

CURRENT RESEARCH, MONITORING, AND EDUCATION PROJECTS

2005 - 2006

Baruch Marine Field Laboratory (BMFL)

**North Inlet-Winyah Bay
National Estuarine Research Reserve
(NERR)**

University of South Carolina



**Belle W. Baruch Institute
for Marine & Coastal Sciences**



**North Inlet-Winyah Bay
National Estuarine Research Reserve**

Current Research Projects 2005-2006

Introduction

More than 590 scientific research projects and about 350 student theses and dissertations have been completed by Baruch Institute research associates since 1969. This work has resulted in the publication of more than 1,413 scientific articles, reports, and books that contribute new information in subject areas ranging from molecular biology to landscape ecology. The accumulating information provides a fundamental understanding of the structure, function, and condition of coastal ecosystems. Results of research projects are used by educators, coastal resource managers, health and environmental regulators, legislators, and many other individuals and organizations interested in maintaining or improving the health of estuaries in the face of increasing human activities in the coastal zone.

The following annotated list summarizes 89 of the projects currently being conducted at the Baruch Marine Field Laboratory (BMFL) by staff, graduate students, and faculty associated with the University of South Carolina and other institutions. The University of South Carolina is the home institution for 40 faculty, 20 technician, and 30 student investigators conducting research at the BMFL. In addition, 47 faculty, 3 technicians, 23 students and 10 volunteers representing 28 other institutions are carrying out projects at the BMFL. Dozens of other graduate and undergraduate students assist these scientists throughout the year to obtain hands-on training in field research methods. A wide variety of basic and applied research is represented. This list includes only those projects that make regular use of the site. Most of the studies that involve field measurements and collections are being conducted within the North Inlet-Winyah Bay National Estuarine Research Reserve.

The projects are randomly grouped and each project summary includes title, investigator(s), affiliation, and project abstract. Projects that focus on long-term monitoring and research are grouped under the heading Long-term Studies. Education, Outreach, and Data Management Projects are described in another section.

Funds for these research projects are provided by a variety of sources, including the National Science Foundation (NSF), Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA) (National Estuarine Research Reserve System, NERRS, and SC Sea Grant Consortium), US Department of Energy (US DOE), the Office of Naval Research (ONR), National Aeronautics and Space Administration (NASA), and the SC Department of Health and Environmental Control (SC DHEC). The Friends of the Institute, an independent organization that supports Baruch Institute activities, also provides assistance and the Belle W. Baruch Foundation provides the long-term stewardship of Hobcaw Barony to maintain it in a natural state for research and education. For more information, please contact the individual investigators, or contact Dr. Dennis Allen or Dr. Scott Neubauer at 843-546-3623. Information may also be obtained from the Institute's web site <http://www.baruch.sc.edu>, which contains links to many related sites.

Author and Title List

Novakowski, Torres	7
Characterization of intertidal zone creek networks	7
Torres, Zhou	7
A high accuracy micro-topographic determination of marsh topography	7
Zhou, Torres	8
Long-term and short-term sediment accumulation rates in a salt marsh setting	8
DePratter	8
Georgetown county clam shell midden inventory	8
Wargo, Styles	8
Along channel particle sorting in North Inlet, South Carolina	8
Styles, Torres, White, Jurissa	9
Morphological controls on marsh creek network flow patterns.....	9
Styles, Traynum	9
Sediment exchange near a tidal node.....	9
Montane, Williams	10
Modern and historical sedimentation cycles and their instability on a mesotidal marsh island, North Inlet, South Carolina.....	10
Springer, Williams, Karabanov, Mock, Benitez-Nelson	10
Paleotempestology upon the South Carolina coastline: A calibration of the sedimentary historical record	10
Carter, White	11
Seasonal variability in groundwater flow and saltwater intrusion from a geophysical monitoring along forest-marsh transects.....	11
Silliman	11
Top-down grazer effects on marsh grass growth and marsh dieback	11
Silliman	11
Effects of global warming and marsh grass growth.....	11
Long, Feller	12
Quantifying blue crab predation on periwinkle abundance: Visual and immunological assay of gut contents.....	12
Lincoln	12
Plant defense by volatile emissions	12
Arnold	12
Induced sink strength in <i>Spartina alterniflora</i> : Reallocation of carbohydrates as a first step towards herbivore defense	12
Pennings	13
Latitudinal variation in plant-herbivore interactions in Atlantic Coast salt marshes	13
Chuan-Kai Ho	13
Plant-herbivore interactions: Latitudinal variation and impacts of climate change	13
Denno, Goeriz, Hines, Murphy, Wimp	13
Latitudinal variation in the top-down control of salt marsh herbivores by invertebrate predators	13
Coull, Baguley	14
Genetic variation and cryptic speciation in harpacticoid copepod populations	14
Burnette, Halanych	15
Phylogeographic patterns in the parchment-tube worm, <i>Chaetopterus varioopedatus</i> (Annelida)	15
Halanych, Blasczyk, Struck	15
WormNet: Recent advances in annelid systematics, development, and evolution	15
Costanza, Boumans, Swarth, Burdick, Cahoon	15
Sediment elevation dynamics in tidal marshes: Functional assessment of accretionary biofilters	15
Morris, Sundberg	16
Sediment accretion in North Inlet salt marshes	16

Morris, Sundberg	Experimental varying of the marsh platform and macrophyte response.....	16
Stalter, Baden	Interspecific competition among some salt marsh perennials in South Carolina.....	16
Stalter, Baden	Effect of wrack accumulation on salt marsh vegetation	17
Bretsch, Allen	Nekton behavior in salt marsh intertidal creeks: Patterns and mechanisms of tidal movement	17
Allen, Hampel, Foley	Nekton use of intertidal creek pools; a spatial analysis of relationships between geomorphology and nekton occupation during low tide.....	18
Dame, Allen, Young, Luthy, Foley	Mobile link organisms (MLO's) as processors and transporters of materials within a marsh-estuarine ecosystem	18
Abel, Gandy, Knott, Copen, Gary	Longline survey of sharks on Winyah Bay and nearby waters	18
Yednock, Abel	Assessment of habitat utilization by multiple coastal shark species in a North Inlet subtidal creeks.....	19
Vecchio	Catch and release mortality in South Carolina's red drum recreational fishery	19
Beseres, Feller	Juvenile white shrimp, <i>Litopenaeus setiferus</i> , potential reduction of macrobenthos abundance in southeastern US salt marshes.....	20
Coggins, Feller	Ghost fishing by blue crab pots	20
Matsui, Fletcher	Microbial observatory: The microbial community and distribution associated with the roots of select salt marsh plants	21
Johnson, Morris, Fletcher	Estuarine eutrophication and microbial community composition	21
Johnson	Microbial community responses to eutrophication in a Southeastern US salt marsh estuary.....	21
Bernot	Nitrogen fixation rates in a coastal ecosystem under different nutrient addition regimes	22
Lovell, Woodin, Lincoln, and students	Chemically mediated interactions in a sedimentary assemblage	22
Lovell and students	Colonization of man-made surfaces in the marine environment	22
Lovell, Matsui	Infaunal burrows and their impacts on sediment microbiota.....	23
Lewitus, DeMattio, Tymowski, Heidenreich, Ringwood	Identity, physiological ecology, and toxicity of the red tide dinoflagellate, <i>Kryptoperidinium</i> sp.	24
Lewitus, Hymel, Tymowski, White	Application of the CHEMTAX model in estuaries. Deriving phytoplankton composition from HPLC pigment profiles.....	24
Zingmark, Lewitus, Tymowski	Functional relationships (coupling) between epiphytic microalgae and food webs in a saltmarsh estuarine system and their management implications.....	24
Stancyk, Ansell	Brittlestar chemo-detection of a predator <i>Luidia clathrata</i>	25
Stancyk	Zooplanktivory by the burrowing brittlestar, <i>Hemipholis elongata</i> : Tests on natural plankton assemblages	25
Marshallonis, Pinckney, Richardson	What are the environmental impacts of gelatinous zooplankton (hydromedusae) on carbon dynamics of the North Inlet ecosystem?	25

Jost, Helmuth	
The effects of microhabitat and mussel body position on survivability, growth, and reproduction of <i>Geukensia demissa</i>	26
Shapo, Galloway, Woodley	
An evaluation of antimicrobial activity of the western Atlantic octocoral, <i>Leptogorgia virgulata</i> (Lamarck)	27
Porter, Lewitus, Chandler, Aelion, Decho, Scott, Ferry, Fulton, Siewicki	
Urbanization and Southeastern Estuarine Systems (USES)	27
Porter, Siewicki, Allen, Aelion, Kelsey, Walker	
Development of a GIS-based database management program to characterize sources and effects of natural parameters and anthropogenic impacts of coastal ecosystems.....	28
Porter, Klemas, Jensen, Field, Field, Walker, Malhotra	
The NOAA-NERRS remote sensing applications assessment project (RESAAP).....	29
Walker, Porter	
Use of integrated remote sensing and field techniques for assessing and managing the distribution of invasive plant species in Southeastern estuaries	29
Chekalyuk, Moore, White, Porter	
Advanced Laser Fluorescence (ALF) technology for estuarine and coastal environmental biomonitoring	30
Peterson, Gonzalez, Bain	
Identification of toxicant-responsive genes in the mummichog (<i>Fundulus heteroclitus</i>).....	31
Walters, Coen, Sacks	
Impact of boat wakes on intertidal reefs of the oyster <i>Crassostrea virginica</i>	31
Bushek, Kenny, Schmidt, Toline	
Testing an alternative oyster reef restoration strategy	31
Bushek, Heidenreich, Porter	
Temporal patterns of Dermo disease in North Inlet.....	32
Schmidt,	
LIDAR-based watershed modeling of North Inlet.....	32
Brodie, Reichert	
Settlement and metamorphosis of three species of fiddler crabs in a South Carolina salt marsh	32
Borgianini, Godley, Brodie	
Salinity and its effects on <i>Uca minax</i> , <i>U. pugilator</i> , and <i>U. pugnax</i> survivorship during larval, megalopal and juvenile stage.....	33
Borgianini, Styles, Jurissa, Brodie	
Recruitment of megalopae to freshwater, upriver areas	33
Thurman, Bennett, Brodie	
Ontogeny of salinity tolerance and osmoregulatory capabilities in <i>Uca pugilator</i> , <i>U. pugnax</i> , and <i>U. minax</i>	33
Borgianini, Brodie	
Groundwater flow and its effects on the distribution of <i>U. minax</i> and plant zonation	34
Brodie, students	
Research experience for undergraduates summer 2005 project descriptions	34
Tankersley	
Selective Tidal Stream Transport (STST) behavior of fiddler crab larvae in the Winyah Bay Estuary	34

Long-term Studies

Morris, Sundberg	
Long-term measurements of production and physiological ecology of <i>Spartina alterniflora</i>	35
Ogburn-Matthews, Gardner	
Tide level: Long-term monitoring at Oyster Landing Pier in Crab Haul Creek	35
Smith, Cook	
Weather and climate measurements: Long-term monitoring at Oyster Landing Pier.....	36

Smith, Keesee, National Atmospheric Deposition Program (NADP)	36
Smith, Buck Physical characteristics of estuarine waters: Long-term monitoring at four sites in North Inlet Estuary	36
Smith, Johnson, Keesee Chemical characteristics of estuarine waters: Long-term monitoring at four sites in North Inlet Estuary.....	37
Smith, Buck Long-term monitoring of emergent salt-marsh vegetation in the North Inlet estuary	37
Lovell, Fletcher, and students Diversity of plant-associated diazotrophic bacteria and their distributions within specific vegetation zones along an environmental gradient - The North Inlet Microbial Observatory.....	37
Lewitus, Amatya, Brown, DeMattio, Habrun, Hayes, Heidenreich, Hymel, Jackson, Keppler, Liu, Johnson, Mason, Shuler, Tymowski, Wilde, Williams, and collaborators The South Carolina Harmful Algal Bloom Program	39
Coull, Feller North Inlet benthos program: Long-term monitoring of meiofauna and macrobenthos	39
Allen, Buck, Kenny, Ogburn-Matthews Interannual and seasonal patterns of use of flooded marshes and creeks by migratory fishes and crustaceans	40
Allen, Stancyk, Kenny, Buck, Ogburn-Matthews Long-term zooplankton time series: Tracking and interpreting changes in the occurrence of larval and permanent taxa in the North Inlet Estuary	40
Young Ecological role and habitat utilization patterns of bottlenose dolphins in the North Inlet Estuary and adjacent waters	41
Brabson, Baughn, Allen, Buck, Foley, Toline, volunteers Sea turtle nest monitoring on Debidue Beach/Hobcaw Barony.....	41
Van Dolah, Jutte, Reikerk, Levisen, Chestnut South Carolina Estuarine and Coastal Assessment Program	41

Education, Outreach, and Data Management

Thomas High School water Quality Program – National Estuarine Research Reserve.....	42
Thomas Education activities – National Estuarine Research Reserve.....	42
Thomas South Carolina Chamber of Commerce High Performance Partnership.....	43
Pollack Coastal Training Program for local decision-makers	43
Ogburn-Matthews Long-term coastal data and metadata rescue and product dissemination by USC’s Baruch Institute	44
Porter, Small, Burmeister, Friedmann, Lail, Yedinak The National Estuarine Research Reserve System Centralized Data Management Office.....	44

Research Locations in North Inlet - Map	46
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Author Index.....	47
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Characterization of intertidal zone creek networks

Investigators: Karyn I. Novakowski and Dr. Raymond Torres
Department of Geological Sciences, USC

Tidal creeks and channels dissect the marsh landscape and produce discrete islands with well-defined drainage basin networks. Estuarine habitat structure results from the interactions between salt marshes, channel networks and land use. Therefore, any influence on channel network geometry may influence habitat structure and population density of marsh flora and fauna. Hence, channel network form and processes play an important role in estuarine ecology and stability.

Urban and suburban developments encroaching onto coastal environments may cause alterations to the channel platform. These alterations increase shear stress, perhaps negatively impacting habitat structure, thereby requiring rehabilitation. While marsh habitat creation and rehabilitation efforts are an important part of ecosystem stabilization, the critical question is: Restoration to what? Scaling in estuarine channel network geometry may yield useful indices to describe drainage density equilibrium. It may also elucidate controls on spatial variability of biological processes, which in turn can be used to define restoration goals and objectives.

The objectives of this proposed research are to 1) quantify estuarine channel network properties at North Inlet NERRS and 2) test terrestrial concepts for channel network evolution in estuarine systems. I propose to use Hack's law ($L = m \times A^n$, where L is total stream length, m is a parameter derived experimentally, A is drainage basin area, and n is a scaling exponent) to test for power law scaling in estuarine channel systems. I expect to reveal the utility of exponential scaling which may serve as an index needed to assess the large-scale health and stability of estuarine systems. It may also be the basis for channel system design in reconditioned coastal landscapes. This project is funded by EPA and will continue through 2007.

A high accuracy micro-topographic determination of marsh topography

Investigators: Drs. Raymond Torres and Xiaobo Zhou
Department of Geological Sciences, USC

Salt marshes are dynamic environments being modified by every ebb and flood of the tides. Do the incoming tides and their drainage define the creek network or is it the pre-existing topography that determines the form and development of tidal creek networks?

We use relatively new Real-Time Kinematic (RTK) Global Positioning System (GPS) technology within a calibrated network of published geodetic benchmarks to ensure control and accuracy of data. This method of topographic/hydrographic surveying yields approximately 2 cm accuracy data. These data effectively reveal the subtle marsh surface morphology that conventional mapping methods have thus far portrayed as flat.

Preliminary interactive computer visualization and profiling of the micro-topography has shown subtle troughs and ridges on the marsh platform between creek networks that have previously only been suspected to be real geomorphic features. Ongoing analysis of the marsh topography may better define the spatial control of pre-existing topography in the development of creek and channel networks.

Channel network structure, marsh platform and their processes are vital to estuarine ecology. A better interpretation of topographic forces or control (versus tidal forcing) may aid in the overall understanding of marsh surface development and to that of the creeks and channels that dissect it. Understanding development and stability of salt marshes is scientifically valuable for many efforts, these include: biological, environmental, habitat and ecological as well as economical objectives.

Funding for this project is through NSF EAR. The field study was initiated in January 2002 and is ongoing. See map location #16

Long-term and short-term sediment accumulation rates in a salt marsh setting

Investigators: Drs. Xiaobo Zhou and Raymond Torres
Department of Geological Sciences, USC

Sediment accumulation rates depend on microtopography and local geomorphology. We are using radiogenic isotopic techniques to estimate long-term sediment accumulation and the filter paper method to assess short-term accumulation. We emplaced 74 filter papers over a salt marsh island and extracted 36 sediment cores of 0.9 to 1.7 meters in length to investigate the spatial and temporal variability of sediment accumulation. The elevation of each location is known to within 0.05m of the geoid. Funding for this project is through EPA. The field study was initiated in January 2004 and will continue until 2007. See map location #16.

Georgetown county clam shell midden inventory

Investigator: Dr. Chester DePratter
South Carolina Institute of Archaeology and Anthropology, USC

I will be investigating clam shell middens located in marshes west of Litchfield Beach and Hobcaw Barony. I will be mapping the middens, collecting pottery from the surface, and excavating test pits to obtain artifact samples, food remains, and shells for radiocarbon dating. Some of these shell middens may be shell rings in the 3,000 to 4,000 year-old range, but the only dates currently available are from one of the Hobcaw sites that is c. 1,000 years old. My interests in these sites include determining whether any of these middens are truly shell rings, because if they are they will extend the known range for such sites 40 miles north of their current known extent. At least a couple of the sites in the study area may be shell rings.

I am also interested in determining the factors involved in local Indians harvesting clams rather than oysters found in nearly all other coastal shell middens. I believe this is related to the gradual deposition of a series of spits, (Litchfield Beach, Pawleys Island, and Debidue Island) which resulted in formation of tidal flats at their progressive southern ends and later at inlets between them which were good clam habitats. Once those spits/barriers had completely formed, then the marshes we see today could have formed in those back barrier environments, and at those points oysters would have been more readily available than clams. The radiocarbon dating portion of this research will perhaps help document this sequence of events as reflected in the shell middens.

Over the past 30 years, I have worked on sea level fluctuations as reflected in the evidence from archaeological sites on the coasts of Georgia and South Carolina. In investigating these north coastal shell middens, one of the things I will be doing is contour mapping each midden and determining the position of the base of each midden relative to present mean sea level. This elevational data combined with radiocarbon determinations should provide good information on the position of sea level at the time the middens were occupied.

Along channel particle sorting in North Inlet, South Carolina

Investigators: Christopher Wargo¹ and Dr. Richard Styles²
Department of Geological Sciences, USC¹
Department of Geological Sciences and Marine Science Program, USC²

Physical understanding of large-scale geomorphological entities, such as tidal inlets, is one of the main requirements for establishing a rigorous scientific basis for the management and sustainable development of coastal systems. The physics governing the dynamics of inlets are poorly understood because of their complex nature, scale of motion and geomorphic change. In this study we investigate the along channel distribution of the dominant grain size class in terms of mean flow speed and local current shear.

