# CURRENT RESEARCH PROJECTS

# 2003

## Baruch Marine Field Laboratory (BMFL)

## North Inlet – Winyah Bay
## National Estuarine Research Reserve
## (NERR)

## University of South Carolina

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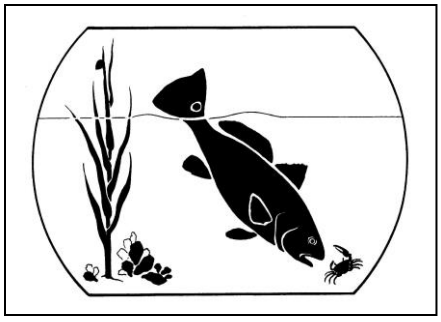

**North Inlet – Winyah Bay**
**National Estuarine Research Reserve**

# Current Research Projects 2003

## Introduction

More than 550 scientific research projects and about 310 student theses and dissertations have been completed by Baruch Institute research associates since 1969. This work has resulted in the publication of more than 1359 scientific articles, reports, and books, which 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 75 of the projects currently being conducted at the Baruch Marine Field Laboratory 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 36 faculty, 19 technician and 20 student investigators. In addition, 34 faculty, 16 technicians, 5 students and 10 volunteers representing 27 other institutions participate as investigators. 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. The list includes only those projects that make regular use of the site. Most of the studies which involve field measurements and collections are being conducted within the North Inlet-Winyah Bay National Estuarine Research Reserve (see map).

The Projects are randomly grouped and each Research Summary includes title, investigator(s), affiliation, and project abstract. Projects which focus on long-term monitoring and research are located in the back section of the document

Funds for these research projects are provided by a variety of sources, including the National Science Foundation, Environmental Protection Agency, National Oceanic and Atmospheric Administration (National Estuarine Research Reserve System, and SC Sea Grant Consortium), U.S. Dept. of Energy, the Office of Naval Research, National Aeronautics and Space Administration, and the SC Dept. of Health and Environmental Control. The Friends of the Institute, an independent organization which 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, Dr. Dennis Allen, or Paul Kenny at 843-546-3623. Information may also be obtained from the Institute's web site http://www.baruch.sc.edu, which contains links to many related sites.

# Research Summary Author and Title List

Characterization of intertidal zone creek networks

Investigators: Karyn I. Novakowski and Dr. Raymond Torres
Department of Geological Sciences, University of South Carolina

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, $L \propto A^n$, where $L$ is total stream length, $A$ 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 the NERR-GRF program for the period June 2001-May 2003.

Groundwater dynamics at the forest-marsh boundary

Investigators: Dr. L. Robert Gardner
Department of Geological Science, USC

The effects of fresh groundwater flow from upland forests on adjacent salt marshes, such as at North Inlet, are not yet well understood. We have installed bundles of piezometers at numerous stations along three forest-marsh transects across the Crabhaul Creek basin at the North Inlet National Estuarine Research Reserve site (map location #12) in order to study the dynamics of groundwater flow and the effects of sea level rise on the salinization of this shallow water table aquifer. Between 1993 and 1996 bimonthly measurements of salinity were made in this network of 309 piezometers. Most of the

piezometers were also instrumented with pressure transducers and data loggers for periods ranging from one month to about one year, yielding a spatially and temporally dense data set of 15 minute interval time series of water elevations (heads). These data reveal that fresh groundwater seeps upward in the high marsh on the western side of the basin adjacent to the extensive mainland forest. This prevents salinization of the marsh soil water and colonization of the marsh by salt tolerant plants such as *Salicornia* and cedars. Conversely, along the eastern margin of the basin where only a narrow strip of forest is present, groundwater seepage has a strong downward component of flow which allows the infiltration and subsequent evapoconcentration of saline tidal water. As a result, a zone of hypersaline soil has formed and colonization by *Salicornia* has been successful. Efforts currently are directed towards developing a numerical flow model using the USGS code SUTRA to simulate the observed dynamics and salinity distribution across the system. We are also using the head time series along with measured soil parameters (hydraulic conductivity, porosity and specific yield) and meteorological data to develop water budgets for stations along the transects. The water budget components being estimated include losses due to evapotranspiration and seepage and gains due to recharge by tides and rain as well as seepage. These fluxes in turn control soil water salinity and thus botanical zonation and their estimation is therefore critical to understanding controls on the forest-marsh ecotone.

Papers related to this work are listed below:

Gardner, L.R., and D.E. Porter, Stratigraphy and geologic history of a southeastern salt marsh basin, North Inlet, South Carolina, USA, Wetlands Ecology and Management, V. 9, 371-385, 2001.

Gardner, L.R., H.W. Reeves, P.M. Thibodeau, Groundwater dynamics along forest-marsh transects in a southeastern salt marsh, USA: Description, interpretation and challenges for numerical modeling, Wetlands Ecology and Management, V.10, 145-159, 2002.

Goni, M.A., C.C. Jones, L.R. Gardner, E. Tappa and W. Johnson, Dissolved organic carbon dynamics in a shallow coastal aquifer: A study of a subterranean estuary, Limnology and Oceanography, submitted.

Gardner, L.R. and H.W. Reeves, Seasonal patterns in the soil water balance of a *Spartina* marsh site at North Inlet, South Carolina, USA, Wetlands, V. 22, 467-477, 2002.

Gardner, L.R. and H.W. Reeves, Spatial patterns in soil water fluxes along a forest-marsh transect in the southeastern United States, Aquatic Sciences, V. 64, 141-155, 2002.

