CURRENT RESEARCH, MONITORING, AND EDUCATION PROJECTS

2007 - 2008

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 Projects 2007-2008

Introduction

More than 600 scientific research projects and about 360 student theses and dissertations have been completed by Baruch Institute research associates since 1969. This work has resulted in the publication of more than 1,452 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 26 faculty, 23 technicians, and 18 student investigators conducting research at the BMFL. In addition, 47 faculty, 3 technicians, 13 students and 6 volunteers representing 29 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 listed randomly 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.cas.sc.edu/baruch/), which contains links to many related sites.

Author and Title List

Visiting Scientist Awards

Long-term Studies

Characterization of intertidal zone creek networks

Investigator: 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.
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. Map location 16

Morphological controls on marsh creek network flow patterns

Investigators: Dr. Richard Styles[1], Dr. Raymond Torres[2], Kevin White[3], and Joseph Jurissa[3]
Department of Geological Sciences and Marine Science Program, USC[1];
Department of Geological Sciences, USC[2]; Marine Science Undergraduate Major, USC[3]

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. Map location 3.

Integrative acoustic mapping of sedimentary processes and benthic environments

Investigator: Dr. Scott M. White
Department of Geological Sciences, USC

The primary goal of this project is a system-wide map of the sedimentary environments within the major channels in the North Inlet estuary. This map will be based on the classification of acoustic geophysical data acquired using a multi-frequency side-scan sonar, 10 kHz sub-bottom profiler, and high frequency depth sounder. Previously published and on-going work in sediment sampling by other investigators will be used to constrain models of sediment type and grain size based on the acoustic data. Maps will be created showing the locations of distinct benthic environments based on integrative GIS maps of sediment type, thickness, and structure. Data collection for this project began in Summer 2006 and we expect to complete the first maps during Fall 2007. Funding for this project is provided through the USC College of Arts and Sciences, and the Department of Geological Sciences.

Exchange flow between two estuaries connected by a shallow tidal channel

Investigators: Dr. Richard Styles[1] and Steven Traynum[2]
Department of Geological Sciences and Marine Science Program, USC[1]
Marine Science Program, USC[2]

Estuarine flow is highly dependent on a number of factors, including freshwater discharge, wind and tides. In multi-inlet bar built systems, the flow can further be driven by mutual forcing between adjacent inlets. In the North Inlet/Winyah Bay National Estuarine Research Reserve, two distinct estuaries are connected by a subtidal tidal channel at No Mans Friend. Within the channel, simultaneous tidal forcing from both ends produces a nodal point. To determine the implications of forcing from both ends on net exchange, an RDI ADCP and a SonTek ADP were placed on either side of the nodal region for 35 days beginning in March 2005. Asymmetries in tidal forcing on either side of the node lead to significant shifts in the timing of flow reversals. The longer ebb associated with the more distorted Winyah Bay tide causes flow reversals to occur at mid-ebb in Winyah Bay. In addition to tidal asymmetries, subtidal flow patterns during periods of strong wind forcing varied greatly, yielding persistent net volume exchange between the two estuaries for periods of up to several days. Application of simple momentum balance arguments indicates that the observed subtidal exchange is consistent with local setup/setdown in the larger exposed Winyah Bay that generates pressure gradients at the fringe of North Inlet that drive the observed flow in the channels. However, local forcing alone does not explain the exchange during periods of persistent upwelling conditions, in which the implied setup at the fringe fails to maintain the direction and magnitude of the current. Rather, the low passed filtered exchange in the channel initially vanishes and then reverses direction around the period of maximum wind stress. Funding for this study was provided by the SouthEast US Atlantic Coastal Ocean Observation System (SEACOOS). This study was initiated in November, 2005 and is ongoing. Map location 2A

Application of a UHF Radar surface current mapping system to an intertidal salt marsh

Investigators: Dr. Richard Styles[1,2], Steven Traynum[2], Hannuman Bull[3], Dr. Calvin Teague[4], Megan Schuler[5], Dr. Donald Barrick[4], and Peter Lilleboe[4]
Department of Geological Sciences, USC[1]; Marine Science Program, USC[2]; Pritchards Island, USC-Beaufort[3];CODAR Ocean Sensors, Palo Alto, CA[4], Belle W. Baruch Institute, USC[5]

This note discusses a novel application of UHF (Ultra High Frequency) radar technology in an intertidal salt marsh. In November 2005, a UHF RiverSonde radar was deployed in a tidal salt marsh near Georgetown, South Carolina to determine the accuracy of this technology to track currents in sinuous tidal channels. For this proof of concept application, a single radar was deployed along the fringe of a subtidal channel near the NOAA weather station located at Oyster Landing. In order to validate its accuracy, an acoustic Doppler current profiler (ADCP) was deployed in a large subtidal channel directly in the path of the radar. Upon comparison, the UHF radar yielded current measurements consistent with both the ADCP and known tidal variations for this region. Additionally, results from this project demonstrate that increased wind speed, up to a threshold of about 4 m/s, results in greater radar coverage. However, there are notable constraints on a UHF radar system specific to an intertidal salt marsh environment. For example, radar coverage fluctuates throughout the tidal cycle as some areas become exposed during low tide, then flood again during high tide. Overall, this UHF radar system performed well in the subtidal channel. A promising future application involves using two UHF radars simultaneously to record the complete vector field. Funding for this project was provided by a NOAA CICEET grant to Richard Styles. This study was initiated in November 2005.

Sedimentation cycles in relation to underlying subsurface structures on a mesotidal marsh island, North Inlet, South Carolina

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

Utilizing high-resolution seismic stratigraphy from CHIRP and StrataBox instruments, reflection profiles are correlated with lithostratigraphy derived from 15 cores, revealing new aspects of subsurface structure and

depositional history within and around a marsh island. The study site is located within the North Inlet-Winyah Bay NERR site, South Carolina, USA. Reflection surfaces were recorded as shallow as 0.25 m and as deep as 25 m below surface. These data were acquired utilizing innovative methodology to investigate the unconsolidated sedimentary lense from a floating platform.

Little is known regarding the long-term history of sedimentation, stratigraphy, and evolution of salt marsh systems, especially in relation to Pleistocene-Holocene paleo-sedimentation patterns and their intrinsic control on present surficial features. By analyzing the nature and characteristics of these evolutionary processes, both through traditional and innovative remote sensing approaches, the goal of this research is to advance our understanding of the modern geologic marsh system.

Results of this study will yield a detailed description of the shallow geological framework and subsurface stratigraphy including the effects of this subsurface structure on the long-term (Holocene) sedimentation and geomorphology. Defining the shallow-subsurface geologic framework provides a foundation for future process-orientated and ecological studies and offers insight into the evolution of coastal marshes. Map location 16

Recent Holocene sea level trends and environmental impacts on a freshwater tidal wetland; Thousand Acre Marsh, SC, USA

Investigators: Abby Springer[1], Drs. Douglas F. Williams[1], Scott White[1], Camelia Knapp[1], Robert Gardner[1], and Paul Gayes[2]
Department of Geological Sciences, USC[1], Center for Marine and Wetland Research, Coastal Carolina University[2]

Thousand Acre Marsh is a freshwater tidal wetland surrounded by higher elevated Pleistocene beach ridges and Winyah Bay to the south. Though this area has been historically cultivated as a rice field, this low-lying area should still contain evidence of recent Holocene sea level fluctuations within the subsurface materials. The objectives of this investigation include 1) defining lithology, stratigraphy and Holocene environmental change within Thousand Acre marsh to further expand the general knowledge of freshwater tidal wetlands and 2) to identify facies migration due to sea level fluctuations within the environment and utilize that response to construct a recent Holocene sea level curve that hopefully will be applicable to other southeastern marsh environments.

Stratabox and ground penetrating radar (GPR) will be implemented to image the subsurface layers. Auger cores will determine the initial lithological changes while vibracores will be used to describe lithology, stratigraphy, to groundtruth the seismic profiles and to define facies migration. Samples from sediment cores will be analyzed by one of several techniques to provide age ranges to facies and sediment accumulation rates. Also, palynological analyses using the presence of particular rice pollen will decipher the period in which Thousand Acre Marsh was used to cultivate rice. The significance of this project is the construction of a southeastern Holocene sea level curve along with the further definition of little understood freshwater tidal marshes. The project began in January, 2007 and is planned to be completed by August, 2009. Support is being sought through Geological Society of America (GSA), American Association of Petroleum Geologists (AAPG), Sea Grant and NOAA.

Salt marsh hydrology and acute marsh dieback

Investigators: Drs. Alicia Wilson[1] and James Morris[2]
Department of Geological Sciences, USC[1]; Belle W. Baruch Institute for Marine and Coastal Sciences, USC[2]

The goal of this work is to understand links between salt marsh hydrology and ecological productivity. An important hypothesis for this work is that acute marsh dieback at the site was caused by rapid changes within the normal range of marsh conditions during drought conditions. We have installed 7 piezometer nests (3 piezometers in each nest) to monitor temperature and fluctuations in hydraulic head. Monthly monitoring is in progress. Vibracores taken adjacent to each piezometer nest indicate that marsh stratigraphy changes near the dieback area. Data from a detailed RTK GPS survey is being analyzed to determine local surface topography. We will use data we collect in the field (topography, stratigraphy, well tests, monitoring data) to construct numerical models of groundwater flow and salinity in the marsh island. Once the models are tested, we will use the models to estimate

the hydrologic conditions (and the rate of change in those conditions) during the drought that peaked in 2002. Map location 2B. Funded by South Carolina Sea Grant Consortium 6/1/2006-5/30/2008.

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 predators and herbivores, measuring herbivore damage to salt marsh plants and traits of the plants, and evaluating plant palatability in multiple sites from Florida to Maine. At Baruch, we work about halfway along Goat Island and at the end of the 3rd Boundary Cutoff Road (map locations 9 & 9A). This project will test a long-standing biogeographic theory that has received little experimental attention. This project was funded in 2002-2005 by the National Science Foundation and is affiliated with the Georgia Coastal Ecosystems Long-Term Ecological Research program.

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

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

This study addresses the top-down and bottom-up control of insect herbivores (planthoppers) inhabiting *Spartina alterniflora* marshes. We are specifically interested in 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 S*partina* 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.

Predicting the persistence of coastal wetlands to global change effects

Investigators: Drs. Glenn R. Guntenspergen, Donald Cahoon, Karen McKee, and J. Grace
U.S. Geological Survey, National Wetlands Research Center and
Patuxent Wildlife Research Center

The survival of coastal wetlands in the face of global change impacts will be determined by the ability to maintain wetland surface elevations relative to sea-level rise. Within the context of this conceptual framework, we will address the following goals in our extensive network study:

1. Understand the linkages and feedback effects that control habitat stability of coastal wetlands, specifically how wetlands maintain surface elevations relative to sea level.
2. Determine how external forcing functions (sea-level rise and nutrients) interact with these internal processes to affect ecosystem stability.
3. Develop a predictive capacity to forecast future responses of coastal wetlands to changes in external forcing functions.