Field sampling was conducted in North Inlet, South Carolina during two complete tidal cycles in May of 2003. Sampling was along two transect lines that connect the inlet throat to the main creek systems that feed the marsh. The first ran from the intersection of Town Creek and Old Man Creek to a point approximately 0.5 km offshore of the inlet throat. The second survey was conducted from a point approximately 2 km up Jones Creek to approximately 1 km up Debidue Creek. Spatial sampling included an ADCP (Acoustic Doppler Current Profiler) to measure full water column currents, a CTD to measure salinity, temperature and depth, a submersible pump to

collect water samples, a surface grab sampler to collect bed sediments, and a LISST (Laser In Situ Scattering Transmissometer) to measure suspended sediment concentration and particle size distribution.

Results show a strong link between turbulence, sediment resuspension and bedform morphology. Bathymetric variability occurs on two major scales that directly affect the flow and sediment resuspension processes. A large 2 km variation shows a geometry that is consistent with smaller sand waves found in rivers. It possesses a gentle stoss slope and a much steeper lee slope. It is oriented in an ebb flow direction, which is consistent with the ebb dominance of the inlet. Highest concentrations are found in the trough of this feature. This is also the location of the highest shear stresses. Significant along channel salinity gradients also exist throughout both major creek systems. Between Debidue Creek and Old Man Creek suspended sediment concentrations are higher during flood. This may be a result of stratification on ebb that suppresses mixing. This study was initiated in May 2002 and will conclude in the summer of 2005.

Morphological controls on marsh creek network flow patterns

Investigators: Dr. Richard Styles¹, Dr. Raymond Torres², Kevin White³, and Joseph Jurissa³
Department of Geological Sciences and Marine Science Program, USC¹;
Department of Geological Sciences, USC²; Marine Science Undergraduate Major, USC³

An experimental study to investigate flow characteristics and salt marsh morphology was carried out in the North Inlet South Carolina. Acoustic Doppler current meters (ADVs) were placed at the terminus of two abutting creek networks that were separated by a topographic divide. An additional acoustic profiler was placed near the mouth of one of the creeks. Flow patterns observed during spring tide indicated an abrupt switch in current direction during flood tide before vanishing at slack high water. This reversal in flow direction was mirrored during the ebb phase, in which initial ebbing did not drain the creek but rather flowed further onto the marsh surface. This pattern was also seen in the profile measurements at all depths. In contrast, the current moved up both creeks on flood and out on ebb during the neap phase. The marsh surrounding the study site is located within a meander of the main tidal channel. Although the cause of the spring tide flow pattern is not completely understood, it may be related to inundation of the marsh island producing a net fluid transport down the pressure gradient formed by the propagating tidal wave. Therefore, topography exerts the dominant control on the flow over the marsh surface during neap tide, yet topography and hydrodynamics exert control during spring tide.

Funding for this project was provided by NSF to Ray Torres, a Research and Productivity Scholarship (RPS) grant to Richard Styles, and a John Hodges award to Kevin White. This study was initiated in May 2004 and is ongoing.

Sediment exchange near a tidal node

Investigators: Dr. Richard Styles¹ and Steven Traynum²
Department of Geological Sciences and Marine Science Program, USC¹
Marine Science Undergraduate Major, USC²

In October of 2004, an observational program to examine flow and sediment transport in a subtidal marsh system was conducted in the North Inlet/Winyah Bay NERRS located near Georgetown, South Carolina. Time series of current and acoustic backscatter profiles were obtained from a moored upward looking ADCP deployed in a tidal channel. The channel serves as a conduit between Winyah Bay, a large brackish estuary, and North Inlet, a saline subtidal marsh system. During flood, tidal waters entering from the two systems converge at a node point separating the two water masses. Spatial and temporal salinity and current measurements suggest that during early ebb, Winyah Bay water is transported into North Inlet. As ebb continues, lateral advection from the marsh surface and tidal creeks leads to an increase in salinity, suggesting that North Inlet water is mixing with the Winyah Bay water. Resuspension is greatest during the latter ebb phase with concentrations exceeding 300 mg/l. These results indicate net particulate transport from Winyah Bay to North Inlet over a tidal cycle.

Funding for this project was provided by a Research and Productivity Scholarship (RPS) grant to Richard Styles, and a Honors College Senior Thesis grant to Steven Traynum. The University of South Carolina Marine and Aquatic Research Experience (MARE) program also contributed funding to support this research. This study was initiated in October 2004 and is ongoing.

Modern and historical sedimentation cycles and their instability on a mesotidal marsh island, North Inlet, South Carolina.

Investigators: Juana M. Montané and Dr. Douglas Williams
Department of Geological Sciences, USC

Salt marshes are dynamic environments about which little is known regarding the history of sedimentation, evolution and its relation to the underlying Pleistocene and Holocene back-barrier and marsh surfaces. There is a need to better understand how sedimentation on marsh islands is related to drainage features, especially small tidal creeks, which have been shown to be critically important to nekton production in a marsh.

The goal is to reconstruct a 50 to 100 year record of historical cycles of sedimentation on a salt marsh island from sediment core analyses, seismic data and surface and subsurface topographic trend analysis for potentially emerging patterns will reveal the stratigraphic framework and allow the story to be told of the island's present nature and the evolutionary processes and inheritances that created it. Understanding development and stability of salt marshes is scientifically valuable for many efforts, these include: biological, environmental, habitat and ecological as well as economic objectives. This study could also have implications for pressures to develop residential properties on marsh settings. Funding for this project comes from GAANN Fellowship and Dr. Williams. The field study was initiated in January 2002 and is ongoing. See map location #16.

Paleotempestology upon the South Carolina coastline: A calibration of the sedimentary historical record

Investigators: Abby Springer¹, Dr. Doug Williams¹, Eugene Karabanov¹, Dr. Cary Mock², and Dr. Claudia Benitez-Nelson³
Department of Geological Sciences, USC¹; Department of Geography, USC²; Marine Science Program, USC³

Paleotempestology is the branch of science that attempts to identify the frequency and intensity of historic hurricane landfall through the use of sedimentological and geochemical proxies in coastal environments. The objectives of this study include: 1) investigation of a coastal pond to determine if a paleotempestological study in South Carolina is viable, 2) to enhance the field of paleotempestology by introducing a new computer-based micro-structural analysis that will be able to conclude the lateral extent of coastal flooding due to intense hurricane events, and 3) utilization of this new analysis to identify multiple or clustered events within a single sand layer.

Sediment cores were taken in a transect perpendicular to the beach to capture the extent of overwash fans in Middleton Pond, Georgetown County, SC. After cores were opened, digitally photographed and described multiple analyses were performed including magnetic susceptibility and bulk density. Samples were also taken from the cores to be used for geochemical analysis including Carbon/Nitrogen ratios, ¹⁴C, ²¹⁰Pb and ¹³⁷Cs. To obtain the micro-structural approach thin-walled aluminum boxes were used to take undisturbed samples from selected intervals of the core face. These flat subcores were thin sectioned after freeze drying using the methodology developed by Von Merkt (1971) and Francus (1997). Special Software made available to us by Pierre Francus will be used to perform computer assisted examinations of the composition and sedimentary micro-structures of the sub cores. The back-scattered electron (BSE) images will provide quantitative data of size, shape, orientation and packing of the grains forming the sedimentary structures (Francus and Karabanov, 2000).

This research is important scientifically because it will identify and correlate historical hurricanes with their footprints, overwash sand layers. This knowledge can provide a way of predicting and modeling future hurricane events. The 2004 hurricane season was an extremely busy one. It was also extremely costly. The ability to predict future clustered hurricane events will provide a way to prevent loss of life and property in coastal regions.

Currently this project is being supported by the Department of Geological Sciences (stipend for Springer) and from overhead funds provided by the South Carolina Honors College August 2003-2005.

Seasonal variability in groundwater flow and saltwater intrusion from geophysical monitoring along forest-marsh transects

Investigators: Erin Carter and Dr. Scott M. White
Department of Geological Sciences, USC

The forest-marsh boundary constitutes the major interface between terrestrial and marine environments throughout the Southeast. Groundwater flow across this interface may control botanical zonation as well as the flow of nutrients and contaminants into the marsh. Previous studies have identified very steep gradients and marked asymmetry in the groundwater salinity around tidal creeks. These studies used only shallow well data to interpolate groundwater flow patterns, but have suggested that seasonal precipitation patterns may affect the salinity distribution at depth. This project is a pilot study to use electrical resistivity geophysical techniques to identify the zones of highly saline groundwater, and map the changes in groundwater salinity through time. Monthly resistivity measurements are being made along pre-existing well transects across Crabhaul Creek. Very strong resistivity gradients have been measured in accordance with the existing data from well measurements. Continued resistivity measurements will allow us to track the changes in salinity through a complete annual cycle, and examine the seasonality of the salinity cycle. This project is supported by the University of South Carolina. See map location #14.

Top-down grazer effects on marsh grass growth and marsh die-back

Investigator: Dr. Brian Silliman
Department of Ecology, Brown University

Large expanses of southeastern salt marsh (100's of km²) are currently experiencing unprecedented die-back. I have surveyed four die-off areas in Georgia and found snail densities to exceed 2000/m². No studies currently investigating marsh die-off, however, incorporate top-down effects into their experimental framework. Therefore, I am examining the extent to which snail grazing contributes to marsh die-off in GA, FL, LA, and here in SC. To address this goal, I am excluding snails from die back and non affected areas to examine their relative contribution to marsh die back. The consequences of marsh die-off are far-reaching for the ecology and economy of Southeast shoreline communities, since marsh grasses provide essential habitat and nutrients for almost all associated fauna (e.g., oysters, drum, trout, spot and shrimp). Results from this and other current investigations will allow marine managers to predict potential effects of eutrophication and predator depletion (e.g., blue crab declines) and to formulate effective multi-site strategies for marsh conservation. The study sites are located on the marsh in front of the main laboratory complex and adjacent to the lookout tower at Clambank (map locations # 8 & 10). This project is funded from March 2004 to October 2006 and is supported by a Visiting Scientist Award from the BMFL.

Effects of global warming and marsh grass growth

Investigator: Dr. Brian Silliman
Department of Ecology, Brown University

Marshes, like other coastal communities, will be increasingly exposed to global climate change. To examine potential consequences of global warming to marsh primary production and extent of salt pans in high marsh habitat, I will be deploying mini-greenhouses in the short *Spartina* zone and on the edges of salt marsh pans. Grass productivity and pan border movement will be monitored in greenhouse and control areas over two years. Results will help predict how marsh structure and function will respond to increasing temperatures as a result of global warming. The study sites are located on the marsh in front of the main laboratory complex and adjacent to the lookout tower at Clambank (map locations # 8 & 10). This project is funded from March 2004 to October 2006.

Quantifying blue crab predation on periwinkle abundance: Visual and immunological assay of gut contents

Investigators: Michael Long¹ and Dr. Robert Feller²
Department of Biological Sciences, USC¹; Department of Biological Sciences and Marine Science Program, USC²

Periwinkles will be regularly (biweekly or monthly) censused and measured and crabs will be collected in a stratified random design at four stations along the salt marsh elevation gradient from high marsh to the tidal creek. Area of study will be located to the left of road leading to Clambank, the same vicinity Brian Silliman monitored cages in 2004 as a BMFL visiting scientist. Crab gut contents will be analyzed visually and/or immunologically for presence/absence of snail opercula or solubilized tissues using a polyclonal antiserum (Feller et al., 1979). Lab feeding studies (serial sacrifice) will be conducted to determine how long snail meals can be detected in blue crabs. Same size crabs will be fed a known amount of snail mass (operculum still attached but without shell) and sacrificed over specified time intervals to establish a known digestion profile based on numbers of precipitin lines found.

The overall objective is to provide quantitative data with which to measure the predation intensity that blue crabs exert upon the periwinkle snail population. The immunoassays will provide information on the interactions between the predator (crab) and prey (snail). The snail population census will help determine if the snail population increases through time or if it decreases. It will also establish how the size-frequency distribution of the snail population does or does not change through time. Analysis of the data provided by this experiment may provide a basis for assessing the overall strength and ecological significance of the trophic cascade if it is present. Funding is provided by SC Sea Grant.

Plant defense by volatile emissions

Investigator: Dr. David E. Lincoln
Department of Biological Sciences, USC

Many, perhaps most, plants produce odorous emissions from their leaves. Recent investigations have demonstrated that such emissions of leaves that are stimulated by herbivore wounding can attract the enemies of herbivores and thus initiate a third trophic level defense of plants. The goal of the proposed research is to understand the defensive capacity of such herbivore stimulated leaf emissions through attraction of third trophic level enemies in a native setting. Experiments focus on the relationship of herbivore density and the resulting emissions to plant defense, how qualitative and temporal variation in emissions among plants shift their third trophic level defense, and how plant community context can alter the defensive effectiveness of herbivore stimulated emissions. These studies are taking place in the plant community on the edge of the marsh and the adjacent forest at Goat Island. See map locations # 3 & 8 for project location.

Induced sink strength in *Spartina alterniflora*: reallocation of carbohydrates as a first step towards herbivore defense

Investigator: Dr. Tom Arnold
Department of Biology, Dickinson College, Carlisle, Pa

Plant fitness in the face of insect attack depends upon the induced production of chemical defenses; however, all plant tissues are not equally responsive. We have recently shown that, for trees, responsiveness is dependent on the "sink strength" of wounded leaves. In some woody plants, wounded leaves become strong physiological sinks, importing resources from nearby source tissues *via* the plant vascular system for use in the construction of polyphenolics. With this knowledge, the magnitude of herbivore-induced defenses can be predicted: Disruptions of long-distance carbohydrate flow to wounded leaves reduces or eliminates induced defense responses, whereas increased flow generates unusually strong defense responses. This induced sink strength (ISS) links wound-induced activities of sucrose-cleaving enzymes to increases carbohydrate flow and to the production of one particular type of chemical defense. It is likely that ISS is a common, "first-step" for plants under attack by herbivores. To test this hypothesis the wound-response of saltmarsh cordgrass, *Spartina alterniflora*, will be examined at the Baruch site. If ISS is present in *S. alterniflora*, it could have important implications for saltmarsh communities since above-ground

herbivory would then redirect carbon away from roots, reducing the stability of marsh root systems and the input of organic carbon to sediments. This project is funded by a Visiting Scientist Award from BMFL.

Latitudinal variation in plant-herbivore interactions in Atlantic Coast salt marshes

Investigator: Dr. Steven C. Pennings
Department of Biology and Biochemistry, University of Houston

Biogeographic theory predicts that consumer-prey interactions are more intense at lower latitudes, leading to increased defenses of prey. My students and I are testing this hypothesis in Atlantic Coast salt marshes. We are counting herbivores and measuring herbivore damage to salt marsh plants in ten sites in the South Atlantic Bight and ten sites in New England. At Baruch, we work about halfway along Goat Island and at the end of the 3rd Boundary Cutoff Road (map locations # 9 & 9A). We will transplant standard marsh plants into a subset of our 20 sites for brief periods (ca. 1 month) to determine if standard salt marsh plants receive more herbivore damage in the south than in the north. This project will test a long-standing biogeographic theory that has received little experimental attention. This project is funded by the National Science Foundation.

Plant-herbivore interactions: Latitudinal variation and impacts of climate change

Investigator: Chuan-Kai Ho
Department of Biology and Biochemistry, University of Houston

Latitudinal variation in plant-herbivore interactions in salt marshes has been studied for several years. Data have supported that salt marsh plants at higher latitudes (New England) are more palatable than those at lower latitudes (FL, GA, SC) (Pennings et al. 2001). My research will follow up and examine if there is a correlation between this herbivore preference pattern and herbivore performance. My approach is to use 13 NERR and 3 Long-Term Ecological Research (LTER) sites along the Atlantic Coast as a network to examine this plant-herbivore interaction.

Using a combination of greenhouse experiment and field sampling, my research will focus on four common marsh plant species (*Solidago sempervirens*, *Spartina alterniflora*, *Iva frutescens*, *Baccharis halimifolia*) and their most common six herbivore species (aphid, *Uroleucon pieloui*; planthopper, *Prokelisia marginata*; beetle, *Ophraella notulata*; beetle, *Paria aterrima*; aphid, *Uroleucon ambrosiae*; and beetle, *Trirhabda baccharidis*). This is a 3-year project, focused on one plant species each of the first two years and two in the third year. Each spring, I will conduct field sampling to nondestructively measure herbivore densities, damage to plants from herbivores, and herbivore weights. A small number of herbivore individuals (<25) will be collected from each NERR or LTER site to conduct herbivore performance experiments in the greenhouse. In the fall, I will collect seeds from < 20 plants (except in the case of *Spartina*, for which I will collect five clonal ramets) for the next year's greenhouse experiments. Both of the goals of this project, understanding latitudinal differences in plant-herbivore interactions and understanding impacts of climate change, will be of interest to a broad range of ecologists and marsh scientists. In addition, by using standardized approaches at 13 NERR and 3 LTER sites, this project will enhance efforts to use these sites as a network to examine large-scale ecological processes. This project is supported by a NERR Graduate Research Fellowship (host reserve is the ACE Basin Reserve).

Latitudinal variation in the top-down control of salt marsh herbivores by invertebrate predators

Investigators: Dr. Robert F. Denno, Rachel Goeriz, Jessica Hines, Dr. Shannon Murphy, and Dr. Gina Wimp
Department of Entomology, University of Maryland

The historical controversy over the importance of natural enemies versus host plant resources in the population and community ecology of phytophagous insects has given way to a more unified view. The current perspective is that both so-called "top-down" and "bottom-up" forces contribute to herbivore suppression, and the present focus is on factors that alter the balance in favor of one force, either natural enemies or plant resources. For instance, habitat complexity, physical disturbance, and characteristics of the herbivores themselves can all influence

the relative strengths of bottom-up and top-down control. Notably, interactions among species at higher trophic levels such as intraguild predation can drastically alter top-down impacts. Also, structural features of vegetation can moderate intraguild predation and increase the overall impact of the natural-enemy complex on insect herbivores. The integration of such information has led to a more sophisticated understanding of factors that influence top-down and bottom-up impacts on insect herbivores. Nonetheless, most information regarding the effects of host plants and natural enemies on insect herbivores has been generated in the context of closed-system dynamics.

What remains poorly understood, although potentially critical in determining local herbivore dynamics, is how spatial subsidies and allochthonous resources from neighboring systems (nutrients, detritus, competitors, and predators) might influence the relative strength of top-down and bottom control, alter food web dynamics, and influence the probability for trophic cascades. Surprisingly, dynamics arising from spatial subsidies are rarely incorporated into ecological studies, and their consideration in the context of the top-down and bottom-up control of insect herbivores is virtually non-existent. Some information is available regarding the consequences of basal resource subsidies such as nutrients and detritus on local consumers and ramifications for trophic dynamics. However, little is known about predator subsidies and their effects on local insect herbivores. Even less is understood about the spatial scale of the predator subsidy and the consequences of predator subsidies for herbivores and food-web dynamics at different distances from the source. Also, no information is available about how predator subsidies might interact with basal resources (vegetation complexity) and existing natural enemies (predators) to influence insect herbivores. If predator subsidies involve intraguild predators, their immigration into neighboring communities may dramatically alter food-web dynamics, increase reticulate interactions, promote the attenuation of enemy impacts, and buffer communities against trophic cascades.

Thus, the thrust of this proposal lies in extending our work on the top-down and bottom-up control of insect herbivores (planthoppers) inhabiting *Spartina alterniflora* marshes to include the effects of an extensive spatial subsidy of intraguild predators (*Pardosa* wolf spiders and other invertebrate predators) from neighboring upland habitats (e.g., *Spartina patens* and other upland vegetation types). In northern marshes, spiders typically move from upland over-wintering habitats into *Spartina* marshes where they can suppress herbivore populations during the summer months. Using extensive surveys during the *Spartina* growing season (mid May through Mid September), our initial objective is to examine latitudinal variation in the abundance of invertebrate predators in relation to spatial changes in vegetation structure (the cover of upland habitats, and the standing crop biomass and leaf litter in *Spartina* marshes), factors that are known to influence the abundance of predators. Preliminary data suggest that both upland cover and leaf litter associated with *Spartina alterniflora* decrease along the Atlantic coast from New England to Florida. Associated with this spatial change in marsh vegetation structure is a dramatic decrease in the abundance of the ground-foraging community of predators (mostly hunting spiders) that colonize the low marsh from upland habitats. Thus, our expectation is that predator control of insect herbivores in *Spartina* will diminish from north to south along the Atlantic Coast. We aim to verify this latitudinal expectation by sampling vegetation structure and arthropod community composition in *Spartina* marshes along the Atlantic coast. At each marsh we will sample vegetation structure across the elevation gradient from tall-form *Spartina alterniflora* near tidal creek low marsh habitat to *Spartina patens* in high marsh upland habitat. Furthermore, we will use sweep nets and d-vac vacuum samplers to appraise the density of insect herbivores and their predators in the same salt marsh habitats. Our ultimate goal is to understand how this predator subsidy interfaces with spatial variation in vegetation structure to influence latitudinal changes in predator-prey dynamics and food-web interactions in *Spartina alterniflora*. Toward this end, southern-Atlantic marshes (e.g., Clambank in Baruch, SC) represent critical study areas because they characterize differences in structure between north and south Atlantic areas where invertebrate predators are abundant and rare respectively. Thus, such marshes present an ideal opportunity to elucidate factors underlying the dramatic latitudinal change in predator abundance with extended consequences for herbivore control.

This research is funded by NSF grant DEB-0313903: Ecological Studies Division of Environmental Biology to RFD.

Genetic variation and cryptic speciation in harpacticoid copepod populations

Investigators: Drs. Bruce C. Coull^{1,2,3} and Jeffrey G. Baguley¹
Belle W. Baruch Institute for Marine and Coastal Sciences, USC¹;
School of the Environment, USC²; Department of Biological Sciences, USC³

We are currently working on projects investigating genetic variation in two estuarine meiobenthic copepods, *Nannopus palustris* and *Microarthridion littorale*. We have previously revealed a genetic basis for morphological

variation in female *N. palustris*, suggesting the presence of cryptic species rather than polymorphism within the species. Collections of *N. palustris* will continue in an attempt to find similar variation in the male of the species. Populations of *N. palustris* from North Inlet, SC are also being compared to populations from Massachusetts and Louisiana in order to further investigate the phenomenon of cryptic speciation and genetic variation with geographic distance. Investigations involving *M. littorale* will focus on variation in multiple nuclear gene loci. Previous investigation has found three distinct mitochondrial DNA haplotypes, suggesting a possible cryptic species complex. However, nuclear gene evidence is needed to further support this hypothesis. Both projects will employ DNA extraction, PCR, DNA sequencing, and/or RFLP techniques to determine genetic variation. All collections will be performed around the Oyster Landing Pier (map location # 3).

Phylogeographic patterns in the parchment-tube worm *Chaetopterus variopedatus* (Annelida)

Investigators: Adriene Burnette and Dr. Kenneth M. Halanych
Department of Biological Sciences, Auburn University

Chaetopterus variopedatus is often reported as having a cosmopolitan distribution. In the USA, it is commonly found along the East Coast into the Gulf of Mexico. It has also been reported along the Pacific Coast. Many recent molecular studies have demonstrated that organisms with such broad geographic ranges are often cryptic species complexes (invasive species notwithstanding). Because *C. variopedatus* is one of the best studied annelids in terms of developmental mechanisms and because of its ecological importance, the boundaries of genetically distinct populations need to be delineated for comparative purposes. To this end, we are using mitochondrial DNA markers to determine genetic diversity and patterns in Western Atlantic and Gulf populations of this worm.

WormNet: Recent advances in annelid systematics, development, and evolution

Investigators: Dr. Kenneth M. Halanych, Heather Blasczyk, and Dr. Torsten Struck
Department of Biological Sciences, Auburn University

Understanding metazoan phylogeny has been confounded by interpretations of the degree and nature of segmentation in body plans. In particular, the Annelida, commonly called segmented worms, has been central to debates on the role of segmentation in animal evolution. Recent evidence suggests that several nonsegmented or partially segmented worm taxa, previously regarded as separate phyla, are within the annelid radiation. Genomic approaches are being used to reconstruct the early phylogenetic events of the “Annelida”, which includes several previously recognized phyla. Interpreting the segmentation, a hallmark of annelids, in the context of the phylogeny will allow novel insights on the role and plasticity of segmentation during animal evolution. We have visited the Baruch Marine Field Laboratory so that we may build a representative collection of annelids from the southeastern USA.

Sediment elevation dynamics in tidal marshes: Functional assessment of accretionary biofilters

Investigators: Drs. Robert Costanza¹, Roelof Boumans¹, Christopher Swarth², David M. Burdick³, and Donald Cahoon⁴
Institute for Ecological Economics, University of Maryland¹; Jug Bay Wetlands Sanctuary, MD²;
Jackson Estuarine Laboratory, University of New Hampshire³; Wetlands National Research Center, Lafayette, LA⁴

We are developing a data depository on sediment elevation changes in estuarine habitats in cooperation with NERES research coordinators and participating scientists across the country. The database built during this project will serve national estuarine research goals of establishing baseline data of sediment elevation changes from a variety of estuaries, a standardized protocol for use and analysis of data collected by means of the SET (Sediment Erosion Table), and criteria that will be used to assess success in created and restored critical habitats. The database will contain data from SET stations and marker horizons along with bibliographic references. We will use the

database also to establish restoration assessment guidelines (success criteria) with respect to measures of elevation change in critical estuarine habitats. Our project creates an enormous potential for regional and nation-wide comparisons and predictions of estuarine habitat sustainability. The database and protocol will establish NERRS as a leader in providing restoration assessment guidelines with respect to habitat elevation measures, criteria, analysis and interpretation. The NERR sites involved in the project are Jug Bay, MD; Great Bay Estuary, NH; Webhanet River Estuary, Wells, ME; Waquoit Bay, MA; Prudence Island, RI; Tijuana River, CA; Rookery Bay, FL; and North Inlet-Winyah Bay, SC. The project is funded by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).

Sediment accretion in North Inlet salt marshes

Investigators: Dr. James Morris and Karen Sundberg
Department of Biological Sciences and Marine Science Program, USC

The objective of this study is to understand how the elevation of the marsh surface is regulated. A major hypothesis being tested is that eutrophication initiates a sequence of changes in the sediments, beginning with a decrease in volume due to enhanced decomposition of organic matter. In fact, sediment accretion in experimentally fertilized marsh plots has increased. This is probably due to an increase in sedimentation caused by a higher density of plant stems in fertilized plots. Results of a model linking plant production and sedimentation with sea level indicate that the marsh maintains its elevation with respect to mean sea level for a range of rates of sea level rise, up to a threshold. The elevation of the marsh platform with respect to mean sea level is inversely proportional to the rate of sea level rise. Map locations #2A,B,C, D.

Experimental varying of the marsh platform and macrophyte response

Investigators: Dr. James Morris and Karen Sundberg
Department of Biological Sciences and Marine Science Program, USC

The objective of this study was to design a simple experiment in order to investigate how varying the marsh platform in relation to mean sea level would affect macrophyte production, stand dynamics, and biomass allocation patterns of *Spartina alterniflora*.

Our goal was to ascertain aboveground and belowground allocation patterns and quantify where the bulk of belowground biomass was located in relation to marsh elevation and sea level. There are six treatments ranging from supra optimal elevation (i.e., floods only on spring tides) to completely inundated (i.e., waterlogged) with 0.013 m separation between pipes with six replicates per treatment. Monthly stem height measurements are obtained each year from April to October. Plants were harvested at the end of both growing seasons from Oyster Landing, North Inlet, South Carolina (map location #3).

The frequency of inundation results in significant variation in stand densities and plant heights. While macrophyte production may not vary with treatment, these changes in stand densities and macrophyte morphology may have profound effects on the ability of salt marshes to accrete allochthonous sediments and maintain pace with sea level rise. Furthermore, allocation patterns may ultimately influence net annual primary productivity within salt marshes. Funding for this project came from NSF LTER, USGS, and Louisiana DNR for the period April 2002-Spring 2004.

Interspecific competition among some salt marsh perennials in South Carolina

Investigators: Drs. Richard Stalter¹ and John Baden²
St. John's University, NY¹; US Army Corps of Engineers, Wilmington, NC²

Salt marsh vegetation in the United States is characterized by distinct zonation of vascular plants. Zonation is less pronounced in brackish versus high salinity marshes. Previous transplant experiments indicated several species could not tolerate conditions in areas where they are not normally found. These experiments, however, failed to differentiate the effects of abiotic and biotic (namely interspecific competition) factors. Controlled, reciprocal

transplant manipulations have been performed. Growth and survival are being monitored to measure the relative importance of interspecific competition and abiotic factors as determinants of zonation patterns between the salt marsh cord grass, *Spartina alterniflora*, and the black needle rush, *Juncus roemerianus*. See map location # 6A.

Effect of wrack accumulation on salt marsh vegetation

Investigators: Drs. Richard Stalter¹ and John Baden²
St. John's University, NY¹; US Army Corps of Engineers, Wilmington, NC²

The objective of this ongoing study is to investigate the effect of wrack coverage on salt marsh vegetation in five vegetation zones in a South Carolina salt marsh. A second objective will be to monitor seedling establishment and survival in plots in four arrays during the growing season, 2005.

Four arrays consisting of a string of permanent plots were established in the above communities (map location #9A). A fifth array was established in a pure stand of *Spartina alterniflora* in March, 2005. Each array was 1.8 meters wide and consisted of eight 1m x 1.8m plots in a row roughly parallel to the water's edge. Within each of these plots, a central 0.5m x 1m sample plot was marked off, surrounded by a 0.25m wide buffer zone including a 0.5m buffer between adjacent sample plots within the array. In early March 2004, wrack was collected and placed on each array except for one control plot at a thickness of 15-cm. Fish netting with a 6.5 cm mesh was laid over the wrack covered arrays and held in place with a peripheral rope tied to stakes at the corners of the array and attached to the netting with special snap clips purchased from Forestry Suppliers, Jackson, MS. Wire staples were used to anchor the rope and netting to the ground. In April 2004, one plot in each array was uncovered and sampled. Subsequently, one plot in each array was uncovered in May, August and October, 2004. During mid October, 2004, vegetation within each experimental plot and the control were sampled with three randomly located 20 x 20cm quadrats located within the larger plots. Stems were counted by species. Vegetation of all species within the quadrats were cut at ground level and standing crop (gms of vegetation/m²) was determined.

This is the first study of the effect of wrack on the survival of salt marsh vegetation in a South Carolina salt marsh. With the exception of *Spartina patens*, all salt marsh species experienced 100% kill after wrack cover for two months. *Spartina patens* experienced a 50-75 percent reduction in density though some *S. patens* survived wrack cover for a period of one year.

The investigators greatly appreciate the support of the Baruch Institute for providing us with a vehicle and lodging, and for the helpful assistance of staff who removed wrack from one of the arrays during a hurricane surge during the summer of 2004. BMFL staff also provided the investigators with pictures of the vegetation in the arrays during the growing season of 2004, and in March, 2005. The senior investigator thanks St. John's University for providing equipment and travel funds to support this research.

Nekton behavior in salt marsh intertidal creeks: Patterns and mechanisms of tidal movement

Investigators: Drs. Kurt Bretsch¹ and Dennis Allen²
Marine Science Program, USC¹; Baruch Marine Field Laboratory, USC²

Nekton (motile fishes, shrimps, and crabs) are thought to play a vital role in the transfer of intertidal production within salt marshes. A new sampling device, the sweep flume, was used to determine the timing (water depth) and sequence of migration of taxa into three flooding intertidal creeks. The depth of peak movement varied among taxa, and the sequence of occupation was similar among creeks, suggesting that partitioning use of intertidal creek habitat is a broadly based phenomenon. Significant density correlations and presence/absence associations between pairs of dominant taxa suggested that biotic interactions may affect depth selection during migration. To determine if biotic factors affect depth selection, I am investigating the hypotheses that 1) depth preferences of individual nekton taxa (grass shrimp, spot, pinfish, mummichog, mullet) change in the combined presence of other taxa, 2) grass shrimp and mummichog select shallower depths in the presence of predatory pinfish. All experiments are being conducted on the lab grounds in a pair of large, multilevel (20, 40, and 60 cm water depths) tanks designed to represent conditions in flooding intertidal creeks. The results of this research will contribute to the scientific understanding required to measure, model, maintain, and/or restore the integrity and sustainability of salt marsh ecosystems. This project started in Spring 2001 and has a tentative end date of Summer 2005. Support is provided

by NOAA's Dr. Nancy Foster Scholarship Program, the USC Marine Science Program, the NI-WB NERR, and the Baruch Marine Field Laboratory.

Nekton use of intertidal creek pools; a spatial analysis of relationships between geomorphology and nekton occupation during low tide

Investigators: Dr. Dennis M. Allen¹, Dr. Henrietta Hampel², and Kimberly Foley¹
Baruch Marine Field Laboratory, USC¹; Royal Belgian Institute of Natural Sciences, Brussels²

Recent studies in North Inlet demonstrated strong relationships between geomorphological features of intertidal creeks and the densities of nekton that occupied them at high tide. Although most of the tidal migratory fishes, shrimps, and crabs leave the creeks with the ebbing tides, large numbers remain in isolated pools of water along the axis of the creeks. Previous studies revealed differences in the composition and abundance of nekton among pools. Measurements of pool morphology, positions, water quality, and nekton within and among intertidal creeks of different configurations are being conducted to determine relationships between geomorphology and patterns of occupation by motile animals. Information on the physiological tolerances, swimming behavior, and trophic relationships among pool occupants is providing insights into factors controlling assemblage composition and levels of habitat use. Mark-recapture techniques will be used to examine site fidelity and home ranges for grass shrimps and other common species. This project was initiated with a BMFL Visiting Scientist Award to H. Hampel and has been expanded with partial support from the NSF (Ecosystem Studies) Links Project.

Mobile Link Organisms (MLO's) as processors and transporters of materials within a marsh-estuarine ecosystem

Investigators: Drs. Richard Dame¹, Dennis Allen², Robert Young¹, and Stacy Luthy¹
and Kimberly Foley²
Department of Marine Science, Coastal Carolina University¹
Baruch Marine Field Laboratory USC²

This new study will expand our understanding of the roles that MLO's (nekton) play in connecting well-defined intertidal and subtidal subsystems within the estuarine landscape. Diverse and abundant assemblages of fishes, shrimps, and crabs migrate from subtidal channels into intertidal creeks, oyster reefs, mudflats, and marshes with flooding tides to forage. Through bioturbation, prey handling, and excretion, these animals contribute dissolved nutrients to the water column. Experiments conducted by S. Haertel-Borer demonstrated that, collectively, these migratory assemblages comprise a major source of inorganic nitrogen and phosphorus in the system. In the present study, synoptic measurements made at multiple sites on varying time scales will allow us to determine fluxes of nutrients within and between subsystems. Experimental manipulations involving measurements in creeks and other subsystems with and without nekton will enable us to understand relationships between nutrient dynamics and the activities of nekton on short time scales. Hypothesized decreases in inorganic fluxes following the exclusion of nekton from intertidal creek basins, particularly during the dark period, will provide an empirical measure of the role of these animals in material processing. We will also quantify changes in nekton biomass and production over periods of weeks and seasons as cohorts of resident and transient taxa grow and export accumulated organic matter across subsystem boundaries. The Links Project will provide research-based training for undergraduates who will conduct independent studies throughout the three year grant period. Funding is from the National Science Foundation, Ecosystems Studies Program.

Longline survey of sharks of Winyah Bay and nearby waters

Investigators: Dr. Daniel C. Abel, David Gandy, Elisabeth Knott, Brad Copen, and Samuel J. Gary
Marine Science and Biology Departments, Coastal Carolina University

Recent surveys of sharks along the Southeast coast have shown declines in several species, e.g., sandbar and dusky sharks. These and other sharks inhabit coastal waters and/or estuaries, and use the latter as nurseries. We are

undertaking a long-term longline study to survey the sharks of Winyah Bay and nearby waters; to determine which sharks use the Bay as a nursery; and to understand habitat selection by selected species in the Bay. We will thus understand more about the life history, diversity, abundance, and seasonality of sharks in Winyah Bay and nearby waters. Sampling will occur from April through October of 2005 and consist of 500 ft demersal longlines with 25 hooks. 12/0 circle hooks will be used to target neonates, young-of-year and juveniles; and 16/0 circle hooks will be used to sample larger individuals. Longlines will be set in the Lower Bay (closest to the ocean), Middle Bay, and Upper Bay. Variables such as water temperature, salinity, and dissolved oxygen, as well as secchi depth and set depth will be measured. Detailed information arising from this study will contribute to a greater understanding of the health of this group along the Southeast coast.

This project is supported by the Coastal Atlantic States Shark Pupping and Nursery (COASTSPAN) program, Georgetown Environmental Protection Society, National Fish and Wildlife Foundation/Sustainable Universities Initiative.

Assessment of habitat utilization by multiple coastal shark species in a North Inlet subtidal creek

Investigators: Bree K. Yednock and Dr. Daniel C. Abel
Coastal Marine and Wetland Studies Graduate Program, Coastal Carolina University

This is the second year of an ongoing shark nursery ground assessment of North Inlet and an investigation of habitat utilization, with respect to tide and creek size, for juvenile sharks. We expect to find juvenile sharks concentrating in the larger creeks during low tide and expanding their range into smaller creeks at high tide. Sampling will occur from April through October 2005 and consist of 500 ft demersal longlines with 25 12/0 circle hooks set in three sampling areas. Each sampling area will include one main channel creek site and one smaller adjacent tidal creek site: Town and Bread and Butter, Old Man and Bass Hole Bay, and Jones and Duck (map locations # 2D, 5, 7, 13). Every site will be sampled once a month at high and low tide. Additional longlines with 16/0 circle hooks will be set in each large creek site once a month at high and low tide to target larger individuals. This study will provide information on the diversity and abundance of sharks utilizing North Inlet as well as their spatial and temporal partitioning throughout the sampling season. Understanding habitat and early life history requirements of sharks is essential in establishing appropriate management measures for this group. In addition, the near-pristine quality of North Inlet Estuary makes this study an ideal benchmark to which future studies and anthropogenic effects can be compared.

This project is supported by the Coastal Atlantic States Shark Pupping and Nursery (COASTSPAN) program, Georgetown Environmental Protection Society, Slocum-Lunz Foundation, National Fish and Wildlife Foundation/Sustainable Universities Initiative.