The data generated by this project can now be obtained from the following web site:
http://links.baruch.sc.edu/data/GardnerGrnWater/CrabHaulgrndWater.htm

<u>Intertidal marsh hydrology and geomorphology</u>

Investigators: Dr. George Voulgaris[1] and Raymond Torres[2]
Department of Geological Sciences and Marine Science Program, USC[1] ,
Department of Geological Sciences, USC[2]

This project is designed to understand the development of tidal creek networks and to examine the applicability of terrestrial river network theories to intertidal environments. This will be accomplished by the development of a high resolution, high-density digital elevation model of an intertidal creek network using DGPS and bathymetric surveying. Measurements of flow and turbulence at various locations and for various tidal creek sizes will be examined. A 2-D numerical model will result.
This project is significant in providing the theoretical background for wetland restoration and is supported by the National Science Foundation from March 2003 until February 2004. See map location #16

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. We are testing this hypothesis in Atlantic coast salt marshes. We are counting herbivores and measuring herbivore damage to plants in ten sites in the South Atlantic Bight and ten sites in New England. We will transplant standard marsh plants into a subset of these sites to determine if standard salt marsh plants receive more herbivore damage in the south. This project will test a long-standing biogeographic theory that has received little experimental attention. This project is funded by NSF through October 2004

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

Investigators: Drs. Robert Costanza[1], Roelof Boumans[1], Christopher Swarth[2], David M. Burdick[3], and Donald Cahoon[4]
Institute for Ecological Economics, University of Maryland[1], Jug Bay Wetlands Sanctuary[2], Jackson Estuarine Laboratory, University of New Hampshire[3], Wetlands National Research Center, Lafayette, LA[4]

We are developing a data depository on sediment elevation changes in estuarine habitats in cooperation with NERRS research coordinators and participating scientists across the country. The database built during this project will serve national estuarine research goals of establishing baseline data of sediment elevation changes from a variety of estuaries, a standardized protocol for use and analysis of data collected by means of the SET (Sediment Erosion Table), and criteria that will be used to assess success in created and restored critical habitats. The database will contain data from SET stations and marker horizons along with bibliographic references. We will use the database also to establish restoration assessment guidelines (success criteria) with respect to measures of elevation change in critical estuarine habitats. Our project creates an enormous potential for regional and nation-wide comparisons and predictions of estuarine habitat

sustainability. The database and protocol will establish NERRS as a leader in providing restoration assessment guidelines with respect to habitat elevation measures, criteria, analysis and interpretation. The NERRS sites involved in the project are: Jug Bay, MD, Great Bay Estuary, NH; Webhanet River Estuary, Wells, ME; Waquoit Bay, MA; Prudence Island, RI; Tijuana River, CA; Rookery Bay, FL and North Inlet-Winyah Bay, SC. The project is funded by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET)

Sediment accretion in North Inlet salt marshes

Investigator: Dr. James Morris
Department of Biological Sciences and Marine Science Program, USC

The objective of this study is to understand (1) the factors that cause the volume of sediment to change and (2) how changes in the volume of sediment relate to sedimentation. 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. See map location #2A,B,C.

Dynamics of DMSP in a salt marsh tidal creek

Investigators: Dr. Duane C. Yoch and Nitin R. Kulkarni.
Dept. of Biological Sciences, USC

We are studying the factors in the salt marsh that affect the level of dimethylsulfide (DMS) emitted into the atmosphere. DMS emission is a key step in the global sulfur cycle. This organosulfur compound is released by bacterial decomposition of dimethylsulfoniopropionate (DMSP), a tertiary sulfonium compound which is produced in high concentrations by certain species of marine algae and plant halophytes for regulation of their internal osmotic environment. It is released into seawater as dissolved DMSP by grazing activity of zooplankton or by senescence of algae. We are studying the $DMSP_p$ (particulate) levels and Chl a levels as an indicator of phytoplankton biomass in the tidal creek and oceanic waters. $DMSP_p$ concentrations may be influenced by various factors like salinity, light, tidal phase, time of the day, phytoplankton community, nutrient concentration in the waters, and zooplankton grazing. We have observed consistent correlation between the $DMSP_p$ : Chl a ratios, which is an indicator of phytoplankton DMSP levels, and the tidal stage which is not observed in the oceanic (near shore) waters. At this point, we are evaluating the factors that are responsible for

the changing $DMSP_p$ : Chl a ratios. We are studying the changes in the phytoplankton community at different tidal stages that may be the key factor in these variations. We are also looking at how different salinity levels affect the levels of $DMSP_p$ in a given estaurine system.

Resuspension of benthic flora and their contribution to this change is also being examined. Along with this specific problem, we are also monitoring the annual changes in $DMSP_p$, Chl a, total bacterial counts by AODC, total viable counts, and counts of microbes producing DMS. We are also preserving samples to estimate qualitative changes in phytoplankton populations by monitoring changes in the pigment profile every month.

In the future we also plan to study if there is any sparing effect of nutrients like N, P, N+P and Fe on the DMSP production of the marine cordgrass *Spartina alterniflora*. Our study sites include Clambank, Oyster landing, Thousand acres rice field, Pawleys island, Goat island and Black and Pee Dee River at the marina in Georgetown.

A high accuracy micro-topographic determination of marsh topography

Investigators: Juana M. Montané and Dr. Raymond Torres
Department of Geological Sciences, USC

Salt marshes are dynamic environments being modified by every ebb and flood of the tides. Do these 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 a relatively new Real-Time Kinematic (RTK) Global Positioning System (GPS) technology coordinated within a calibrated network of published geodetic benchmarks to ensure accuracy of data and control. This method of topographic/hydrographic surveying yields ~ 2cm accuracy and effectively deduces the subtle morphology of the marsh surface that conventional mapping methods have thus far described as flat.

Preliminary interactive computer visualization and profiling of the micro-topography derived by RTK GPS has shown subtle troughs and ridges within the marsh surface 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 and processes are vital to estuarine ecology. A better delineation of the topographic forcing or control may help in the overall understanding of marsh surface development and that of the creeks and channels, which dissect it. Understanding the stability and development of salt marshes is scientifically valuable for many efforts including biological, environmental, habitat and ecological as well as economical objectives.

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

Spatial-temporal characterization of microbial growth processes at North Inlet, SC based upon time-series dataflow measurements

Investigators: Drs. Eric Koepfler[1], Alan Lewitus[2], Chris Madden[3], Olcay Akman[4], and Raph Tymowski[5] and Dr. Chris Buzzelli[5]
Marine Science Department, Coastal Carolina University[1], Baruch Marine Laboratory, USC and SCDNR[2], South Florida Water Management District[3], Math and Statistics, Coastal Carolina University[4], Baruch Marine Laboratory, USC[5]

High resolution spatial sampling of in-situ; chlorophyll, DOM, DO, pH, salinity, and temperature are being collected over the seasonal phytoplankton bloom period from Spring to Summer of 2003 in the tidal creeks of North Inlet. Collection of this information is from an equipment package called DATAFLOW, which samples every 2 seconds from a moving vessel. Each sampling date results in GIS data of high slack, mid-ebb, and low slack tidal characterizations. Sampling dates are every two weeks during the spring lunar tide stage. Spatial and temporal variability from these surveys are to be examined by statistical multivariate time-series analysis and mathematical modeling to determine the nature and mechanisms of physical and biological control over microbial productivity (phytoplankton, bacteria) in the estuary. Maximum short-term (tidal stage) temporal variability is expected to occur in the spring whereas maximum spatial variability is expected to occur in the summer. The strong temporal and spatial correlations between chlorophyll, DOM, and DO collected on two dates indicated a highly dynamic interaction between microbial trophic groups.

Temporal patterns of Dermo disease in North Inlet

Investigators: Drs. David Bushek[1] and Dwayne Porter[2]
Baruch Marine Field Laboratory[1], Belle W. Baruch Institute for Marine and Coastal Sciences, USC[2]

The protozoan parasite *Perkinsus marinus* causes Dermo disease in oysters. The disease is not harmful to humans, but can be deadly to oysters. Seasonal patterns of intensification and remission in North Inlet correspond to the well-known seasonal effects of temperature observed in other areas. In North Inlet and throughout the southeast, however, oysters do not appear to succumb to the disease as readily as they do in the larger bays of the mid-Atlantic or Gulf Coasts. This observation has lead to a series of directed investigations on resistance, transmission and thermal tolerances of the parasite relative to the oyster. Analysis of monthly data from 1995 through early 2002 has revealed a long-term trend of increasing infection intensity that correlates significantly with a long-term increase in salinity resulting from current drought conditions. The effect is not significant across shorter time intervals. This observation supports hypotheses from other directed research on transmission dynamics and the role of flushing.

Role of an exotic species as a novel prey item in an oyster reef ecosystem

Investigators: Mary Jo Hartman, Dr. Andrew Lohrer and Dr. Stephen Stancyk
Marine Science Program, USC

Invasive organisms can have significant effects on ecosystems due to competition for resources, disruption of habitats and changes to trophic systems. Many studies have examined the role of a new predator to a system, but less is known of the effect of a novel prey item. *Petrolisthes armatus*, the green porcelain crab, has recently invaded South Carolina and we are monitoring its distribution by monthly collections at three sites in North Inlet . Sampling of *P. armatus* is being conducted by placing trays filled with oyster shell at each of two zones (subtidal and intertidal). Trays are left in the field until the next sampling period when all *P. armatus* are collected as well as other components of the oyster reef community, which are being quantified to determine whether *P. armatus* densities affect biodiversity. *P. armatus* was abundant (50-200 crabs/$m^2$) during summer and early fall of 2000. Coincident with an unusually cold winter, *P. armatus* densities declined dramatically and it was not detected in monthly samples from January through July 2001. It has reappeared in low numbers in the fall and winter of 2001. This study continues to provide baseline information on the invasion, and is being used in the design of experiments to examine the influence of *P. armatus* on South Carolina oyster reefs. To quantify the response of native predators to a novel prey type, we are simulating pre- and post-invasion scenarios in laboratory mesocosms. Specifically, we use toadfish (*Opsanus tau*), blue crab (*Callinectes sapidus*) and pinfish (*Lagodon rhomboides*) as the native predators and the invasive crab (*P. armatus*), and the native xanthid crab (*Panopeus herbstii*), as prey items. We estimate the functional responses of each predator feeding on xanthid crabs in the presence and absence of *P. armatus* (and at varying densities). Because xanthid crabs are important predators of oyster spat, the invasions by *P. armatus* may have indirect (negative) consequences on the recruitment of oysters to reefs. This project started in May 2000 with a tentative end date of Spring 2003, and has been funded by NERR-GRF, USC Marine Science Program and the Baruch Marine Field Laboratory.

Status and distribution of hummingbirds in the coastal plain of SC

Investigator: Gary Phillips
Hummer/Bird Study Group, Clay, Alabama

Although commonly seen in area gardens and woodlots during the breeding season and apparently becoming more common winter residents, little is known of hummingbird specifics in North or South Carolina. Little is known about migration routes, population biology, and effects of habitat change of Ruby-throated hummingbirds. As neo-tropical migrants, their future is as uncertain as that of a number of other bird species so classified. This project will document the status and distribution of

hummingbirds in the coastal plain of South Carolina. Specific topics of investigation include migration route fidelity, breeding site fidelity, territory size for male Ruby – throated hummingbirds during breeding season, assessment of territory quality and requirements, and comparison of morphometric data collected from individuals at various study sites in the region. Goals are also to increase the number of banded birds in the Atlantic flyway to aid in the determination of migration pathways, stop over sites and winter destinations, to increase knowledge of post-breeding dispersal movements, and through subsequent recaptures gather data with regard to hummingbird longevity/survivorship. Long-term data collection will add to the existing body of hummingbird knowledge and be useful in assessing conservation needs. Data collected from hummingbirds at Hobcaw Barony will also be used as part of a larger scale study.

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

Investigators: Kurt Bretsch[1] and Dr. Dennis Allen[2]
Marine Science Program, USC[1], Baruch Marine Field Laboratory, USC[2]

Within salt marshes, nekton (motile fishes, shrimps, and crabs) are thought to play a vital role in the transfer of intertidal production to the estuary. Many investigators have shown that nekton make regular migrations into salt marsh intertidal creeks with the flood tide, yet little is known about the timing of their migrations, or about interactions while nekton occupy flooded creeks. During summers 2001-2002, a new sampling method, the sweep flume, was used to determine the timing (water depth) and sequence of migration of taxa into flooding intertidal creeks. The depth of peak movements into the creeks varied among species, and the sequence of occupation was similar among creeks, suggesting that partitioning use of the intertidal creek habitat is a broadly based phenomenon. During Summer 2003, biotic causal mechanisms of migration will be investigated by testing the hypothesis that depth preferences of individual nekton taxa (grass shrimp, spot, pinfish, mummichogs, mullet) change in the presence of other species. Additional experiments will be conducted in which the effect of predator presence on the depth distribution of grass shrimp will be investigated. All experiments will be conducted on the lab grounds in large tanks designed to represent conditions in flooding intertidal creeks. The results of this research will contribute to the scientific understanding required to measure, model, maintain, and/or restore the integrity and sustainability of salt marsh ecosystems. This project started in Spring 2001 and has a tentative end date of Fall 2003. Support is provided by the USC Marine Science Program, the NI-WB NERR, and the Baruch Marine Field Laboratory.

Regulation of macrobenthos by juvenile white shrimp, *Litopenaeus setiferus*, in southeastern U.S. salt marshes

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

Coastal development has led to physical and hydrological changes in salt marshes along the southeastern U.S. coast, with continuing growth threatening nursery habitat for juvenile marine species dependent upon benthic organisms as food. Previous work has suggested that the presence of juvenile predators within the salt marsh may regulate benthos abundance. In particular, numerous studies have documented white shrimp (*Litopenaeus setiferus*), carnivory in salt marshes. Within North Inlet-Winyah Bay (NI-WB), SC, the Baruch long-term database provides correlative evidence that macrobenthos numbers decline more than usual when white shrimp are very abundant; leading to the hypothesis that white shrimp predation is a density-dependent force regulating macrobenthos abundance.

This study proposes manipulative field experiments to measure the use of intertidal Spartina marsh and subtidal creeks as foraging grounds for juvenile white shrimp in two NERRS sites: principally NI-WB, SC (Crabhaul Creek, see map location #3), and secondarily Sapelo Island, GA. Laboratory studies will determine density-dependent white shrimp consumption rates of macrobenthos. Results from the field and this functional response study will be used to create a STELLA model of white shrimp effects on seasonal changes of macrobenthos abundance. Geographic Information Systems (GIS) modeling will be used to quantify the marsh area available for juvenile shrimp foraging. This study will provide information to coastal resource managers on white shrimp foraging in salt marshes, with implications for conservation of estuarine habitats and sustainability of commercial and recreational fisheries. This project is funded by a National Estuarine Research Reserve Graduate Research Fellowship through June 2006.

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

Investigators: Dr. Alan J. Lewitus[1,2], Jason Kempton[2], Dr. Amy Ringwood[2], Raphael Tymowski[1], and Megan Heidenreich[1]
Baruch Marine Laboratory, USC[1], and MRRI, SCDNR[2]

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

enhance bloom species identification and detection, and determining the physiological stress responses of oysters to the SC blooms.

This project is supported by ECOHAB (NOAA, NSF, EPA,NASA, ONR). PI with J.W. Kempton. 2 September 2002 to 31 August 2005.

Pigment responses of phytoplankton to UV-induced fluoranthene toxicity: A USES project substudy

Investigators: Dr. Alan Lewitus[1,2], Jennifer Wolny[3], Andrew Shuler[1], and Megan Heidenreich[1]
Baruch Marine Laboratory, USC[1], MRRI- SCDNR[2], and Florida Marine Research Institute[3]

Results from the USES program have yielded recognition of several byproducts of urbanization that affect ecosystem functioning in Murrells Inlet estuary. Of these, demonstrable effects of PAH loading on fauna have been documented in several USES publications. To further explore the potential effects of PAHs on ecosystem degradation, we are examining the physiological response of phytoplankton to UV-activated fluoranthene toxicity, a topic rarely studied. We hypothesize that the relatively low photosynthetic efficiency of phytoplankton communities in Murrells Inlet (Kleppel and Lewitus in prep) is related, in part, to compensatory responses to physiological stress caused by fluoranthene toxicity. Specifically, Murrells Inlet phytoplankton may require a greater expenditure of metabolic energy and material on the synthesis of protective carotenoids (e.g. ß-carotene) at the expense of biosynthesis of photosynthetic machinery (e.g. light-harvesting pigments). The study combines monitoring of North Inlet and Murrells Inlet microbial food web structure and PAHs, bioassays testing the effects of UV-induced fluoranthene inhibition on natural communities, and physiological response experiments using axenic cultures of estuarine phytoplankton isolates. Results from this study will improve our understanding of the potential adverse effect of PAH loading on phytoplankton community composition, production, and photosynthetic efficiency and capacity. This study is funded from 1999-present.

The nutritional physiology of the toxic dinoflagellate, *Pfiesteria piscicida*

Investigators: Dr. Alan Lewitus[1,2], Kenneth Hayes[1,3]
Baruch Marine Laboratory, USC[1], MRRI, SCDNR[2], and SCDHEC[3]

The nutritional versatility of dinoflagellates is a complicating factor in identifying potential links between nutrient enrichment and the proliferation of harmful algal blooms. For example, although dinoflagellates associated with harmful algal blooms (e.g. red tides) generally are considered to be phototrophic and use inorganic nutrients such as nitrate or phosphate, many of these species also have pronounced heterotrophic capabilities either as osmotrophs or phagotrophs. Recently, the widespread occurrence of the heterotrophic toxic dinoflagellate, *Pfiesteria piscicida* has been documented in turbid

nutrient-rich estuarine waters, and thought to be the causative factor in several NC fish kills and a Chesapeake Bay fish kill in the summer of 1997. *P. piscicida* has a relatively proficient grazing ability, but also has an ability to function as a phototroph by acquiring chloroplasts from algal prey, a process termed kleptoplastidy. The potential impact of P. piscicida on fish communities may be related to the abundance of nontoxic zoospores that serve as seed populations that fuel toxic outbreaks. Laboratory and field evidence suggests that nontoxic zoospore abundance can be stimulated by nutrient enrichment, either indirectly (by enhancing phytoplankton prey abundance) or directly (through saprotrophic nutrient uptake). We are testing a working hypothesis that depicts a seasonal transition in the mechanism of nutrient stimulation of the growth of nontoxic *P. piscicida* zoospores that serve as precursors of summer toxic populations. This research has implications toward the potential link between nutrient loading and *P. piscicida*-related toxic outbreaks. This study is funded for the period 1 Sept. 1998 to 31 August 2003 and supported by ECOHAB (NOAA, NSF, EPA,NASA, ONR).

The distribution and physiological ecology of *Pfiesteria piscicida* and other harmful algal blooms (e.g. red tides) in South Carolina: an ECOHAB study

Investigators: Dr. Alan Lewitus[1,2], Kenneth Hayes[1,3], Raphael Tymowski[1], Dr. JoAnn Burkholder[4], Dr. Howard Glasgow[4], and Dr. Patricia Glibert[5]
Baruch Marine Laboratory, USC[1], MRRI, SCDNR[2], SCDHEC[3], North Carolina State University[4], and Horn Point Laboratory, University of Maryland[5].

ECOHAB: This is a regional comparison (Delaware, Maryland, North Carolina, South Carolina) of the physical, nutritional, and trophodynamic mechanisms that contribute to blooms of *Pfiesteria* and other dinoflagellates that cause harmful blooms. We hypothesize that certain attributes of *Pfiesteria* and related dinoflagellates contribute to their ability to form and maintain blooms under certain conditions. These attributes include the ability to use diverse nutrient and energy sources for growth and survival. For instance, many of these dinoflagellates are capable of alternating between phototrophic (plant-like) and heterotrophic (animal-like) nutrition, which allows them great flexibility in adapting to changing or extreme environments. One of the key issues addressed in the ECOHAB study is whether nutrient loading is linked to *Pfiesteria* toxic outbreaks, and, if so, what types of nutrients are stimulatory to *Pfiesteria* activity, and in what ways. Through a combination of field efforts relating the distributional relationships between *Pfiesteria* and nutrient regimes, and laboratory experiments on the physiological response of *Pfiesteria* to nutrient enrichment, the ECOHAB study seeks to determine whether or to what extent and how, nutrients produced by man's activities are contributing to the proliferation of *Pfiesteria* and other harmful dinoflagellate blooms. This project is supported by ECOHAB (NOAA, NSF, EPA,NASA, ONR). 1 Sept. 1998 to 31 August 2003

A harmful algal bloom initiative for South Carolina: Assessing the potential environmental impacts of red tides, *Pfiesteria*, and toxic algae/ South Carolina Task Group on Harmful Algae

Investigators: Dr. Alan Lewitus[1,2], Krista DeMattio[2], Sarah Habrun[1], Kenneth Hayes[1,3], Megan Heidenreich[1], Sabrina Hymel[1], Chad Johnson[2], Jason Kempton[2], Jiqing Liu[1], Lara Mason[2], Andrew Shuler[1], Raphael Tymowski[1], Susan Wilde[1], and collaborators from NOS-Charleston, SC Sea Grant, SCDHEC, SCDNR, Clemson, MUSC, USGS, Baruch Marine Laboratory, USC[1], MRRI, SCDNR[2], and SCDHEC[3]

The SC Task Group on Toxic Algae was formed in late 1997, with the goal to develop a coordinated state strategy to cope with the possible consequences of a *Pfiesteria* toxic outbreak. The Task Group has since expanded to include assessments of harmful algal blooms in general. One of the first accomplishments of the group was to implement a program to respond to fish kills or lesion events in SC estuaries, and determine the potential association with harmful algal blooms. Efforts of the Task Group led to NOAA funding in support of the South Carolina Harmful Algal Bloom Program (SCHABP), the first statewide effort to assess the distribution and potential adverse effects of HABs in South Carolina estuaries. This study will 1) determine the present distribution of harmful algae in SC estuaries; 2) determine environmental factors that favor HAB formation in SC estuaries so future effects can be predicted; and 3) establish a statewide HAB surveillance system. The monitoring effort consists of an intensive statewide spatial monitoring (on a monthly to annual basis) to determine existing physical, chemical and biological parameters (including algal distribution) throughout the state. In addition, known "hot spots", which are areas with previous algal blooms and/or lesioned fish, are monitored on a more frequent basis (biweekly), in order to document the physical, chemical, and biological factors which exist previous to a bloom event, should one occur. In the event of a potentially harmful algal bloom, an event response method was formulated to standardize the measurement of environmental parameters that exist at the time of the bloom. Additional water samples are collected for the purposes of identification, isolation, and culturing of the bloom species. These cultured algal species will be used for bioassays to determine the role of nutrient quantity and quality in HAB stimulation. NOAA NOS. 1 Oct. 2002 to 30 Sept. 2003.

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

Investigators: Alan J. Lewitus[1,2], Raphael G. Tymowski[1], David White[1], and Sabrina Hymel[1]
Baruch Marine Laboratory, USC[1], and MRRI, SCDNR[2],

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.

Salt marsh mesocosm

Investigators: Drs. James Morris[1] and Bob Gardner[2]
Department of Biological Sciences[1] and Department of Geological Sciences[2], USC

A set of 8 replicate salt marsh mesocosms is being used to investigate the effects of hydrology and nutrient loading on the productivity and sediment biogeochemistry of salt marshes. Each marsh mesocosm (1 m x 10 m) is filled with inorganic sediment and planted with *Spartina alterniflora*. The sediment surface has a slope of approximately 20 cm/10 m. A computer-controlled pump will simulate the spring and neap diurnal tides. Flood water will be loaded with combinations of N and P fertilizer in a factorial design to determine how primary production and the accumulation of organic matter in sediments vary as a function of the N and P supply. The experiment will allow researchers to better understand the dynamics of organic matter production and accumulation in salt marshes. This study is funded through the National Science Foundation

Habitat utilization of North Inlet, SC, by bottlenose dolphins and red drum:
An examination of potential predator-prey interactions

Investigators: Dr. Rob Young[1], Elizabeth Moses[1], and Dr. Dennis Allen[2]
Marine Science Department, Coastal Carolina University[1]
Baruch marine Field Laboratory, USC[2]

We are concurrently studying the size and habitat utilization patterns of the dolphin population and their potential prey fish populations in North Inlet. We hypothesize that dolphins in winter and early spring will focus on creeks with overwintering red drum aggregations. Our goal is to estimate the proportion of the total fish in winter drum aggregations that are removed by dolphin predation. Since 1997, we have conducted an ongoing study of North Inlet dolphins using photo-identification and focal follows. Fish population estimates and movements will be determined by tag and

recapture trammel net surveys. A 400 foot trammel net is used to sample 12 sites per month from among 30 randomized sites throughout the North Inlet system. Dolphin dietary patterns are determined by matching the fatty acid signatures of potential dolphin prey species with the fatty acids signatures stored in dolphin blubber. Blubber biopsies are taken from resident dolphins using rifle-mounted biopsy darts. This study has a direct impact on the management of the red drum fishery, and is in cooperation with SCDNR and Dr. Charlie Wenner who oversees the red drum management research in South Carolina.

Source of support: Subcontract to the grant, "Contributions to the Biology of the red drum, *Sciaenops ocellatus*, in South Carolina," an Unaligned Management Project funded by the National Marine Fisheries Service (PI - Charlie Wenner, SCDNR). The study runs from October, 2001 – December, 2004

Chemically mediated interactions in a sedimentary assemblage

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

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

Population dynamics of rhizosphere nitrogen fixing bacterial assemblages

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

This project examines nitrogen fixing bacterial (NFB) assemblages associated with several species of salt marsh plants, focusing on the environmental stresses and plant host characteristics affecting them. Stress factor gradients and interspecies interactions in salt marshes result in a number of well-defined vegetation zones. The smooth cordgrass *Spartina alterniflora* occurs in a tall form at the banks of tidal creeks to less productive short form plants at higher elevations. The black needlerush *Juncus roemerianus* occurs at high marsh elevations near the fringes of the terrestrial biome and in isolated patches within the short *Spartina* zone. The perennial glasswort *Salicornia virginica* occurs in sporadic monotypic meadows in the high marsh and can also grow in association with

short *Spartina* and with *Juncus*. Differences in abundance and activity of rhizosphere NFB, which contribute nitrogen to these plants, may also be explained by the stress gradients that contribute to formation of the vegetation zones, as well as by the host plant responses to them. Field *Spartina* and *Juncus* plots will be experimentally manipulated and the resulting effects on NFB assemblages determined using DNA denaturing gradient gel electrophoresis and quantitative DNA-DNA hybridization methods. Studies to date have defined the NFB assemblages of tall and short *Spartina* and explored some of their responses to changing environmental parameters. Current studies are focused on the NFB assemblages of *Juncus* and *Salicornia* and employ a variety of manipulations in order to explicitly define the interaction of NFB with their plant host and with the environmental parameters that control the abundance, productivity, and distribution of both the plants and their microflora. Parallel sampling at the Plum Island Sound and Sapelo Island LTER sites allows the generality of results from North Inlet to be assessed for most of the Atlantic coast range of *Spartina alterniflora.* See map locations 18 and 2. This project is supported by the National Science Foundation (1994-2007, so far).

Some of the most recent publications associated with the work:

Population dynamics of rhizosphere nitrogen fixing bacterial assemblages
Beeson, K., D.L. Erdner, C.E. Bagwell, C.R. Lovell, and P.A. Sobecky. 2002.

Differentiation of plasmids in marine diazotroph assemblages determined by randomly amplified polymorphic DNA analysis. *Microbiology* 148:179-189.

Lovell, C.R. 2002. Plant-microbe interactions in the marine environment. In: G. Bitton (ed.) *Encyclopedia of Environmental Microbiology*, pp. Wiley, New York, NY, (in press)

Bergholz, P.W., C.E. Bagwell, and C.R. Lovell. 2001. Physiological diversity of rhizoplane diazotrophs of the saltmeadow cordgrass, *Spartina patens*. Implications for host specific ecotypes. *Microbial Ecology* 42:466-473.

Bagwell, C.E., M. Dantzler, P.W. Bergholz, and C.R. Lovell. 2001. Host specific ecotypic diversity of rhizoplane diazotrophs of the perennial glasswort, *Salicornia virginica* and selected salt marsh grasses. *Aquatic Microbial Ecology* 23:293-300.

Leaphart, A.B., and C.R. Lovell. 2001. Recovery and analysis of formyltetrahydrofolate synthetase gene sequences from natural populations of acetogenic bacteria. *Applied and Environmental Microbiology* 67:1392-1395.

Lovell, C.R., M.J. Friez, J.W. Longshore, and C.E. Bagwell. 2001. Recovery and phylogenetic analysis of *nifH* sequences from diazotrophic bacteria associated with dead aboveground biomass of *Spartina alterniflora*. *Applied and Environmental Microbiology* 67:5308-5314.

Lovell, C.R., C.E. Bagwell, M. Czako, L. Marton, Y.M. Piceno, and D.B. Ringelberg. 2001. Stability of a rhizosphere microbial community exposed to natural and manipulated environmental variability. *FEMS Microbiology Ecology* 38:69-76.

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: Dr. 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:

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.

Biogenic bromophenols: Community structuring agents?

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

Many polychaete and hemichordate worms produce brominated aromatic compounds. These compounds are similar to another group of compounds (chlorophenols) released by pulp mills and other industries. Sediments contaminated by these noxious organic compounds have been shown in previous studies to act as negative recruitment cues and as predator deterrents. Areas where the sediments are appreciably contaminated by these compounds may act as chemical refuges from predation. Many of the worms that produce these compounds are very small (< 5 cm in length). In a series of laboratory and field experiments, we are exploring how the predator deterrency of these compounds is affected by the community context in which they occur, including patch

density, size and composition. These studies will further explore how biogenic brominated aromatic compounds affect infaunal community structure. See map location #17

Geochemical solutes: Negative recruitment cues?

Investigators: Dr. Sarah Woodin[1], Dr. Roberta Marinelli[2], and Erin Wolfe[1]
Department of Biological Sciences and Marine Science Program, USC[1];
Chesapeake Biological Laboratory, University of Maryland[2]

Many infaunal organisms alter the characteristics of the sediment surface during their feeding and defecation activities, as do physical erosion and deposition events and predatory digging. In many of these cases the chemical signature of the disturbed surficial sediments resembles that of a subsurface sediment, lowered oxygen concentration and elevated ammonium concentration. We previously demonstrated that new juveniles show rejection behaviors in response to such surfaces in still water experiments. We are running a series of field and laboratory flume experiments to determine whether our assumption that these rejection behaviors result in lowered retention rates of the juveniles is correct. We are also initiating a series of experiments to separate the effects of lowered oxygen and elevated ammonium on larvae in the field. See map location #17

Brittlestar population studies: Use of skeletal growth rings as markers

Investigators: Drs. Stephen Stancyk[1] and William Dobson[2]
Marine Science Program and Department of Biological Sciences, USC [1],
and Appalachian State University[2]

Large populations of brittlestars, which live in sediments in the North Inlet Estuary, have been the subjects of many physiological studies over the past decade. In this study, animals from a natural population are sized, marked with calcein dye, and returned to the same area. Replaced animals are confined in plastic cores so that the same individuals can be relocated and brought into the lab for inspection. The goal is to determine the efficacy of using growth rings in arm vertebral ossicles as markers for aging individuals and for correlating growth bands to temporal events, which may alter rates of brittlestar development and regeneration. Additional studies are also being undertaken to determine how variability in environmental parameters, e.g. physical stress, nutrient load, and temperature affects the rate of growth ring production. The objective is to establish an explicit analysis regarding the mechanism of deposition of coarse-pored or fine-pored stereom in vertebral ossicles. This information will help elucidate environmental effects on brittlestar growth. See map location #17

Zooplanktivory by the burrowing brittlestar, *Hemipholis elongata*: Tests on natural plankton assemblages

Investigators: Dr. Stephen Stancyk and Frank Helies
Department of Biological Sciences and Marine Science Program, USC

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

Cryptic Speciation in *Nannopus palustris* at North Inlet Estuary

Investigators: Lisa Wickliffe[1], Lesya Garlitska[2], and Drs. Joseph Staton[3] and Bruce Coull[4]
Marine Science Program, USC[1], Visiting Scientist, Ukraine[2], Belle W. Baruch Institute for Marine and Coastal Sciences[3], School of the Environment, USC[4]

The primary objective of this study is to analyze the genetic basis for a morphological polymorphism in the estuarine meiobenthic copepod *Nanopus palustris.* Monthly collections of *N. palustris* at Kinorhynch Creek (off the middle north side of the dock at Oyster Landing). Extract DNA and PCR a mitochondrial and nuclear gene and analyze the data using molecular evolutionary techniques. This study is funded by SC Sea Grant and the USC's School of the Environment through 2003.

Structure, dynamics and functional relationships between phytoplankton, epiphytic microalgae, and foodwebs in a salt marsh estuarine system

Investigators: Dr. Richard Zingmark[1] and Alan J. Lewitus[1,2], M. Gabriella Jackson[1], Raphael Tymowski[1]
Baruch Marine Field Laboratory, USC[1] and SC DNR / Marine Resources Research Institute[2]

This project examines and quantifies the fate of phytoplanktonic carbon from the ocean as it passes into a tidal creek. Past studies have shown that the Bly Creek Basin is a highly productive system, with fairly high inputs of particulate organic carbon (POC). However, the functional mechanisms for processing this POC influx are not well understood. To this end, the planktonic and epiphytic communities of *Spartina* are to be identified and quantified, both by pigment analysis and microscopy, along transects of the marsh, during spring and neap tides for one year. We will compare seasonal patterns of phytoplankton and epiphyte taxonomic structure, biomass, and dynamics on live vs. dead *Spartina* plants, tall vs. short *Spartina*, leaves vs. stems, and at high tide vs. low tide. Grazing experiments will determine the impact of direct grazing by zooplankton, periwinkles, benthic suspension feeders (clams, oysters, mussels), and insects. Artificial *Spartina* substrate experiments will determine the rate of epiphyte community development, the impact of epiphytic mucus production on the passive filtration of phytoplankton, and the subsequent availability of the resulting epiphyte/phytoplankton aggregates to herbivores. This is an on-going project, with funding coming from New Jersey Sea Grant and South Carolina Sea Grant Consortium.

Estuarine eutrophication and microbial community compositions

Investigators: Wes Johnson[1], and Drs. James Morris[2], Peter Noble[3] and Madilyn Fletcher[3]
Marine Science Program[1], Department of Biological Sciences[2], and Belle W. Baruch Baruch Institute for Marine and Coastal Sciences, USC[3]

This project examines the effects of water chemistry and primary productivity on planktonic microbial community composition. Microbial compositions of planktonic communities are determined by amplifying 16S rRNA using polymerase chain reaction (PCR) and separating the amplified products using denaturing gel electrophoresis (DGGE). The study is being conducted at the Baruch Marine Field Laboratory and University of South Carolina (Columbia). Comparison of the five sampling sites indicates compositional changes along salinity gradients, as well as seasonal changes relating to phosphate concentrations. The relationship of primary production to microbial community structure is currently being investigated. The study is supported by EPA/NOAA/NASA, CISNET: Molecular to Landscape-Scale Monitoring of Estuarine Eutrophication. The project period for this study is from September 1999-August 2002

Microbial community responses to eutrophication in a southeastern U. S. salt marsh estuary

Investigator: Wes Johnson
Marine Science Program, USC

This study examines the effects of nutrient loading (nitrogen and phosphorus) on microbial communities in salt marsh sediments. Chemical fertilizers are applied to

selected plots of salt marsh within the North Inlet system from which sediment and porewater samples are collected monthly. The microbial community compositions are determined using polymerase chain reaction/denaturing gradient gel electrophoresis of 16S rDNA. Profiles generated by these methods will be used to assess any changes in the extant microbial community structure. This research will help determine what impact, if any, nutrient loading has upon salt marsh ecosystems in the southeast. This study is supported by the NOAA/NERRS Graduate Research Fellowship Program, and will be conducted from June 2001- June 2003.

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] and 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 is being monitored to measure the relative importance of interspecific competition and abiotic factors as determinants of zonation patterns between the salt marsh cord grass Spartina alterniflora and the black needle rush *Juncus roemerianus*. See map location # 6C.

Recruitment, habitat utilization, and growth of estuarine dependent fishes, with emphasis on the ecology and life history of the fringed flounder, *Etropus crossotus*.

Investigator: Dr. Marcel Reichert
Belle W. Baruch Institute for Marine and Coastal Sceinces, USC

Field data and various laboratory experiments revealed that the life cycle of the fringed flounder in the South Atlantic Bight is foremost characterized by the short life span of 15 months, which makes the fringed flounder one of the very few known annual flatfish species. Within this period fringed flounder grow up to an adult size and reproduce during one extended spawning season. Adult fringed flounder inhabit the shallow coastal waters. Although the presence of newly settled juveniles and reproductively active females can be found in almost all months of the year, the peak in spawning activity takes place from March through August. Multiple batches of pelagic eggs (9,000 - 47,000 eggs per batch) are spawned in the shallow coastal waters. There are no indications that spawning takes place in the estuaries. The eggs are about 0.5 mm in diameter. The total fecundity was estimated to be between 112,500 and 587,500 eggs, meaning that a female can produce her own weight in eggs over the spawning season.

Larvae and metamorphosing juveniles migrate into the estuarine nursery areas. The newly settled juveniles start their demersal life in the marsh creeks at a standard length of about 9 mm. Following settlement, juvenile fringed flounder find favorable temperatures and an abundance of food in the form of copepods, small epibenthic crustaceans, and polychaetes, a diet that shifts little during ontogenetic development. A bioenergetics growth model developed for juvenile fringed flounder indicated that growth rates are highest from May through August. With increasing size, they gradually move to deeper areas. Since few fringed flounder larger than 6cm standard length are found in the estuary, it is assumed that most juveniles reaching that size migrate out of the estuary. In the fall both the temperatures and the densities of the important food items decrease, and growth conditions depreciate. Juveniles large enough to migrate to the coastal waters grow there to an adult length and complete gonadal development. Females can potentially reach sexual maturity at a standard length of 7cm, but 50% maturity of the population occurs between 8 and 9 cm standard length. Although fringed flounder hatched early in the reproductive season can potentially reach sexual maturity after their first summer, there is virtually no spawning activity in the fall.

Distribution and abundance of various other flatfish species are currently analyzed to provide information on the habitat utilization of these species. This project was initiated in 1992 and is ongoing.

This project is funded, in part, by the Belle W. Baruch Institute.

Urbanization and southeastern estuarine systems

Investigators: Drs. Dwayne E. Porter[1,2], John Vernberg[1], Winona Vernberg[1,2], David Bushek[1], Alan Lewitus[1,2], