organic matter and its decomposition, marsh plant production (both above and below ground) and the feedbacks on sedimentation rates, bioturbation by crabs, and even herbivory by insects to develop models aimed at predicting changes in marshes over the coming decades. Our results 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.

Recent work on microbial communities in the marshes and tidal creeks at the VCR (as well as 9 other coastal systems as part of a cross-site

comparison study) contribute to our understanding of what abiotic and biotic factors determine microbial community structure and the scales over which microbial communities vary. Linking information about variation in microbial community structure and microbially controlled processes (e.g., nitrogen-fixation), will allow prediction of how critical ecosystem processes will be affected by disturbance. (Blum)

BARRIER ISLANDS

Within the realm of coastal sciences, our work continues to show that barrier island plant communities are sensitive to climate change. These may serve as sentinels to climate change due to a rapid response to shoreline migration and storm related disturbances. The results our work to date have increased our understanding of dynamic vegetation changes and their causes in coastal barrier island ecosystems. We have established that landscape position is they key factor controlling the pattern of plant community development and production on the islands, with distance from the shore (and susceptibility to salt spray and overwash disturbance) and elevation (and distance to the groundwater) as the important factors defining landscape position. New cross site and cross species analyses are linking meteorological and climatological drivers to plant production. This analysis is revealing complex patterns showing that all species and sites do not respond similarly to meteorological drivers.

To date, one of our most significant contributions has been to demonstrate that biotic interactions are very important in the coastal environment of the VCR, which we often define as being dominated by physical parameters. We have demonstrated the importance of the presence of a soil actinomycete, Frankia, for the successful establishment of Myrica cerifera. Myrica usually is usually the first woody species to establish in these environments. Once established, Myrica rapidly forms extensive thickets in coastal environments. These thickets are excellent indicators of island stability and may be precursors to the establishment of maritime forest.

On a broader scale, our long-term work continues to identify and quantify mechanisms for shrub expansion. Nearly all published studies have focused on the causes and consequences of woody expansion with a very limited understanding how or why species are so successful at expanding.

Twenty years of research in shrub thicket ecology has provided excellent background and experience for studying the potential for invasive species in coastal environments. This is especially true for the weedy grass, Phragmites australis. Populations of Phragmites are establishing and rapidly expanding throughout the VCR as well as in coastal environments of the mid-Atlantic region. Phragmites often establishes in habitats similar to those of shrub thickets. The detailed understanding of the ecology of P. australis with respect to nutrient uptake and competitive relationships provide a basis for predictions regarding its ultimate distribution.

Studies of island-dwelling organisms, such as those underway at VCR, have long played an important role in testing ecological and evolutionary theory about patterns and processes related to

distribution and abundance of species and genetic variation within and among natural populations. The Virginia coast is a highly dynamic, frequently disturbed landscape, and the Virginia barrier islands are the only undeveloped barrier system on the Eastern seaboard. As such, this system affords a unique opportunity to study phenomena associated with island systems, including fragmentation of habitats and populations, local extinction, dispersal, and colonization, which are also important issues in conservation biology. The relative isolation of the islands also provides an excellent opportunity for assessing the roles of parasitism and disease in overall vertebrate population dynamics.

The role of mammals and predation on the large waterbird community has been chronicled, and continues to show annual changes. Managing foxes and raccoons at selected barrier islands has dramatically enhanced the reproductive success of a number of species of ground-nesting waterbirds, including the federally threatened piping plover. Nonetheless, fewer colonies (but larger) of nesting terns (4 species) and black skimmers have consolidated onto fewer islands over the past decade compared to the distribution pattern in the 1970-80s.

SYSTEM-WIDE INTEGRATION

One of the questions we have begun to address is what the composition and structure of the VCR landscape patterns will be in the future and what processes will drive ecological states changes in those landscapes. We are using two types of models to synthesize our long-term monitoring and experiments and shorter-term process studies to address the causes and consequences of state change on the VCR landscape. The goal of this modeling effort is to be able to predict the non- linear and threshold responses of the VCR ecosystems to long-term environmental change and short- term disturbance events.

Landscape modeling:

The data compiled so far have enabled tests of previously recently developed untested conceptual models. Additionally, the data are contributing to a long-term predictive model of barrier island morphodynamics. These data will provide climate change assessments along one of the longest natural, mixed-energy barrier island systems in the world. We have coined the term 'maintainer feedback' to apply to processes that maintain low elevations (in contrast to the more typically considered 'dune-builder feedback,' which leads to increases in island elevation). Our work on the maintainer feedback has improved our understanding of the role of combined physical and vegetative processes in barrier island evolution. We have found evidence to suggest that this feedback, working in conjunction with physical processes alone, has the potential to accelerate large-scale shifts from dune-dominated to overwash-dominated barrier morphologies with climate change-induced increases in storm intensity and sea-level rise.

Modeling of northern and southern Metompkin Island has improved our understanding of how the Virginia barrier islands may evolve in the future. Results to date suggest that while island migration rates can be expected to accelerate, Metompkin Island (and islands having similar characteristics) is likely to avoid disintegration or

inundation, remaining subaerial because of sufficient substrate sand quantities and an adequately upward sloping substrate, both of which reduce the amount of sand needed to keep up with sea level rise. (Brenner and Moore, 2010)The new ecomorphodynamic model of barrier island evolution synthesizes our work on physical and ecological barrier island processes and improves our ability to qualitatively predict future island evolution along the continuum from high islands to low islands.

Previous VCR efforts focused on developing various conceptual and mathematical models of limited parts of the landscape and demonstrated a need to integrate the diverse spatial and temporal information into a regional model for the VCR ecosystem. In response, we have begun developing a mechanistic, process-based ecological basin model to understand the coupling between hydrologic and geomorphic free surface changes and the ecological responses of state change on scales that vary from local to the entire coastal reserve. The model integrates physical and ecological processes over a grid of landscape cells. Each cell contains a unit ecosystem model that represents a certain habitat type and incorporates location-specific algorithms to quantify fluxes of materials between cells. Hydrodynamic, soil, and plant productivity modules are dynamically coupled via a unit ecosystem model (Reyes et al. 2000, 2004). The model also contains a habitat-switching module that tracks habitat characteristics for each land parcel within the model boundary, such that long-term processes and ecological responses can be examined.

An important asset to support landscape modeling is LiDAR data obtained during 2010 that provides a highly accurate (18 cm or better) elevation data for all of Northampton and Accomac Counties. This data was purchased by the VCR/LTER and The Nature Conservancy under the condition that all the data be made available to other researchers and to the general public.

We have used NOAA data to assess changes in land use/land cover in the VCR watersheds for the last 20 years. For all the VCR watersheds, we found that changes over time were typically very small, illustrating how little development pressure the VCR watersheds receive relative to other watersheds in the mid-Atlantic region. These watersheds can be compared with more developed watersheds in the mid-Atlantic region to compare the effects of different levels of development and eutrophication on coastal bay processes.

Our modeling of the evolution of barrier islands reveals that substrate composition, followed by sea- level rise rate, and sediment supply rate, is the most important factor in determining barrier island response to sea-level rise. These results suggest that although barrier island migration rates may increase significantly in the future, barrier islands with sufficiently thick and sandy substrates are likely to persist as long as landward migration is not impeded and shoreface erosion can occur quickly enough to liberate sand volumes necessary to maintain subaerial exposure. We are now building on this work to address the biotic feedbacks of island vegetation structure on the island geomorphodynamics.

Network modeling: Ecological network analysis is an effective tool for evaluating both the biogeochemical and trophic consequences of state

We have used ecological network analysis at the VCR to evaluate nitrogen cycling within mainland marshes (Thomas and Christian 2001) and the lagoon (Voss et al. 2005) and also the food web structure of salt marsh ponds (Dame 2005). We are expanding this effort to include states across the entire VCR landscape to provide assessments of nitrogen cycling relative to the contributions of biomass storage, recycling, physical and biotic exchanges. In addition, co-PI Bob Christian has furthered the use of network analysis within the ecological community via publications and workshops sponsored by NSF biocomplexity and the LTER network. Several groups within and beyond the LTER network have begun using the tools.

Contributions to Other Disciplines:

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

With supplemental funds, we have supported work of a natural resource economist to understand public valuation of ecosystem services related to seagrass and marsh restoration. The 'willingness to pay' experiments give information on public opinions that influence policy and management decisions in the region.

In 2011, we initiated an Artist-in-Residence Program to explore the value of the arts in communicating an understanding and appreciation of coastal ecosystems and the services they provide. Paintings from this program are on display at the local Barrier Island Center and the Science and Engineering Libarary at UVA.

Additionally, our workshops on network analysis have exposed a broad group of scientists to the field or network ecology. Social scientists have also used network analysis, and one of our accomplishments has been to bring awareness of the different approaches to the broader group.

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. During 2006-2007 the VCR Information Manager participated in the Cyberinfrastructure-Core group and we hosted a modeling workshop that focused on the cyberinfrastructure needs of advanced ecological modleling. He has continued work as an elected member of the LTER Network Information System Advisory Committee.

Through our support and collaboration with resource economist Stephen Swallow at the University of Rhode Island, we have helped develop new understandings of the tradeoffs involved in environmental conservation. Some recent presentations include: - 'Consumer Willingness-to-Pay for Coastal Restoration ? Ecosystem Services and

Individualized Pricing' -- Presented at International Institute of Fisheries Economics and Trade Conference. Montpellier, France (2010) -'Selling Ecosystem Services as Public Goods to Consumer-Beneficiaries: An Auction Experiment on Restoration of Seagrass and Bird Habitat in Virginia Coastal Reserve' -- Presented at The Soil and Water Conservation Society Conference. St Louis, Missouri (2010) -'Generating Revenues from WTP for Ecosystem Restoration: An Auction Experiment on Public Goods' Presented at The Agricultural & Applied Economics Association Conference. Denver, Colorado (2010)

Contributions to Human Resource Development:

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 20 - 30 graduate students who conduct their M.S. and Ph.D. projects at the VCR site. Each summer, 3-4 undergraduate students receive REU funding for 10-week research internships, partnering with a graduate student and P.I., and during the academic year 5 - 10 undergraduate students work in university laboratories of LTER P.I.s. Also, each year 1-4 local high school students are supported for 8 week internships at the VCR and work with undergraduate-graduate-P.I. teams. We have found this tiered mentoring to be extremely effective.

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. Each year, over 200 local students are exposed to LTER science.

The VCR field facility hosts 3 - 5 undergraduate classes, involving 60 - 100 students.

Contributions to Resources for Research and Education:

The VCR/LTER web page is widely used. Since the start of the current grant cycle over 5.1 terabytes of information have been downloaded by over 700,000 distinct clients (http://atlantic.evsc.virginia.edu/analog/Nov2006toAug2010/). On a daily basis an average of over 3.7 gigabytes of information are transferred. However, such raw statistics can be misleading because search engines (e.g., Googlebot) make up a large number of the 'hits.' More telling is that users came from over 190 different countries or international organizations (as shown by network domains). Countries with over 100,000 requests included India, Switzerland, Netherlands, Czech Republic, Russia, Canada and China, and 32 additional countries each had over 10,000 requests. Similarly the large number of distinct hosts (550,000) reflects a wide user community.

A more important measure of impact is datasets that are formally downloaded. These formal data requests require users to fill out a data license form. During the current grant, we have had 1,760 formal data requests. Not surprisingly, roughly one half of the data requests (557, 57%) came from faculty and students in some way associated with the project, almost entirely for research purposes. However,

researchers and students not associated with the VCR/LTER requested 419 datasets. Most (52%)were for educational use (class projects, etc.), with the remaining 48% for research uses. An additional 790 datasets were requested by automated programs using the LTER Data Access Server.

Through our Schoolyard LTER supplement, we have been able to provide equipment such as global positioning system, taxonomic guides and water chemistry analysis kits and equipment to the Northampton Co. VA Public Schools. This program now extends from grades K-12 through the Northampton Co. elementary, middle and high schools.

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.

PI Reidenbach and his students have developed new instrumentation to conduct underwater particle image velocimetry (commonly known as PIV). 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. The housing is sealed and the laser is pulsed on and off using a magnetic switch controlled from outside the housing. Imaging of the illuminated particles is done using a high definition camcorder (Sony HDR-HC7) that can obtain images up to 60 frames per second. Both the laser and camera are attached to a rigid frame and can be deployed in the coastal ocean where suspended sediment particles are tracked.

PI Berg has developed a new instrument to measure sediment-water column fluxes in aquatic habitats, based on eddy correlation. The new technique measures fluxes under true in situ hydrodynamic and light conditions.

Contributions Beyond Science and Engineering:

We have engaged in studies designed aid the conservation of avian fauna and better understanding of the extent and change in exotic plant species in the coastal zone in conjunction with The Nature Conservancy (TNC).

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.

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 presence. 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 lagoons, and the fate of nutrients within lagoons 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. The VCR lagoons are also a model system to understand the important role of plants in mediating nutrient export from coastal watersheds to the open ocean (McGlathery et al. 2007).

Linking information about variation in microbial and fungal community structure and fungal and microbially controlled processes (e.g., nitrogen-fixation, decomposition), will allow prediction of how critical ecosystem processes will be affected by disturbances due to human activities in the coastal zone.

Activities with the UN programs on observing global change along coastal ecosystems have significance for broad aspects of public welfare and environmental protection. One of the greatest potential contributions from PI Christian's work at the VCR LTER are to the global observing systems and the ability to detect and assess global change in coastal ecosystems. The Coastal Module of GTOS is being developed to complement the Coastal GOOS program and highlights terrestrial, wetland, freshwater, and transitional ecosystems. Further and importantly it explicitly includes socio-economic components of global change in the coastal zone. This is the first significant introduction of the human dimension into the global observing systems.

Finally, we continue the monthly public seminar series begun in the summer of 2007 on environmental issues and research activities at the ABCRC was established with support from the Coastal Zone Management and Seaside Heritage Program of the Commonwealth of

Virginia. During the seminars, VCR/LTER researchers provide information on their research to the general public.

Conference Proceedings

Sundback, K;McGlathery, KJ;Anderson, IC, Lagoons and shallow bays as filters in the coastal ecosystem, "MAY 27-29, 2008", 2008 IEEE/OES US/EU-BALTIC INTERNATIONAL SYMPOSIUM, : 516-519 2008

Christian, RR;Brinson, MM;Dame, JK;Johnson, G;Peterson, CH;Baird, D, Ecological network analyses and their use for establishing reference domain in functional assessment of an estuary, "APR, 2008", ECOLOGICAL MODELLING, 220 (22): 3113-3122 Sp. Iss. SI NOV 24 2009

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Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Selected Findings

Seagrass state change in coastal bays

The long-term state change experiment documents the recovery of key ecosystem functions related to primary productivity, carbon and nitrogen sequestration, increased water column clarity, and sediment stabilization with a change from bare sediments to seagrass dominance (Fig. 4). Changes in shoot density drove changes in functional characteristics. After 9 yr, *Zostera marina* meadows had 20x higher rates of areal productivity than 1 to 3 yr old meadows, double the organic matter and exchangeable ammonium concentrations, 3x more carbon and 4x more nitrogen, and had accumulated and retained finer particles than bare, unvegetated sediments. The long-term data indicate that at least a decade is required for these functions to be restored fully. Survivorship along a depth gradient showed that ~1.6 m (mean sea level) is the maximum depth limit for *Z. marina*, which matches the 'tipping point' for survival predicted for this system from a non-linear hydro dynamic/seagrass growth model. Seagrass meadow expansion 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%).

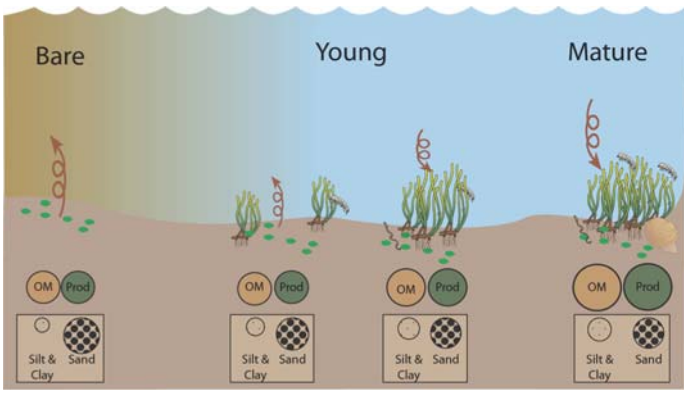

Fig. 4. Schematic showing changes in structural and functional aspects of the benthic community with a state change, resulting from large-scale restoration, from a bare sediment state to a seagrass-dominated state.

In 10-year old meadows, the relationships between ecosystem respiration and gross primary productivity changed significantly throughout the seasons, likely due to seasonal changes in shoot density and temperature. The meadow was in metabolic balance in fall, and was autotrophic in winter and early summer, and heterotrophic in late summer. This is the first study to show the impact of large-scale restoration on carbon accumulation in seagrass meadows. 10-year old meadows accumulated carbon at approximately 100 g-C$yr^{-1}m^{-2}$; 4-year old meadows accumulated carbon at approximately 45 g-C$yr^{-1}m^{-2}$. These data are being used by Restore America's Estuaries to develop a methodology to be approved by Verified Carbon Standards to establish guidelines for issuing carbon tax credits related to seagrass restoration.

Ecological implications invasion by a non-native macroalga

Gracilaria vermiculophylla is a cryptic, invasive red macroalga that is native to Southeast Asia and has invaded many temperate estuaries in North America and Europe. The high tolerance of this alga to desiccation and temperature stress has allowed it to proliferate on the marsh and mudflat where other macroalgal species cannot. Genetic analysis verified the widespread distribution and diversity of *G. vermiculophylla* in the Virginia coastal bays. Studies on the ecological impacts of G. vermiculophyll invasion show both positive and negative effects. An ^{15}N tracer addition experiment showed that the addition of this macroalga to marsh and mudflat systems subsidized nitrogen supply to the sediments, vegetation, and invertebrates. At the same time, *G. vermiculophylla* presence can increase rates of denitrification on mudflats. In addition, at current densities, *G. vermiculophylla* may increase food availability to, and foraging intensity of, migrating shorebirds.

On the negative side, pathogenic bacterial species (*Vibrio parahaemolyticus*) is found associated with *G. vermiculophylla* tissue. *V. parahaemolyticus* can cause severe gastrointestinal infections when raw or undercooked shellfish are consumed that contain the bacteria, and is therefore a serious concern for monitoring water quality regional fisheries. Recent results indicate that oysters growing on mudflats with mats of *G. vermiculophylla* have higher levels of *V. parahaemolyticus* in their tissue than those growing on bare mudflats.

Lagoon hydrodynamics and sediment transport

The hydrodynamic calculations of the FVCOM and Delft3D models were compared with measurements of currents and waves in Hog Island Bay from the winters of 2002 (one site, included estimates of suspended sediment concentration (SSC) as well as currents; waves not well resolved) and 2009 (focus wave on wave measurements from 5 sites). The results, shown in Fig. 5 for Delft3D, are good and give us confidence that the models are able to capture the important hydrodynamics and their spatial variations within the VCR.

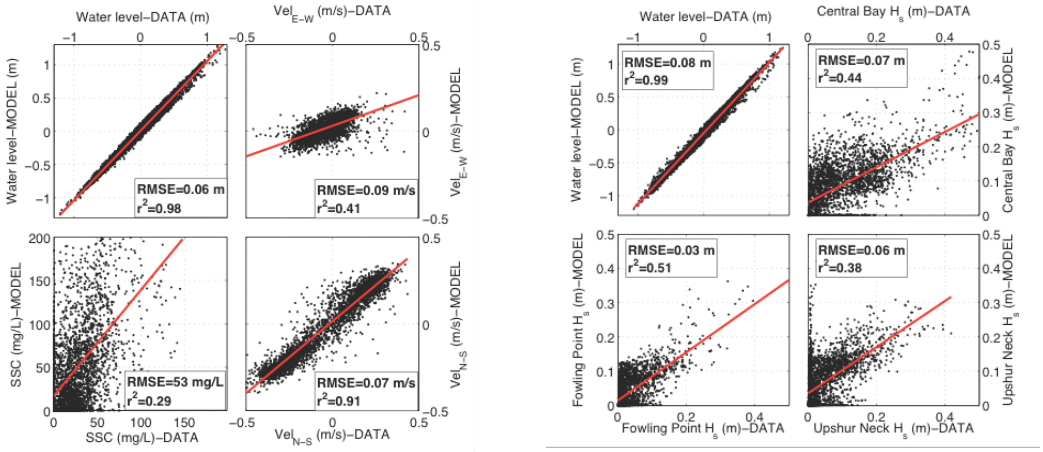

Fig. 5. Comparison of measured and modeled water level, velocity and suspended sediment concentrations in Hog Island Bay (left) in winter 2002 and water level and significant wave height at 3 locations in Hog Island Bay (right) in winter 2009.

Residence time calculations show a distinct pattern of increasing residence time with distance away from the inlet and shorter residence time for high-tide releases, as could be anticipated given that water that exchanges with the ocean every tidal cycle has the shortest residence time. No-wind simulations result in longer residence times than those with wind. Gargathy Bay (most northeasterly bay showing residence times in Fig. 6) has a longer and less variable residence time than the other bays that were considered due to its small size and relative isolation from the ocean. Mean residence time is smallest in Hog Island Bay and South Bay. Each bay exchanges water with the ocean through the 2 proximal inlets, with one inlet accounting for about 2/3 of the exchange in most cases. Exchange among bays is greatest for the central bays and lowest for South Bay.

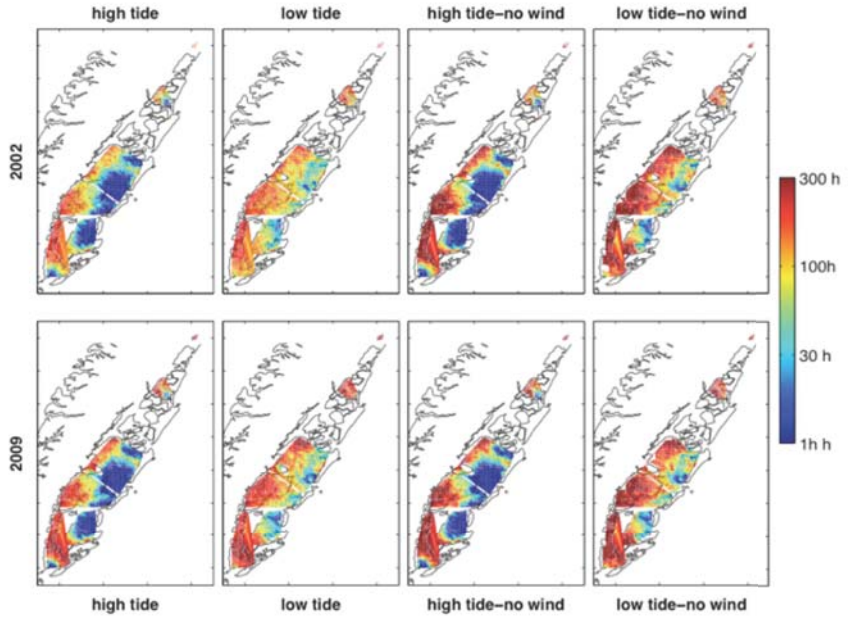

Fig. 6. Residence times calculated for 5 bays in the VCR using FVCOM for representative wind conditions (left 4 panels) and no wind (right 4 panels) in 2002 and 2009. Calculations were made based on the paths of neutrally buoyant particles released in the bay during low tide and high tide conditions.

Oyster reef armoring of mainland marsh shorelines

Site characterizations, wave measurements and erosion rate analysis from historical aerial photographs (1957 – 2009) from the 4 study sites were completed. Table 1 shows the general characteristics of each site. The 2 sites in Hog Island Bay (SEB3 and CRM4) were muddy and had larger natural reefs compared to the sandier sites near Ramshorn Bay (BT5 and BT6) where the reefs were constructed either from whelk shell or oyster castles.

Table 1. Characteristics of study marsh sites with adjacent oyster reefs.

	SEB3	CRM4	BT5	BT6
Shoreline length (m)	870	1,560	290	300
Sediment type	mud	mud	sand	sand
Reef area (m^2)	29,203	8,833	1,148	1,670
Oyster density (per m^3)	1,254	1,313	1,342	1,342
Reef base material	natural	natural	whelk shell	oyster castle, oyster shell
Distance from shore (m)	110	110	80	50
Biomass (g/m^2)				
Aboveground	45	64	62	41
Belowground	1,491	1,013	644	671
Burrow density	0.50%	0.85%	0.95%	1.30%

Rates of change of marsh edge position are given in Table 2, While all sites have exhibited long-term erosion, rates have not been constant. The results from the Box Tree (BT5, BT6) sites in particular indicate that erosion rates have increased significantly from the 1960s to the early 2000s. Since average wind and wave conditions in the VCR have not changed significantly over the last 50 years, it is unlikely that this can explain the variation in observed rates.

Table 2. Rate of change of marsh-edge position (m/yr) at the study sites.

	All years	1957-1966	1966-1994	1994-2002	2002-2009
SEB3	-0.18 ± 0.02	-0.30 ± 0.03	-0.21 ± 0.03	-0.09 ± 0.05	-0.12 ± 0.04
CRM4	-0.24 ± 0.01	-0.28 ± 0.02	-0.34 ± 0.02	0.24 ± 0.08	-0.40 ± 0.06
BT5	-0.13 ± 0.07	0.05 ± 0.13	-0.10 ± 0.06	-0.41 ± 0.12	-0.76 ± 0.14
BT6	-0.1 ± 0.02	-0.07 ± 0.02	-0.04 ± 0.03	-0.42 ± 0.09	-0.44 ± 0.09

Hydrodynamics and sediment motion within seagrass beds

Tidally driven flows, waves, and suspended sediment concentrations were monitored seasonally within a *Zostera marina* (eelgrass) meadow located in a shallow (1-2 m depth) coastal bay. Eelgrass meadows were found to reduce velocities approximately 60% in the summer and 40% in the winter compared to an adjacent unvegetated site. Additionally, the seagrass meadow served to dampen wave heights for all seasons except during winter, when seagrass density was at a minimum. Although wave heights were attenuated over the canopy (Fig. 7), orbital motions caused by waves were able to effectively penetrate through the canopy (Fig. 8), inducing wave enhanced bottom shear stress (τ_b). Within the seagrass meadow, τ_b was greater than the critical stress threshold (= 0.04 Pa) necessary to induce sediment suspension 80-85% in the winter and spring, but only 55% of the time in the summer. At the unvegetated site, τ_b was above the critical threshold greater than 90% of the time across all seasons (Fig. 9). During low seagrass coverage in the winter, near-bed turbulence levels were enhanced, likely caused by stem-wake interaction with the sparse canopy. Reduction in τ_b within the seagrass meadow during the summer correlated to a 50% reduction in suspended sediment concentrations, but in winter

suspended sediment was enhanced 2.5x compared to the unvegetated site. With minimal seagrass coverage, τ_b and wave statistics were similar to unvegetated regions; however, during high seagrass coverage, sediment stabilization increased light availability for photosynthesis and created a positive feedback for seagrass growth.

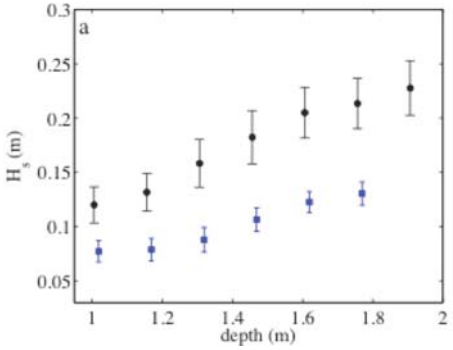

Fig. 7. Significant wave height plotted as a function of water depth for summer deployments (June 2010) at the seagrass meadow (blue squares) and compared to summer conditions at the unvegetated reference site (black circles). H_s data were averaged using a running mean with a 0.3 m averaging window for depth and 0.8 m s^{-1} averaging window for wind speed.

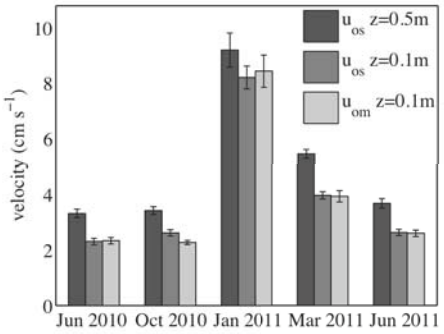

Fig. 8. Horizontal orbital velocities, u_{os}, above (z = 0.5 m) and within (z = 0.1m) seagrass meadows from spectral analysis, as well as expected orbital velocities, u_{om}, calculated via linear wave theory. Linear wave theory predictions were never significantly greater than horizontal orbital velocities measured from spectral analysis (one-way ANOVA, $p<0.05$). Error bars represent ±1 standard error.

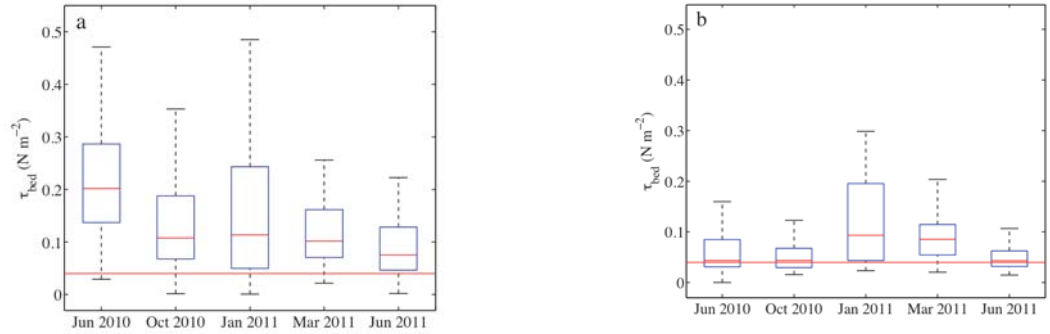

Fig. 9. Bed shear stress, τ_b within the (a) unvegetated site and (b) seagrass meadow. Horizontal line within the box indicates median τ_b, while the lower and upper edges of the box represent the 25th and 75th percentiles respectively. Whiskers extending from the box indicate the minimum and maximum measured τ_b. Horizontal red line across both plots represents the critical stress threshold for the suspension of sediment.

Flow dynamics and larval settlement onto intertidal oyster reefs and adjacent restoration sites

Restoration efforts to enhance *Crassostrea virginica* oyster populations along the Virginia coastline are focused on creating benthic habitat suitable for larval recruitment, survival and growth. To determine how benthic flow processes impact larval recruitment, velocity and turbulence data were collected over multiple intertidal benthic surfaces including a mud bed, a *C. virginica* oyster reef, and two restoration sites comprised of deposited *C. virginica* oyster shell or the relatively larger *Busycom canliculatum* whelk shell. Mean estimates of the drag coefficient, C_D, used as a measure of hydrodynamic roughness, over the *C. virginica* reef were found to be 2 times greater than the restoration sites and 5 times greater than the mud bed. Enhanced fluid shear increased both peak Reynolds stresses and vertical momentum transport above the reef, but within the interstitial areas between individual oysters, velocities and turbulence were reduced. Larval settlement plates of varying triangular-shaped benthic roughness

were used to mimic the natural topographic variability found along oyster reefs. The greatest larval recruitment occurred along interstitial regions between high-roughness topography (Fig. 10), where shear stresses and drag forces, which act to dislodge larvae, were found to be up to 20 times smaller than along exposed surfaces (Fig. 11). Greater recruitment was also found on the more hydrodynamically rough whelk shell compared to the oyster shell restoration site. Results suggests that restoration efforts should consider creating 3-dimensional benthic topography similar to established oyster reefs to provide hydrodynamic conditions and settlement surfaces that promote larval recruitment, prevent burial by sediment, and provide refuge from predation.

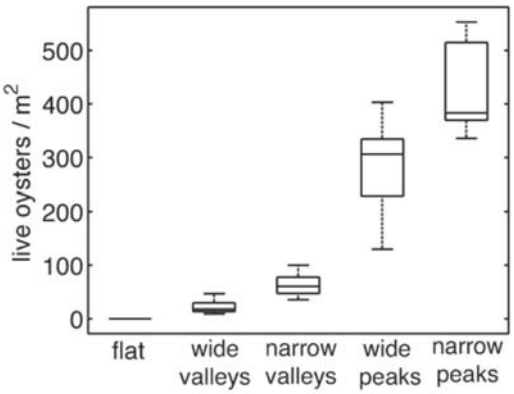

Fig. 10**.** Recruitment of juvenile oysters on settlement plates. The peaks of structures (upper half of roughness elements) along narrow spaced roughness (height:roughness= 2) had the greatest recruitment and the valleys of structures (lower half of roughness elements) with wide spaced roughness (height:spacing= 1) had the least recruitment. No recruitment was found on the flat settlement plates. Horizontal line within the box indicates median, while the lower and upper edges of the box represent the 25th and 75th percentiles respectively. Vertical lines extending from the box indicate the minimum and maximum measured oysters m^{-2}.

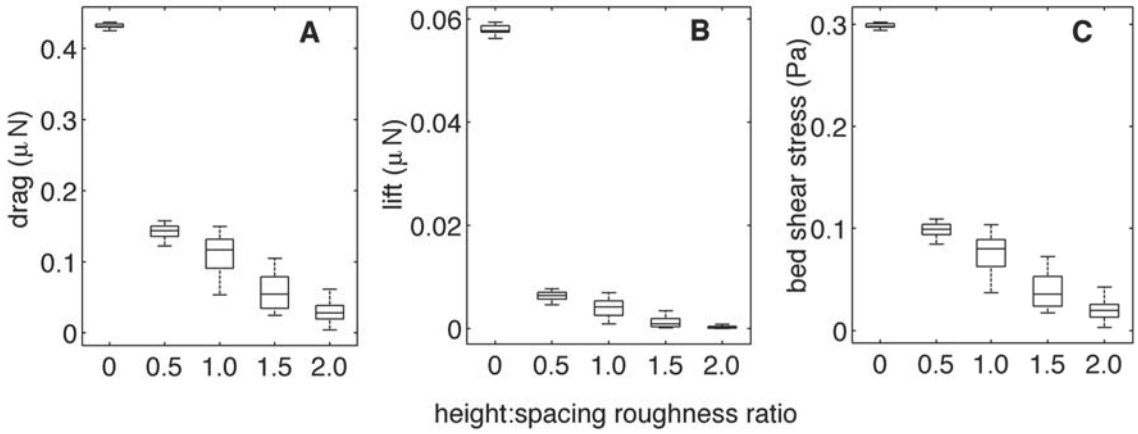

Fig. 11. (A) Drag and (B) lift forces on a 300 μm diameter larva settled along the surfaces of various height:spacing ratio topography. Values shown are for a mean flow of 15 cm s^{-1}, while similar trends occurred for all other mean flows tested between 5 and 20 cm s^{-1}. A height:spacing ratio=0 indicates the surface was flat. (C) Bed shear stress along the surfaces of various height:spacing ratio topography. Settlement location was along the mid-point of the roughness, as shown in Figure 9. Horizontal line within the box indicates the median value, while the lower and upper edges of the box represent the 25th and 75th percentiles respectively. Vertical lines extending from the box indicate the minimum and maximum measured values.

A dynamical model for the coupled evolution of channels and tidal flats

The morphological model shows that, without wind waves, a flat bottom is unstable and the only stable configuration is a channel without tidal flats (Fig. 12). For intermediate wave conditions, a non-trivial stable equilibrium arises, characterized by a channel flanked by tidal flats. Intense waves suppress the channelization process, and a flat bed becomes then only stable equilibrium. Finally, relative sea level rise allows the coexistence of channels and tidal flats, even in absence of waves.

Modeling the effect of tides and waves on benthic biofilms

Model results show that, for disturbances with the same intensity, the biofilm is eroded or not depending on its current biomass, which is a function of the past trajectory of growth. Because of the

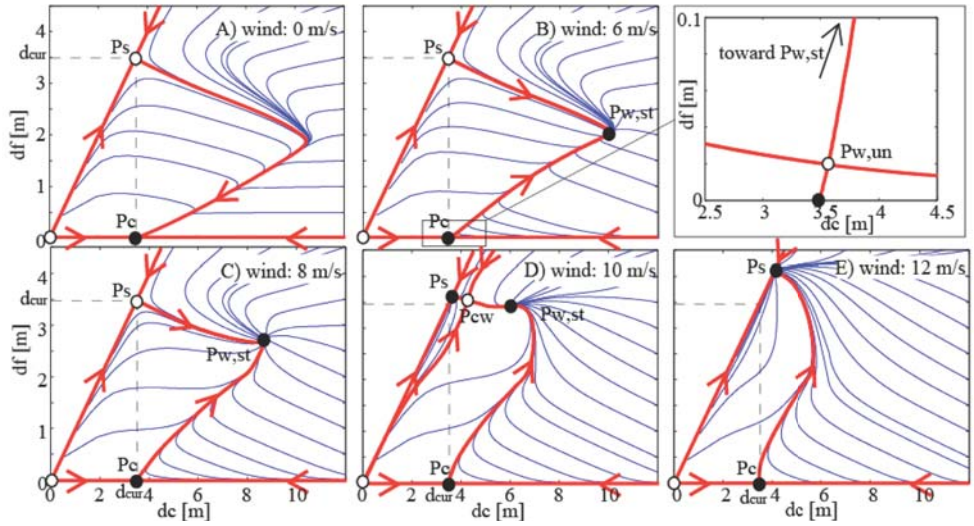

Fig. 12. Phase space plot of channel depth (dc) and tidal flat depth (df). Wind speed is varied from 0 to 12 m/s. The major stable (solid dots) and unstable points (empty dots), manifolds (red lines), and some indicative trajectories (blue lines) are reported.

finite time needed for a biofilm to develop, both the intensity and frequency of periodical disturbances, such as tidal currents, determine whether the biofilm can approach its equilibrium biomass (Fig. 13). Spring-neap tidal modulation favors biofilm development, since the reduction of the current shear stress associated with neap tides allows biofilm growth, thus increasing biostabilization and the biofilm's likelihood to withstand the subsequent energetic spring tides. On the other hand, diurnal tidal modulations are negative for biofilm development, because the diel biofilm growth is almost negligible. Under stochastic disturbances associated with wind waves, there are two most probable states for the biofilm biomass: either close to zero or close to the equilibrium value, depending on wave intensity. If biostabilization is reduced or eliminated, the probability of intermediate values for biofilm biomass also becomes significant. The role of biostabilization is hence to exacerbate the probability of the end-member states. Finally, because of the non-monotonic relationship between water depth and wave induced bed stresses, only extremely shallow and deep areas favor biofilm persistence. If light attenuation with depth is considered, deep water becomes unsuitable for biofilm growth when water turbidity is high.

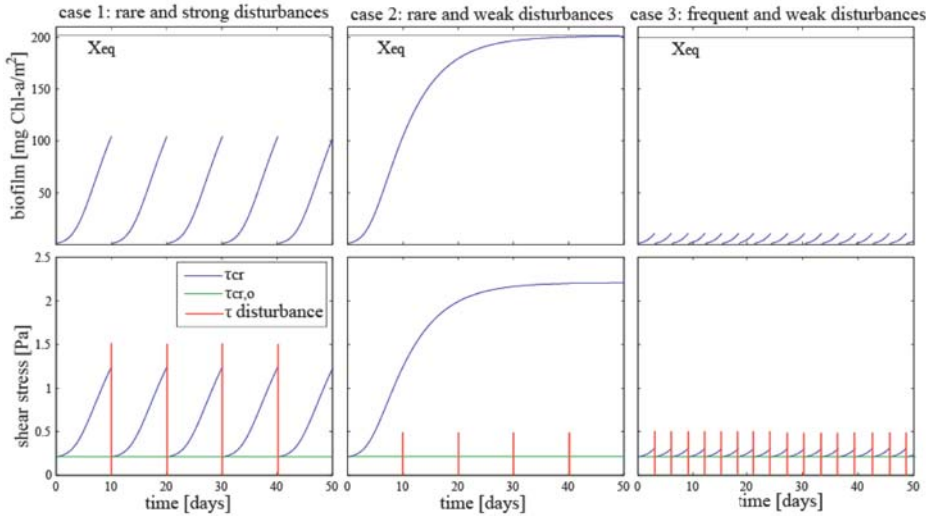

Fig. 13: Biofilm dynamic under three scenarios of deterministic, single frequency, hydro-dynamic disturbances. The upper panels show the biofilm biomass, the bottom panels show the biofilm's critical shear stress and the disturbance's shear stress.

Back-barrier flooding by storm surges and overland flow

Low-elevation areas within a sandy barrier island are subject to flooding via saturating overland flow following moderate storm surges and rainfall events (Fig. 14). Results of simple hydrology models using a high-resolution topographic survey show that return flow velocities are of the same magnitude as the critical velocity necessary to mobilize sand when a hydraulic connection between the watershed and back-barrier bay is present. Storms of moderate strength and rainfall intensity may be sufficient to keep the return channels open within the back-barrier, thus providing natural conduits for water exchange from overwash events during extreme storm surges triggered by hurricanes.

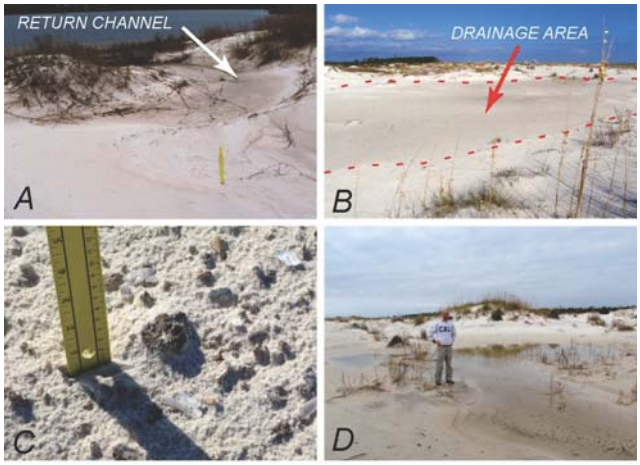

Fig. 14. a) Return channel surveyed on November 24, 2009; b) drainage area connected to the return channel indicated in a) the dotted line separates the dry sand from the moist sand after the storm of December 2, 2009; c) rainsplash effect on sand substrate, indicating 1cm deflation; d) water ponding on sand after the storm of December 2 2009.

Channel-tidal flat sediment exchange: The channel spillover mechanism

From velocity profiles and suspended sediment concentrations, a lateral circulation, perpendicular to the direction of the main channel, was observed to be associated with high sediment discharge directed from the channel to the tidal flat at the beginning of flood. This sediment discharge is able to explain the turbid tidal edge, which is a common feature of many tidal flats. An analytical model describing the lateral circulation and a conceptual model describing the sediment spillover from the channel indicates that the tidal flat sediment dynamics are strongly influenced by the sediment input from the main channel during fair weather, a process that is often overlooked in simplified models of tidal flat morphodynamics.

Modeling landscape-level effects of seagrass meadow patchiness on sediment suspension

Because of the down tidal current direction sheltering effect of a meadow, seagrass meadows footprint an area larger than they inhabit. This introduces an effective fractional cover of seagrasses on a landscape, which has important controls on the distributions of shear stress, suspended sediment and the resulting light environment across the landscape. As fractional cover increases, the effective fractional cover increases dramatically, whereas, given a homogenous meadow landscape, disturbances on that landscape, the effective fractional cover diminishes slowly. This hysteresis in effective fractional cover has significant implications regarding the resilience of contiguous seagrass landscapes to disturbances that remove fractional cover. Moreover, modified optimum landscape light environments in meadows appear in depth ranges in which the light environment of a bare landscape is inhospitable to establishment of seagrass meadows, introducing the notion of optimum habitats existing in low resilient states.

Subsidies to aquacultured hard clams

There were significant distinctions among source materials in their isotopic composition, especially when considering three isotopes. Deuterium was most useful in separating seagrass (*Zostera marina*) and marsh grass (*Spartina altenaflora*) from algae. Further, some species of macroalgae (e.g. *Ulva lactuca*) had distinct deuterium signatures. A Bayesian mixing model that formally incorporates uncertainty in isotope measurements (sampling error) and isotopic processes such as fractionation to evaluate clam isotopic composition showed that clams rely mainly on a combination of macro- and

microalgae (Fig. 15a, b, c). Several species of macroalgae are important resources (Fig. 15b). When sources are grouped, the strong contribution of macroalgae is evident (Fig. 15d). Clams likely use macroalgal detritus, fragmented living macroalgae particles, and possibly macroalgal dissolved organic matter. Microalgae are also an important food resource (Fig. 15c, d).

Support of clam aquaculture is an ecosystem service provided by the VCR coastal lagoons. The resource use determined by our study is significant in this regard because resource abundance and availability may change as a function of eutrophication, species invasion, sea-level rise, and climate warming. Further, in most aquaculture settings phytoplankton and/or benthic microalgae are the main clam resources. This is not the case in the VCR. Pace and new M.S. student Kyle Emory are now beginning a study to determine if macroalgae are also key sources of organic matter supporting the abundant oyster populations and scallops - a re-emerging resource species in seagrass medows.

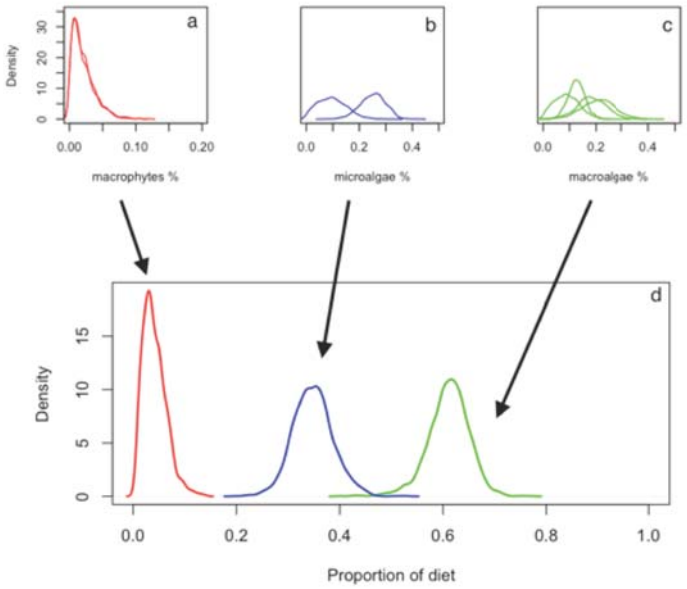

Fig. 15.. Probability distributions of post-model grouping of sources as macrophytes (red), microalgae (blue), and macroalgae (green). Small panels (a–c) show posterior distributions from Bayesian model of individual sources from each of the 3 groups which were summed to form post-model group distributions (d).

Metabolism of coastal streams

The open water technique for measuring stream metabolism showed that the impact of changing weather such as heat waves, drought, and storms could be quantified. With the eddy correlation technique, shorter-term effects of hour-to-hour perturbations in temperature, water velocity, and sunlight could be quantified. Fluxes calculated using the open water technique were 250 mM less than concurrent fluxes calculated using the eddy correlation technique (Fig. 16). The differences may be in part due to lateral groundwater inflow, which would occur within the footprint of the open water technique but generally outside of the footprint of the eddy correlation technique, which was aligned on the center of the stream.

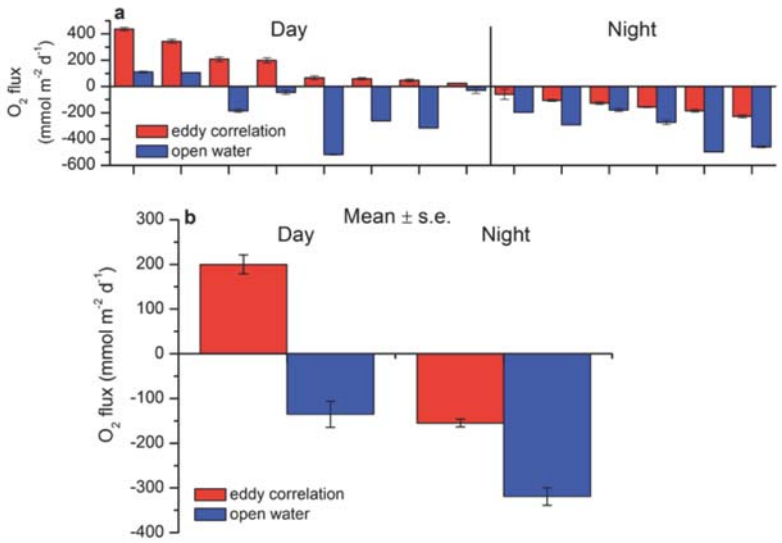

Fig. 16. Paired oxygen fluxes calculated using the eddy correlation and open water techniques where the method footprints overlapped for identical time intervals. **a** Ranked by eddy correlation oxygen flux there was no time interval in which the open water flux exceeded the eddy correlation flux. **b** The difference between the fluxes measured by the two techniques indicates that different proportions of metabolic processes are determined by them. Specifically, lateral groundwater inflow may be more represented in open water fluxes.

Dynamic interactions between barrier islands and marshes

Preliminary experiments indicate that if back-barrier conditions are conducive to fringe marsh development, island migration rates decrease because reduced accommodation space behind the island decreases the amount of sand that must be eroded from the shoreface to maintain island position above sea level. However, once the marsh has existed long enough for it to be exposed at the shoreface (as a stratigraphic layer), island migration rates will increase because there is less sand available in the shoreface (since the marsh unit is made up predominantly of fine-grained sediment). In this case, more of the shoreface must be eroded to liberate the same amount of sand. Initial results also suggest the potential for climate change to alter the feedbacks between barrier islands and back-barrier marshes. For example, as storm intensity increases, the delivery of more sand to fringing marshes through overwash may increase the rate at which they aggrade and prograde. At the same time, a higher rate of sea level rise will increase erosion at the fringing marsh edge. Model experiments suggest that which processes ultimately win out will depend on factors such as sea-level rise rate, antecedent morphology and marsh composition.

The role of ecomorphodynamic feedbacks in barrier island response to climate change

Consistent with observations, model results indicated that dune morphology depends primarily on grass species, with some grasses building long dune ridges and others creating sparse hummocky dunes, while some grasses may even prevent dune formation. In a next step, Moore added the effect of storms to study the evolution of island relief under a series of storm impacts. By changing average storm intensity and impact frequency, it is then possible to mimic some of the potential effects of climate change. For a sufficiently low storm frequency, and constant, moderate storm intensity, dunes were able (on average) to recover from an impact before the next storm occurs. In this case, dunes were only partially eroded during a storm, allowing them to eventually re-attain their potential maximum size for a given set of external conditions. Under such a scenario, the island reaches a relatively stable "high elevation" state having minimum vulnerability to storms. In contrast, for a sufficiently high storm frequency, the island entered a feedback of ever more-widespread overwash and increasing dune erosion, leading to an ever weaker dune recovery. Hence, the island ends up in a "low elevation" state having maximum vulnerability to storms. Therefore, by increasing storm frequency from one run to another as an initial proxy for different climate change scenarios, the island transits from a "high" to "low" state nonlinearly, such that a small increase in frequency leads to an abrupt change in vulnerability.

Potential geomorphic consequences of wave climate alterations along cuspate coastlines

Initial results of a comparative study between Virginia and North Carolina suggest that the influence of shoreline stabilization efforts (primarily beach nourishment, one jetty and a few groins) has overwhelmed any wave-climate change response that may otherwise have been detectable surrounding Cape Fear, NC. For Fishing Point, VA there were no discernable wave-climate related trend in shoreline change, suggesting that wave climate changes have not been of a significant magnitude to significantly influence patterns of erosion and accretion along this stretch of coastline. Coastline Evolution Model (CEM) simulations that account for beach nourishment, jetty emplacement and an increasingly high-angle wave climate produced shoreline change rate differences that were comparable to observations. This work suggests that in areas of increasing wave energy, shoreline stabilization efforts may temporarily mask the effects of changing wave conditions on coastline response, but that changes in coastal response may be discernable via changes in shoreline stabilization efforts.

Barrier island vegetation dynamics in response to climate change

Considering impacts of predicted increases in sea-level, storms, and alterations in precipitation patterns on geomorphological and associated ecological processes, woody vegetation dynamics may serve as sentinels to climate change on barrier islands. Young and Zinnert examined island-scale conversion of land (i.e. sand to grassland to woody cover) and related patterns to the importance of climate variables on the rate of woody expansion. Light Detection and Ranging (LiDAR) was used to evaluate potential distribution of woody species based on distance to shoreline and elevation. Using Landsat TM imagery, changes in island size and vegetation classes (1984 – 2010) revealed conversion of grassland to woody cover (285% increase) that was closely linked to air temperature, precipitation, and atmospheric [CO_2].

LiDAR data indicated that woody species have not expanded completely into their potential range (Figs. 17, 18). These results suggest that woody species are responsive to climate change, thus serving as sentinels on Virginia barrier islands.

Landsat TM data (Fig. 19) showed that the normalized difference vegetation index (NDVI) is a good indicator of groundwater availability in dry years (2007) as the freshwater lens becomes the main source of water for woody vegetation due to high ET and low precipitation. During wet years (2004), water table depth was relatively stable as water uptake by plants was compensated by rainfall-infiltration events. These findings have helped Young and Zinnert to develop a conceptual model for bistability which will be tested. Fifty groundwater wells and ~100 seed traps have been installed across the active shrub thicket encroachment zone on the southern third of Hog Island. These measurements will be supplemented with microclimatic measurements of surface soil temperature in shrub thicket, grassy swale and in the transition zone.

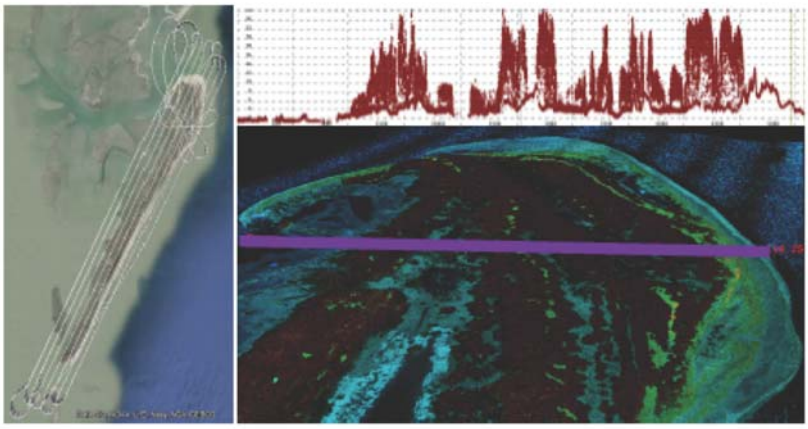

Fig. 17. (Left) LiDAR flight lines over Hog Island. The star pattern on the northern end represents the multiple flight orientations. (Right) LiDAR data on the northern portion of the island. The top graph shows the data points across the purple transect.

Fig. 18. Current habitat (red) and potential range (gray) range of woody expansion using recent LiDAR data and the habitat polygon of *Myrica cerifera*. The theoretical niche of *M. cerifera* occupies 92 ha of Hog Island, leaving 54% unoccupied and available for future expansion.

Bachman's remote sensing

A priority for the remote-sensing campaign was to collect and model relationships between hyperspectral imagery, acquired from the aircraft at a variety of different phase angles, and geotechnical properties of beaches and tidal flats as well as biophysical properties of vegetation. The phase angle is the angle between the vectors linking the positions of the sun and the sensor to a particular point on the ground. In addition, detailed measurements of the so-called "hot spot" (vegetation) or "opposition effect" (granular surfaces) were emphasized. This phenomenon is the well-known increase in reflectance in the vicinity of zero phase angle (the retro-

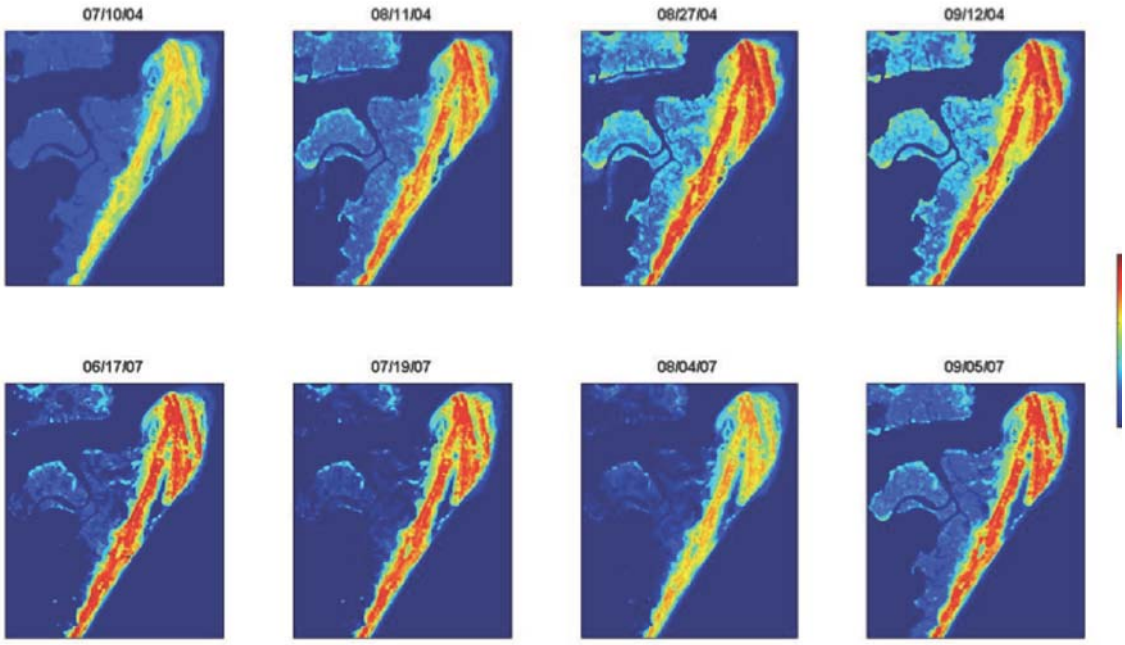

Fig. 19. NDVI from Landsat TM5 images along the growing season in 2004 and 2007

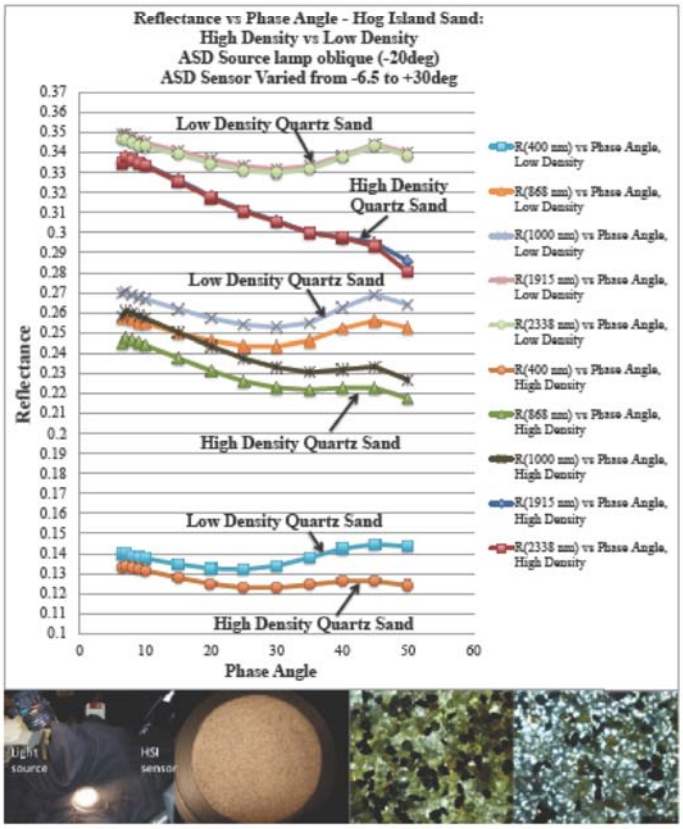

Fig. 10. Hyperspectral reflectance varies in characteristic ways with phase angle depending on sand density. This can be exploited to estimate sand density from single- and multi-look HSI. (Bottom, left) Table-top goniometer configuration with ASD light source and spectrometer and sand sample in Delrin holder; (bottom, right) sand samples in higher (left) and lower density (right) cases imaged.

reflectance direction). The shape of the hyperspectral reflectance about the retro-reflectance direction is closely related to important geophysical parameters such as grain size and density (for granular surfaces) and biophysical parameters such as biomass and leaf area index (LAI) for vegetation (Fig. 20).

Economic valuation of ecosystem services

Using data from a framed field experiment with residents of Virginia in Accomack and Northampton Counties, VA, Swallow and Ph.D. student Smith estimated resident's willingness to pay (WTP) (a measure of economic value) for restoration of half-acre units of seagrass or bird habitat using a theoretically valid method (incentive compatible) to obtain the WTP estimate. They showed that bids through the Lindahl-inspired auction process fell within the confidence interval for WTP for marginal (half-acre) units of ecosystem restoration; this result is contrary to the 90-years of consensus in economics on Lindahl's theory, and represents the first direct experimental test of that theory. In addition, the research estimated that participants in this experiment were willing to pay $20 - $65 for half-acre units of restoration in the Lindahl-inspired auction, with higher bids offered for the first few units of restoration and bids declining as more restoration was implemented. These empirical results demonstrated a real commitment of economic resources from the volunteers participating in the field experiment.

Virginia Coast Reserve (VCR) LTER ANNUAL REPORT 2011 - 2012

Major Activities

Site Science and Collaborative Research

Seagrass state change in coastal bays

In shallow coastal systems, seagrasses provide important ecosystem services including stabilizing sediment, sequestering carbon (C) 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 (VIMS) and The Nature Conservancy (TNC) in a large-scale ecosystem-level experiment to reverse the state change. This has resulted in >17 km^2 of restored habitat in a chronosequence of seagrass meadows 0 – 10 years since seeding. P.I. Karen McGlathery and her students continued annual monitoring of this long-term experiment, including measurements of plant (production, biomass, areal coverage, nitrogen and carbon sequestration) and sediment (organic and nutrient content, grain size, carbon storage) characteristics and faunal diversity and abundance. In addition, McGlathery's students are working on individual projects related to the seagrass state change, including: (1) M.S. student Jennie Rheuban's study on benthic metabolism using the new eddy correlation technique; (2) M.S. student Jill Greiner's study of carbon burial in restored seagrass meadows – this study is the basis for a new collaboration on using the VCR restoration to demonstrate the potential for carbon tax credits; (3) M.S. student Alia Al-Haj's study of variation in light requirements of eelgrass in relation to sediment characteristics and the implications for habitat suitability; and (4) Ph.D. student Laura Reynolds studies on the genetics of seagrass restoration and metapopulations along the U.S. Atlantic coast. Ph.D student Joel Carr and P.I. Steve Macko are characterizating $\delta^{13}C$ and TOC in marine sediments of the VCR coastal bays to identify sources of carbon before and after the state change.

Ecological implications invasion by a non-native macroalga

Species invasions can have both positive and negative effects on trophic structure and habitat composition and function. *Gracilaria vermiculophylla* is a widespread invasive macroalga that is highly tolerant of stress and can therefore form dense aggregations in a variety of subtidal and intertidal habitats. As part of on-going studies on the impacts of G. vermiculophylla to intertidal habitats, Ph.D. student Dana Gulbransen and Karen McGlathery addressed the question of mats *G. vermiculophylla* associated with intertidal oyster reefs acted as a reservoir for toxic bacteria within the *Vibrio* genus and thus affected water quality and the safety of oyster consumption in VA.

Hydrodynamics and sediment motion within seagrass beds

P.I. Matthew Reidenbach and Ph.D. student Jennifer Hansen finalized their ongoing project within South Bay, studying boundary-layer flow dynamics and the deposition and erosion of sediments within the bay. This study was performed in the coastal lagoons off the Delmarva Peninsula in South Bay, Virginia during three different times of the past year: January, May and June 2011, while analysis and writing was performed in Fall 2011 and Spring 2012. Flow and sediment dynamics were quantified using Nortek acoustic Doppler velocimeters (ADVs) and optical backscatter systems (OBSs) deployed in tandem for 72 hours. Water velocity, turbulence, and wave dynamics were correlated with *in situ* turbidity and therefore sediment transport mechanisms were explored. In addition, M.S. student Emily Thomas studied large scale flow and attenuation of waves across the seagrass bed. Four Richard Branker Research (RBR) wave and tide recorders were deployed for 18 day periods at 4 different times of the year between 2011-2012 to determine the impacts of seagrass growth and senescence on wave activity and sediment transport.

Modeling landscape-level effects of seagrass meadow patchiness on sediment suspension

Some authors have linked disturbances and environmental conditions to seagrass meadow patchiness and general meadow landscape patterns. However, the effect of patch density on sediment resuspension and the resultant light environment as it pertains to seagrass growth and survival, and the emergence of bistable dynamics, has not been studied. Over the past year, post-doctoral associate Joel Carr and P.I. Paolo D'Odorico have developed a simplified modeling approach to explore how the patchy structure of seagrass meadows on a landscape may affect sediment resuspension and the consequent light environment under tidal and wind-wave forcing. The presence of seagrass affects sediment suspension, and may influence the sediment supply available for accretion in adjacent salt marshes. Carr, D'Odorico, and P.I. Sergio Fagherazzi are developing a coupled lagoon salt march bio-geomorphological model to investigate the possible feedbacks and transitions between coastal morphological features and the presence or absence of seagrass and marsh vegetation.

Economic valuation of ecosystem services related to habitat restoration and/or loss

Ph.D. student Liz Smith, working with collaborator Steven Swallow tested whether economic incentive mechanisms could be used to lead ordinary citizens to make bids that reflect their personal benefit for the provision of public goods, such as the restoration of seagrass and bird habitat in the VCR. The research created a novel auction process that tested the practicality of "Lindahl Pricing," suggested by Eric Lindahl in 1919. A survey is also being developed to establish a more clear understanding of the range of ecosystem resources or ecosystem services that may be of high value to different segments of the residents near the VCR. The survey data will provide background data on how habitat valuation influences priorities for coastal management and policy.

Lagoon hydrodynamics and sediment transport

P.I. Patricia Wiberg and post-doctoral associate Ilgar Safak used two open source models that account for circulation, surface waves, wave-current interaction, and sediment processes (FVCOM and Delft3D) to investigate hydrodynamics (wind- and tide-induced circulation, surface waves, particle residual time) and sediment transport due to combined wave-current flow in the barrier island-lagoon-marsh system of the Virginia Coast Reserve. FVCOM (Finite Volume Coastal Ocean Model, Chen et al., 2003) is an unstructured grid hydrodynamic model that is fully coupled with a surface wave model and a 3-D Lagrangian particle tracking model. Delft3D (Lesser et al., 2004) has a stronger focus on morphodynamics, and version 4.0 has been open source since January 2011. The models were validated with field observations of waves and currents in Hog Island Bay from the winters of 2002 and 2009; the 2002 data also include indirect data on suspended sediment concentration.

Water and particle exchange within the VCR and between the VCR and the ocean was examined with the Lagrangian particle-tracking module of FVCOM. Five bays with varying bathymetry and coastline geometry were modeled: Hog Island Bay, South Bay, Magothy Bay, Gargathy Bay and Cobb-Outlet-Ramshorn-Shallow Bay (CORS Bay). Residence time is calculated from the lengths of time that neutrally buoyant particles released in the bays remain in the bays. The effects of tidal phase of particle release, winds and particle release locations on residence time are investigated. The results are also used to identify the bay capture areas of the tidal inlets in the VCR. They are also investigating the effects of wave-current flow on sediment redistribution within the bays in response to storms over event and seasonal time scales. This is being done with Delft3D.

Changes in marsh spatial coverage in response to climate change (sea-level rise, storms)

M.S. student Sean McLaughlin, P.I.s Patricia Wiberg and Karen McGlathery, and post-doc Ilgar Safak have been examining the relationship between rates of retreat of marsh edges fringing Hog Island Bay and wave energy or power at the marsh edges. Wave energy dissipation on the marsh edge is expected to be the main driver of marsh-edge erosion for marshes facing open water. Initial analysis of erosion rates and wave power at the study sites did not reveal a significant relationship. However, a recent study (Marani et al 2012) suggests that a stronger relationship may exist between wave power and volume of marsh erosion rather than between wave power and the linear rate of marsh retreat. The implication is that high marsh edges may erode more slowly than low edges. To investigate this possibility, initial surveys of marsh-edge elevation at the study sites was extended to the larger extent of

each marsh edge considered in the erosion analysis. Wave power was recalculated for each site, dividing the sites into segments to capture variations in edge orientation that might change the effective wave power at the marsh edge. The results are being compared with the results found by Marani et al (2012) in Venice Lagoon.

Numerical models of salt marsh and tidal flat bistability

Salt marshes are delicate landforms at the boundary between the sea and land. These ecosystems support a diverse biota that modifies the erosive characteristics of the substrate and mediates sediment transport processes. P.I. Sergio Fagherazzi's work focuses on developing models that describe the coupling between geomorphological and ecological processes and on how feedbacks influence the fluxes of water, organic matter, and sediments in salt marshes in the context of long-term climatic change (Fig. 1). The numerical models capture the dynamics of the marsh-open water boundary and the progradation or regression of the marsh over time. Tidal channels are also key features of the marsh landscape, influencing flooding and draining of the marsh platform and providing a source of sediments and nutrients to the marsh ecosystem.

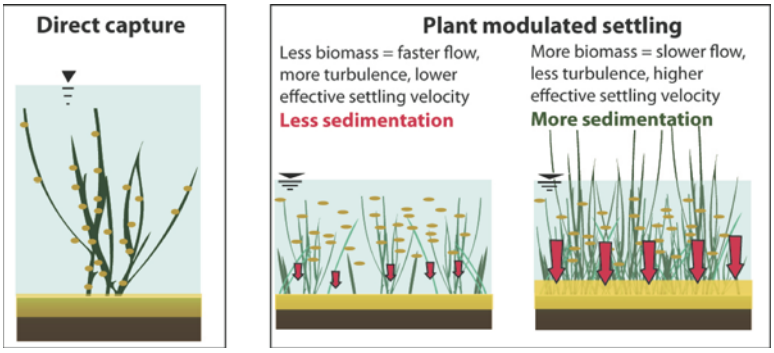

Fig. 1. Cartoon showing plants capturing suspended particles and affecting particle settling rates.

Fagherazzi and Ph.D. student Guilio Marani have developed a dynamical model for the morphological evolution of channels and tidal flats. Both channels and tidal flats are schematized as sediment reservoirs, whose depths are the only two dynamical variables of the system. The two reservoirs exchange sediments through the tidal dispersion mechanism. The reference concentrations are determined by currents and waves, which are function of the geometry of the system. The hydrodynamic component of our simplified model is compared to the numerical model Delft3D, showing good agreement. Fagherazzi and his students have also developed a simple model for tidal flats that includes the growth of a benthic biofilm subject to variable hydrodynamic disturbances and the effects of the biofilm on erodability (biostabilization).

Low-elevation areas within a sandy barrier island are subject to flooding via saturation overland flow following moderate storm surges and rainfall events. Using a high-resolution topographic survey and simple hydrology models, Fagherazzi and his students estimated the discharge and velocities from storm surge return flow and saturation overland flow.

Fagherazzi and his students also evaluated the influence of tidal channels on sediment transport and tidal flat morphodynamics. Velocity profiles and suspended sediment concentrations were simultaneously measured by for 46 days in a major flow-through channel, in a dead-end tributary channel, on the channel bank, and on the adjacent tidal flat, encompassing periods with and without wind waves.

Oyster reef armoring of mainland marsh shorelines

M.S. student Sara Taube, working with P.I. Patricia Wiberg, is investigating the role of oyster reefs in the protection of mainland salt marshes. Previous studies have shown that oyster reefs can help to mitigate erosion of the marshes behind them, with some measured erosion rates that were negative (i.e., lateral accretion). They have focused on four marsh sites along the mainland of the Virginia Eastern Shore, all of which face seaward onto open water but are partially blocked by oyster reefs: 2 sites near Ramshorn Bay in the area known as Box Tree and 2 sites near the most landward edge of Hog Island Bay. Each site has been characterized in terms of sediment size, elevation, biomass density and species, crab burrow counts, waves and tidal currents. To delineate shoreline position through time, Sara made GPS surveys over the course of a year and analyzed digital photographs from as far back at 1956. Waves were measured on both sides of reefs in the study sites for a 2-week period to characterize the wave conditions

and to quantify wave dissipation from one side of the reef to the other. Currents were measured near the reef ends. One of the study sites (Box Tree Marsh) has been selected by TNC for an experimental oyster reef emplacement to determine its effect on the adjacent marsh.

Flow dynamics and larval settlement to intertidal oyster reefs and adjacent restoration sites

P.I. Matthew Reidenbach and M.S. student Elizabeth Whitman collaborated with Barry Truitt of The Nature Conservancy (TNC) to determine how the composition, topography, and benthic roughness of the ocean floor impacts settling success of oyster larvae.

Subsidies to aquacultured hard clams

The VCR supports extensive bivalve populations. This past year, P.I. Michael Pace and M.S. student Kelly Hondula completed a study of the organic matter sources that provide support to aquacultured hard clams (*Mercenaria mercenaria*). They used stable isotopes of carbon (C-13), nitrogen (N-15), and hydrogen (H-2) to study contributions of various materials to clam diets. Potential sources included terrestrial vegetation, marsh grass, seagrass, several macro-algal species, benthic micro-algae, and phytoplankton. They were also particularly interested in the specific issue of whether deuterium (H-2) is a useful tracer for food web studies in the VCR and by inference in other coastal ecosystems.

Watershed nitrogen loading to coastal bays

P.I. Aaron Mills and collaborator J. Herman continued long-term monitoring of the watersheds draining into the coastal bays. Permanent gauging stations are operating in 5 streams for which there are now multi-year records of stream stage. Point measurements of stream discharge are used to develop rating curves for the conversion of stream stage to discharge. In addition, a drive-point manometer is being used in 6 streams to obtain vertical groundwater head profiles and samples from incremental depths in stream sediments to obtain profiles of nitrate concentration in the zone immediately beneath the sediment surface. M.S. student George McFadden is making these measurements across transects in each stream to get a detailed view of the spatial heterogeneity with respect to nitrate discharge in each of the streams. Two M.S. students are addressing processes that remove nitrogen from coastal streams and thus decrease nitrogen loading to adjacent coastal bays. Meg Challand is determining the extent to which water column processes such as photosynthetic production reduce nitrate concentrations in stream waters beyond that afforded by denitrification in stream sediments. Anne Dunckel is measuring at the production of N_2O during denitrification in stream sediments, and how changing climate conditions (most notably temperature) can increase or decrease the proportion of denitrification products that are N_2O.

Metabolism of coastal streams

Stream metabolism is important to not only understand the respiration and storage of terrestrial carbon, but also for its impact on downstream water quality. Freshwaters are responsible for storing or transforming over half of net terrestrial ecosystem production, and riverine respiration is a driver of nitrogen removal through denitrification. Ph.D. student Dirk Koopmans and P.I. Peter Berg are quantifying the drivers of seasonal metabolism in a stream ecosystem by applying the traditional open water diel change technique in conjunction with the eddy correlation technique developed by Berg. They used propane additions to determine a depth-dependent piston velocity for the stream and calculated a continual open water oxygen flux during each season. When the open-water measurements were made they also used the eddy correlation technique intermittently to calculate the oxygen flux across a well-defined area of the stream for comparison.

Marsh dynamics in response to sea-level rise and nitrogen enrichment

P.I.s Blum and Christian are continuing the long-term records or marsh elevation changes (Surface Elevation Tables, SET) and End-of-Year Biomass (EoYB). Kirwan et al. (2012) used the data to assess the inter-annual and inter-site variation in EoYB of *Spartina alterniflora* and the 'tipping point' of marsh vulnerability to sea-level rise. M.S. student Traci Davis, working with P.I. Enrique Reyes is addressing inter-annual and inter-site variation in EoYB for high-marsh plants. M.S. sudent Talia Dibbell is working with P.I.s Linda Blum and Matt Kirwan to determine the optimum elevation for *Spartina alterniflora* production (Fig. 2). These projects will support modeling efforts to predict effects of sea-

level rise on the distribution of marshes across the VCR landscape (Kirwan, Fagherazzi, and Reyes). Christian and Blum continue to measure ground ground cover of permanent plots at the interface of *Juncus roemerianus* patches, and a synthesis of 20 years of data will be done by M.S. student Sherer Etheridge.

Related to the EoYB sampling, P.I.s Christian and Reyes and their students (undergraduate Sherer Etheridge, M.S. student Traci Davis) are studying the influence of nitrogen availability on high-marsh primary production and ecosystem state dynamics. In addition, Christian continues to use network analysis to synthesize information on a variety of systems. He is collaborating with others in the LTER network and with others to study ecological and social network analysis of N cycling (Christian et al. 2012) and food webs (Christian and Allen 2011 and in preparation).

Blum is examining the role of sediment deposition and plant production on marsh accretion. She is collaborating with Earl Davey (EPA Narragansett) using computer-aided tomography imaging to quantify salt marsh plant root volume and root system architecture (Fig. 3). If this approach can be reliably applied to VCR salt marsh plant communities, it will become possible to make measurements of plant production belowground as well as aboveground over the long term at marshes representing the range of geomorphic types found at the VCR.

VCR scientists are addressing "blue carbon" sequestration in coastal marshes. Collaborator Eduardo Leorri (Geology, ECU) has collected soil samples within the Upper Phillips Creek marsh and had black carbon within them dated using 14C. Kirwan model the effects of climate change on carbon storage in collaboration with Simon Mudd (U. Edinburgh); the work was based in part on decomposition data collected by Blum at the VCR.

Fig. 2. Marsh "organs" in which plants are submerged at different depths. The plants submerged deepest experience the highest sea levels. The plants elevated highest experience the lowest sea levels.

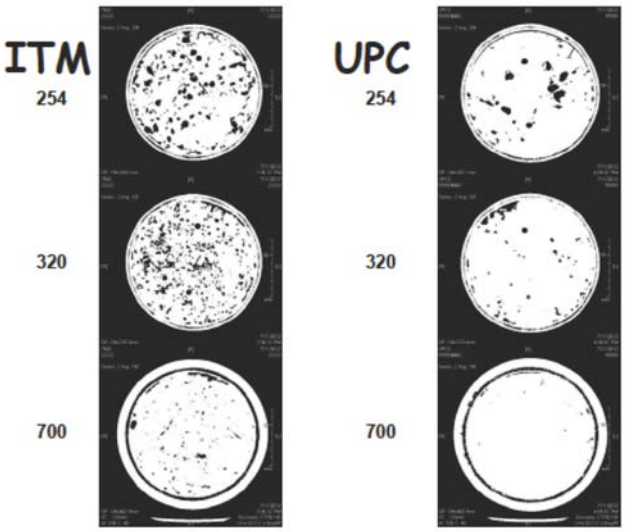

Fig. 3. CT scan image of cores taken at Upper Phillips Creek (UPC) and Indiantown Creek (ITM) salt marshes. Dark spots show distribution of roots largner than 1mm in diameter. Three depths are shown that are approximately 2 cm (254), 8 cm (320), and 25 cm (700 below the marsh surface. Note the higher density of roots at the ITM site.

Barrier Island Geomorphology

P.I. Laura Moore and her students have developed a new model to better understand the couplings between barrier islands and back-barrier environments, which was first tested for Metompkin Island. She has also developed an "ecomorphodynamic" model of island evolution based on grass species composition, and the effects of storm frequency and magnitude to assess climate-change effects on island morphodyamics. To address the geomorphic consequences of changes in wave climate on barrier island shorelines, she obtained shorelines from NOAA, the USGS, and the North Carolina Department of Natural Resources, and the LTER-VCR and used the Digital Shoreline Analysis System (DSAS) to calculate shoreline change rates for historic (pre-1975) and recent (post-1975) time periods. The 1975

breakpoint was chosen to correspond with the timing of reported increases in hurricane-generated (summer) wave heights.

Barrier island vegetation dynamics in response to climate change

P.I. Don Young and collaborator J. Zinnert continue to focus on landscape-level comparisons ov vegetation across the terrestrial portions of the VCR barrier islands. Their objectives are to understand and quantify important fluxes among the VCR landscape units, and to place results in the context of the knowledge base for other barrier systems, coastal landscapes, and terrestrial ecosystems in general. This year they have focused on mechanisms related to the expansion of shrub thickets on barrier islands and also the potential responses of island thickets to climate change.

P.I. Frank Day and his students continue to work on three major objectives: long-term monitoring of plant community structure on barrier island dunes, determination of fine-scale thresholds governing state change on barrier islands, and evaluation of the significance of island freshwater marshes to the blue carbon budget. His M.S. students Dominic Graziani and Emily Adams are working on projects associated with the threshold and blue carbon questions. In 1991, permanent plots (4 x 4 m) were established on three dunes along the Hog Island dune chronosequence. Half of the plots were fertilized with nitrogen for the first 10 years of the study; the remaining plots served as controls. Plant cover and density have been monitored annually since 1991. Aboveground and belowground decomposition rates were determined to assess the influence of fine-scale environmental effects on decomposition. Elevation, groundwater level, vegetation composition and soil N-content are being analyzed for correlations with spatial patterns observed in decomposition rates.

"Upward trophic cascades" between vegetation, predators and waterbirds

One of the most visible ecological functions of the Virginia barrier islands is the provision of nesting habitat for beach-nesting and colonial waterbirds. Both the incidence of meso-predators and their impact on ground-nesting avian species have increased on the Virginia barrier islands over the past 35 years. Twelve islands, ranging in area from 38 to 9,344 ha and spread over 1,000 km^2, support resident raccoon populations. P.I.s Dueser, Moncrief and Porter compiled and edited a 10-year (1999-2010) geo-referenced database on predator movement within and between islands. This study of island connectivity examined four lines of evidence about predator movement: (1) movement of ear-tagged animals, (2) movements of radio-collared animals, (3) movement of translocated animals, and (4) re-colonization of islands from which meso-predators have been removed.

Mainland-island movement is relatively important at the northern and southern ends of the barrier island complex; inter-island movement is particularly important on the central (and more isolated) islands. Based on this understanding of predator movement, Porter, Dueser and Moncrief developed a least-cost path analysis to identify specific islands on which predator removal efforts are most likely to be successful in aiding the recovery of beach-nesting and colonial waterbirds.

Bachman's remote sensing

In June 2011, P.I. Chip Bachmann led a multi-sensor airborne remote sensing campaign at the VCR with a coordinated ground and water calibration and validation effort. NRL was the lead institution in a team of researchers and students that also included participants from the University of Virginia, George Mason University, Cornell University, Princeton University, Stephen F. Austin State University, NASA Goddard, and Virginia Commonwealth University) with logistical support from both UVA and The Nature Conservancy. Remote sensing imagery acquired during the ten-day exercise included hyperspectral imagery (NRL CASI), topographic LiDAR, and thermal infra-red imagery, all acquired simultaneously from the same aircraft. Airborne synthetic aperture radar (SAR) data acquisition occurred for a smaller subset of sites later approximately two months later. The primary focus areas of this campaign were properties of beaches and tidal flats and barrier island vegetation and, in the water column, shallow water bathymetry and water column properties.

Storminess at LTER Sites(1885-1996): Updating to 2012.

23,000 surface weather maps for continental North America and the adjacent oceans have been a downloaded for the period 1997-2012 to be used to follow the tracks of centers of low pressure and to

record the frequency of storms crossing 2.5 lat by 5.0 lon designated. NOAA has provided these weather maps for this project at no cost.

Network analysis of LTER collaboration

P.I. Bob Christian was co-PI of a LTER network mini-grant using network analysis to understand the network of collaboration within the LTER program. Interviews are planned for the upcoming All Scientists Meeting to extend information on factors affecting collaboration. A RAPID proposal is under review at NSF (Shawn Dalton, with Christian, R. Waide and J. Johnson) to develop a tool to assess such factors.

Information Management

There have been a number of improvements in the functionality of the VCR LTER Information System in the past year. A major task was a complete rewrite of the front-end of the data catalog. The previous version of the data catalog had been in place since 1997 and consisted of dynamically-generated HTML generated from our metadatabase. With increasingly sophisticated and attractive metadata displays proliferating through the network, although functional, it was showing its age. We replaced it with an EML-based system that uses stylesheets to generate an attractive and functional tabbed display directly from EML documents. Supplement funds were used to hire David Richardson, who served as assistant VCR IM during 1993-1994 to oversee the revision. He customized style sheets that had been previously worked on by Margaret O'Brien and M. Gastil-Buhl at the SBC and MCR LTER sites that were in turn based upon stylesheets developed by Chris Jones. An advantage of moving to an EML-based catalog system is that it effectively decouples the backend metadatabase system, which is used to generate the EML documents, from the display system, allowing us to modernize parts of the system without needing to revise all aspects at the same time. Also by focusing on EML the tools developed are more likely to be applicable to other sites and can be shared across the network.

The usability of many LTER datasets was enhanced by including additional ancillary data, as well as the primary data tables. This ancillary data consist of earlier versions of the data, often in a variety of forms. In some cases, it includes scans of field data sheets for cross checking with digitized data and for capture of non-digital data such as marginal comments etc. Although we expect most users to make use of the primary data tables, the ancillary data helps to improve interpretability and to spot any problems in the data processing workflows.

With supplement funding, former VCR student Bridget Long worked with P.I.s to revise all the dataset titles to make them more useful at a national scale by assuring that spatial and temporal coverages were referenced in the titles (e.g., "Tide Data" changed to "Tide Data for the Virginia Coast Reserve 1990-2012"). Dataset abstracts are being written to provide the same degree of clarity and completeness. The web page was upgraded to include new sections on VCR/LTER Research Themes and Research Highlights. The major work on this was done by student Cat Wolner working with VCR lead-P.I. Karen McGlathery. Each Research Theme is connected to a list of investigators and featured datasets.

The VCR LTER has also been active in a number of network educational activities. VCR LTER I.M. John Porter participated and made presentations in the SensorNIS and several training workshops aimed at training investigators in advanced I.M. techniques. With Paul Hanson from the NTL LTER and Chau-Chin Lin from the Taiwan Forestry Research Institute he published a review paper on information management for sensor networks as part of a special issue of Trends in Evolution and Ecology. Continuing work on the LTER Controlled Vocabulary took an international turn with participation in an ILTER workshop in Shanghai China focusing on semantic approaches to multilingual data discovery of ILTER data. Web services created for use with the U.S. LTER controlled vocabulary were modified to interface with the RDF-based and multilingual EnvThes thesaurus to create a prototype system for multilingual searching. A poster on this work was presented at the 2012 LTER All-Scientists' Meeting. Porter has been actively working on interfacing VCR LTER data with PASTA and have several exemplar datasets ingested, with many more ready to ingest as PASTA becomes ready to take them. That work has stimulated additional activities in the area of developing web services that facilitate analysis of LTER data by automating the routine programming tasks associated with writing code to ingest LTER data into statistical software. With the PASTAprog web service, one can go from searching for an LTER dataset to

having a working R, SAS or Matlab (thanks to Wade Sheldon of GCE) program that has ingested the data and provided a statistical summary in less than one minute (video available).

Porter also has been working with P.I. Bruce Hayden and the LTER Climate Committee on extending a long-term dataset on storm frequency. Between 1885 and 1996 various US government agencies (notably NOAA) developed storm track maps that were used in 2003 to generate long-term storm frequency records for individual LTER sites. However, since 1996 such storm-track data has not been produced. Hayden is working on the laborious task of going through some 23,000 individual weather maps to construct the record from 1997 through 2012. Porter has been working on automating GIS processing of marked-up maps to extract storm locations and to connect them into storm tracks. Python code using the arcPy module from ArcGIS is being used to process long sequences of images. Again, a poster on this work was presented at the 2012 LTER ASM.

Education and Outreach

High school student training

Art Schwarzschild, VCR Site Director and Science Outreach Coordinator continues to maintain our partnership with Northampton High School by supporting the Environmental Science II class, and by supplying water quality monitoring equipment/materials and logistical support for field activities. Schwarzschild visited the high school throughout the year, met with teachers to determine equipment and material needs, and gave guest lectures for science classes. These activities provide support to 4 of the 5 science courses offered at Northampton High School.

In 2011-12, Schwarzschild continued to serve as a member of the LTER Education Executive Committee and co-chair of the Higher Education Working Group.

Undergraduate and graduate student training

Five undergraduate science interns were supported in summer 2012. They worked on projects ranging from studying the impacts of seagrass restoration on ecosystem services in the coastal bays of the VCR to examining the implications of climate change and sea-level rise on local salt-marsh and barrier island plant communities. Our on-going partnership with The Nature Conservancy supported a local High School student as a summer intern who worked with a graduate students on the relationship between water quality, light availability and seagrass growth.

36 M.S. and Ph.D. students from 7 institutions (UVA, VCU, ODU, BU, ECU, UNC, URI) were supported with LTER funds to conduct their graduate work at the VCR. In addition, we supported two LTER cross-site student projects, also involving the PIE and GCE sites.

Teacher training

Through our ongoing partnership with Chesapeake Experience, the VCR LTER again offered 2 professional development classes for area teachers (Fall Migration Ecology October 2011 and Coastal Bay Ecology May 2012), with a combined enrollment of 28 teachers. In April, the VCR LTER hosted a new workshop for Art Teachers that linked instruction in Plein Aire painting techniques with our place-based research on salt marsh ecology. Nine teachers (4 from Northampton County) participated in the workshop, and an exhibit of the artwork and ecology essays they produced is on display at the Barrier Islands Center Museum on the Eastern Shore of VA September 20 - October 5, and will move to the Brown Science and Engineering Library at UVA October 26 – November 2. The success of this program has resulted in a grant awarded by the Buckner W. Clay Endowment for the Humanities, which will support 2 additional Art and Ecology workshops for public school Art teachers (Observational Drawing scheduled for October 2012 and Plein Aire painting scheduled for April 2013).

Two additional new programs were initiated in 2011-2012. In September 2011, we recruited and trained 6 local teachers (at least one teacher from every public and private school in Northampton County) to participate in the VA Oyster Gardening program. Field trips were run for 3 schools, involving over 40 local school children, to release the oysters they had grown onto local oyster reef sanctuaries. Groups from 2 other schools forged partnerships with the Chesapeake Bay Foundation to release their oysters at sanctuaries in the Chesapeake Bay.

Artist-in-Residency Program

In June, we hosted our first Artist in Residence at the VCR. Alice McEnerney Cook, the Plein Aire instructor spent 2 weeks on location, producing 15 landscape paintings of local salt marsh and coastal ecosystems. She presented her work at our monthly public seminar series in June and many of these pieces will be included in an exhibit, "Ecological Reflections Art and Ecology" will be on display in the Charles L. Brown Science & Engineering Library at UVA starting on October 26th.

Public outreach and education

Schwarzschild continued to serve as an instructor for the Eastern Shore chapter of the VA Master Naturalists program, lecturing on ecology, seagrass ecology, climate change, sea-level rise, and ichthyology. He also coordinates our monthly seminar series focusing on VCR-LTER research for the general public. This seminar series has become popular with the local high school science teachers who regularly offer extra credit to their students who attend seminar and present an oral summary of the information they learned to their science class. Master Naturalists may also receive advanced training credits towards their certification for attending seminars.

Schwarzschild continued his membership in the Eastern Shore Climate Adaptation Working group, a partnership between TNC, local, regional and federal agencies. He also is part of a regional committee formed to examine current zoning regulations and the potential economic and ecological impacts of developing commercial poultry production.

In May 2012, the VCR LTER co-hosted a "listening sessions" to assess local citizen responses to climate change issues with UVA's Institute for Environmental Negotiation (http://ien.arch.virginia.edu/projects-current/virginia-sea-level-rise).

Supplemental Funds

The information management and education/outreach sections above describe in detail the use and results of supplemental funding to the VCR LTER. In short, the following activities have been supported by supplemental funds in 2011-2012.

IM supplement results

The VCR/LTER received supplement funds to help make VCR Data "PASTA-ready." We hired student and professional programming help to prepare datasets and to enhance VCR/LTER systems, so that now all VCR Datasets are "PASTA-ready" and all types of data are now accessible through the LTER-wide Data Access Server. Numerous sample datasets have been uploaded to PASTA without difficulty, and we are awaiting the fully functional system to do a complete upload of all VCR/LTER datasets into PASTA (the current PASTA test system lacks sufficient resources to handle many of our largest datasets). We have also implemented web services that automate production of statistical programs (e.g., R, SAS, SPSS, Matlab) based on EML metadata. These were demonstrated during several workshops at the LTER All-Scientists Meeting in Sept. 2012. Additionally, we participated in SensorNIS and GeoNIS workshops and will be participating in a postponed GCE Toolbox workshop this fall. We are working on co-authoring a paper on quality control and assurance for sensor data, along with other participants on the SensorNIS workshop.

Education/Outreach supplement results

- Support of the Environmental Science II class at Northamption High School (200 students)
- 2 professional development classes for area teachers (Fall Migration Ecology, Coastal Bay Ecology) (28 teachers)
- Professional development workshop for art teachers combining instruction in Plein Aire painting techniques and place-based studies on salt marsh ecology (9 teachers)
- REU support for 5 undergraduate summer interns
- Summer intern support for one high school student
- Initiation of Oyster Gardening program (6 teachers)
- Artist-in-Residency program
- Public seminar series, climate adaptation working group, public "Listening Sessions"

Table 1. Ancillary projects leveraging VCR LTER funding

Project	Principal Investigator	Funding Agency	Funding	LTER data / infrastructure
Biogeomorphic controls on barrier island evolution in response to climate change	Moore, Young	DOE National Institute for Climate Change Research	$142,000	Data, infrastructure
Coastal geomorphic consequences of wave climate change	Moore	NSF	$155,071	Data, infrastructure
Modeling the influence of canopy type on tactical foliage penetration by airborne active sensor platforms	Zinnert	Army Corps of Engineers	$702,000	Data, infrastructure
Characterization of vegetation photopigment decay for remote sensing of hazardous materials	Zinnert	Army Corps of Engineers	$735,000	Data, infrastructure
Spatial-temporal variability in vegetation hyperspectral indices to characterize terrain state	Zinnert	Army Corps of Engineers	$795,000	Data, infrastructure
Quantifying wave-driven mixing and mass transport processes within coastal ecosystems	Reidenbach	NSF	$531,428	Data, infrastructure
Developing strategies to sustain hard clam aquaculture while minimizing impacts	Anderson	Virginia Sea Grant	$140,000	Data
Forecasting watershed loading and lagoon response along the Delmarva Peninsula due to changing land use and climate	Anderson	Virginia-Maryland-Delaware Regional Sea Grant	$139,000	Data
Assessing ecosystem-level effects of hard clam aquaculture on water quality and nutrient dynamics	Anderson	Virginia Sea Grant	$39,893	Data
Sustainable segrass restoration in the Virginia coastal bays	McGlathery, Wiberg, Schwarzschild	Virginia Sea Grant	$30,000	Data, infrastructure
A comprehensive study of the N cycle in Bahia Falsa, Baja California	Camancho (collaborator), Christian, Anderson, McGlathery	CONACyT, Mexico	$250,000	Data

Economics experiments of valuation of ecosystem services	Swallow	DelFavero Faculty Fellowship UConn	$5,000	Infrastructure
Multi-Sensor Remote Sensing at the Virginia Coast Reserve	Bachman	NRL/ONR	$670,000	Infrastructure
Terrestrial Support of Aquatic Food Webs: A Multi-Isotope Approach	Pace	NSF	$244,884	Data, infrastructure
Ecological Reflections at the Virginia Coast Reserve	Schwarzschild	Buckner W. Clay Endowment	$7,200	Infrastructure
Understanding Interactions within the LTER Network in Support of Improved Collaboration	Christian	LTER Network Office	$13,000	Data, infrastructure
Hydrodynamic modeling of the VCR – Post-doc funding	Wiberg	UVA	$45,000	Data, infrastructure
Contribution to VCR LTER staff salaries	McGlathery	UVA	$33,000	Infrastructure
Graduate Student Fellowships	McGlathery	UVA	$90,000	Data