Catch and Release Mortality in South Carolina's Red Drum Recreational Fishery

Investigator: Julie Vecchio
Marine Science Program, College of Charleston

The red drum, *Sciaenops ocellatus* Linnaeus (Sciaenidae), is a near-shore and estuarine fish species found along the south Atlantic and Gulf coasts. Due to the popularity of red drum and the strict regulations, catch and release has become an integral part of the red drum fishery in South Carolina as well as other south Atlantic states. A rigorous study of hook type, placement and 48 hour survival in sub-adult red drum will be conducted by the graduate student, project personnel of the SCDNR inshore fisheries section.

During each fishing trip surface temperature, surface salinity, bottom temperature, bottom salinity, and bottom dissolved oxygen (DO) will be recorded. Each time a fish is caught, fish TL, hook type, hook location, a bleeding category, and landing time will be recorded. If a fish is hooked below the pharyngeal teeth (recorded as gut hooked), the leader will be cut as close to the hook as possible and the hook left in place.

All angled red drum will be held in 4 m diameter 1 m depth fiberglass tanks for 48 h. Fish will not be fed during the holding period. Temperature, salinity, and DO will be monitored every 15 minutes by an automatic data logger. Mortality will be monitored every 12 h. If a fish dies, a necropsy will be performed to determine cause of death, extent of bleeding, and hook injuries. Upon release, fish will be tagged with internal anchor or steel dart tags to facilitate the identification of fish used in the study. This will help to verify longer-term survival.

This study will also determine which variables contributed significantly to the mortality rates found among fish caught in the study. Several studies used linear models to investigate which variables significantly affected mortality (Aguilar et al. 2002; Lucacovic and Uphoff 2002; Murphy et al. 1995; Pauley and Thomas 1993). These variables included hook type, hook position, fish size, landing time, handling time, transport time, water temperature, and depth of capture. All statistics will be performed using R statistical package and a statistical text (Sokal and Rohlf 1995).

Juvenile white shrimp, *Litopenaeus setiferus*, potential reduction of macrobenthos abundance in southeastern US salt marshes

Investigators: Jennifer Beseres¹ and Dr. Robert Feller²
Marine Science Program and Baruch Marine Field Laboratory, USC¹
Department of Biological Sciences and Marine Science Program, USC²

Many juvenile estuarine species rely on the detritally-driven food webs in salt-marsh habitats and are capable of ingesting large numbers of benthic prey. Long-term monitoring conducted by the Baruch Marine Field Lab in North Inlet-Winyah Bay (NI-WB), SC shows that macrobenthos abundances typically decline in early spring with the recruitment of predatory transient estuarine species such as brown shrimp *Farfantepenaeus aztecus* and many juvenile fishes. This database has also provided correlative evidence that macrobenthos numbers decline more than usual during years when white shrimp (*Litopenaeus setiferus*) are very abundant, leading to the hypothesis that white shrimp predation is capable of significantly reducing macrobenthos abundances.

This field study first used manipulative caging experiments to test this hypothesis in NI-WB, SC (Crabhaul Creek, map location #3), and Sapelo Island, GA (Factory Creek). Normal and elevated white shrimp densities were held in inclusion cages and allowed to feed on subtidal macrobenthos for 7 days. Macrobenthos abundance significantly decreased over a 7-day period in our shrimp treatment cages. Follow up laboratory experiments indicated that shrimp predation reduced macrobenthos abundance to a greater extent than disturbance or emigration. Thus, white shrimp may be responsible for changes in macrobenthos abundance and community composition in subtidal creeks. Future experiments are being designed to measure shrimp consumption rates on macrobenthos. This project is funded by a NOAA/NERR Graduate Research Fellowship through 2006.

Ghost fishing by blue crab pots

Investigators: Bonnie Coggins and Dr. Robert Feller
Department of Biological Sciences and Marine Science Program, USC

The blue crab fishery is large and economically important in South Carolina. Millions of pounds of blue crabs are caught annually by thousands of crab pots. It has been found that perhaps as many as 25% of pots are lost each year. A lost pot is usually the result of the buoy becoming detached from the pot. Research has found that lost pots continue to fish and retain crabs even after the bait is gone. This study will feature two types of experiments. In the first experiment, crabs caught by a baited pot will be labeled and placed in an unbaited pot. These pots will be monitored daily and weekly to determine the ability of crabs to escape and the occurrence of new crabs in an unbaited pot. The second experiment will mimic a truly lost pot as closely as possible. Pots will be baited and placed in typical locations. Buoys will not be attached to the pots, but they will be easily found using other markers. These pots will be checked weekly, monthly, or every three months. In both experiments, data will be recorded on size, sex, and sponge status of blue crabs. Other organisms present in the pot will also be recorded.

Microbial observatory: The microbial community and distribution associated with the roots of select salt marsh plants

Investigators: Drs. George Y. Matsui¹ and Madilyn Fletcher^{1,2}
Belle W. Baruch Institute for Marine and Coastal Sciences, USC¹
Department of Biological Sciences and Marine Sciences, USC²

The root-associated microbial communities directly influence the growth of many plants. This is especially true in plants that are subjected to nutrient limitations or soil constituents that may inhibit growth. Within the salt marsh, nitrogen limitations exist as well as high levels of sulfide that have been shown to limit plant growth. It is believed that microorganisms associated with the roots of salt marsh plants aid in mediating these factors. The purpose of this study is to 1) examine the microbial communities found on the roots of *Spartina alterniflora* and *Juncus roemerianus*, 2) determine how these communities are distributed along the roots, and 3) determine what factors contribute to differences in microbial community and distribution. The roots of *S. alterniflora* and *J. roemerianus* and the sediment associated with those plants will be collected and microbial DNA will be extracted from the samples. Microbial communities will be examined by 16S polymerase chain reaction-denaturing gradient gel electrophoresis (PCR-DGGE) for differences in the communities of the roots and the associated soils. The distribution of microbial communities associated with the roots of the plants will be determined by fluorescence *in situ* hybridization (FISH) of 16S used in conjunction with confocal laser scanning microscopy (CLSM). PCR-DGGE or FISH of either specific phylogenetic groups or functional genes will be used to examine functional differences within the communities. Pore water will be collected to determine environmental parameters that may affect microbial communities associated salt marsh plant roots. The results of this study will provide a better understanding of factors that affect primary production and the microbial influence on carbon and nitrogen cycling within the salt marsh (Map locations # 10 & 8). Support provided by NSF award MCB-0237854 and the Belle W. Baruch Institute.

Estuarine eutrophication and microbial community composition

Investigators: Wes Johnson¹ Drs. James Morris², and Madilyn Fletcher³
Marine Science Program, USC¹; Department of Biological Sciences, USC²;
Belle W. Baruch Institute for Marine and Coastal Sciences, USC³

Microbial communities play critical roles in the processing of matter and energy in estuarine ecosystems. The composition, structure, and function of these complex assemblages are thought to be controlled by either top-down mechanisms (grazing), or by bottom-up effects (nutrient availability, temperature, and salinity). This project examines the bottom-up effects of water chemistry and primary productivity on planktonic microbial community composition. Compositions of planktonic bacterial communities are determined by amplifying 16S rDNA using polymerase chain reaction (PCR) and subsequent separation of the amplified products using denaturing gel electrophoresis (DGGE). The study is being conducted at the Baruch Marine Field Laboratory and University of South Carolina (Columbia). Comparisons of the five sampling sites indicate compositional changes along salinity gradients, as well as seasonal changes relating to phosphorus availability. The relationship of primary production to microbial community structure and identification of the members of the community are currently being investigated. The study is supported by EPA/NOAA/NASA, CISNET: Molecular to Landscape-Scale Monitoring of Estuarine Eutrophication.

Microbial community responses to eutrophication in a Southeastern US salt marsh estuary

Investigator: Wes Johnson
Marine Science Program, USC

This study examines the effects of nutrient loading on microbial communities in salt marsh sediments. Chemical fertilizers are applied to selected plots of salt marsh within the North Inlet system from which sediment and pore water samples are collected monthly. The microbial community compositions are determined using polymerase chain reaction/denaturing gradient gel electrophoresis of 16S rDNA. Analysis of the resulting profiles

has indicated that there is no measurable change in the composition of the bulk bacterial communities attributable to the addition of inorganic nitrogen (N) and/or inorganic phosphorus (P). The number of bacteria is not significantly different between controls, P additions, or N additions, however cell counts increase significantly with simultaneous addition of both P and N. This finding suggests that N and P dynamics are coupled in the sediment system. Currently, experiments involving the addition of labile carbon (C) substrates to sediments are being conducted to determine the effects C availability may have on bacterial growth and community composition. This study is supported by the NOAA/NERRS Graduate Research Fellowship Program.

Nitrogen fixation rates in a coastal ecosystem under different nutrient addition regimes

Investigator: Dr. Melody J. Bernot
Department of Biological Sciences, University of Notre Dame

The proposed study consists of two primary components to measure nitrogen fixation rates. First, a survey of ^{15}N natural abundance will be conducted in organic pools (sediments, plants) of existing experimental nutrient amendment plots. Second, laboratory assays for dinitrogen fixation rates will be conducted for independent verification of nitrogen fixation rates. The proposed research will aid in development of new collaborations while addressing a fundamental ecological question of broad interest. Data collected via the proposed research will allow me to test a firm hypothesis and, in combination with existing data on sediment chemistry, produce a publishable result. Additionally, the proposed research will provide background data needed to go forward with future research proposals. This project is funded by a Visiting Scientist Award from BMFL.

Chemically mediated interactions in a sedimentary assemblage

Investigators: Drs. Charles R. Lovell, Sarah Woodin, David Lincoln, and students
Department of Biological Sciences and Marine Science Program, USC

In this study, investigators are evaluating impacts of toxic chemicals (bromophenols) produced by burrowing polychaetes on marine sediment microflora. Respiration and assimilation rates of bacterial communities are being conducted using radiotracer techniques. Phospholipid fatty acid analysis has provided insights into microbial community ecology and how microbial communities respond to chemical stresses. Field and laboratory measurements indicate that natural microbial communities are adept at mineralizing these compounds and that their modes of growth in the sediments provide them with protection from toxic chemicals. Bacterial species highly active in compound mineralization may be useful in cleaning up chemically impacted sites. See map location # 17. This project has been supported by NSF, ONR, and EPA.

Colonization of man-made surfaces in the marine environment

Investigators: Dr. Charles R. Lovell and students
Department of Biological Sciences and Marine Science Program, USC

Microorganisms colonize submerged surfaces very efficiently. This colonization process provides numerous benefits to the microorganisms, including access to surface-bound nutrients and protection from certain types of predators. The accumulation of these organisms and their extracellular products on surfaces ultimately results in the formation of biofilms, which contribute very substantially to the process of biofouling. Biofouling of man-made materials creates numerous problems. The dense accumulation of organisms and polymers impedes thermal transfer in heat exchange pipes, creates drag on ship hulls, and produces unique corrosion processes that can destroy the surface in question. The consequences of surface colonization are clear, but the sequence of events leading to biofouling is poorly understood. We have been studying the early stages of surface colonization and have identified the primary colonists (i.e., the first species to attach to the surface) on a variety of surfaces. We have also tracked the seasonal dynamics of these primary colonists and are now determining their interactions with other types of organisms. In some biofilm systems, the primary colonists greatly facilitate the attachment of other species, leading to biofouling. If the primary colonists in marine systems have this same essential role in the generation of marine

biofouling communities, they may hold the key to controlling biofouling. This project has been supported by the Department of Defense.

Recent publications associated with the work:

- Dang, H., and C.R. Lovell. 2002. Numerical dominance and phylotype diversity of marine *Rhodobacter* during early colonization of submerged surfaces in coastal marine waters as determined by 16S rDNA sequence analysis and fluorescence in situ hybridization. *Applied and Environmental Microbiology* 68:496-504.
- Dang, H., and C.R. Lovell. 2002. Seasonal dynamics of particle-associated and free-living marine *Proteobacteria* in a salt marsh tidal creek as determined using fluorescence in situ hybridization. *Environmental Microbiology* 4:287-295.
- Dang, H., and C.R. Lovell. 2000. Bacterial primary colonization and early succession on surfaces in marine waters as determined by amplified rRNA gene restriction analysis and sequence analysis of 16S rRNA genes. *Applied and Environmental Microbiology* 66:467-475.

Infaunal burrows and their impacts on sediment microbiota

Investigators: Drs. Charles R. Lovell and George Matsui
Department of Biological Sciences and Marine Science Program, USC

Marine infauna create and maintain burrows in soft sediments. These structures vary in composition, properties, and longevity, but in all cases house abundant and highly active microbiota. The increased surface area provided by burrows greatly enhances diffusive exchange between the sediments and overlying seawater and the irrigation of the burrows by the resident infauna introduces oxygenated seawater into sediments that are otherwise highly anoxic. The microbiota of the burrow linings occur in thick biofilms and consists of both oxygen requiring and oxygen sensitive species. A major focus of this project is the impact of oxygen introduction by irrigation on key species of anaerobic bacteria, particularly the sulfate reducing bacteria. We are performing field sampling and experimental manipulations in the laboratory to determine whether the sulfate reducers in burrow lining biofilms are sensitive to introduced oxygen, or are sheltered through growth in anaerobic microzones. Such microzones could arise from growth of sulfate reducers in association with oxygen consuming species. Another possibility is strong chemical reduction of the surroundings by high levels of sulfate reduction activity, which produces hydrogen sulfide. It is also possible that the sulfate reducers have no special refugia from oxygen and are exposed to oxygen when burrows are actively irrigated. We are using fluorescence in situ hybridization and fluorescent redox potential probes to determine which of these growth strategies are employed by sulfate reducers to maintain activity and viability in the strongly irrigated tubes of the onuphid polychaete *Diopatra cuprea*.

Publications associated with the work:

- Matsui, G.Y., D.B. Ringelberg, and C.R. Lovell. 2004. Sulfate reducing bacteria in tubes constructed by the marine infaunal polychaete *Diopatra cuprea*. *Applied and Environmental Microbiology* 70:7053-7065.
- Marinelli, R.L., C.R. Lovell, S.G. Wakeham, D. Ringelberg, and D.C. White. 2002. An experimental investigation of the control of bacterial community composition in macrofaunal burrows. *Marine Ecology Progress Series* 235:1-13.
- Noble, P.A., J.S. Almeida, and C.R. Lovell. 2000. Application of neural computing methods for interpreting phospholipid fatty acid profiles of natural microbial communities. *Applied and Environmental Microbiology* 66:694-699.
- Watson, J., G.Y. Matsui, A. Leaphart, F.A. Rainey, J. Wiegel, and C.R. Lovell. 2000. Reductively debrominating strains of *Propionigenium maris* from burrows of bromophenol producing marine infauna. *International Journal of Systematic and Evolutionary Microbiology* 50:1035-1042.
- Phillips, T.M. and C.R. Lovell. 1999. Distributions of total and active bacteria in biofilms lining tubes of the onuphid polychaete *Diopatra cuprea*. *Marine Ecology Progress Series* 183:169-178.

Identity, physiological ecology, and toxicity of the red tide dinoflagellate *Kryptoperidinium* sp.

Investigators: Dr. Alan J. Lewitus^{1,2}, Krista DeMattio², Raphael Tymowski¹, Megan Heidenreich^{1,2}, and Dr. Amy Ringwood³
Baruch Marine Field Laboratory and Hollings Marine Laboratory, USC¹; Marine Resources Research Institute, SCDNR², University of North Carolina at Charlotte³

Kryptoperidinium sp. is a dinoflagellate responsible for red tides in several South Carolina estuaries from Georgetown to Hilton Head in spring 1998-2001 (the first red tides reported to be localized to SC estuaries). These blooms have recently been shown to cause physiological stress to oysters. Given their widespread distribution and potential to adversely affect shellfish, the ecological and economic impacts of these newly observed blooms might be considerable. This study examines the identity of the bloom organism(s), the factors driving bloom dynamics, and potential bloom impacts on shellfish health. The blooms appear to coincide with heavy spring rain events that produce increased run-off of terrestrial humic substances. The use of this dissolved organic matter (DOM) as an energy source may be beneficial for its growth in estuarine waters. Our objectives are to determine *Kryptoperidinium*'s physiological responses to DOM and inorganic nutrient enrichment in order to determine whether nutrient loading plays a role in bloom stimulation. Furthermore, we are developing molecular tools to enhance bloom species identification and detection, and determining the physiological stress responses of oysters to the SC blooms. This project is supported by ECOHAB (NOAA, NSF, EPA, NASA, ONR) for the period September 2, 2002 to August 31, 2005, and NOAA NOS for the period 1 October 2004 to 30 September 2006.

Application of the CHEMTAX model in estuaries. Deriving phytoplankton composition from HPLC pigment profiles

Investigators: Dr. Alan J. Lewitus^{1,2}, Sabrina Hymel¹, Raphael G. Tymowski¹, and Dr. David White³
Baruch Marine Field Laboratory and Hollings Marine Laboratory, USC¹; Marine Resources Research Institute, SCDNR², NOAA, Hollings Marine Laboratory³

CHEMTAX is a modeling program used to derive the abundance and class composition of phytoplankton from HPLC pigment data. Although it has been applied successfully to open-ocean algae, it produced inaccurate results in an estuarine system. Further study indicated that CHEMTAX output is accurate only if the pigment ratios used to calibrate the model are near those of the phytoplankton in the community being examined. Thus, a model calibrated using open-ocean phytoplankton is not applicable to an estuary containing similar taxa. The main goal of the current study was to produce a set of calibration pigment ratios that would allow the model to be used in several SC estuaries. Phytoplankton composition derived using the newly calibrated CHEMTAX model was compared to that determined through microscopic enumeration. The results of the two methods agree closely, although additional research is required to achieve greater resolution between algal classes.

Functional relationships (coupling) between epiphytic microalgae and food webs in a saltmarsh estuarine system and their management implications

Investigators: Dr. Richard Zingmark¹, Dr. Alan J. Lewitus^{2,3}, and Raphael Tymowski²
Department of Biological Sciences, USC¹; Baruch Marine Field Laboratory and Hollings Marine Laboratory, USC²; Marine Resources Research Institute, SCDNR³

North Inlet Estuary (NIE) is a typical, near-pristine, highly productive, *Spartina alterniflora*-dominated, salt marsh estuary that has been well characterized in recent years with respect to material and energy flow. Numerous subsystems have been identified that vary in direction and magnitude of material flux. One such typical subsystem, the tidally driven Bly Creek basin, is an exceptionally productive area that receives a diel net input of particulate organic carbon (POC) (including phytoplankton) from the coastal ocean. Some of the phytoplankton is sequestered by and becomes incorporated into the epiphytic community on the stems of *S. alterniflora*. Although the net flux of POC into Bly Creek was previously estimated, specific functional mechanisms (e.g., trophic links) responsible for processing it are not understood. This proposed research seeks to describe and quantify linkages between "phytoplanktonic" carbon transported from the coastal ocean through Bly Creek and its various trophic

compartments. By identifying and quantifying trophodynamic mechanisms regulating phytoplankton flux through Bly Creek, the proposed research will fill gaps in our understanding of how highly productive salt marshes are linked to and process primary production from the coastal ocean to help fuel estuarine secondary production (including that of commercially and recreationally important fish and shellfish species) in this and other salt marsh estuarine systems. Results of this study will provide a strengthened scientific basis to guide protective management decisions in salt marshes. This study is funded by South Carolina Sea Grant Consortium, 1 March 2005 to 28 February 2007.

Brittlestar chemo-detection of a predator *Luidia clathrata*

Investigators: Dr. Stephen Stancyk^{1,2} and Christine Ansell²
Department of Biological Sciences, USC¹; Marine Science Program, USC²

Many marine organisms rely on chemoreception to recognize conspecifics, potential prey items, or potential predators. A fast moving prey that can detect a slower moving predator has an increased chance of survival. Chemical signals released by predator may be intrinsic to the predator or may be cues that are released based upon dietary choices. Chemical cues released in conjunction with diet may decrease the foraging effectiveness of a predator and give prey an evolutionary advantage. The purpose of this research is to determine if brittlestars can distinguish between 1) *Luidia clathrata* starved, fed conspecifics or fed clams 2) whole brittlestars and brittlestar extracts and 3) whole clams and clam extracts. In all trials, 1 mL aliquots of the treatment stimuli will be pipetted above the aboral surface of the brittlestar and the behavioral response recorded. The experiments will start in June and run through August.

Zooplanktivory by the burrowing brittlestar, *Hemophilic elongate*: Tests on natural plankton assemblages

Investigator: Dr. Stephen Stancyk
Department of Biological Sciences and Marine Science Program, USC

Most burrowing brittlestars are in the family Amphiuroidae, and obtain nutrition from surface and subsurface deposit-feeding on detritus. *Hemophilic elongate*, however, is in a different family (Ophiactidae) and has been shown to readily feed on brine shrimp and copepods. Because most zooplanktivorous brittlestars are found in the deep sea or Antarctica, the presence of *H. elongate* in North Inlet provides an opportunity to learn more about feeding responses and prey selection in ophiuroids. To develop feeding response curves and prey preference information, individual brittlestars are placed in cores and allowed to feed on known densities and mixtures of unnatural (brine shrimp, *Artemia*) and natural (field-collected copepods, larvae, etc) prey assemblages. *H. elongate* is uncommon in North Inlet and lives around tube-caps of the polychaete, *Diopatra cuprea*, only in muddy sands. See map location #17.

What are the environmental impacts of gelatinous zooplankton (Hydromedusae) on carbon dynamics of the North Inlet ecosystem?

Investigators: Dino Marshalonis, Dr. J.L. Pinckney, and Dr. Tammi L. Richardson
Department of Biological Sciences, USC

Hydromedusae (thimble jellyfish) are gelatinous zooplankton that are major predators of other zooplankton species. Their ability to reproduce rapidly coupled with their extremely high prey consumption rates enables them to exert control over energy flow and nutrients in estuarine waters. Gelatinous zooplankton are major components in a trophic cascade in which they consume microzooplankton and the microzooplankton are primary grazers on nanophytoplankton. Therefore, gelatinous zooplankton can affect phytoplankton community composition indirectly by consuming phytoplankton herbivores. Seasonal abundances of Hydromedusae have been recorded for North Inlet, South Carolina during the last 15 years as a part of their LTER and NERRS Programs and have been shown to be the dominant gelatinous predator in this system in terms of numerical abundance.

The study location for the proposed research will be Clambank Creek in North Inlet, South Carolina (Map Location 6B). There are four main testable hypotheses for this project. First, we will examine whether grazing by hydromedusae stimulates a shift in phytoplankton community composition from small to large phytoplankton. Secondly, we will evaluate the effects of temperature and species on ingestion rates and assimilation efficiencies for hydromedusae in North Inlet. Third, we will compare respiration rates for oblate and prolate hydromedusae species, as well as actively feeding and non-feeding organisms. Finally, we will test if seasonal nutrient excretion by different gelatinous animal species to North Inlet exerts a bottom up effect on phytoplankton abundance.

In situ bioassays will examine relationships between gelatinous zooplankton and the rest of the estuarine plankton in this system. These results will be compared to our determination of species specific metabolism through respiration rates. Determination of ingestion and assimilation rates will quantify the grazing impacts hydromedusae in North Inlet will impart on the rest of the plankton. Finally, we shall examine potential nutrient amplification to the North Inlet system from gelatinous zooplankton excretory products, which could substantially influence phytoplankton growth and community composition. Collectively, these values can be scaled up for the entire estuary using long term data for gelatinous animal abundance in North Inlet. The sum result of these experiments can be incorporated into a carbon based food web model to demonstrate how and to what degree gelatinous animals influence carbon flows for the North Inlet plankton system, as well as the potential impact of increased gelatinous animals in the future.

This project is funded by NOAA's National Estuarine Research Reserve System (NERRS) Graduate Research Fellowship Program from June 1, 2005 – May 2008

The effects of microhabitat and mussel body position on survivability, growth and reproduction of *Geukensia demissa*

Investigators: Jennifer Jost and Dr. Brian Helmuth
Department of Biological Sciences, USC

With global climate change becoming an ecologically pressing issue, there has been a recent interest in the ability to predict the effects of climate change on the earth's ecosystems. This requires that we first understand the effects of temperature on organisms within their habitat, in terms of what range of body temperatures are experienced by the organism and what aspect of this body temperature (maximum temperature, minimum temperature, or the cumulative effects of temperature over time) has the greatest effect on survival and growth rates in the field.

Past research has examined the effects of body size, marsh site, and mussel body position on mussel body temperature of *Geukensia demissa*. Thermally matched temperature loggers (empty mussel shells filled with silicone and equipped with an iButton temperature logger) with an accuracy of $\pm 1^\circ\text{C}$, were placed in the field near Oyster Landing at three marsh microhabitats. Three body sizes (4-6cm, 6-8cm and 8-10cm shell length) and three body positions (0cm, 3cm, and 6cm shell length exposed above sediment surface) were examined beginning March 2004. The data suggest that body position is high significant, marsh microhabitat is somewhat significant and body size has no effect on mussel body temperature. Based on these preliminary results, mussel loggers are still in position to continue to record and monitor estimated mussel body temperature. However, the variable body size has been eliminated.

Currently, I am setting up both a field and seawater laboratory experiment to run from May to September 2005. In the field I plan to set up three temperature experiments. One will be a control with no material over the mussels, one will be shade cloth and one will be glass plates designed to increase heat at the marsh level. Within each treatment, I will notch mussels at the start of the summer. Once a month, I will return to the marsh, record the level of growth for each mussel and remove a portion of the mussels to be dissected. Once dissected, mussel shell length, mussel body dry weight and mussel gonad dry weight (if applicable) will be measured and recorded. Once the mussels appear to be reproductively mature, all mussels will be harvested and dissected for final analysis. I expect to see a decrease in both growth and gonad weight in the treatment with added heat.

The seawater lab experiment also plans to examine the effects of various body temperatures on mussel body growth, reproductive output and survivability. I will house mussels in artificial marsh tanks with an artificial tidal cycle. During low tide, mussels will be heated to one of 6 treatment temperatures: 30, 35, 40, 45, 50 or 55 degrees C. These temperatures span the range of temperatures recorded in the field in the summer of 2004. In addition, mussels will be heated in a manner similar to that seen in the field, with heat lamps turning on at 6AM and off (following peak temperature) at 3PM. Mussels will be cooled in air, and will experience high tide conditions only

during the night. This corresponds to the typical conditions seen on hot days at Oyster Landing marsh sites. There will be 2 replicates of 20 mussels for each treatment. Initial measurements will include shell length, width and height. Final measurements include shell size, dry weight and dry gonad weight. Again, I expect to see an increase in mortality with increase in treatment temperature as well as a decrease in growth and reproduction with an increase in treatment temperature.

An evaluation of antimicrobial activity of the western Atlantic octocoral, *Leptogorgia virgulata* (Lamarck)

Investigators: Jacqueline Shapo^{1,2}, Dr. Sylvia Galloway², and Cheryl Woodley²
Graduate Program in Marine Biology, College of Charleston and NOAA/NOS/CCEHBR¹;
NOAA/NOS/CCEHBR²

Soft corals (Octocorallia: Gorgonacea) are often colonized by bacteria and other microbes that may be pathogenic as well as surface fouling. The immune system of these corals, just as that of other invertebrates and vertebrates, relies on swift, innate identification of a pathogen, localized inflammation of the injured area, and as one systemic response, the synthesis of specific antimicrobial compounds at the cell surface or within a cell to target microbial infection. Soft corals are important to the structure, biomass, and trophic dynamics of coral reefs worldwide; yet, little is known about the specific mechanisms of their host defense immunology or how they interact with their environment on a molecular level to prevent microbial attacks. As greater than 60% of coral reefs globally are threatened by a plethora of natural and anthropogenic stressors, including disease, the evaluation of antimicrobial activity of the widespread South Carolina sub-species of the colorful seawhip, *Leptogorgia virgulata*, will be used to enhance our understanding of coral innate immunity, such that laboratory and field tools may be developed to predict disease outbreaks, assess the source of stressors impacting disease outbreaks, and identify disease agents and their etiology. To further my current investigation of antimicrobial activity in *L. virgulata* to include corals impacted by low levels of damage and stress, I plan to collect branches of *L. virgulata* from study sites adjacent to the floating dock at Clambank boat landing and at the uppermost portion of the oyster shoals on upper 60 Bass Creek between May and October 2005. This project is supported by NOAA base funding for Coral Health and Disease Investigation and by researchers at the NOAA/CCEHBR facility in Charleston, SC, from October 2004 to May 2006.

Urbanization and Southeastern Estuarine Systems (USES)

Investigators: Drs. Dwayne E. Porter^{1,2}, Alan Lewitus^{1,2}, Tom Chandler^{1,2}, Marj Aelion^{1,2}, Alan Decho^{1,2}, Geoff Scott^{2,3}, John Ferry¹, Mike Fulton^{2,3}, and Tom Siewicki^{2,3}
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Left unmanaged, anthropogenic activities threaten the environmental health and economic vitality of coastal estuaries. Historically, the dynamic and complex nature of critical estuarine ecosystems inhibited the successful development of models that could effectively be used by coastal zone and fisheries managers. In response to these concerns and the identified need for spatial models to support sustainable coastal development, a long-term study was initiated in 1990 to define, measure and model the impacts of urbanization on coastal estuaries of the southeastern United States. The Urbanization and Southeastern Estuarine Systems (USES) project began 1 June 1990. The primary objectives of this long-term study are: to delineate the impact of multiple stresses resulting from urbanization on high-salinity estuaries; and to develop models that will provide a scientifically valid basis for land-use management decision-making in the coastal zone.

Emphasis has been placed on watershed dynamics, including an examination of land-use patterns and the impacts associated with watershed loadings. By comparing the short-term trends and long-term variability in system responses at the North Inlet-Winyah Bay NERR with those of an adjacent developed estuary, a clearer assessment of the impacts of development can be made than basing management strategies on one estuarine system. The models incorporate land-use patterns and practices, integrated toxicological and risk assessment modeling, and Geographic Information Processing (GIP) approaches. A strength of the USES project is that it is a long-term monitoring and research project focusing on current issues of both ecosystem health and public health. As proposed in the multi-

year plan, out years are extremely crucial to the continuing success of the project. It is during this time that the integration of sub-study components via data syntheses; modeling development, testing and calibration; and outreach to coastal zone managers takes place. In addition to the two primary study sites, associated researchers have expanded into additional estuarine systems of the Southeast to conduct similar experiments and compare results and test developed models. As driven both by our science and the needs of natural resource and public health managers, we are able to adjust our research thrusts to focus on those issues most critical to the Southeast.

This project is funded by the Coastal Oceans Program/NOAA/Department of Commerce from 08/01/04 through 07/31/05 (www.urbanestuary.org).

Development of a GIS-based database management program to characterize sources and effects of natural parameters and anthropogenic impacts of coastal ecosystems

Investigators: Drs. Dwayne E. Porter^{1,2}, Tom Siewicki^{2,3}, Jeff Allen⁴, Marj Aelion^{1,2}, and Heath Kelsey², and Sam Walker²
Belle W. Baruch Institute for Marine and Coastal Sciences, USC¹
The Norman J. Arnold School of Public Health, USC²
NOAA's Center for Coastal Environmental Health and Biomolecular Research³
The Strom Thurmond Institute, Clemson University⁴

According to a 1995 NOAA report, the top priorities for coastal resource managers were to acquire 1.) information on nonpoint sources of pollution and preventing wetland habitat loss; 2.) scientific data linking development activity to adverse resource impacts; and 3.) techniques for managing development impacts and mediating multiple use conflicts.

The advent of database management programs, the Internet and the World Wide Web (WWW), and Geographic Information Systems (GIS), particularly when coupled to statistical modeling, allow new approaches to managing development of our coastal ecosystems. The South Atlantic Bight Land Use - Coastal Ecosystems Study (LU-CES) will combine existing and newly gathered data into a single (virtual) archive for use in forecasting impacts to coastal and estuarine ecology in the SC&GA region. The project will then be able to devise alternative development strategies to minimize these impacts. This project also seeks to predict human source fecal coliform contamination and nutrient levels in the surface and groundwaters of golf course associated developments, based on land use characteristics in the vicinity of monitoring points. The project is testing the hypothesis that fecal coliform levels from human sources are significantly higher in areas close to certain land use characteristics, and determining whether the source of the bacterial contamination is from human or non-human sources.

The South Carolina Department of Health and Environmental Control (DHEC) uses fecal coliform levels measured in surface waters to classify shellfish harvesting areas based on the Interstate Shellfish Sanitation Conference (ISSC) guidelines. Under the ISSC guidelines, shellfish harvesting areas can be classified as approved, conditionally approved, restricted, conditionally restricted, or prohibited based on the fecal coliform concentrations measured by DHEC. Shellfish in areas with high fecal coliform levels in the surface water are assumed to have potentially dangerous levels of fecal coliforms (and human pathogens) as well. However, fecal coliforms can be deposited in surface waters from both human and wildlife sources, and it may be important to differentiate between these sources. The transport of fecal coliforms to surface waters from human sources and wildlife sources may be very different, and their differentiation could lead to changes in the classification of some shellfish harvesting areas. Additionally, if the prediction of fecal coliform from human and animal sources is possible using land use characteristics, it may be possible to develop a land use based classification system of harvesting areas.

This project will differentiate the fecal coliform levels measured in Murrells Inlet into fecal coliforms from human and animal sources. This will be accomplished by comparing patterns of Multiple Antibiotic Resistance (MAR) in *E. coli* obtained from human sources and from surface water samples. In general, bacteria from human sources exhibit more antibiotic resistance than from animal sources, and have different patterns of multiple resistance. The MAR technique will help to determine if fecal coliforms measured in an area are from human or wildlife sources.

Geographic Information Systems (GIS) are used to characterize various land uses within the study areas. Data from the fecal coliform classification are incorporated into the GIS to examine the spatial distribution of human and animal source fecal coliforms. Using the land use characterizations and the fecal coliform distribution, GIS and statistical procedures will be used to attempt to predict the fecal coliform levels from human and animal sources based on the land use characteristics. Specific land use characteristics characterized include septic tank density,

population density, housing density, vegetation, impervious surfaces, sewage treatment outfalls, and stream locations and volumes. Additional variables include rainfall, salinity, temperature, and tidal fluctuation. Statistical procedures include kriging, multiple regression and logistic regression. This project is funded for the period from 07/01/04 to 06/30/05 by SC Sea Grant Consortium.

The NOAA-NERRS Remote Sensing Applications Assessment Project (RESAAP)

Investigators: Drs. Dwayne E. Porter^{1,2}, Victor V. Klemas³, John R. Jensen⁴, Richard T. Field³, and Don W. Field⁵; and Samuel P. Walker² and Amit Malhotra⁵
Belle W. Baruch Institute for Marine and Coastal Sciences and the Baruch Marine Field Lab, USC¹; The Norman J. Arnold School of Public Health, USC²; College of Marine Studies, University of Delaware³; Department of Geography, USC⁴; NOAA-NMFS Center for Coastal Fisheries and Habitat Research⁵

NOAA's National Estuarine Research Reserve System (NERRS) has been employing remote sensing technologies for a number of years for a variety of applications. However, the NERRS is exploring the design and adoption of a more comprehensive strategy to address remote sensing activities within the sites that comprise the System. In response to this need the Remote Sensing Applications Assessment Project (RESAAP) was developed as part of a larger evaluation and monitoring effort within NOAA's Estuarine Research Division. The RESAAP investigation comprises research with and adoption of remote sensing in four Reserves: Padilla Bay (WA); Grand Bay (MS); ACE Basin (SC); and Delaware (DE), with anecdotal research efforts in a fifth Reserve (North Inlet-Winyah Bay, SC).

The main goal of the RESAAP effort is to provide the NERRS with a technical document that will enable easy adoption and implementation of remote sensing technology to assist with science and resource management efforts within Reserves. This technical report will incorporate the NERRS land cover classification system that is being adopted for use system-wide. The investigation focuses on three main components that relate to the application of remote sensing protected coastal ecosystems. These areas of primary focus include: 1) the design, implementation, and management of a remote sensing project at an existing NERR site; 2) the remote monitoring and analysis of estuarine health in Estuarine Research Reserves; and 3) the communication of results to the resident science community and beyond. During the course of the study investigators will examine specific applications across a range of habitats including: submerged aquatic vegetation; emergent marsh vegetation; and an urban dominated estuary.

This (RESAAP) project is funded from 6/1/2004 to 5/31/2005 by a grant through the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) at the University of New Hampshire (<http://ciceet.unh.edu>).

Use of integrated remote sensing and field techniques for assessing and managing the distribution of invasive plant species in southeastern estuaries

Investigators: Samuel P. Walker and Dr. Dwayne E. Porter
The Norman J. Arnold of the School of Public Health, USC¹
The Belle W. Baruch Institute for Marine and Coastal Sciences, USC^{1,2}

The goal of this research is to evaluate an integrated approach combining in situ and remote sensing data collection techniques with digital image processing and geostatistical and statistical modeling to assess the distribution of invasive species in the North Inlet and ACE Basin estuaries.

The three primary goals of this investigation are to:

- Develop a predictive model for the establishment of *Phragmites australis* (common reed) within and adjacent to the NI-WB NERR;
- Evaluate the efficacy of an integrated (*in situ*, remote, and statistical) methodology for developing the predictive model; and
- Document the research data, and transfer the conclusions to local stakeholders for further evaluation and use.

- The study will use an integrated approach combining *in situ* and remote sensing data collection techniques with digital image processing and statistical modeling to assess the distribution of *Phragmites australis* in the North Inlet and ACE Basin estuaries.

A variety of sites will be within and adjacent to the NI-WB NERR, including locations in the abandoned rice fields, East Bay Park, the Thousand Acres Marsh, and along the North Boundary Road.

The project is funded through NOAA and the National Estuarine Research System Graduate Research Fellowship Program. This project is funded through May 2005 by NOAA, and National Estuarine Research Reserve System Graduate Research Fellowship.

Advanced Laser Fluorescence (ALF) technology for estuarine and coastal environmental biomonitoring

Investigators: Drs. Alexander Chekalyuk¹, Kenneth Moore¹, David White², and Dwayne Porter²
Virginia Institute of Marine Science¹
The Norman J. Arnold of the School of Public Health, USC²

The project objective is to develop an advanced laser fluorescence (ALF) technology for environmental biomonitoring estuarine and coastal areas from a small vessel and sample analysis. The ALF technique should be capable of providing high-resolution real-time data for:

- Quantitative assessment of major photosynthetic pigments, phytoplankton physiological and nutrient status and their photosynthetic activity
- Detection of taxonomic changes in phytoplankton populations and dominant algal groups
- Fluorescence measurement of chromophoric dissolved organic matter (CDOM)

These critical variables will provide valuable, currently missing information, which can be utilized along with standard water quality data for detailed bio-environmental characterization of estuarine and coastal areas. In particular, variable fluorescence has been shown to be a sensitive indicator of phytoplankton physiological status and nutrient supply, and can therefore be utilized for monitoring impacts of nutrient enrichment and as an indicator of potential contamination. Monitoring phytoplankton taxonomic variability will allow detection of habitat changes, including potential for detecting toxic algal blooms. In addition, the concentration of CDOM is a useful parameter for further characterization and biomonitoring of estuarine areas.

The ALF technique will utilize the latest advances in laser technology and active fluorescence spectroscopy. Assessment of photosynthetic pigments and CDOM will be conducted by fluorescence spectral analysis with excitation at several wavelengths coinciding with absorption bands specific to these pigments. The fluorescence pigment assessment will also allow detection of taxonomic changes in phytoplankton populations and identification of dominant algal functional groups. Phytoplankton physiological status and photosynthetic activity will be assessed from variable fluorescence, Fv/Fm, measured with pump-during-probe (PDP) fluorescence induction protocols. The application of this technology to estuarine waters with high turbidity, large suspended sediment and detritus loads, elevated concentrations of pigments and dissolved organic matter, and complex phytoplankton taxonomic composition presents significant challenges. A unique house-made Laser Pigment Analyzer will be utilized as a flexible research platform for optimizing ALF technological solutions. The proposed ALF technology will be optimized through research and extensive tests to be conducted at participating NERR sites (North Inlet – Winyah Bay) with contrasting bio-environmental conditions.

The ALF surveys will provide valuable, currently missing information, which can be used along with standard water quality data for detailed bio-environmental characterization of estuarine and coastal areas. Variable fluorescence has been shown to be a sensitive indicator of phytoplankton physiological status and nutrient supply, and can therefore be utilized for monitoring impacts of nutrient enrichment and indication of potential contamination. Monitoring phytoplankton pigment and taxonomic variability will allow detection of habitat changes, including potential for detecting toxic algal blooms. The concentration of CDOM will provide additional useful information for characterization of bio-environmental situation. Utilization of a small vessel as a platform will allow periodical ALF surveying in NERR sites and adjacent areas. Real-time data analysis will allow flexible, ‘observation-driven’ sampling and will provide coastal managers with rapid feedback in the regions with strong socio-economic activity and heavy urban population in the event of rapid bio-environmental changes caused by external sources, including potential eco-terrorism events.

This project is funded from 1/1/2004 through 12/31/2005 and is funded by The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET)

Identification of toxicant-responsive genes in the mummichog (*Fundulus heteroclitus*)

Investigators: Janis S.K. Peterson, Horacio Gonzalez, and Dr. Lisa J. Bain
Department of Biological Sciences, University of Texas at El Paso

Increasing pressure on the coastal environment is resulting in adverse impacts on many estuarine organisms. Thus, more information is needed on the chronic and subtle effects of pollutants on estuarine organisms, and how to adequately detect these adverse sublethal effects before these populations decline further. The area surrounding Charleston Harbor has several impacted estuarine sites that empty into the harbor proper which are heavily contaminated with polycyclic aromatic hydrocarbons (PAHs) and heavy metals. We are using mummichogs (*Fundulus heteroclitus*) as an indicator species to study the chronic effects of contamination by examining altered gene expression in fish from these impacted sites compared to those collected from Town Creek at the North Inlet NERR. We hope to use DNA markers to correlate gene expression with alterations in reproduction, growth, and development, which are parameters that are difficult and time-consuming to assess in the field. Project period: July 2003-October 2005.

Impact of boat wakes on intertidal reefs of the oyster *Crassostrea virginica*

Investigators: Drs. Linda Walters¹, Loren Coen², and Paul Sacks¹
Department of Biology, University of Central Florida¹; SCNDR, Marine Resources Research Institute²

To better understand the impact of recreational boating activities on the eastern oyster *Crassostrea virginica*, field trials were run during the summer of 2004. In narrow, deep, tidal channels with a 1-2 m tidal range in South Carolina and in microtidal (~ 5 cm), shallow-water Florida estuaries, we varied the wake signatures associated with single boat passes by using a variety of hull designs, engine profiles (trim angles) and velocities. On shore, we determined if boat-wake induced shell dispersal was able to injure/destroy mimic juvenile oysters attached to disarticulated shells. Mimics were created from plasticene and measured 1 cm in diameter. Three mimics were randomly placed on either the inner side or outer side of each shell. After the boat passed by and the wake subsided, damage to all mimics on shells in each of three 0.25 m² quadrats (50 shells/quadrat) was recorded. Additionally, maximum wake height, maximum water motion, wind speed, turbidity, and boat speed and distance from shore were recorded for each pass.

Testing an alternative oyster reef restoration strategy

Investigators: Dr. David Bushek², Paul Kenny¹, Laura Schmidt¹, and Dr. Anna Toline¹
Baruch Marine Field Laboratory, USC¹
Haskin Shellfish Research Laboratory, Rutgers University²

During a recent dredging project, oyster reef habitat was inadvertently destroyed when dredge pipes drifted over oyster reefs during high tide and settled on them during low tide. In a collaborative effort between residents from the local residential community and staff from the Baruch Marine Field Laboratory, oyster recruitment stakes were planted to attract settling oyster larvae to the site. Half of the stakes were coated with a thin layer of concrete, which has been anecdotally reported to increase recruitment. Stakes were planted in June 2003 (see map location # 11). Recruitment during 2003 and 2004 was low indicating that the populations in the upper reaches of the canal system may be slow to recover. Oysters that did settle on stakes, however, were 100 times more likely to settle on cement coated stakes than bare stakes. Support for this project was provided by the Debordieu Colony Community Association, the North Inlet-Winyah Bay NERR, and the Baruch Marine Field Laboratory.

Temporal patterns of Dermo disease in North Inlet

Investigators: Dr. David Bushek¹, Megan Heidenreich², and Dr. Dwayne Porter³
Haskin Shellfish Research Laboratory, Rutgers University¹, Baruch Marine Field Laboratory,
USC², Belle W. Baruch Institute for Marine and Coastal Sciences, USC³

The protozoan parasite *Perkinsus marinus* causes Dermo disease in oysters. The disease is not harmful to humans, but can be deadly to oysters. Seasonal patterns of intensification and remission in North Inlet correspond to the well-known seasonal effects of temperature observed in other areas. In North Inlet and throughout the southeast, however, oysters do not appear to succumb to the disease as readily as they do in the larger bays of the mid-Atlantic or Gulf coasts. This observation has led to a series of directed investigations on resistance, transmission and thermal tolerances of the parasite relative to the oyster. Analysis of monthly data from 1995 to date has revealed a long-term correlation of infection intensities with long-term changes in salinity. The effect is not significant or apparent across shorter time intervals. This observation supports the hypothesis that system flushing and water residence time, which are often correlated with salinity, may be more important in controlling infection intensities than salinity. This research is supported by the USES project and the North Inlet-Winyah Bay NERR.

LIDAR-based watershed modeling of North Inlet

Investigator: Laura Schmidt
North Inlet-Winyah Bay NERR, Baruch Marine Field Laboratory, USC

The goal of this project is to model sediment and surface water movement in the North Inlet watershed. The project started in 2002 with the acquisition of LIDAR data. We are developing parameters suitable for input in the AGNPS model. Using the AGNPS model, we will predict problem areas for non-point source pollution (sediment). This project requires several sources of ancillary data, including a LIDAR-derived elevation model, and a current land cover map. The LIDAR data were used to delineate the North Inlet watershed. The land cover map will be developed from various sources of digital imagery, including IKONOS satellite imagery and digital orthophoto quads. This work will give the North Inlet-Winyah Bay NERR staff a better understanding of the development pressures influencing North Inlet.

Settlement and metamorphosis of three species of fiddler crabs in a South Carolina salt marsh

Investigators: Drs. Renae Brodie¹ and Marcel Reichert²
Marine Science Program and Department of Biological Sciences, USC¹
Marine Resources Research Institute, SC DNR²

South Carolina has three species of estuarine fiddler crabs: *Uca pugilator* and *Uca pugnax*, which are high salinity crabs and *Uca minax*, which occupies low salinity and freshwater habitats as an adult. All three of these undergo larval development in offshore waters, then return to the estuary at the end of the larval period where they metamorphose and remain as juveniles and adults. We would like to understand this reinvasion process better. Namely, we would like to know if the three species target specific areas for settlement and metamorphosis as they move into tidal creeks, or if they settle randomly. To this end, we will be sampling returning fiddler crab larvae along the creek that runs past Oyster Landing, using light traps (see map location #3). Larvae caught by the traps will be brought back to the lab, where they will be counted and identified to species using a molecular analysis (the larvae look identical and hence can only be identified genetically). Collections will be made in the Oyster Landing Basin (see map location # 3)

Salinity and its effects on *Uca minax*, *U. pugilator*, and *U. pugnax* survivorship during larval, megalopal, and juvenile stages

Investigators: Stephen Borgianini¹, Jenice Godley, and Dr. Renae Brodie
Department of Biological Sciences

The 2005 field season will encompass a continuation of last year's project (salinity fluxes and *Uca* juvenile survivorship) and a few new lab-based projects addressing questions that arose from the aforementioned study. Salinity measurements, and *Uca* juvenile collection, will be taken from July 1 to August 31 at two sites on the Baruch property: Hell Site and Clambank Bridge (see attached map). The long-term collection of data will help us to see trends that occur from year to year with salinity and the *Uca* populations at these two sites. Collection of the *Uca* juveniles will occur twice a week and the salinity data will be collected biweekly. We also plan to map out the adult *Uca* distributions along salinity gradients, in the creeks and rivers, throughout the summer in the North Inlet Estuary.

As for the lab-based projects, we plan on investigating the effects of salinity on survivorship of the larvae, megalopae and juveniles of the three *Uca* species to see if there is any differential survivorship among the species at various salinities. The larval project will begin May 15 with a collection of brooding females in the Georgetown area. The megalopal and juvenile experiments will be done throughout the summer, dates depending on when we start an experiment. The megalopae and juveniles for these experiments will be reared at the Baruch Marine Field Lab. With the continuation of field work and these experiments more light will be shed on how much of a role salinity plays in the *Uca* spp. distribution and what it takes for them to successfully reach settlement. Project period: May 15- August 31, 2005

Recruitment of megalopae to freshwater, upriver areas

Investigators: Stephen Borgianini¹, Dr. Richard Styles², Joseph Jurissa³, and Dr. Renae Brodie
Department of Biological Sciences, USC¹, Department of Geological Sciences and Marine Science Program, USC², Marine Science program³, Department of Biological Sciences, USC¹

We will develop a data base for all available flow data vs. tidal data for the Little Pee Dee River and the Black River. Data will be acquired through available data bases maintained by the South Carolina Department of Health and Environmental Control (SCDHEC), North Carolina Department of Natural Resources (NCDNR), and the U.S. Geological Survey (USGS).

Field sampling will be conducted every two weeks from June through September. The sampling regime will include: 1. surface light trap; 2. current flow profiles; 3. pump sampling at three depths (surface, mid-depth, 2ft. from bottom).

The data generated will be compared to distribution data, physiography, and flow data to attempt to highlight any trends in recruitment when compared to adult distribution.

Ontogeny of salinity tolerance and osmoregulatory capabilities in *Uca pugilator*, *U. pugnax*, and *U. minax*

Investigators: Dr. Carl Thurman, Chad Bennett¹, and Dr. Renae Brodie²
Department of Biology, University of Northern Iowa¹
Department of Biological Sciences, USC²

Postlarval and juvenile fiddler crabs are exposed to far greater fluctuations in temperature and salinity than adults because they remain exposed on sediment at low tide. The selective pressure for tolerance of salinity extremes in juveniles may explain why adults of many fiddler species in laboratory are able to tolerate a range of salinity conditions far greater than those ever measured in their habitats. We will examine the hypothesis that the physical conditions experienced during early stages in life will shape the physiological tolerance of adult fiddler crabs. Between June 1 and July 1, 2005, we will measure 1) the environmental salinity and temperature conditions experienced by megalopal and juvenile fiddler crabs in the salt marsh at Oyster Creek and Clambank, and 2) the salinity tolerance and osmoregulatory capabilities of megalopal and juvenile crabs of *U. pugilator*, *U. pugnax* and *U. minax* in the laboratory using nanoliter osmometry. Since there is little information on the ability of the postlarval

and juvenile stages in *Uca* to withstand osmotic stress, this project will broaden our perspective of physiological regulation within this genus. This project is funded, in part, by the University of Northern Iowa and by a Visiting Scientist Award from BMFL.

Groundwater flow and its effects on the distribution of *U. minax* and plant zonation

Investigator: Stephen Borgianini and Dr. Renae Brodie
Department of Biological Sciences

Within the North Inlet estuary we will be investigating the dynamics of groundwater flow and salinity distribution along ten (10) forest/upland-salt marsh transects. Five (5) groups of nested transects (two transects each) will be located at locations in the estuary that have unique physiographic characteristics. Groundwater level elevations and salinity will be collected every 2 to 5 days from piezometers located along each transect. In addition, salinity data loggers will be installed at three (3) of the nested transects. At the time the groundwater data are collected observations will be made regarding the distribution of *Uca* congeners and plant species distribution across each transect.

These data will be collected in order to determine how groundwater flow from forest/upland to marsh to tidal creek effects the distribution of *U. minax* as well as plant zonation. Additionally, the affects of changes in groundwater salinity caused by natural events such as rainfall and tides will be compared to the biodistribution measurements collected.

Research experience for undergraduates summer 2005 project descriptions

Investigators: Dr. Renae Brodie and students
Department of Biological Sciences

Completion of the blue crab predation project

The predation of fiddler crabs of the genus *Uca* by juvenile blue crabs (*Callinectes sapidus*) was observed last field season. The *Callinectes* juveniles (< 4" carapace width) were observed utilizing specialized foraging behavior when seeking *Uca* prey. In response *Uca* were observed exhibiting predator avoidance behaviors that were unique. Six observational events were completed last season. We will continue the project into this season (with some additions).

Rafting of *Uca minax* juveniles

We will be examining potential recruiting mechanisms of *U. minax* juveniles to supratidal positions on the fringes of the salt marsh. Specifically, we will be investigating if *U. minax* juveniles utilized "rafting" on *Spartina* wrack as a possible distribution mechanism. On ebbing spring tides *Spartina* wrack from the brackish upper reaches of the marsh are transported toward inlets by the amplified ebb tidal current. On ebbing spring tides we will use 1m² net to collect free-floating *Spartina* wrack rafts. The rafts will be sorted by hand and juvenile *Uca* individuals will be collected for PCR and/or RFLP analysis in the laboratory.

Selective Tidal Stream Transport (STST) behavior of fiddler crab larvae in the Winyah Bay Estuary

Investigator: Dr. Richard Tankersley
Department of Biological Sciences, Florida Institute of Technology

Larvae of many estuarine crabs develop in coastal waters before they return and settle in juvenile nursery areas. Tidal currents often facilitate seaward transport of larvae that are spawned within marshes and develop in the high salinity coastal ocean. By coupling vertical migration to the phases of tidal currents, a behavioral mechanism referred to as selective tidal stream transport, larvae may enhance their export from the estuary. By timing periods of active swimming and passive sinking relative to flooding and ebbing tides larvae can move between the upper and lower estuary. Their behavior may be in response to environmental factors (e.g., salinity, temperature, turbulence) and/or endogenous rhythms with a circatidal period. Dispersal patterns and the underlying mechanisms for

movements in estuaries with complex tidal and river discharge patterns are not well understood. During Summer 2005, we will conduct laboratory experiments to test the hypothesis that newly hatched *Uca minax* larvae exhibit endogenous rhythms in swimming activity that promote ebb-tide transport and match the tidal regime at the adult release sites in Winyah Bay. This project is funded, by a Visiting Scientist Award from BMFL

Long-Term Studies

The summaries listed below document the long-term studies that are ongoing in North Inlet. One of the valuable resources provided by the BMFL are the long-term ecological monitoring data of the relatively pristine North Inlet Estuary. These data enable scientists to distinguish natural cycles that may span decades or more from anthropogenic impacts and appropriately attribute trends in the data from their shorter, more focused research. Moreover this information allows scientists to develop hypotheses and design experiments to identify mechanisms that control the world around us. In many cases, BMFL data sets are either the longest continuous data sets or the most comprehensive data sets available. Many of these data may be obtained via our web site (www.baruch.sc.edu) using links to the National Estuarine Research Reserve Centralized Data Management Office (CDMO) or the National Science Foundation's Long-Term Ecological Research (LTER) site.

Long-term measurements of production and physiological ecology of *Spartina alterniflora*

Investigators: Dr. James Morris and Karen Sundberg
Department of Biological Sciences and Baruch Institute, USC

Salt marsh grass, *Spartina alterniflora*, dominates the intertidal marsh in North Inlet Estuary. Regular measurements of grass density, height, stem width, and other characteristics allow for estimates of growth and primary production rates. Manipulative field experiments and long-term measurements of abiotic conditions including pore water salinity are providing insights into factors that affect production. Large monthly and interannual variations in the amount of organic material produced by the cordgrass are related to such factors as sea level and precipitation patterns. See map locations # 3 and 8

Tide level: Long-term monitoring at Oyster Landing Pier in Crab Haul Creek

Investigators: Virginia Ogburn-Matthews¹ and Dr. L. Robert Gardner²
Baruch Marine Field Laboratory, USC¹; Department of Geological Sciences, USC²

Partners: Tom Mero, NOAA/NOS/OPSD, and Lewis Lapine, SC Geodetic Survey

Begin and End Date of database: May 2001 to present (ongoing) (missing data from July 2002-February 2003)

The tide gauge measures water level in reference to MLLW in Crabhaul Creek (Oyster Landing Pier) every six minutes. The data are transmitted to NOAA via NOAA's Geostationary Operational Environmental Satellites (GOES), making the data available on-line in near real-time (three hour delay). Data are available to the public, and are useful in showing tidal anomalies, observing sea level rise, and modeling local phenomenon in North Inlet Estuary.

This state-of-the art tide gauge is accurate to ± 3 mm with a resolution of ± 1 mm. The gauge is part of the NOS's National Water Level Observation Network (NWLON); NOS oversees all data management. The National Tidal Datum Epoch has been updated to the 1983-01 epoch on April 21, 2003. The updated bench mark sheets are available on the CO-OPS website: http://co-ops.nos.noaa.gov/datum_update.shtml. For viewing the on-line near real-time data for North Inlet, visit NOAA's website at <http://tidesonline.nos.noaa.gov/geographic.html> [Select SC on the map and then Oyster Landing, SC (North Inlet Estuary)]. Historical data are also available at http://co-ops.nos.noaa.gov/data_res.html under Verified/Historical Water Level Data, select Unlisted Station, type in 8662245 for Station ID.

Support: National Science Foundation (NSF) Grant No. 9907650. NOAA/NOS/OPSD and the SC Geodetic Survey also supply technical services. See map location #3.

Weather and climate measurements: Long-term monitoring at Oyster Landing Pier

Investigators: Dr. Erik Smith and Amy Cook
Baruch Marine Field Laboratory, USC and North Inlet-Winyah Bay NERR

As part of the North Inlet–Winyah Bay National Estuarine Research Reserve (NERR), a fully functional meteorological station (National Weather Service installation) is located on the Oyster Landing Pier at North Inlet. Wind speed and direction, air temperature, humidity, barometric pressure, solar radiation, and precipitation are recorded at 15 minute intervals. A computerized data acquisition system provides regular uploads of data to the laboratory via a short haul modem. For most parameters, records have been collected for more than 13 years. Long-term, continuous weather records provide base-line data valuable for determining the effects of climatology on the various biological and physical processes being studied in the North Inlet estuary. Weather data in real time is available over the Internet at <http://www.baruch.sc.edu/weather/>. See map location # 3.

National Atmospheric Deposition Program (NADP)

Investigators: Dr. Erik Smith and Jennifer Keese
Baruch Marine Field Laboratory, USC and North Inlet-Winyah Bay NERR

The North Inlet–Winyah Bay NERR established a precipitation chemistry monitoring site in North Inlet Estuary in January 2002. Atmospheric deposition data are collected according to NADP/National Trends Network (NTN) protocols. The work is made possible by the US EPA National Estuary Program and the SC Department of Health and Environmental Control. This partnership was formed to better represent coastal areas in our nation's deposition monitoring networks and also to gain a better understanding of the atmospheric deposition in the North Inlet estuary. The site is equipped with an automated collector that ensures sample collection occurs only during precipitation events (wet-only sampling). Precipitation is collected weekly and sent to the NADP Central Analytical Laboratory, where it is analyzed for pH, sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium). North Inlet NADP data can be obtained from the following web address: <http://nadp.sws.uiuc.edu/>. See map location #3.

Physical characteristics of estuarine waters: Long-term monitoring at four sites in North Inlet Estuary

Investigators: Dr. Erik Smith and Tracy Buck
Baruch Marine Field Laboratory, USC and North Inlet-Winyah Bay NERR

As part of the NERRS System-Wide Monitoring Program, the physical characteristics of water within four tidal creeks of the North Inlet NERR are monitored using YSI 6600 ESD data loggers. These data loggers are deployed at 0.5 m above the sediment surface and record water depth, temperature, salinity, pH, dissolved oxygen, and turbidity at 30 min intervals throughout the year. The instruments are calibrated and deployed according to strict NERRS protocols. The consistent, long-term collection of this physical data allows for the characterization of short-term variability and long-term change in North Inlet waters, and provides base-line data critical for various studies of biological and physical processes in the North Inlet estuary. Data, along with detailed metadata, are sent to the NERRS Centralized Data Management Office (CDMO) for quality assurance and quality control. Data can be accessed via the CDMO website: <http://cdmo.baruch.sc.edu/>. See map location # 2C, 3, 6A, 6B.

Chemical characteristics of estuarine waters: Long-term monitoring at four sites in North Inlet Estuary

Investigators: Dr. Erik Smith, William Johnson, and Jennifer Keese
Baruch Marine Field Laboratory, USC and North Inlet-Winyah Bay NERR

Chemical analyses of North Inlet estuarine water samples began in the late 1970s. The NI-WB NERR 20 day water chemistry sampling was initiated in June of 1993 to monitor concentrations of suspended solids, dissolved organic carbon, total nitrogen, ammonium, nitrate-nitrite, total phosphorus, orthophosphate, and chlorophyll *a* at four locations within North Inlet. Water samples are collected with ISCO automated water sampling devices at intervals of 2 hours and 4 minutes over two complete tidal cycles. Sampling and chemical analyses adhere to strict national protocols developed as part of the NERRS System-Wide Monitoring Program. The consistent, long-term collection of water chemistry variables allows for the characterization of short-term variability and long-term change in key water quality parameters, and also provides base-line data critical for various studies of biological and physical processes in the North Inlet estuary. Data, along with detailed metadata, are sent to the NERRS Centralized Data Management Office (CDMO) for quality assurance and quality control, and then made available via the CDMO website: <http://cdmo.baruch.sc.edu>. See map location # 2C, 3, 6A, 6B.

Long-term monitoring of emergent salt-marsh vegetation in the North Inlet estuary

Investigators: Dr. Erik Smith and Tracy Buck
Baruch Marine Field Laboratory, USC and North Inlet-Winyah Bay NERR

As part of a NERRS system-wide initiative in biological monitoring, the North Inlet-Winyah Bay NERR will begin biological monitoring of salt-marsh emergent vegetation. The long-term goal is to assess the effects of rising sea level on the community dynamics of emergent salt marsh vegetation in the North Inlet-Winyah Bay NERR. Specifically, this project seeks to quantify how salt marsh macrophyte community structure (species composition, relative abundance, and biomass) varies along an elevation gradient, from creek bank to upland forest edge, in response to long-term changes in tidal height and flooding frequency due to sea level rise. In accordance with established NERRS protocols, a stratified sampling approach using fixed transects and repeated measures within permanent sample plots will be used. Three segments along the central axis of Crabhaul Creek will be defined from the head of the creek to near the creek mouth, representing a gradient in marsh chronosequence (map location #14). Within each segment, 3 fixed transects will be randomly established (specific locations yet to be determined) from creek bank to the western, upland edge of the marsh platform. Each transect will delineate a total 20 permanent sampling plots. Groundwater wells will be installed adjacent to each permanent plot. Sampling will include: percent cover for each species or cover category; species' shoot/stem density; species' maximum canopy height; species' aboveground biomass by non-destructive sampling techniques; and porewater salinity.

Diversity of plant-associated diazotrophic bacteria and their distributions within specific vegetation zones along an environmental gradient – The North Inlet Microbial Observatory

Investigators: Drs. Charles R. Lovell¹ and Madilyn Fletcher^{1,2}, and students
Department of Biological Sciences, USC¹
Belle W. Baruch Institute for Marine and Coastal Sciences, USC²

The diazotrophic (nitrogen fixing) bacteria are extraordinarily diverse, and apart from a few select groups, such as cyanobacteria and rhizobia, are very poorly characterized. Diazotrophs associated with the roots of non-crop plant species are particularly understudied. The North Inlet Microbial Observatory (NIMO) focuses on diazotrophs in a salt marsh ecosystem, which is characterized by strong zonation patterns of a very limited number of plant species growing along distinct environmental gradients, and a great diversity of plant root-associated diazotrophs, many of which appear to be novel taxa. The zonation patterns and biota of salt marshes provide a unique opportunity to explore the diversity and distribution patterns of this key bacterial functional group and to evaluate the underlying effectors that control these parameters. The objectives of this program are 1) To build an extensive collection of culturable diazotrophs, including both O₂ utilizing and anaerobic bacteria. 2) To determine the phylogenetic affiliations of culturable diazotrophs through 16S rRNA and *nifH* sequence analysis, to determine

relevant phenetic characters, and to formally describe new taxa. 3) To determine which taxa actively express *nifH* in association with salt marsh plants. 4) To determine numerical representations of taxa which express *nifH in situ* and are isolated into pure culture in the course of this study. 5) To examine the microscale distributions and specific associations of selected diazotrophs on the roots of salt marsh plants. 6) To investigate the macroscale distributions of the diazotrophs by relating their occurrence to host plant distributions and local environmental gradient conditions. Vegetated sediments and plant roots will be collected from 6 specific vegetation zones and diazotroph species diversity will be assessed on the basis of differences in *nifH* genes that are both characteristic of and exclusive to these organisms. Culturable diazotrophs will be isolated using both classical and novel strategies, and collections of aerobic and anaerobic strains will be established. Diazotrophs that actively participate in N₂ fixation will be identified from *nifH* mRNA sequences and comparison of these sequences with the growing *nifH* database. The numerical representations of these organisms will be determined by quantitative DNA-DNA hybridization. The associations of selected diazotrophs with plant roots will be characterized by localization on root surfaces using specific fluorescent oligonucleotide probes and confocal laser scanning microscopy. Through this work, the diversity of diazotrophs and the distributions of specific taxa will be determined, providing information on diazotroph ecology, including diazotroph-plant host interactions and host colonization at the microscale level. Moreover, by analyzing the distributions of specific diazotroph phylogenetic and physiologic groups with respect to the different vegetation zones, new understanding of diazotroph diversity and distribution at the macroscale will be obtained.

The importance of the diazotrophs to the productivity of both natural and agricultural systems provides a strong motivation for this project. The project will produce a detailed phylogenetic and phenetic examination of plant associated diazotrophic bacteria in a system where these bacteria are very important, very diverse, and, so far, mostly unknown to science. Many novel species of diazotrophs will be discovered and, through examination of host specificity and key ecological effectors, a far better understanding of the types of diazotrophs that interact with plants and actively fix N₂ in these associative interactions will be gained. Salt marsh and other wetlands restoration projects are often unsuccessful, at least within the 5-10 year expected duration of many projects, and the interactions of the dominant plant species with essential microbial “hidden players” have not been adequately considered. The interactions between marsh plants and diazotrophs may be particularly important since nitrogen is a key nutrient and a focus of interspecific competitive interactions. Greater understanding of the diversity of salt marsh diazotrophs, their specificity for host plants, and of their responses to environmental variables may contribute to more consistent success of restoration and conservation efforts.

This project is a continuation of work pursued over the last ten years and is supported by the National Science Foundation (1994-2008, so far). See map locations 8 and 10.

Some of the most recent publications associated with the work:

- Bagwell, C.E. and C.R. Lovell. 2004. A DNA-DNA hybridization method for the detection and quantification of specific bacterial taxa in natural environments. In: J.F.T. Spencer and A.L. Ragout de Spencer (eds.) *Environmental Microbiology*, pp. 169-174. *Methods in Biotechnology* Series, Humana Press, Totowa, NJ.
- LaRocque, J., P.W. Bergholz, C.E. Bagwell, and C.R. Lovell. In press. Influence of host plant-derived and abiotic environmental parameters on the composition of the diazotroph assemblage associated with roots of *Juncus roemerianus*. *Antonie van Leeuwenhoek*.
- Lovell, C.R. In press. Belowground interactions among salt marsh plants and microorganisms. In: E. Kristensen, J.E. Kostka, and R.H. Hease (eds.) *Interactions Between Macro- and Microorganisms in Marine Sediments*, Coastal and Estuarine Studies Series. American Geophysical Union, Washington, D.C.
- Brown, M.M., M.J. Friez, and C.R. Lovell. 2003. Expression of *nifH* genes by diazotrophic bacteria in the rhizosphere of short form *Spartina alterniflora*. *FEMS Microbiology Ecology* 43:411-417.
- Leaphart, A.B., M.J. Friez, and C.R. Lovell. 2003. Formyltetrahydrofolate synthetase sequences from salt marsh plant roots reveal a diversity of acetogenic bacteria and other bacterial functional groups. *Applied and Environmental Microbiology* 69:693-696.
- Beeson, K., D.L. Erdner, C.E. Bagwell, C.R. Lovell, and P.A. Sobecky. 2002. Differentiation of plasmids in marine diazotroph assemblages determined by randomly amplified polymorphic DNA analysis. *Microbiology* 148:179-189.
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- Bergholz, P.W., C.E. Bagwell, and C.R. Lovell. 2001. Physiological diversity of rhizoplane diazotrophs of the saltmeadow cordgrass, *Spartina patens*. Implications for host specific ecotypes. *Microbial Ecology* 42:466-473.

- Bagwell, C.E., M. Dantzer, P.W. Bergholz, and C.R. Lovell. 2001. Host specific ecotypic diversity of rhizoplane diazotrophs of the perennial glasswort, *Salicornia virginica* and selected salt marsh grasses. *Aquatic Microbial Ecology* 23:293-300.
- Leaphart, A.B., and C.R. Lovell. 2001. Recovery and analysis of formyltetrahydrofolate synthetase gene sequences from natural populations of acetogenic bacteria. *Applied and Environmental Microbiology* 67:1392-1395.
- Lovell, C.R., M.J. Friez, J.W. Longshore, and C.E. Bagwell. 2001. Recovery and phylogenetic analysis of *nifH* sequences from diazotrophic bacteria associated with dead aboveground biomass of *Spartina alterniflora*. *Applied and Environmental Microbiology* 67:5308-5314.
- Lovell, C.R., C.E. Bagwell, M. Czako, L. Marton, Y.M. Piceno, and D.B. Ringelberg. 2001. Stability of a rhizosphere microbial community exposed to natural and manipulated environmental variability. *FEMS Microbiology Ecology* 38:69-76.

The South Carolina Harmful Algal Bloom Program

Investigators: Dr. Alan Lewitus^{1,2}, Azal Amatya², Dr. Patrick Brown¹, Krista DeMattio², Sarah Habrun¹, Kenneth Hayes¹, Megan Heidenreich^{1,2}, Sabrina Hymel¹, Wes Jackson³, Chuck Keppler², Jiqing Liu¹, Chad Johnson², Lara Mason², Andrew Shuler^{1,2}, Raphael Tymowski¹, Dr. Susan Wilde¹, Patrick Williams², and collaborators from NOS-Charleston, SC Sea Grant, SCDHEC, SCDNR, Clemson University, MUSC, USGS Baruch Marine Field Laboratory and Hollings Marine Laboratory, USC¹; Marine Resources Research Institute, SCDNR²; Medical University of South Carolina, Marine Biomedicine and Environmental Sciences³

The SC Task Group on Toxic Algae was formed in late 1997, with the goal to develop a coordinated state strategy to cope with the possible consequences of a *Pfiesteria* toxic outbreak. The Task Group has since expanded to include assessments of harmful algal blooms in general. One of the first accomplishments of the group was to implement a program to respond to fish kills or lesion events in SC estuaries, and determine the potential association with harmful algal blooms. Efforts of the Task Group led to NOAA funding in support of the South Carolina Harmful Algal Bloom Program (SCHABP), the first statewide effort to assess the distribution and potential adverse effects of HABs in South Carolina estuaries. This study will 1) determine the present distribution of harmful algae in SC estuaries; 2) determine environmental factors that favor HAB formation in SC estuaries so future effects can be predicted; and 3) establish a statewide HAB surveillance system. The monitoring effort consists of an intensive statewide spatial monitoring (on a monthly to annual basis) to determine existing physical, chemical and biological parameters (including algal distribution) throughout the state. In addition, known "hot spots", which are areas with previous algal blooms and/or lesioned fish, are monitored on a more frequent basis (biweekly), in order to document the physical, chemical, and biological factors which exist previous to a bloom event, should one occur. In the event of a potentially harmful algal bloom, an event response method was formulated to standardize the measurement of environmental parameters that exist at the time of the bloom. Additional water samples are collected for the purposes of identification, isolation, and culturing of the bloom species. These cultured algal species will be used for bioassays to determine the role of nutrient quantity and quality in HAB stimulation. NOAA NOS. 1 October 2004 to 30 September 2006.

North Inlet benthos program: Long-term monitoring of meiofauna and macrobenthos

Investigators: Drs. Bruce Coull¹ and Robert Feller²
School of the Environment, USC¹; Marine Science Program, USC²

Regular (biweekly or monthly) collections of two size fractions of animals that live in the sand or mud have been made at the same locations in the North Inlet Estuary since 1972 (meiofauna) and 1981 (macrofauna). Small invertebrates, less than 0.5 mm in size, comprise the meiofauna. The meiofauna study is the longest estuarine meiofauna time-series in the world. Although collections of both meiofauna and macrobenthos continue to be collected, sample processing has lagged behind. Although these benthic communities contain hundreds of different species, only dominant taxa are identified regularly. The meiofauna are dominated by nematodes and harpacticoid copepods, while the macrobenthos consists mostly of polychaete and oligochaete worms, bivalves, and small

crustaceans. Both size groups of organisms demonstrate annual cycles of abundance, peaking in winter. Simultaneous measurements of physical conditions in the water, sediment, and air help investigators to determine causes of variations over time. Data from undisturbed North Inlet habitats provide a baseline to which other areas, including contaminated areas, can be compared. These studies also provide an opportunity to examine the recruitment dynamics of soft-bottom benthos. See map location # 7.

Interannual and seasonal patterns of use of flooded marshes and creeks by migratory fishes and crustaceans

Investigators: Dr. Dennis Allen, Tracy Buck, Paul Kenny, and Ginger Ogburn-Matthews
Baruch Marine Field Laboratory and NI-WB NERR, USC

In this study, the timing and the magnitude of nekton migrations onto the vegetated marsh surface are measured by enclosing a one acre area of flooded marsh at high tide and determining the taxonomic and life stage composition of the fauna leaving the area with the ebbing tide. These biweekly high tide collections in Oyster Landing Basin relate short-term, seasonal, and interannual changes in the abundance and composition of resident and transient species to flooding depth (sea level), freshwater runoff, and other environmental conditions. Comparisons of high tide collections at this site with same-day seine collections from the adjacent creek from 1996 to 2002 revealed that the composition and abundance of nekton remaining in the low tide pool was representative of the nekton using the flooded marsh. Low tide collections (1984-2003) showed long-term stability in the composition and production of the nine dominant transient fishes and shrimps that occupied the intertidal habitat. Relationships between OL Basin nekton and larval fish catch data from the long-term zooplankton series indicate the importance of recruitment success in determining annual production of some taxa. This information is providing a foundation for the development of new experimental approaches to understanding habitat requirements and interactions among co-occurring tidal migrants. Results have implications for the management of marsh creeks and watersheds proximal to nursery habitat. See map location # 3.

Long-term zooplankton time series: Tracking and interpreting changes in the occurrence of larval and permanent taxa in the North Inlet Estuary

Investigators: Dr. Dennis M. Allen¹, Dr. Steve Stancyk², Paul Kenny¹, Tracy Buck¹, and
Ginger Ogburn-Matthews¹
Baruch Marine Field Laboratory and NI-WB NERR, USC¹;
Department of Biological Sciences and Marine Science Program, USC²

Collections have been made at the same location, stage of tide, and time of day using the same sampling technique every two weeks since 1981. Oblique tows with 153 micron mesh nets collect copepod and small invertebrate larvae, and 365 micron epibenthic sled collections take larval fishes, shrimps, and crabs and other large zooplankton species. Seasonal and interannual changes in abundance and species composition of the assemblages are documented and correlated to fluctuations in the physical characteristics of the estuary. These data sets are among the most complete and longest running in the world. They reveal rates and directions of change in an undisturbed estuarine ecosystem. A high level of stability in species composition and relative abundance has been demonstrated over the period, but effects of extended periods of low salinity such as those that occur in the winter-spring seasons of ENSO (El Nino) events are apparent. Since many of the zooplankton species are developmental stages of larger animals, the study provides indications of the reproductive and potential recruitment success of several commercially and/or recreationally important species. See map location # 10.

Ecological role and habitat utilization patterns of bottlenose dolphins in the North Inlet Estuary and adjacent waters

Investigator: Dr. Rob Young
Department of Marine Science, Coastal Carolina University

This project, began in September 1997, seeks to identify resident populations of bottlenose dolphins in the North Inlet and Winyah Bay systems and to identify their patterns of habitat utilization. This information is used to model the trophic role of dolphins within the system, to model the potential impact of dolphins upon prey populations, and to examine resident dolphin bioenergetics, social structure, and behavior. Photo-identification is used to identify and catalog individual dolphins based on the shape of the dorsal fin, and focal follows are used to establish habitat utilization patterns. Our initial studies have determined that the dozen or so resident dolphins in the North Inlet system consume a significant proportion of the prey fish populations (11-14 metric tons per year) and that 3 - 7% of the annual primary production in North Inlet is required to support them. Due to their changing seasonal patterns in North Inlet, dolphins may serve as a highly visible indicator species for changes and movements in the prey community. This research also contributes to the NMFS Mid-Atlantic Bottlenose Dolphin Catalog whose aim is to determine the stock structure of coastal migratory dolphins between New Jersey and Florida.

Young, R.F. and H.D. Phillips. 2002. Primary production required to support bottlenose dolphins in a salt marsh creek system. *Marine Mammal Science* 18(2):358-373

Sea turtle nest monitoring on Debidue Beach/Hobcaw Barony

Investigators: Betsy Brabson¹ and Robin Baughn¹ (Debidue Beach Coordinators), Wendy Allen², Tracy Buck², Kimberly Foley², Anna Toline², and other volunteers
DeBordieu Colony¹; Baruch Marine Field Laboratory, USC²

Nesting activity of the threatened loggerhead sea turtle, *Caretta caretta*, on the Hobcaw Barony portion of Debidue Beach is monitored by trained volunteers, May-October. This beach, owned by the Belle W. Baruch Foundation, is undeveloped and is about 2.2 miles in length. Staff from the Baruch Marine Lab, residents of DeBordieu Colony, and members from surrounding communities participate in the monitoring program. Volunteers walk the beach early in the morning during the nesting and hatching season, record information on false crawls and nests, and protect nests from predators with screening. Nests laid in areas subject to flooding by tides are carefully relocated to higher areas. Volunteers also monitor the hatching success of the nests. Nest inventories are conducted 72 hours after the major hatch, indicated by dozens of baby turtle tracks in the beach sand. Volunteers excavate the nest chamber and record the number of empty shells, number and stages of development of unhatched eggs, and number of live hatchlings in the nest, if any. Nest inventories are conducted near dark and usually draw a crowd of interested visitors, providing an excellent opportunity to share information about the natural history and conservation of sea turtles. The volunteers are members of a larger volunteer group, the South Carolina United Turtle Enthusiasts (SCUTE), which covers the northern beaches of the state from the southern, undeveloped end of Debidue Beach known as Hobcaw, to North Myrtle Beach. Debidue Beach that includes the Hobcaw Beach plus the middle and north sections to Pawley's Inlet typically accounts for 30-50% of all nests in the Waccamaw region. A final report summarizing nesting activity and success for the SCUTE region is prepared and submitted to the South Carolina Department of Natural Resources that oversees the volunteer sea turtle program for the state. See map location # 1.

South Carolina Estuarine and Coastal Assessment Program

Investigators: Drs. R.F. Van Dolah, P.C. Jutte, G. Riekerk, M.V. Levisen, and D.E. Chestnut
SC Department of Natural Resources
SC Department of Health and Environmental Control

In 1999, the South Carolina Department of Natural Resources (SCDNR) and the South Carolina Department of Health and Environmental Control (SCDHEC) initiated a major new collaborative coastal monitoring program. The goal of the South Carolina Estuarine and Coastal Assessment Program (SCECAP) is to monitor the condition of

the state's estuarine habitats and associated biological resources on an annual basis. This program significantly expands current ongoing monitoring efforts being conducted by each Department by drawing upon the expertise of both in a cooperative effort. SCECAP integrates measures of water and sediment quality with multiple measures of biological condition at a large number of sites throughout the state's coastal zone. It also expands historical monitoring activities that have primarily focused on open water habitats (e.g., bays, sounds, tidal rivers) to include an assessment of conditions in tidal creeks, which serve as important nursery habitat for most of the state's economically valuable species. Many of these tidal creeks are also the first point of entry for non-point source runoff from upland areas and therefore can provide an early indication of anthropogenic stress. The SCECAP program, combined with the other cooperating programs, provides a number of direct and indirect benefits to the citizens of South Carolina. These include:

- 1) The ability to identify areas of South Carolina's estuarine habitat that are impaired or degraded with respect to a suite of sensitive biological, chemical, and physical measures.
- 2) A standardized protocol that is used by both the SCDNR and SCDHEC that is cost-effective and consistent with protocols common among other U.S. coastal states. This will allow South Carolina managers to relate conditions in our coastal waters relative to the overall southeastern region, and it will allow better regional prioritization of stressors and impacts.
- 3) More comprehensive periodic reports on the condition of water quality and habitat condition throughout the state's coastal zone than could be accomplished by the individual programs alone.

To date, three sites have been sampled in the North Inlet estuary as part of the program and another is planned for sampling in 2005. Many more stations have also been sampled in the adjacent Winyah Bay system. The relatively small size of the North Inlet estuary limits the number of sites that would be identified through the random, probability-based sampling approach, but it does provide an opportunity to compare conditions within North Inlet to other locations in the state.

Education, Outreach, and Data Management

High School Water Quality Program — National Estuarine Research Reserve

Investigator: Beth Thomas
North Inlet-Winyah Bay NERR, Baruch Marine Field Laboratory, USC

Education and outreach focusing on water quality is targeted to local high schools in Georgetown and Horry Counties to teach high school students and others about the importance of healthy water quality and the value of watersheds and estuaries. This program is an offshoot of the former Estuary-Net volunteer water quality monitoring project (<http://www.northinlet.sc.edu/estnetweb/estnet.html>) developed by the National Estuarine Research Reserve System (NERRS). It includes a complete curriculum with both classroom and field activities that provide a hands-on approach for investigating non-point source pollution and its impacts on estuaries. Teachers and students from local school districts work with Reserve staff to study water chemistry and quality, sample bodies of water near their schools, and compare their findings with local and national estuarine data collected from the NERRS' System-Wide Monitoring Program (SWMP). Participating schools work closely with the Reserve's Education Coordinator and receive an introductory classroom visit highlighting the Reserve System and the North Inlet Winyah Bay NERR, the water quality project, and instruction on monitoring equipment and sampling protocols for a variety of sampling variables. Reserve site visits, estuarine ecology, follow-up school visits and sampling assistance (including testing equipment) are also offered.

Education activities — National Estuarine Research Reserve

Investigator: Beth Thomas
North Inlet-Winyah Bay NERR, Baruch Marine Field Laboratory, USC

Educational activities that integrate findings from research are offered throughout the year. The Baruch Lecture series provide an informal means for people of all ages to learn about current and ongoing research

programs at the coast. Other regular offerings include programs on estuarine ecology, open houses, and the ‘Fishes of North Inlet Estuary’ program whereby participants help Reserve scientists sample and process collections of fishes, shrimps and crabs made on a bi-weekly basis. Field trips for high school students, homeschool students, and special groups such as Elderhostel, Boy and Girl Scouts, and 4H clubs are also available. Contact the Reserve for a schedule of events at (843) 546-6219 or visit the Reserve’s web site at: www.northinlet.sc.edu.

South Carolina Chamber of Commerce High Performance Partnership

Investigator: Beth Thomas
North Inlet-Winyah Bay NERR, Baruch Marine Field Laboratory, USC

The South Carolina Chamber of Commerce’s High Performance Partnership (HPP) includes the Belle W. Baruch Foundation/Hobcaw Barony, Clemson University’s Belle W. Baruch Institute for Coastal Ecology and Forest Science, and USC’s North Inlet-Winyah Bay National Estuarine Research Reserve, all partnering to provide educational opportunities to our selected partner school, Pleasant Hill Elementary in Georgetown, SC. The HPP was established as part of a federal GEAR UP (Gaining Early Awareness and Readiness for Undergraduate Programs) grant that also includes state funding and business contributions. The program identifies eligible K-12 schools and pairs them with community businesses to provide unique opportunities for improving academic achievement. The Baruch Foundation and Institutes’ goals are to provide environmental education programs on site and in the classroom, open houses and training opportunities for teachers, and special programs to increase parent and community involvement in the school.

Coastal Training Program for local decision-makers

Investigator: Jeff Pollack
North Inlet-Winyah Bay NERR, Baruch Marine Field Laboratory, USC

The Coastal Training Program (CTP) offers science-based information, tools, and training to coastal decision makers in order to promote informed, forward-thinking decision-making related to coastal resources. A coastal decision maker is anyone whose professional or personal decisions impact the health of coastal resources. Local planners, town and county council members, public works officials, and developers are among the target audiences of the North Inlet-Winyah Bay CTP. Training topics encompass a wide range of timely coastal issues; recent training events have addressed stormwater management, shoreline management, and development and planning alternatives for watershed protection.

CTP training can be conducted in a variety of settings and formats, and training is always tailored to the specific needs of the audience. All training sessions include take-home reference materials and digital access (through the CTP website: www.northinlet.sc.edu/training) to training materials. CTP training events typically involve a variety of instructors, such as university professors, industry practitioners, and technical experts. Training is designed to be practical and is based on local case examples in the North Inlet-Winyah Bay NERR watershed whenever possible. Technological exhibitions, participatory field activities, and panel or round table discussions are included when appropriate to create an open, cooperative learning environment.

The four central partners of the North Inlet-Winyah Bay CTP are the ACE Basin NERR, SC DHEC - Office of Ocean and Coastal Resource Management (OCRM), South Carolina Sea Grant Consortium, and the NOAA Coastal Services Center (NOAA CSC). These agencies constitute the South Carolina CTP Coordinating Committee that provides oversight, guidance, and statewide coordination for the Coastal Training Programs that are administered by the two South Carolina NERRs.

Long-term coastal data and metadata rescue and product dissemination by USC's Baruch Institute

Investigator: Ginger Ogburn-Matthews
Baruch Marine Field Laboratory, USC

Baruch Institute has many valuable ecological and environmental coastal long-term databases that date from the late 1970s through the 1990s that are not readily accessible to the public and researchers. Technology and information management has changed dramatically just in the last 5 years with the growth and availability of the Internet. The goal of this project is to verify, rescue, organize, archive, and disseminate each database and its documentation (metadata) in a variety of forms (paper, Compact Disk (CD), and web).

First the data and the documentation for each database is assessed. All data are graphed, verified, and documented for missing data and outliers. All previous documentation, programs, summary data, and processed files are organized and documented. After the data are verified error-free, final graphics are created, and exported in a .jpg format. All documentation is verified with the data, and summarized in a standardized form, using the Federal Geospatial Data Committee (FGDC)/National Biological Information Infrastructure (NBII) format. All raw datasheets are scanned and saved as .jpg formatted images. Raw data images, processed data (including programs and earlier documentation), and final data are archived to a CD. All final data, metadata, and graphics are printed out; these hardcopy versions along with the CDs are placed in a three-ring binder notebook that is kept in the computer lab at the Baruch Marine Field Laboratory. The final data, graphics, and metadata are also posted to Baruch's Website (<http://links.baruch.sc.edu/data/>) and the metadata is posted to Baruch's Isite Node that is registered with the NOAA CSC (<http://www.csc.noaa.gov/CID/>), NBII (<http://mercury.ornl.gov/nbii/>), and FGDC (<http://clearinghouse2.fgdc.gov/>) clearinghouses. This project is supported by NOAA/Coastal Services Center, Charleston. This project began August 1, 2002 and is ongoing.

The National Estuarine Research Reserve System Centralized Data Management Office

Investigators: Dr. Dwayne E. Porter^{1,2}, Tammy Small¹, Ashly Burmeister¹, Jesse Friedmann¹, Scott Lail¹, and Kirk Yedinak¹
Belle W. Baruch Institute for Marine and Coastal Sciences and the Baruch Marine Field Lab, USC¹; The Norman J. Arnold School of Public Health, USC²

NOAA's National Estuarine Research Reserve System (NERRS) acknowledges the importance of both long-term environmental monitoring programs and data and information dissemination through the support of the NERRS System-wide Monitoring Program (SWMP). The goal of the SWMP is to "identify and track short-term variability and long-term changes in the integrity and biodiversity of representative estuarine ecosystems and coastal watersheds for the purpose of contributing to effective national, regional and site specific coastal zone management". This comprehensive program consists of three phased components: estuarine water quality monitoring (phase I), biodiversity monitoring (phase II), and land-use and habitat change analysis (phase III).

The Centralized Data Management Office (CDMO) was established in support of the System-wide Monitoring Program involving 25 sites around the US and Puerto Rico. The purpose of the CDMO, housed at the North Inlet-Winyah Bay NERR, is the management of the infrastructure and data protocol to support the assimilation and exchange of data, metadata and information within the framework of NERRS sites, coastal zone management (CZM) programs, and other education, monitoring and research programs.

The CDMO and the CDMO Data Management Committee (comprised of representation from the Managers, Research Coordinators, Education Coordinators, NOAA, and state CZM programs) have established six priority areas in support of the System-wide Monitoring Program.

- 1) **The continuation and advancement of the System-wide Monitoring Program data and information management program.** This priority area will support data management protocols for water quality and meteorological data and associated metadata, documentation, data archival, development of software-specific programs to assist with data QA/QC procedures, and data and information dissemination. The CDMO will continue efforts to (a.) improve the process for making SWMP monitoring data and associated metadata available via the SWMP/CDMO web presentation; and (b.) support applications and programs to assist with the processing, quality control, management and metadata of data collected using the water quality data loggers and meteorological stations. Once operational, the CDMO will also be responsible for the data assimilation, management, and documentation as related to expanded phase I data collection efforts.

- 2) **Maintain the on-line data and information server.** Via an on-line information server (<http://cdmo.baruch.sc.edu/>), the CDMO will continue to provide access to data and metadata collected as part of the SWMP program. The CDMO will also continue to support listserves for the Reserve program, for Research Coordinators, and for the SWMP.
- 3) **To continue to provide technical support services via telephone, e-mail, and individual and group training.** The CDMO has taken a leadership role in providing technical support for issues not only related to data management but also computer hardware and software technology, telecommunications, connectivity, and training. On-site training and support will be on a limited basis contingent upon available funds.
- 4) **The continuation of the CDMO Data Management Committee annual workshop to provide an additional avenue for the exchange of ideas and information related to database management, technological advances, and other data collection and monitoring program.** This dynamic group is also responsible for the identification of ways to improve and enhance individual NERRS site data management capabilities and the CDMO. A two-day workshop will be held in the summer of 2006 at the North Inlet-Winyah Bay NERR.
- 5) **The continuation of the CDMO Technicians' Training Workshop series to provide training for NERRS research technicians working on SWMP initiatives.** The CDMO will again conduct a multi-day workshop series to provide hand-on assistance to research technicians in support of SWMP equipment setup, operation and maintenance; data collection and management; and QA/QC activities. The workshops will be held in the late winter 2006.
- 6) **Provide technical support for special NOAA projects and provide for information management and outreach support for NOAA, Reserve Managers, Educators, and Research Coordinators, and state CZM agencies.** Attention will be focused on providing support to NERRS research and educational activities for group communications, technology upgrades and implementation, and the assimilation and dissemination of data, standard products, and other identified information. In addition, the CDMO will continue to participate in OceanUS activities to promote the role of the NERRS SWMP and the CDMO in support of developing a national integrated coastal ocean observing system.

This project is funded from 09/01/04 to 02/28/06 by NERRS/NOAA/Dept. of Commerce. The CDMO website is cdmo.baruch.sc.edu

Research Locations in North Inlet



Author Index

Abel, D.C.	18, 19	Fletcher, M.	21, 37
Aelion, M.	27, 28	Foley, K.	18, 41
Allen, D.M.	17, 18, 40	Friedmann, J.	44
Allen, J.	28	Fulton, M.	27
Allen, W.	41		
Amatya, A.	39	Galloway, S.	27
Ansell, C.	25	Gandy, D.	18
Arnold, T.	12	Gardner, L.R.	35
		Gary, S.J.	18
Baden, J.	16, 17	Godley, J.	33
Baguley, J.G.	14	Goeriz, R.	13
Bain, L.J.	31	Gonzalez, H.	31
Baughn, R.	41		
Benitez-Nelson, C.	10	Habrun, S.	39
Bennett, C.	33	Halanych, K.M.	15
Bernot, M.J.	22	Hampel, H.	18
Beseres, J.	20	Hayes, K.	39
Blasczyk, H.	15	Heidenreich, M.	24, 32, 39
Borgianini, S.	33, 34	Helmuth, B.	26
Boumans, R.	15	Hines, J.	13
Brabson, B.	41	Ho, C-K.	13
Bretsch, K.	17	Hymel, S.	24, 39
Brodie, R.	32, 33, 34		
Brown, P.	39	Jackson, W.	39
Buck, T.	36, 37, 40, 41	Jensen, J.R.	29
Burdick, D.M.	15	Johnson, C.	39
Burmeister, A.	44	Johnson, W.	21
Burnette, A.	15	Johnson, Wm.	37
Bushek, D.	31, 32	Jost, J.	26
		Jurissa, J.	9, 33
Cahoon, D.	15	Jutte, P.C.	41
Carter, E.	11		
Chandler, T.	27	Karabanov, E.	10
Chekalyuk, A.	30	Keesee, J.	36, 37
Chestnut, D.E.	41	Kelsey, H.	28
Coen, L.	31	Kenny, P.	31, 40
Coggins, B.	20	Keppler, C.	39
Cook, A.	36	Klemas, V.V.	29
Copen, B.	18	Knott, E.	18
Costanza, R.	15		
Coull, B.C.	14, 39	Lail, S.	44
		Levisen, M.V.	41
Dame, R.F.	18	Lewitus, A.J.	24, 27, 39
Decho, A.	27	Lincoln, D.E.	12, 22
DeMattio, K.	24, 39	Liu, J.	39
Denno, R.F.	13	Long, M.	12
DePratter, C.	8	Lovell, C.R.	22, 23, 37
		Luthy, S.	18
Feller, R.	12, 20, 39		
Ferry, J.	27	Malhotra, A.	29
Field, R.T.	29	Marshallonis, D.	25
Field, D.W.	29		

Mason, L.	39	White, S.M.	11
Matsui, G.	21, 23	Wilde, S.	39
Mock, C.	10	Williams, D.	10
Montané, J.M.	10	Williams, P.	39
Moore, K.	30	Wimp, G.	13
Morris, J.	16, 21, 35	Woodin, S.A.	22
Murphy, S.	13	Woodley, C.	27
Novakowski, K.I.	7	Yedinak, B.K.	19, 44
Ogburn-Matthews, V.	35, 40, 44	Young, R.	18, 41
Pennings, S.C.	13	Zhou, X.	7, 8
Peterson, J.S.K.	31	Zingmark, R.	24
Pinckney, J.L.	25		
Pollack, J.	43		
Porter, D.E.	27, 28, 29, 30, 32, 44		
Reichert, M.	32		
Reikerk, G.	41		
Richardson, T.L.	25		
Ringwood, A.	24		
Sacks, P.	31		
Schmidt, L.	31, 32		
Scott, G.	27		
Shapo, J.	27		
Shuler, A.	39		
Siewicki, T.	27, 28		
Silliman, B.	11		
Smith, E.	36, 37		
Small, T.	44		
Springer, A.	10		
Stalter, R.	16, 17		
Stancyk, S.E.	25, 40		
Struck, T.	15		
Styles, R.	8, 9, 33		
Sundberg, K.	16, 35		
Swarth, C.	15		
Tankersley, R.	34		
Thomas, B.	42, 43		
Thurman, C.	33		
Toline, A.	31, 41		
Torres, R.	7, 8, 9		
Traynum, S.	9		
Tymowski, R.	24, 39		
Van Dolah, R.F.	41		
Vecchio, J.	19		
Walker, S.	28, 29		
Walters, L.	31		
Wargo, C.	8		
White, D.	24, 30		
White, K.	9		