We will use long-term observations and analyses of wetland elevation dynamics from a geographically broad network of elevation monitoring stations with standard sampling protocols to understand the trends in coastal wetland response to sea-level rise and nutrient addition.

In addressing this objective, we will measure key processes and soil characteristics. Predictive models using these relationships will be used to assess and understand coastal wetland elevation response to an interacting set of external drivers. We will use coastal brackish wetlands as our focus because they are dominated by plant species with C_3 and C_4 photosynthetic pathways and are exposed to multiple external stressors.

We will select 15 brackish sites ranging from the Gulf of Mexico to the Maritime Provinces of Canada in a space for time substitution experiment to assess the trends in surface elevation response to different rates of subsidence and tidal range (proxies for SLR). Network sites will be deliberately selected to span a broad range of environmental conditions to provide greater predictive potential. At each of the15 brackish wetland sites, the full range of process measures will be conducted seasonally for at least two years, then twice per year thereafter.

At each site, we will establish four plots. Each plot will consist of an area with a deep benchmark and four shallow benchmarks (SET) to measure surface elevation, marker horizons to measure sediment deposition, an area for non-destructive plant and soil sampling, and an area for destructive plant and soil sampling. Two plots will be located at a higher elevation and two plots at a lower elevation relative to each other. In each set of two plots, one plot will serve as a control and the other plot will be fertilized.

Statistical Analyses: The work conducted in this research program is designed to both test hypotheses and predict effects. To accomplish both of these objectives, we will use structural equation modeling, SEM, (McCune and Grace 2002, Pugesek et al. 2003) as a framework for both multivariate hypothesis testing and for forecast modeling. The results from SEM applications can be readily converted to forecast models capable of producing predictions of system responses to a wide variety of scenarios. This integrated use of SEM and forecast modeling has distinct advantages over conventional modeling in (1) providing input parameters that are statistically partitioned from other effects and (2) by permitting detailed feedback from data to the forecast model structure. Map location 20

Sediment accretion in North Inlet salt marshes

Investigators: Dr. James Morris and Karen Sundberg
Belle W. Baruch Institute for Marine and Coastal Sciences, 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 2(A, B, C, D), 4, 9, 22.

Experimental varying of the marsh platform and macrophyte response

Investigators: Dr. James Morris and Karen Sundberg
Belle W. Baruch Institute for Marine and Coastal Sciences, 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 various saltmarsh plants.

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. Currently there are three independent experiments. Each experiment has six treatments ranging from supra optimal elevation (i.e., floods only on spring tides) to completely inundated (i.e., waterlogged) with 0.13 m separation between pipes with six replicates per treatment. One experiment examines effect of marsh platform on *Spartina alterniflora*, one focuses on the effect of marsh platform on *Juncus roemerianus*, and the third examines competitive interactions between the two macrophyte species. Monthly stem height measurements are obtained each year from April to October. Plants are harvested at the end of the 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 is from NSF LTER, USGS, and Louisiana DNR.

Investigating coastal salt marsh belowground carbon dynamics in North Inlet, SC, USA

Investigators**:** Weihong Wang[1] and Dr. James T. Morris[2]
Marine Science Program, USC[1], Belle W. Baruch Institute for Marine and Coastal Sciences, USC[2]

The preservation and accumulation of organic carbon is thought to be an important mechanism by which coastal wetlands keep pace with rising sea level. The survival of coastal salt marshes is especially challenged nowadays by continuous sea level rise caused by global warming. A fundamental understanding of sediment carbon cycling mechanisms within the salt marsh system will provide a basis for evaluating the capacity of salt marsh to sequester carbon in sediments and the role of this process in maintaining relative elevation. This proposed research addresses (1) the seasonal and annual soil respiration in North Inlet salt marshes; (2) measurement and separation of root respiration from sedimentary organic matter (SOM) decomposition using carbon stable isotopes; (3) measurement of stem CO_2 fluxes and its fate by stable carbon isotope analysis; (4) and measuring the temperature dependence of soil respiration. In this research, three hypotheses will be tested: (1) root respiration and SOM decomposition have different temperature sensitivities; (2) stem CO_2 comes from two sources: CO_2 respired from roots and CO_2 derived from SOM decomposition and is a major pathway for carbon export; and (3) the carbon isotope composition of soil CO_2 is a function of two different carbon sources: root and SOM respiration. Stable carbon isotope analyses, soil respiration and stem CO_2 fluxes measurements, and sediment core incubation experiments will be used in this study to achieve the objectives and test our hypotheses. The results of this proposed research will provide information to policy makers and managers relative to the effects of sea level rise on a vital natural resource, namely our salt marshes. This project will start in Summer 2007 and end in Summer 2009. Support is provided by NOAA NERRS fellowship, the USC Marine Science Program, and the Baruch Marine Field Laboratory. Map location 2B, 22

Interspecific competition among some salt marsh perennials in South Carolina

Investigators: Drs. Richard Stalter[1] and John Baden[2]
St. John's University, NY[1]; US Army Corps of Engineers, Wilmington, NC[2]

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*. Map location 6A.

Effect of wrack accumulation on salt marsh vegetation

Investigators: Drs. Richard Stalter[1] and John Baden[2]
St. John's University[1]; US Army Corps of Engineers, Wilmington, NC[2]

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, 2005-2006.

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 l.8 meters wide and consisted of eight lm x l.8m plots in a row roughly parallel to the water's edge. Within each of these plots, a central 0.5m x lm 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 l5-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 was cut at ground level and standing crop (gms of vegetation/m^2) 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 l00% 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. Map location 9A.

Nekton as processors and transporters of nutrients in intertidal creek basins: Short-term contributions of dissolved nitrogen and phosphorus - Links Study I

Investigators: Dr. Dennis Allen[1], Dr. Robert Young [2], Dr. Stacy Luthy[2], Jason Garwood[1], and Dr. Richard Dame[2]
Baruch Marine Field Laboratory- USC[1], Marine Science Dept., Coastal Carolina University[2]

Nekton participate in the cycling of nutrients in salt marsh ecosystems. We believe that their role is significant and underappreciated. More than 50 species of fishes, shrimps, and crabs (nekton) move in and out intertidal creeks with the tides; summer densities are often 50-100 g/m^3. They forage in the creek bed, mud flats, and oyster reefs when flooded, and some species move onto the marsh during the highest part of the tide. Foraging in the sediments (bioturbation), handling (crushing) prey, and excreting wastes are primary means by which these animals contribute to the pool of dissolved nutrients. In this study, we are quantifying the amount of ammonium and orthophosphate contributed by the nekton while occupying intertidal creek basins. Our focus has been on contributions by nekton occupying residual pools of water in creek beds for several hours around low tide. A series of experiments with multiple treatments has been conducted to quantify levels of nutrient production by nekton, microbial components of the water column, and the biotic components of the sediments. Simultaneous measurements in replicated artificial pools and a nearby natural pool (with naturally recruited populations of nekton) are providing an opportunity to determine what proportion of the total nutrient increase in these isolated water bodies is associated with nekton excretion and feeding. The enriched water is pulsed into the creek with the flooding tide. In the second phase of the study, we will scale up the experiments to quantify nekton in flow-through artificial creek mesocosms and/or natural creeks. The Links project is supported by the National Science Foundation, through the Ecosystems Studies Program (January 2005–September 2008).

Spatial variations in growth, condition, and site fidelity of nekton among intertidal creek basins – Links Study II

Investigators: Dr. Stacy Luthy[2], Dr. Dennis Allen[1], Jason Garwood[1], and Dr. Robert Young[2]
Baruch Marine Field Laboratory- USC[1]; Marine Science Dept., Coastal Carolina University[2]

Previous studies that we conducted in North Inlet revealed that use of intertidal creeks by fishes, shrimps, and crabs (nekton) varied among sites and that consistent differences in the magnitude of use were related to unique physical features of those intertidal creeks. In the first year of this study, we found significant differences in the growth rates of certain transient species among intertidal creek basins. In the second year, we will determine if the spatial pattern of growth is the same, and we will also quantify the overall use of the creek at the end of the season. Initial mark-recapture studies indicated that some individuals return to the same creek tide after tide. This suggests a mechanism by which groups from the same year class can remain segregated for weeks to months and potentially grow at different rates. We are continuing mark recapture studies to determine the extent of site fidelity for multiple common species that use intertidal creeks. Another dimension of the study involves a comparison of stored lipid contents of fishes collected at the different spatial growth sites. Together, these studies will determine: (1) whether growth rates and condition vary spatially for individual species and (2) whether high site fidelity is a possible mechanism for segregation and the expression of different growth responses among locations. In addition to addressing relationships between nekton use and nursery habitat quality, our research will contribute to a broader understanding of the export of living biomass from intertidal salt marsh basins to the lower estuary and ocean. The Links project is supported by the National Science Foundation, through the Ecosystems Studies Program (January 2005–September 2008).

Site fidelity and movements of *Palaemonetes* spp. in North Inlet intertidal creek-basins

Investigators: Krystle Ludwig[1], Dr. Dennis Allen[2], and Dr. Stacy Luthy[1,2]
Marine Science Dept., Coastal Carolina University[1]; Baruch Marine Field Laboratory, USC[2]

Grass shrimps, *Palaemonetes spp*., are important residents of and play major roles in salt marsh estuarine ecosystems; they decompose detritus, consume small invertebrates, contribute dissolved inorganic nutrients (primarily ammonium) through digestion, and provide a source of food for many large predators. Grass shrimp abundances usually surpass those of other crustaceans and fishes in intertidal creek basins, but very little is known about their movements within and among creeks. We are interested in their tendency to remain or return certain locales (high site fidelity) versus roam among sites. The purpose of this study is to determine patterns of movement, via color stain mark-recapture techniques, and to determine what factors affect their distributions from tide to tide. For instance, do grass shrimps remain in the same intertidal creek pools over multiple tidal cycles and days or do they exit and re-enter the same creek tide after tide? Using multiple color stains, we can test hypotheses regarding site fidelity among pools within creeks, between branches of the same creek, and between adjacent creeks. We can also compare movements for different size groups of the two species. Recapture efforts at multiple locations will provide estimates of proportions of resident and roaming shrimps, distances/rates of travel, and tendency for animals marked together to stay together. Combined with information from other ongoing studies, this study will help us to better understand (1) relationships between these keystone salt marsh crustaceans and inter-creek variations in habitat quality, and (2) the patterns and mechanisms of biomass transfer within the tidal landscape. The project is supported by the National Science Foundation Ecosystems Studies Program (January 2005–September 2008).

The role of tidal creeks in foraging and growth rate of juvenile Atlantic sharpnose sharks, *Rhizoprionodon terraenovae*

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

The purpose of this study is to test the hypothesis that estuarine subtidal creeks are critical nursery habitat for juvenile Atlantic sharpnose sharks, *Rhizoprionodon terraenovae*, compared to nearshore environments where this species is also found in abundance seasonally. We will analyze gut contents and estimate growth rates using tag-

recapture and other methods for sharks caught in North Inlet as well as in the nearby nearshore environment. Sampling will occur from May to October 2007 and will consist of hook-and-line fishing, longlines, and/or gill nets. Gut contents will be sampled throughout the sampling season. Each shark that is not sampled for gut contents will be tagged and released. Upon recapture, animals will be measured and a growth rate will be estimated. This study will shed light on the relative importance of isolated estuaries as nurseries for *R. terraenovae*, and will help determine whether North Inlet serves as Essential Fish Habitat (EFH) for this species.

This project is supported by the Coastal Atlantic States Shark Pupping and Nursery (COASTSPAN) program, Georgetown Environmental Protection Society, and Coastal Carolina University's Coastal Marine and Wetland Studies Graduate Program.

Winyah Bay and nearshore waters as shark habitat and nursery grounds

Investigators: Samuel J. Gary, Jr. and Dr. Daniel C. Abel
Coastal Marine and Wetland Studies Graduate Program, Coastal Carolina University

Surveys of sharks along the Southeast coast continue to show declines in several species, (e.g., sandbar and dusky sharks), although other stocks, (e.g., blacktips), may be experiencing recovery. These and other sharks inhabit coastal waters and/or estuaries, and use these as nurseries. We are in the sixth year of 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. Sampling will occur from May through October of 2007 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, Middle Bay and, for the first time, the nearshore environment. Variables including surface and bottom water temperature, salinity, and dissolved oxygen, as well as secchi depth and set depth will be measured. Captured sharks are identified, measured, tagged and released with as little stress to the animal as possible. Early results from this project are in press (Abel, D. C., R. F. Young, J. A. Garwood, M. J. Travaline, and B. K. Yednock. 2007. Survey of the shark fauna in two South Carolina estuaries and the impact of salinity structure. In C. T. McCandless, N. E. Kohler, and H. L. Pratt, Jr., editors. Shark Nursery Grounds of the Gulf of Mexico and the East Coast Waters of the United States. American Fisheries Society, Symposium, Bethesda, Maryland)

This project is supported by the Coastal Atlantic States Shark Pupping and Nursery (COASTSPAN) program, Georgetown Environmental Protection Society, and Coastal Carolina University's Coastal Marine and Wetland Studies Graduate Program.

A comparison of the shark fauna of two S.C. estuaries differing in degree of human impact

Investigators: Mollie M. McDonough and Dr. Daniel C. Abel
Coastal Marine and Wetland Studies Graduate Program, Coastal Carolina University

In 2003, as part of a long-term study of the ecology of sharks of northeast South Carolina, we set 196 bottom longlines throughout North Inlet (a relatively pristine estuary), Murrells Inlet (an urbanized estuary otherwise similar to but slightly smaller than North Inlet), and along Garden City Beach (a nearshore ocean environment), and caught 34, 5, and 26 sharks, respectively. Corresponding Catch Per Unit Effort (CPUE, sharks per 25 hooks, $\mu \pm$ SEM) was $1.83 \pm .06$, $0.07 \pm .002$, and $2.64 \pm .09$. We also caught 5, 19, and 1 batoids, respectively, at the three sites. Because *R. terraenovae* (Atlantic sharpnose sharks) were abundant immediately outside but not in Murrells Inlet, and were plentiful at nearby locations, human impact associated with urbanization may explain their absence in Murrells Inlet, as well as its inability to serve as a nursery for other species of sharks. From May–October 2006 and 2007 we will test this hypothesis by setting 500 ft demersal longlines with 25 12/O and 16/O circle hook gangions at sites in North and Murrells Inlets and correlating CPUE with environmental data from the sites.

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.

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

Investigators: Drs. George Y. Matsui[1] and Madilyn Fletcher[2]
Belle W. Baruch Institute for Marine and Coastal Sciences, USC[1]
School of the Environment, USC[2]

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 romerianus*, 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*, *J. romerianus* and sediment associated with those plants will be collected and the microbial communities on the roots and within the associated sediments will be examined using fluorescence in situ hybridization (FISH) of 16S rRNA used in conjunction with confocal laser scanning microscopy (CLSM). Oligonucleotide probes targeting specific taxonomic groups of bacteria will be used to determine bacterial distribution and differences within the bacterial communities. Pore water will be collected and analyzed 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 location 10. Support is provided by National Science Foundation award MCB-0237854 and the Belle W. Baruch Institute.

Understanding the effects of sea level rise on coastal freshwater wetlands

Investigator: Dr. Scott Neubauer
Baruch Marine Field Laboratory USC

Coastal wetlands are important habitats that buffer terrestrial-aquatic interactions and can exert a significant influence on processes in adjacent coastal waters. One of the more certain impacts of global climate change is sea level rise, which will move the salt gradient upriver into historically freshwater wetlands. The overall focus of this project is on tidal freshwater wetlands, greenhouse gas emissions, and interactions with future climate change (i.e., sea level rise). I will use a two-phase approach to 1) develop and refine methods for *in situ* salinity manipulations, and 2) measure greenhouse gas emissions from a tidal freshwater marsh exposed to elevated salinity, as a proxy for how these systems will respond to sea level rise and salt water intrusion. This research will build upon and contribute to the growing expertise of University of South Carolina in areas of climate change. The research is funded for 2007-2008 by a grant from the USC Office of Research and Health Sciences Research Funding Program.

Carbon dioxide production and dissolved inorganic carbon transport in the North Inlet salt marshes

Investigator: Dr. Scott Neubauer
Baruch Marine Field Laboratory USC

This study will describe some of the spatial and temporal patterns in inorganic carbon fluxes in the North Inlet salt marshes. This project will build upon previous work that has shown that a wide variety of factors including the presence/absence of plants, soil composition, and temperature affect rates of heterotrophic metabolism (i.e. CO_2 production) in tidal marsh soils. A fraction of carbon dioxide produced in marsh soils is exported to tidal waters in the form of dissolved inorganic carbon (DIC), but there have been few studies that have robustly documented how and why DIC concentrations vary over the course of the year. Rates of soil metabolism will be measured on soil cores that have been removed from intertidal marsh zones and processed in the lab under anaerobic conditions. Soil subsamples will be incubated anaerobically in sealed bottles at ambient temperatures. Soil respiration and decomposition rates (i.e., the increase in carbon dioxide within the bottle headspace) will be measured over short (hours to days) and longer (~months) time scales. Specific locations for this part of the research have not yet been

determined. I will measure the DIC concentrations of water samples collected from the Oyster Landing Pier over tidal and diurnal cycles by acidifying water samples and measuring the total amount of evolved carbon dioxide. Furthermore, the partial pressure of carbon dioxide will be measured using a gas equilibrator connected to an infrared gas analyzer. The timing of these analyses will be coordinated with the NERRS System-Wide Monitoring Program to take advantage of other data that are regularly collected at Oyster Landing (e.g., nutrients, dissolved organic carbon, chlorophyll).

Availability and utilization of dissolved organic nitrogen by *Spartina alterniflora*

Investigator: Thomas J. Mozdzer
Department of Environmental Sciences, University of Virginia

This research is part of my doctoral work determining if a latitudinal gradient exists in the availability and utilization of dissolved organic nitrogen in *S. alterniflora* salt marshes. To accomplish this, I have established eight field sites along the Atlantic coast that are being monitored monthly or bi-monthly for porewater nutrients. At the North Inlet site, I am working with Jim Morris who is collecting porewater samples for my analysis. In addition to determining porewater nutrients (both organic and inorganic), I would like to determine if there are differences in how different populations of *S. alterniflora* along the coast of N. America are using available nutrients. My MS research demonstrated the direct utilization of amino acids by *S. alterniflora* and *P. australis*, and I wanted to validate these results in different sites.

To determine DON utilization by *S. alterniflora*, fifteen vegetated 15 cm diameter cores will be withdrawn from the marsh. Porewater will be sampled via a stainless steel probe and frozen for analysis at the University of Virginia. The PVC core plus plant will be placed in individual containers and flooded to a depth of 10cm with ambient creek water. These cores will be subsequently amended with one of three treatments: ^{15}N-ammonium, ^{13}C, ^{15}N-amino acid mix, or a disturbance control. Amino acid treatments are 99% enriched with ^{13}C and ^{15}N, and the ammonium is 99% ^{15}N. Using the stable isotopes as a tracer, I can determine the plant utilization over a 48-hour incubation period. After the 48-hour incubation, above and belowground plant material will be harvested, and shipped on dry ice to the University of Virginia, where it will be freeze dried and analyzed for stable isotope concentrations by the UC Davis Stable Isotope facility. Map location 14.

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. 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, 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.

Factors controlling the transport of *Vibrio parahaemolyticus* between sediments and surface water in an estuarine system.

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

Vibrio parahaemolyticus occurs naturally in temperate coastal waters and is an opportunistic human pathogen, capable of causing illness or death as a result of consuming raw or undercooked shellfish. Recent studies of the North Inlet, SC salt marsh have identified *V. parahaemolyticus* among the vibrios isolated from roots of the marsh grasses *Juncus roemerianus* and short and tall form *Spartina alterniflora*. This research is focused on monitoring and quantifying the transport of *V. parahaemolyticus* in salt marsh sediments. It is hypothesized that tidal flooding and the physical dynamics of porewater advection into and out of the sediments accounts for the transport of *V. parahaemolyticus* to and from the salt marsh rhizosphere. In addition to porewater advection through the sediments, infaunal burrows may also serve as conduits for increased transport of porewater and *V. parahaemolyticus* by providing large open channels from the rhizosphere refugium to salt marsh tidal creeks. Initial studies will focus on the seasonal dynamics of the *Vibrionaceae* population using various microbiological and molecular techniques. Future investigations will use mesocosms to emulate plant zone conditions to quantify the effects of various environmental factors on bacterial transport. Understanding the ecological implications of *Vibrio* transport, as well as their long term survival in the rhizosphere, would contribute greatly to efforts to predict *V. parahaemolyticus* outbreaks in coastal waters and shellfishing areas and may contribute to explaining the increasing occurrence of such outbreaks.

This project, initiating in March 2007, will be conducted in the current NSF funded North Inlet Microbial Observatories site.

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

Investigators: Dr. Susan B. Wilde[1,2], Raphael G. Tymowski[1], and Dr. David White[3]
Baruch Marine Field Laboratory, USC[1], Marine Resources Research Institute, SCDNR[2], NOAA, Hollings Marine Laboratory[3]

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.

The South Carolina Harmful Algal Bloom Program

Investigators: Dr. Susan Wilde[2], Lara Brock[2], Dr. Patrick Brown[1], Krista DeMattio[2], Kenneth Hayes[1], Chuck Keppler[2], Jiqing Liu[1], Andrew Shuler[1,2], Raphael Tymowski[1], Patrick Williams[2], Sarah Williams[2], and collaborators[3]
Baruch Marine Field Laboratory and Hollings Marine Laboratory, USC[1], Marine Resources Research Institute, SCDNR[2], NOS-Charleston, SC Sea Grant, SCDHEC, SCDNR, Clemson University, MUSC, USGS[3]

The South Carolina Harmful Algal Bloom Program (SCHABP) was created in October 2000 to document the statewide distribution of HABs and determine their prevalence, the factors that trigger and sustain them, how and to what extent they impact fish and shellfish, their potential effects on human health, and educate the public on these issues. 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. Sites that are routinely monitored from the Baruch field laboratory will include North Inlet (Clambank Bridge), Murrells Inlet (forested and urban creek), Debordieu ponds and Debidue creek. 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 2006 to 30 September 2007.

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

Investigators: Dr. Richard Zingmark[1] and Raphael Tymowski[2]
Department of Biological Sciences, USC[1], Baruch Marine Field Laboratory, USC[2]

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 SC Sea Grant Consortium, 1 March 2005 to 28 February 2007.

Effects of cadmium on *Amphipholis gracillima* regeneration

Investigators: Katrina Phillips[1,2] and Dr. Steve Stancyk[1,3]
Marine Science Program[1], USC; South Carolina Honors College[2], USC; Dept. of Biological Sciences, USC[3]

Burrowing brittlestars in the Family Amphiuridae have the ability to throw off their arms when threatened by predators, then regenerate the lost tissue. Recent research showed that brittle star arms lost near the disc regenerate faster, but with less skeletal differentiation than arms lost near the tip, which grow at a slower rate but show greater differentiation. Rapid regeneration rates make brittlestars ideal subjects for studies of the effects of toxins on regeneration. Previous work in our laboratory showed that brittle stars in sediment with elevated cadmium levels regenerated more slowly, with thinner arms, less skeleton and more arm segments than those in control conditions.

How cadmium disrupts arm regeneration is not yet fully understood. We hope to clarify which aspects of the regeneration process are most affected by cadmium contamination by exposing brittlestars whose arms have been cut off at different distances from the disk to sublethal levels of cadmium. We expect that when the tip of the arm is removed, regeneration rates will be similar to controls but skeletal growth will be inhibited. Arms removed at the base should show reduced skeleton formation also, but slower rates of growth compared to the controls. Histological comparisons will help pinpoint which aspects of the regeneration process are disrupted by cadmium. This work will be carried out in our laboratory on the USC campus in Columbia between September 2006 and May 2007. We are

using animals, sediment and seawater collected from North Inlet (site 17). Our research is partially funded by a grant from the Magellan Scholars Program through the Office of Undergraduate Research. Map location 17.

Environmental impacts of gelatinous zooplankton (Hydromedusae) on carbon dynamics of the North Inlet ecosystem

Investigators: Dino Marshalonis, Dr. James 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 three 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. 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. 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 will 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.

Ecotoxicology of benzalkonium chloride, a common antimicrobial surfactant

Investigators: Jean Marie Buschur and Dr. James L. Pinckney
Marine Sciences Program, USC

Pharmaceuticals and personal care products (PPCPs) are a relatively new class of chemicals of which little attention has been paid to their long-term environmental effects. One PPCP is benzalkonium chloride (BAC), which has been used as an antimicrobial agent in many products such as pharmaceuticals and household cleaners. BAC is released in high concentrations in wastewater effluent. However, few studies have determined the effect of BAC on phytoplankton.

In this research the affect of BAC natural phytoplankton communities at Clambank Creek, North Inlet, South Carolina will be studied. There are four specific hypotheses. First, a low concentration of BAC (0.6 $\mu g\ L^{-1}$) will have no impact on biomass and community composition. Second, an intermediate low concentration of BAC (1.0 $\mu g\ L^{-1}$) will lower biomass and community composition for cyanobacteria, cryptophytes, and diatoms; it will have no impact on chlorophytes and dinoflagellates. Third, an intermediate high concentration of BAC (1.5 $\mu g\ L^{-1}$) will be lethal for diatoms, cyanobacteria and cryptophytes; and will result in lowered biomass and community composition on for chlorophytes, dinoflagellates. Finally, a high concentration of BAC (2.5 $\mu g\ L^{-1}$) will be lethal for all species.

Each unialgal culture underwent a 7 day EC_{50} laboratory toxicity test with exposure to BAC in the following different geometrically spaced concentrations: 0.0, 0.10, 0.15, 0.25, 0.40, 0.60, 1.00, 1.50, 2.00, and 2.50 $\mu g\ L^{-1}$. The EC_{50} was evaluated at 48, 72, and 168 hours. Short-term phytoplankton bioassays will be used to measure phytoplankton response to BAC in situ. Photosynthetic pigments, algal species identification/enumeration by

microscopy, and primary productivity will be determined at the initiation of the experiment and daily for the 3 day incubation period. Bioassay results will be analyzed using a multivariate analysis of variance procedure. A repeated measures design will be used to determine experimental effects within replicates and between different treatment levels for each bioassay. High performance liquid chromatography (HPLC) will be used to quantify photopigment concentrations in water samples collected from the bioassays and the laboratory EC_{50} tests. ChemTax (CHEMical TAXonomy), a matrix factoring program, will be used to calculate algal class abundances based on the concentrations of algal photopigments. Microscopy will be used to count phytoplankton species and abundances to confirm results of phytoplankton taxa from HPLC.

These results will assess the effects of BAC on phytoplankton. Intermediate effects of BAC will be seen through the shift in community composition of the phytoplankton, determined from HPLC and ChemTax analysis. This is a start to understanding the effect of PPCP's on the environment, and may lead to regulations against their disposal in the environment.

This project is funded by South Carolina Sea Grant Consortium.

Effects of sublethal concentrations of agricultural herbicides on the structure and function of estuarine phytoplankton communities

Investigators: Dr. James L. Pinckney and Jean Marie Buschur
Marine Sciences Program and Department of Biological Sciences, USC

Habitat alteration and loss of biodiversity due to pesticide contamination is rapidly emerging as major ecological threat for wetland and estuarine ecosystems. In aquatic ecosystems, phytoplankton are usually the most atrazine-sensitive biotic components. The proposed research will directly address SC Sea Grant Strategic Goal 3 under the Priority Topic "Investigations of the cumulative effects on key indicator marine organisms of low level, sub-chronic exposure to chemical contamination due to increasing human activities." In this project, the key indicator species will be phytoplankton and the ecological indicators will be phytoplankton community composition and primary productivity. The chemical contaminants will be a common herbicide (atrazine) in waters entering many South Carolina estuaries, growth-limiting nutrients (nitrate and phosphate), and the interactive effects of atrazine and nutrients to simulate pulsed river discharge events.

The experiments are designed to determine the short-term sublethal effects of environmentally-relevant concentrations of atrazine (under high and low nutrient concentrations) on estuarine phytoplankton community structure and function. The specific hypotheses that will be tested are

a. Short-term exposure of estuarine phytoplankton to low atrazine concentrations (1.00 μg $liter^{-1}$) under low nutrient conditions promote shifts in the relative abundance of phytoplankton taxonomic groups and species and a reduction in primary productivity.
b. Under high (non-limiting) nutrient conditions, the effects of sublethal concentrations of atrazine (1.00 μg $liter^{-1}$) on phytoplankton biomass, community composition, and primary productivity are less severe (i.e., are significantly different) than the effects under nutrient-limiting conditions.
c. Trace concentrations of atrazine (0.10 μg $liter^{-1}$) have no effect on estuarine phytoplankton biomass, community composition, or primary production.

Short-term Phytoplankton Bioassays will be used to measure initial phytoplankton responses to different levels of atrazine and nutrient exposure. The purpose of these experiments is to determine the effects of a range of atrazine/nutrient concentrations on phytoplankton primary productivity and biomass of specific algal groups (i.e., diatoms, cyanobacteria, dinoflagellates, cryptophytes, etc.) in natural estuarine phytoplankton assemblages. These data will be used to assess "who" responds to the different levels of atrazine treatments under ambient (light, nutrient, temperature, etc.) conditions. This experimental approach is critical for understanding the mechanisms underlying phytoplankton community responses and dynamics in estuarine ecosystems.

This project is funded by South Carolina SeaGrant.

Utilization of dissolved organic phosphorus (DOP) by phytoplankton in Winyah Bay, South Carolina

Investigator: Melissa Ranhofer
Marine Science Program, University of South Carolina, Columbia, SC

Dissolved organic phosphorus (DOP) can comprise a significant portion of the total dissolved phosphorus pool in aquatic ecosystems. When dissolved inorganic P is low or unavailable, some phytoplankton can use DOP as a P source through expression of the extracellular enzyme alkaline phosphatase. In this study, I used a cell-specific Enzyme Labeled Fluorescence (ELF-97) assay to detect alkaline phosphatase activity (APA) in surface samples taken from a marine and a riverine site in Winyah Bay in the summer of 2006. Also I examined the effects of different inorganic nutrients (nitrate and inorganic phosphate) and site location on the structure of the phytoplankton community (algal group composition). Nitrate additions significantly increased the total phytoplankton biomass (measured as chl a) relative to the controls in May and August, indicating these communities were nitrogen-limited during these times. APA varied by month, with the highest percent of APA positive labeled cells occurring in May (10% ± 0.8 for the riverine site and 33% ± 10.0 for the marine site), and the least percent APA positive labeled (2% ± 1.1 for the riverine site and 1% ± 0.5 for the marine site) occurring in August. There was a significant effect ($p < 0.01$) of site location, nutrient addition, and the interaction of these two factors on APA in May and August respectively. Significantly lower APA was detected in the inorganic phosphate additions when compared to the controls for May, July, and August. Overall, the time course experiments showed a decrease in APA labeling as diatoms increased in abundance. The main organisms labeled were dinoflagellates, including *Gymnodinium sp*., *Protoperidinium sp*. and *Dinophysis sp.*, though APA was also observed in diatoms such as *Odontella sp.* and *Pleurosigma sp.*

Phylogeography and evolution of chemosynthetic endosymbioses in protobranch bivalves of the Family Solemyidae

Investigators: Dr. Coleen Cavanaugh and Frank Stewart
Depart of Biology, Harvard University

Studies of mutualistic associations between sulfur-oxidizing chemosynthetic bacteria and marine invertebrates have yielded tremendous insight into the physiology and evolution of bacteria-eukaryote interactions, as well as the ecology and primary production of marine reducing environments (e.g., deep-sea hydrothermal vents, coastal muds). However, for most chemosynthetic symbioses, intraspecific patterns of genetic and phenotypic variation in both host and symbiont have yet to be described, despite the relevance of these processes to symbiont-host diversification, local adaptation, and speciation. The proposed research aims to reduce this knowledge gap by critically examining the population genetic structure, phenotypic variation, and evolutionary history of chemosynthetic endosymbioses within the protobranch clam Family Solemyidae.

Specifically, we propose a multi-locus analysis of symbiont and host genetic variation among populations of the Atlantic protobranch clam *Solemya velum*. This will be done concurrent with analyses of the kinetic and structural properties of key symbiont and host proteins to assess the potential for adaptive differences in response to temperature variation across the range of the species (Florida to Nova Scotia). We propose using the Baruch Institute as a base for collecting *S. velum* clams from the North Inlet estuary and for processing samples for genetic and protein analyses. Collection of *Solemya velum* from the North Inlet estuary will involve accessing tidal marshes by boat, retrieving and sieving sediment samples, and preserving clam tissue for genetic and protein analyses

The North Inlet is an ideal site for the purposes of this study. *Solemya velum* clams have been collected previously from North Inlet (from the DeBordieu flat area by Dr. Rick Fox, Lander University). Furthermore, the habitat and temperature regime of this southern site provides an interesting contrast to that of the Woods Hole MA region from which *S. velum* clams have been collected for prior physiological and genetic analyses. Comparison of clams from the North Inlet region and from northern sites (e.g., Woods Hole) will provide insight into adaptation to distinct temperature regimes, as well as into the rates of gene flow among geographically isolated populations of estuarine bivalves. Map location 17.

Effects of variation in egg size on embryonic development in the poecilogonous annelid *Streblospio benedicti*

Investigator: Dr. Bruno Pernet
Department of Biological Sciences, California State University, Long Beach

Larvae of some marine invertebrates develop from small eggs and must feed to fuel their development, while larvae of other species develop from large eggs and do not feed until after metamorphosis. I am using a comparative approach to test hypotheses on the developmental events underlying this correlation between egg size and larval nutritional mode, focusing primarily on differences in the timing of gut morphogenesis associated with variation in egg size. At BMFL, I am studying the "poecilogonous" annelid *Streblospio benedicti*, a species in which some individuals produce small eggs that develop into obligately feeding larvae, but others produce large eggs that develop into facultatively feeding larvae. Techniques used include confocal and light microscopy, and functional studies of feeding. Results of this project will provide an important link between the fields of development, larval ecology, and life history evolution in marine invertebrates. This work is supported in part by an internal award from California State University, Long Beach. Collection site is the high marsh near Oyster Landing (map location 3).

The effects of microhabitat and mussel body position on survivability and growth 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 ±1°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 highly 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 2006. In the field I plan to set up two temperature experiments. One will be a control with no material over the mussels, one will be shade cloth. For each treatment, I will select 10 clumps of *G. demissa* in the field. Within each clump, I will notch mussels at the start of the summer, and place iButton temperature loggers (at three vertical body positions) near the living mussels to estimate mussel body temperature in the area. At the end of the summer, I will return to the marsh, record the level of growth for each mussel and remove 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. I expect to see an increase in both growth and gonad weight in the treatment with shade cloth.

The seawater lab experiment also plans to examine the effects of various body temperatures on mussel body growth and survivability. I will house mussels in artificial marsh tanks with a set tidal cycle of 4 hours high tide per day. During low tide, mussels will be heated to one of 4 treatment temperatures: 40, 45, 50 or 55°C. Mussels will be heated in a manner similar to that seen in the field, with halogen heat lamps turning on at 6AM and off (following peak temperature) at 3 PM. 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. A similar study conducted in the summer of 2005 found that there was an increase in mussel mortality at temperatures over 45°C when exposed to that temperature maximum daily. In a similar manner, we will heat mussels to the goal maximum temperatures. However, the max temperature will not occur on a daily basis. There will be 3 regimes: exposure to max temperature daily, exposure to max temperature every 3 days, and exposure to max temperature every 7 days.

On the days that there is no heating regime, the tidal cycle will continue as normal, but the heat lamps will not turn on. There will be 20 mussels for each treatment, with a total of 12 treatments in two identical tanks. 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 with an increase in treatment temperature. Map locations 8 & 10

Urbanization and Southeastern Estuarine Systems (USES)

Investigators: Drs. Dwayne E. Porter[1,2], Susan Wilde[1], Tom Chandler[1,2], Marj Aelion[1,2], Marie DeLorenzo[3] Geoff Scott[2,3], John Ferry[1], Mike Fulton[2,3], Tom Siewicki[2,3], and Angela Halfacre[4]
Belle W. Baruch Institute Baruch for Marine and Coastal Sciences, USC[1]; Norman J. Arnold School of Public Health, USC[2]; NOAA's Center for Coastal Environmental Health and Biomolecular Research[3]; College of Charleston[4]

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 08/01/05 though 07/31/07 (www.urbanestuary.org).

Comparative studies demonstrate the effects of changing land use on tidal creeks

Investigators: Drs. Guy T. DiDonato[1], Derk Bergquist[2], A. Frederick Holland[1], Denise M. Sanger[3], Jill Stewart[4], Robert Van Dolah[2], and Ed Wirth[1]
National Ocean Service, Hollings Marine Laboratory[1]; South Carolina Department of Natural Resources [2]; South Carolina Sea Grant Consortium[3]; National Ocean Service, Center for Coastal Environmental Health and Biomolecular Research[4]

The human population of South Carolina's coastal counties has increased over 30% since 1990, and this influx of people is predicted to continue well into the future. The population boom has been marked by the conversion of forested and agricultural watersheds to suburban and urban ones. Impacts of these landscape changes on South Carolina's tidal creeks were evaluated in winter and summer, 2005. Creeks in the pristine North Inlet-Winyah Bay (NIWB) NERR served as a valuable reference systems for these studies. Creeks from urban, suburban, and forested watersheds were sampled from the upper intertidal reaches down to the subtidal zone. Results demonstrate that the conversion of forested watersheds to suburban and urban ones modifies water and sediment quality. Tidal creek

NOx levels increased with urbanization during both seasons; PO4 also showed a land use signal and was highest in suburban watersheds in summer. Pathogen indicators were highest in urbanized watersheds regardless of season. Sediment contaminants also increased with urbanization. These results demonstrate that changing land use alters the ecological character of tidal creek ecosystems, and sites like those in NIWB and other NERR reserves provide a critical reference for comparative studies and regional assessments.

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], Marj Aelion[1,2], and Heath Kelsey[2], and Sam Walker[2]
Belle W. Baruch Institute for Marine and Coastal Sciences, USC[1], Arnold School of Public Health, USC[2], NOAA Center for Coastal Environmental Health and Biomolecular Research[3]

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 differentiates the fecal coliform levels measured in several estuarine waters 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 07/01/04 to 06/30/07 by SC Sea Grant Consortium. (www.lu-ces.org).

Habitat mapping of North Inlet

Investigator: Jennifer Spicer
North Inlet-Winyah Bay NERR

A habitat map will be developed for the area within the North Inlet Winyah Bay NERR and a land use map will be created for the North Inlet watershed using the NERRS Habitat and Land Use Classification System. Digital aerial photos, ADAR and LiDAR data will be used to map the area to a 1 m resolution. The classification scheme developed by the NERRS Habitat Mapping and Change Committee has a five-level, nested hierarchical structure based on the Cowardin and Anderson classification systems, and will facilitate the exchange of habitat data among reserves. These maps will serve as a baseline for temporal studies that examine trends in land use and land cover change. The North Inlet habitat map will also be used to examine habitat distribution and availability for key species in the reserve.

Examine the salinity tolerance of reared *Uca minax* larvae from upriver areas

Investigators: Stephen Borgianini[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College[2]

In June, July, and August ovigerous *U. minax* individuals will be collected from natural populations of fiddler crabs from a riverine area near Bates Hill Plantation, on the Pee Dee River as well as from the old Highway 17 bridge. We will rear the larvae until the megalopal stage when they will be segregated into test chambers of various salinities. We will conduct a bioassay to determine the LC50 with respect to salinity for reared megalopae. Project period: June 1 - August 31, 2007.

Recruitment and settlement of megalopae to freshwater, upriver areas

Investigators: Stephen Borgianini[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College[2]

We will deploy several arrays of artificial settlement substrates in selected areas in the Pee Dee River and Waccamaw River. These artificial settlement substrates will be monitored relative to tidal currents throughout several nights from July to August 2007 for settled and metamorphose *Uca minax* individuals. *U. minax* populations along the length of the Pee Dee River exhibit broadly heterogeneous population densities. We will be attempting to determine if there are differing megalopal settlement patterns relative to submerged aquatic vegetation (specifically *Nuphar sagittifolia*). Project period: July 1 - August 31, 2007.

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

Investigator: Stephen Borgianini[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College[2]

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 affects the distribution of *U. minax* as well as plant zonation. Additionally, the effects of changes in groundwater salinity caused by natural events such as rainfall and tides will be compared to the biodistribution measurements collected. Project period: May 15- September 30, 2007.

Collect freshwater fish by means of electrofishing in order to determine the extent of predation of planktivorous freshwater fish on *Uca minax* megalopae in the Pee Dee River

Investigators: Stephen Borgianini[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College [2]

In collaboration with SCDNR we will collect fish specimens from freshwater sections of the Pee Dee River and examine the stomach contents for *U. minax* megalopae. These data will be used to develop an estimate of mortality due to predation for *U. minax* megalopae and will be used to calibrate a *U. minax* megalopae transport model. Project period: July 1- August 1, 2007.

Determine the spatial and temporal variability of *Uca minax* adults along the freshwater reaches of the Pee Dee River

Investigators: Stephen Borgianini[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College[2]

In this study we will conduct monthly monitoring of *Uca minax* burrow density on the Pee Dee River. Adult distribution appears to be limited by pre-settlement phenomenon. We are attempting to model adult distributions based upon the larval transport model described within: May 15- September 30, 2007.

Vertical swimming behavior *Uca minax* megalopae in relation to tidal current direction

Investigators: Stephen Borgianini[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College [2]

In order to field validate the flow transport model developed for the Pee Dee River we will conduct field sampling that consists of nocturnal pump sampling at two locations within the Pee Dee river that will be conducted with the simultaneous deployment of two ADCP (Acoustic Doppler Current Profilers). The sampling regime will include: 1. Pump sampling at surface for the duration of flood tidal current; 2. An epibenthic sled sampler will be used to collect megalopae on the river bottom on diurnal ebb tide at several locations on the river.

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. Project period: May 15- September 30, 2007.

Limitations on the dispersal of *Uca minax* (LeConte, 1855) in a river-dominated estuary

Investigators: Stephen Borgianini[1], Dr. Richard Styles[2], and Dr. Renae Brodie[3]
Department of Biological Sciences, USC[1], Department of Geological Sciences and Marine Science Program, USC[2], Biology Department, Mt. Holyoke College[3]

Many estuarine species with relatively immobile adult life histories have pelagic larval life stages that increase their dispersal capabilities. Limitations to the successful recruitment of postlarvae and juveniles back to conspecific adult habitats are dependant on the physiological and developmental constraints on the larvae, biotic interactions (i.e. predation, prey availability, competition), cue recognition and response and physical factors (i.e. physiography of the estuary, tidal amplitude, river discharge, salinity, density gradients, wind).

We developed an empirical one-dimensional flow model for the freshwater, tidal portion of the Pee Dee River that discharges into Winyah Bay, South Carolina. We chose *Uca minax* as our model organism due to its ability to successfully inhabit brackish and freshwater habitats throughout Winyah Bay and its confluent tidal rivers. The coupled larval behavior-transport model is capable of predicting *U. minax* dispersal in the tidal freshwater reaches of the Pee Dee River for any combination of river discharge and tidal amplitude. We have recently begun to calibrate and ground-truth the model.

In our model, we assume that larvae and postlarvae behave as passive particles in the horizontal direction, but have the ability to move vertically in the water column. We have confirmed that megalopae of *U. minax* migrate

toward the surface in response to flood currents and sink during ebb currents. Mean densities of *U. minax* burrows in the Pee Dee River were recorded along a longitudinal river transect and compared favorably with model predictions of expected rates of megalopae settlement. Metamorphosis and survivorship studies were conducted with *U. minax* megalopae to develop metamorphosis/ survivorship function for the model. The results of these studies will be used to calibrate and validate our coupled larval behavior-transport model.

Application and evaluation of ADAR-based habitat suitability modeling for *Uca minax* and *Uca pugilator* in North Inlet

Investigators: Simmone Williams[1] and Dr. Renae Brodie[2]
Department of Biological Sciences, USC[1], Biology Department, Mt. Holyoke College[2]

Advances in remote sensing technologies allow new complimentary approaches to large scale assessment of biodiversity. Within the North Inlet we will integrate remote sensing techniques, statistics and auxiliary data to assess the habitat and population distribution of two adult fiddler crabs, *Uca minax* and *Uca pugilator*.

Habitat parameters such as land cover type will be derived from ADAR imagery. Nine sample sites will be selected within North Inlet and in situ data, such as salinity, will be collected fortnightly along transects between February 15, 2006 and August 31, 2006. Population density will be determined from quadrat counts at sample sites. Both derived and in situ data will be used to build a habitat suitability model that estimates likely variations in habitat and population distribution of adult *U. minax* and *U. pugilator*. We will also evaluate the usefulness of the applied integrated remote sensing, statistics and field approach in large scale assessments of adult *U. minax* and *U. pugilator* habitat and population distribution. Map location 10

Breeding biology of Wilson's plovers in South Carolina: Population status, breeding success, and effects of human disturbance

Investigators: Kerri Dikun and Dr. Chris Hill
Department of Biology, Coastal Carolina University

The breeding population of Wilson's plover in South Carolina, where the species is listed as threatened, will be studied to determine the size of the breeding population within the state and to map the locations where the plovers are breeding. Additionally aspects of nesting biology including nest site selection, nest attentiveness and behavior of the adults at the nest, will be studied to determine if these are similar to what has been observed in other locations. Establishing the dates on which critical nesting events take place, and determining the age at which these birds fledge will also be part of the project. By collecting pertinent data throughout the breeding season nesting success and productivity will be determined and the factors that impact these the most will be established. Finally, special attention will be paid to the impact that human activity has on the nesting success and behavior of Wilson's plovers. North Inlet is being used as one of the study sites because it is relatively pristine and has a low human presence.

To locate nests, the southern portion of North Island will be surveyed on foot, twice a week. When nests are located they will be documented and measurements at the nest will be taken (distance to closest vegetation, slope, distance to water, egg flotation, etc.). Signs of human activity, such as tracks, or the presence of humans will be documented.

When the clutch is complete and the adults have started incubating, a drop trap will be set at the nest to capture adults for color banding. Attempts will be made to band chicks by locating them before they leave the nest on their hatching date. Nest success and productivity will be tracked by checking the nest for eggs once a week until the nest is lost, or until the nest hatches. After the nest hatches, the area near the nest and potential foraging areas will be surveyed to locate the chicks. If the chicks are located, weekly surveys will contiue until they fledge.

Little study has been done on the Wilson's plover throughout its breeding range, and the breeding biology and population status of the Wilson's plover is relatively unknown in South Carolina. It is important to determine the breeding population in the state, how successful these birds are at producing young and what factors contribute to or hinder nest success. Map location 15A

Visiting Scientist Awards

The University of South Carolina's Belle W. Baruch Institute for Marine and Coastal Sciences encourages scientists from other institutions to conduct research at the Baruch Marine Field Laboratory. Each year, funds are awarded competitively to several investigators to support travel and other expenses related to their research activity on site. Faculty level investigators who would benefit from the close proximity of a variety of salt marsh/estuarine habitats and a modern research facility are encouraged to apply for a Visiting Scientist Award. We especially encourage scientists with interests in establishing long-term research programs in the area. Proposals for field-based studies that can be supported by existing infrastructure and extant databases are favored. Additional information about the Visiting Scientist program and a list of previous awardees can be found at http://links.baruch.sc.edu/visitingscientist.html.

Factors shaping spatial and temporal patterns in the biogeography of estuarine bacterioplankton communities

Investigator: Dr. Jude K. Apple
US Naval Research Lab, Washington DC.

Bacterioplankton community composition, salinity and terrestrial dissolved organic matter (DOM) change dramatically along estuarine gradients, yet factors driving changes in community composition and the relationship with transformation of terrestrial DOM remain poorly understood. This study quantifies changes in bacterio-plankton community composition at 4-step intervals along salinity gradients (0-32 psu) in Winyah Bay, including transects in the Sampit, Pee Dee, and Black rivers. We also investigate changes in community composition on small spatial scales and throughout the tidal cycle in the tidal creeks of North Inlet. Shifts in bacterioplankton community composition were identified by denaturing gradient gel electrophoresis (DGGE) of PCR-amplified 16S ribosomal DNA and related to environmental parameters using multidimensional scaling (MDS) and canonical correspondence analysis (CANOCO). The majority of this research was conducted during summer and fall of 2006 and supported by the Belle Baruch Visiting Scientist Award; with additional sampling in Winyah Bay in spring 2007.

Temperature, salinity, nutrients and the coherence of bacterial production and chlorophyll-a in an estuarine system

Investigators: Drs. Jude K. Apple[1] and Erik M. Smith
US Naval Research Lab, Washington, DC[1]; North Inlet-Winyah Bay NERR, Baruch Marine Lab, USC

Using a 4-year dataset from the National Estuarine Research Reserve System (NERRS) System-Wide Monitoring Program (SWMP) combined with principle components analysis (PCA), we identified distinct patterns among 21 NERRS Reserves related to the primary factors shaping physio-chemical variability. This analysis confirmed that salinity and temperature shape estuarine variability, a finding which was further supported by similar analysis of data from 33 published studies of non-NERRS systems representing a wide range of coastal and estuarine ecosystems. We also investigated the response of biological parameters to physio-chemical variability, using the ratio of bacterial production (BP) and chlorophyll-a (BP:CHLA) as an integrative index of the coherence of autotrophic and heterotrophic planktonic processes. Both temperature and salinity had a significant effect on BP:CHLA ratios, suggesting in turn that these properties contribute to the balance between autotrophic and heterotrophic planktonic processes in estuarine ecosystems. We further explored factors regulating the coherence of BP and chlorophyll-a in field studies conducted at two NERRS Reserves, with 10 stations located in the tidal creeks of Monie Bay (Chesapeake Bay), 12 along the longitudinal axis of Winyah Bay and associated tributaries, and 10 among the tidal creeks of North Inlet. Comparison of these systems shows that the coupling of BP and algal biomass is greater in more saline systems with higher ambient water temperatures and may be weaker in mesohaline systems where alternate sources of allochthonous organic matter are available. Collectively, data from the present study represent provides convincing evidence of the universal role of salinity and temperature in shaping the

variability among even the most diverse systems. Our multivariate analysis provides valuable insight into the degree to which environmental conditions vary among and within NERR reserves and as such provides a valuable framework for comparison of reserves within the context of the entire NERRS.

Belowground structure and soil respiration rates among salt marsh plots with varying accretion rates and fertilization status

Investigators: Dr. Cathy Wigand[1], Dr. Earl Davey[1], Karen Sundberg[2], and Dr. Jim Morris[2]
US EPA NHEERL Atlantic Ecology Division[1]; Department of Biological Sciences and the Marine Science Program, USC[2]

We propose that the combination of computer-aided tomography (CT) and soil respiration measures may be a practical and useful approach to monitor condition and assess impairment in coastal salt marshes. CT imaging will be used to examine macro-organic matter and belowground structure in cores collected from long-term fertilized plots, control plots, and salt marsh areas with varying accretion rates. The CT imaging will allow for an estimate of the plant tissue-gas and peat-water volumetric fractions of the salt marsh cores. Coupled with these measures of belowground structure in the salt marsh plots, *in situ* measures of CO_2 efflux, as an indicator of soil respiration, will be determined. We expect an increase in the soil respiration rates in the fertilized plots compared to the control ones, and a decrease in the below-ground macro-organic matter, in particular, the peat-water fraction. We will also report on the belowground structure and soil respiration in plots with varying accretion rates in the North Inlet – Winyah Bay NERR. Summer 2007 funding for this study was provided to visiting scientist C. Wigand from the Baruch Marine Field Laboratory, USC. Map locations 2A, 11, 22

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

Investigator: Dr. Richard Tankersley and Paola Lopez-Duarte
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 (STST), 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. We will examine the role of circatidal rhythms in the STST behavior of fiddler crab larvae. Vertical position and migratory behavior of zoeae and megalopae in the field will be compared to circatidal rhythms in swimming expressed under constant laboratory conditions to determine if they are phased appropriately to underlie STST. The results will provide critical data for the development of a bio-physical model of larval transport within the Winyah Bay estuary.

Carbon sequestration rates in tidal wetland soils

Investigator: Dr. Benjamin Tanner
Department of Geosciences and NRM, Western Carolina University

The most recent report of the Intergovernmental Panel on Climate Change (2007) suggests that anthropogenic contributions of greenhouse gasses to the atmosphere are “very likely” increasing mean global surface temperatures. Consequently, there is increasing interest from scientists and policy makers in finding sinks for atmospheric carbon and determining their importance in the global carbon cycle. Salt marshes are highly productive ecosystems that represent a significant component of the global carbon cycle. I will be studying rates of carbon sequestration in different types of tidal wetlands at and around BMFL, including impounded/formerly impounded wetlands, in order to determine which types of wetlands have the greatest sequestration potential. I will collect soil cores from multiple sites and sub-sample the cores to determine soil organic carbon % (CNS analyzer), soil bulk density, and soil age

(^{210}Pb and ^{137}Cs). Soil carbon accumulation rates will then be calculated as a product of the average soil accretion rate and the average carbon density for each core. Results of this study will be relevant to other scientists and policy makers who are interested in an improved understanding of the role of tidal wetland biospheric feedbacks in the global carbon cycle. This project is funded by a Visiting Scientist Award from BMFL.

Processes affecting EPS production in photosynthetic biofilms

Investigator: Dr. Daniel C. O. Thornton
Department of Oceanography, Texas A&M University

The composition and quantity of extracellular polymeric substances (EPS) in a photosynthetic biofilm may be regarded as an emergent property of the community, as it is a product of the interactions and metabolic processes taking place within the community. Benthic diatoms usually dominate photosynthetic biofilms. These organisms release up to 60% of their primary production into the surrounding environment as colloidal carbohydrates, including EPS. In addition, photosynthetic biofilms support large populations of prokaryotes, which also produce and consume EPS. EPS is the primary structural component of most photosynthetic biofilms and many microorganisms inhabit a microenvironment dominated by EPS. The objective of this research is to determine how microbial processes and community structure affect the quantity and composition of EPS produced by photosynthetic biofilms in estuaries. This research is supported by a Visiting Scientist Award from the Baruch Marine Field Laboratory.

Biological rhythms of an estuarine amphipod

Investigator: Dr. Richard Forward
Duke University Marine Laboratory

The supratidal amphipod *Talorchestia longicornis* is very abundant in estuaries. Past studies of biological rhythms in supratidal amphipods indicate they are have a circadian rhythm in activity, in which they emerge from their burrow during the night. In contrast, preliminary studies of *T. longicornis* suggest that they are active only at the time of low tide at night. To verify this relationship to the tides, further studies are needed in different tidal regimes. These studies will be undertaken at the Baruch Marine Field Laboratory and results compared to those from a North Carolina estuary. The activity rhythms will be studied using a time-laps video system. The study will take place over a two week period in October.

Long-Term Studies

The summaries listed below describe ongoing long-term studies being conducted in North Inlet Estuary. One of the valuable resources provided by the BMFL is 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. They can also be used to facilitate interpretation of data from shorter-term research projects. 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.

Ecology of diamondback terrapins

Investigators: Dr. Peter King and Paige Weaver
Department of Biology, Francis Marion University

Baseline population data will be gathered on the population of diamondback terrapins (*Malaclemys terrapin*) in North Inlet, Winyah Bay, SC. Aspects of their ecology will be investigated including habitat use and diet. Terrapins will be caught using seines around low tides in the small creeks that drain the marsh. Once caught, terrapins will generally be measured and marked individually, with a notch in the marginal scute of their carapace, and then released at the site of capture. Population data will be gathered in subsequent years as animals are recaptured. Some terrapins will be kept overnight to gather feces for examination to determine diet. Telemetry will be employed on a small number of terrapins to investigate movement of individuals in the marsh. Marking of terrapins began in July 2006 in creeks draining into Town and Old Man creeks. Five creeks with marked terrapins will be revisited in 2007 and future years and new creeks will be sampled.

Diamondback terrapins are restricted in their range to coastal marshes. This habitat is increasingly threatened by coastal development. Terrapin populations have been studied in Charleston and Kiawah Island but little is known about the population on the northern coast of South Carolina, including North Inlet, or their habitat utilization. Terrapins are an important species of the marsh and information is needed to allow monitoring of North Inlet as an estuarine reserve and to learn more about terrapins so protective measures can be taken in other unregulated areas. Project started in June 2006. Baseline population data may be collected by 2009, including diet and habitat use but monitoring should continue further into the future.

This project is supported by Francis Marion University Professional Development grant to Peter King and Francis Marion University, Biology Department, Women and Minorities in Science grant to Paige Weaver.

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

Investigators: Dr. James Morris and Karen Sundberg
Belle W. Baruch Institute for Marine and Coastal Sciences, 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. Map locations 9, 22. This time series was initiated in 1986.

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

Investigators: Virginia Ogburn-Matthews[1] and Dr. L. Robert Gardner[2]
Baruch Marine Field Laboratory, USC[1]; Department of Geological Sciences, USC[2]
Partners: Tom Mero, NOAA/NOS/OPSD, and Lewis Lapine
SC Geodetic Survey

Begin and End Date of database: May 2001 to present (ongoing)

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 (one 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 Ocean Service) 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).

Verified historical data for North Inlet's tide gauge Station ID (8662245) are available at http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Historic+Tide+Data

Baruch's web link indicates the availability of the data: http://links.baruch.sc.edu/Data/NIWaterLevel/data/DataAvailabilityTable.Jun2001-Jan07.pdf

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

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

Investigators: Dr. Erik Smith and Amy Willman
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. Data are telemetered via the NOAA GOES satellite system to the NERR Central Data Management Office, and made available in near real time at http://cdmo.baruch.sc.edu. For most parameters, records have been collected for more than 13 years. Long-term, continuous weather records provide data for determining the effects of climatology on the various biological and physical processes being studied in the North Inlet estuary. Map location 3

National Atmospheric Deposition Program (NADP)

Investigators: Dr. Erik Smith and Amy Willman
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. This monitoring program increases representation of coastal areas in our nation's deposition monitoring network and also provides 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/. 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 the water in four tidal creeks of the North Inlet-Winyah Bay 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/. Map locations 6A, 6B, 2C, 3

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

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

As part of the NERRS System-Wide Monitoring Program, 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 the North Inlet – Winyah Bay NERR. Water samples are collected every 20 days 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 detection of long-term change in key water quality parameters. These data also provide critical information 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. Map locations 6A, 6B, 2C, 3. Water chemistry data collected in North Inlet prior to the initiation of the NERRS SWMP sampling (some dating back to 1978) are available via the BMFL Data Archives web site: http://links.baruch.sc.edu/Data/index.html.

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 is conducting 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 is employed. Two segments have been established along the central axis of upper Crabhaul Creek (map location 14). Within each segment, 3 fixed transects were randomly established from creek bank to the western, upland edge of the marsh platform. Each segment delineates a total 20 permanent sampling

plots. Groundwater wells are installed adjacent to each permanent plot. Sampling includes: 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. Map location 10

Plankton community respiration in the North Inlet Estuary

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

Respiration is the fundamental counterpart to primary production (photosynthesis) and represents the largest sink for organic carbon in the biosphere. Although it is at the center of ecosystem functioning, respiration represents a major area of ignorance in our understanding of the marine carbon cycle. Since respiration is the process by which energy is acquired at the cellular scale, and all organisms (save a few obligate fermenters) respire, measures of respiration have the potential to be used as an integrative indicator of energy flow, and thus ecological functioning, at the ecosystem scale.

With support from the NI-WB NERR, this study, initiated in July 2005, seeks to quantify and understand the short-term variability and potential for long-term change in water column respiration rates through a combination of routine field measurements and manipulative experiments. Our focus is on the tidal creeks and open-water portions of the estuary as these represent the conduit for material exchanges between the land-margin and coastal ocean. Routine sampling is conducted on both ebbing and flooding tides at the Oyster Landing site (Map location 3) in conjunction with the NERR 20-day water quality and water chemistry monitoring program. Respiration rates are derived from the consumption of dissolved oxygen during short-term (3-5 h) incubations of creek water contained in replicate 300 mL borosilicate glass BOD bottles, which are maintained at in situ temperatures with a flow-through seawater incubator. Oxygen concentrations are measured by automated Winkler titration employing potentiometric end-point detection. Our goal is to determine the factors that control the magnitude and variability of plankton community respiration rates in this ecosystem, and thus improve our understanding of how carbon flow through the ecosystem may respond to long-term changes associated with coastal land-use and climate alterations.

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. Lovell[1] and Madilyn Fletcher[2], and students
Department of Biological Sciences, USC[1], School of the Environment, USC[2]

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 O_2 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 N_2 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 N_2 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). Map locations 8 and 10.

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Phytoplankton monitoring at the NERRS Sites (North Inlet-Winyah Bay)

Investigators: Dr. Susan B. Wilde[1,2], Raphael G. Tymowski[1], and Dr. Erik Smith[1]
Baruch Marine Field Laboratory, USC[1], Marine Resources Research Institute, SCDNR[2]

We will coordinate our sampling dates within North Inlet/Winyah Bay with the on-going long-term monitoring at the NERRS sites. We collect phytoplankton samples and screen for species composition and utilize HPLC to determine biomass within algal classes. Any algal blooms will be quantified and potentially toxic blooms will be analyzed for toxin production. This additional monitoring will add to the extensive existing data on the North Inlet-Winyah Bay system.

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

Investigators: Dr. Robert Feller
Marine Science Program, USC

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. 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. This unique long-term time series also provides an opportunity to interpret impacts of global climate change on nekton habitat and populations. Results have implications for the management of marsh creeks and watersheds proximal to nursery habitat. 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. Allen[1], Dr. Steve Stancyk[2], Paul Kenny[1], Tracy Buck[1], Ginger Ogburn-Matthews[1], and Dr. Erik Smith[1]
Baruch Marine Field Laboratory and NI-WB NERR, USC[1]; Department of Biological Sciences and Marine Science Program, USC[2]

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 tows capture larval fishes, shrimps, and crabs and other large zooplankton species. Seasonal and interannual changes in abundance, diversity, and species composition of the assemblages are documented and correlated to fluctuations in the physical characteristics of the estuary. Information is collected for more than 50 taxonomic groups and species. 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, and provide an opportunity to assess impacts of climate change. Recent analyses of the large zooplankton component have shown a long-term decrease in total abundance and several individual constituent groups. Taxa varied in their relationships with temperature and salinity, but chaetognaths, which dominate summer catches and originate from the coastal ocean, have decreased coincidentally with the significant decrease in salinity and increase in temperature over the period. Mysids and postlarval spot which dominated winter-spring collections, responded positively to reductions in salinity. The timing of larval production of local grass shrimp, crab, and goby populations has shifted over the decades, perhaps in response to significant increases in winter water temperatures. Since many of the zooplankton species are developmental stages of larger animals, the study provides indications of the reproductive and recruitment success of several commercially and/or recreationally important species. Map location 10A.

Geographic variations in speckled worm eel larvae: Can long-term studies be used to determine large-scale changes in recruitment patterns of oceanic larvae to estuaries?

Investigators: Drs. Ken Able[1], Dennis M. Allen[2], Donald Hoss[3], Stanley Warlen[3], Gretchen Bath-Martin[3], and Perce Powles[4]
Rutgers University Marine Field Station[1], Baruch Marine Field Laboratory USC[2], NOAA National Ocean Service, Beaufort Laboratory[3], Biology Department, Trent University, Canada [4]

The speckled worm eel, *Myrophis punctatus*, is a common and widely distributed fish in Atlantic and Gulf estuaries, but, because of its cryptic habit of remaining buried in shallow muddy substrates, little is known about its life history and ecology. It appears to be an estuarine resident that migrates to unknown ocean areas to spawn. Large and morphologically unique leptocephalus larvae arrive in estuaries during the coldest months. The 25 year large mesozooplankton time series in North Inlet, SC, has revealed large within and among year variations in the occurrence of these planktonic leptocephali. Comparisons of temporal patterns of abundance and the stage and age of larvae at the time of ingress are being made among North Inlet, SC, Beaufort, NC, and Little Egg Inlet, NJ. Protocols for making morphometrical measurements, determining stages of development, and aging based on sagittal otoliths have been established. This information will provide insights into the time and perhaps locations of larval production. We plan to relate variations in environmental conditions in the estuaries and ocean to the characteristics of the recruiting larvae. Being dependent on both ocean currents and estuarine habitats to complete its life cycle, the speckled worm eel may be a good candidate species for understanding potential impacts of climate change.

Long-term monitoring of grass shrimp as a bioindicator of non-point source runoff in South Carolina watersheds

Investigators: Dr. Pete Key, Dr. Michael Fulton, and Blaine West
NOAA, Center for Coastal Environmental Health and Biomolecular Research

Long-term ecological monitoring is important to developing fundamental understandings of both biogenic and anthropogenic effects on ecosystem health. Long-term monitoring may provide great insight into natural factors

such as disease, pests and weather (e.g., global climate change, drought, floods and increased intensity of tropical storms and hurricanes), which may affect populations throughout a geographical region. In addition to population perturbations caused by natural stressors, is the complexity of differentiating "anthropogenic effects" of chemical and biological contaminants in aquatic ecosystems from "natural background effects". There is a clear need to develop accurate "Ecological Forecasts" using long-term ecological data sets. Long-term ecological monitoring data thus can be used not only to ascertain effects of natural and anthropogenic stressors, but also when properly used in conjunction with GIS and advanced modeling techniques may enhance predictive capabilities. The grass shrimp, *Palaemonetes pugio*, is the dominant macrobenthic invertebrate in tidal creek systems of the southeastern United States and is an important prey item for higher trophic levels. The North Inlet Oyster Landing site is maintained as a long-term reference site for comparison to estuarine sites with other land uses. Grass shrimp populations are sampled monthly using a push-netting approach (Leight, A.K., G.I. Scott, M.H. Fulton, J.W. Daugomah. 2005. Long term monitoring of grass shrimp, *Palaemonetes* sp., metrics at sites with agricultural runoff influences. *Integrative and Comparative Biology* 45:143-150). This project is continuing. 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, begun 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 Brabson[1] and Robin Baughn[1] (Debidue Beach Coordinators), Wendy Allen[2], and other volunteers
DeBordieu Colony[1]; North Inlet-Winyah Bay NERR, Baruch Marine Field Laboratory, USC[2]

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 SC Department of Natural Resources that oversees the volunteer sea turtle program for the state. 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.

SCECAP-related efforts, oyster recruitment and continued long-term disease monitoring within the NI-WB NERR

Investigators: Dr. Loren D. Coen and Donnia Richardson
SC Department of Natural Resources, Marine Resources Division, MRRI

The South Carolina Estuarine and Coastal Assessment Program (SCECAP) was initiated in 1999 by the SC Department of Natural Resources (SCDNR) and the SC Department of Health and Environmental Control (SCDHEC) with the goal of monitoring the condition of the state's estuarine habitats. Each year SCECAP measures water and sediment quality, and biological conditions at multiple random sites throughout the state's coastal zone. These measurements are combined into an overall evaluation of estuarine habitat conditions at each site and throughout the entire SC coast. See the program's website (www.dnr.sc.gov/marine/scecap) for project findings and related reports.

During 2005-2006, a sub-set of the SCECAP sites that had oysters and six SCDNR long-term monitoring sites were assessed for oyster condition. Several of these fall within the NERR. We have been monitoring MSX and Dermo, two oyster diseases at six long-term stations since 1996, one of which is at Oyster Landing adjacent to the SWMP sampling array. This monitoring effort is a continuation of work initiated with Dr. David Bushek now at Rutgers University. In 2005 and 2006, oysters were sampled annually in the summer from reefs near the weather

station dock. Samples are processed for Dermo using RFTM methods and standard histopathology for MSX disease diagnosis as a continuation of the long-term monitoring of oyster diseases across SC (see our website for Bobo et al. 1997).

Along with disease sampling, we are assessing in collected oyster tissues several cellular responses (Lysosomal destabilization, Lipid peroxidation and Glutathione concentrations), and bacterial and viral levels. Assays for these parameters were conducted by NOAA staff at the Center for Coastal Environmental Health and Biomolecular Research (CEHBR).

Additionally, replicate shell trays were deployed in the spring 2006 and are being collected in April 2007 to determine annual spat recruitment/growth/ survival for comparison with the numerous other collectors across the state.

General Results:

For oyster populations and recruitment, maximum oyster densities across all SC sites ranged from 750-5,320 oysters m^{-2}, which was greater than the ten-year statewide mean of 2,350 m^{-2}. Recruitment in trays ranged from 890 to >23,500 oysters m^{-2}, with a mean of 7,276, which was greater compared to a statewide mean of 6,885.

For oyster diseases, for 2005 sampling, Dermo prevalence levels generally were >80% and intensity levels <3.0 (scale of 0-6). Only one site had a mean intensity above 3.0. Dermo infection levels at Oyster Landing were 1.48 and 80%. MSX was detected at only two of 21 SCECAP sites with no MSX infections observed at the Oyster Landing station. In 2006, Dermo prevalence levels at 26 SCEAP and six long-term disease (LTD) sites were also generally >80%, although no sites had mean intensity levels above 3.0. Levels at Oyster Landing increased slightly in 2006, where mean intensity was 1.88 (and 96%). MSX was detected at eight sites, although no infections were observed at Oyster Landing.

Most 2005 sites sampled had oysters with normal cellular responses, with only one site scoring poorly on bioassays for all three responses and an additional five sites scored poorly on two of the three bioassays. For two of the three assays (lysosomal destabilization and lipid peroxidation), Oyster Landing had levels indicative of stress responses. In 2006, most sites sampled had oysters with normal cellular responses. Four sites had elevated levels in two of the three bioassays. None of the oysters sampled from Oyster Landing in 2006 had high stress response levels for either assay.

In 2005 and 2006 (both summer and winter sampling), fecal Coliforms, Enterococcus, Coliphages (indicative of human or other animal sources), and noroviruses (an enteric pathogen), as well as *Vibrios* (*V. parahaemolyticus* and *V. vulnificus*) loads were measured in composite oyster tissue samples collected at the SCECAP and long-term sites. Oyster tissue contaminants and metals were also evaluated at a number of these sites. This work included metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. Specific results can be received from NOAA on these results (Dr. Jan Gooch and Mike Fulton, NOAA).

This work, which is supported by funding to SCDNR, the NMFS Coastal Environmental Health and Biomolecular Research (CEHBR) Lab and NOAA's HML. The oyster work will not be continued in 2007.

Research funding from the SC Saltwater Recreational Fisheries License Program, EPA and NOAA-NMFS.

Bobo, M.Y., D.L. Richardson, L.D. Coen, and V.G. Burrell, 1997. A report on the protozoan pathogens *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni (*MSX) in South Carolina Shellfish populations, with an overview of these shellfish pathogens. SCDNR-MRD-MRRI Technical Report, 50 pp.

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 schools in Georgetown, Horry, and other counties, and informs 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 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 staff and receive introductory classroom visits 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

Investigators: 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 Hobcaw Seminar series provides an informal means for people of all ages to learn about current and ongoing research programs conducted on Hobcaw Barony. Other regular offerings include programs on estuarine and beach ecology, open houses, "Bike to the Boardwalk", and the monthly 'Fishes of North Inlet Estuary' program in which 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.

Community Enhancement Activities – National Estuarine Research Reserve and the Baruch Marine Field Laboratory, USC

Investigators Beth Thomas[1] and Dr. Dennis Allen[2]
North Inlet-Winyah Bay NERR[1] Baruch Marine Field Laboratory, USC[2]

The Reserve currently participates in several community enhancement and stewardship activities in partnership with Keep Georgetown Beautiful (KGB), the local chapter of Keep America Beautiful. Reserve and BMFL staff assist in river and marsh cleanups, lead recycling programs for elementary students and afterschool programs, and assist with a county-wide monofilament recycling program. Beth is the designated Reserve staff member serving on the Board of Directors of KGB and she participates in school, beautification, and recycling subcommittees within the organization. Dennis serves as Chairman of the Planning Subcommittee and environmental liaison with the Morgan Park Task Force, which is spearheading the revitalization of a community park located on the Winyah Bay and Sampit River.

Georgetown Chamber of Commerce High Performance School-Business Partnership

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

The High Performance School-Business Partnership (HPSBP) 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 collaborating to provide educational opportunities and resources to our selected partner school, Pleasant Hill Elementary in Georgetown, SC. The HPSBP was established via the South Carolina Chamber of Commerce as part of a federal GEAR UP (Gaining Early Awareness and Readiness for Undergraduate Programs) grant that also includes state funding and business contributions. At the end of the SC Chamber's seven year funding period, the Georgetown Chamber recognized the benefit of the school-business partnership and took on the role as oversight agency for the local program. The Chamber 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, as well as provide teachers and students with additional educational resources.

Coastal Training Program for local decision-makers

Investigator: Nicole Saladin and 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 Department of Health and Environmental Control - Office of Ocean and Coastal Resource Management, South Carolina Sea Grant Consortium, and the NOAA Coastal Services Center.

The National Estuarine Research Reserve System Centralized Data Management Office

Investigators: Dr. Dwayne E. Porter[1,2], Tammy Small[1], Melissa Ide[1], Jesse Friedmann[1], Kirk Yedinak[1], and Jay Poucher[1]
Belle W. Baruch Institute for Marine and Coastal Sciences and the Baruch Marine Field Lab, USC[1], Arnold School of Public Health, USC[2]

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.

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.

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.

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.

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 2007 at the North Inlet-Winyah Bay NERR.

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 late winter 2008.

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 09/01/06 to 02/28/08 by NERRS/NOAA/Dept. of Commerce. The CDMO website is cdmo.baruch.sc.edu

Research Locations in North Inlet

Author Index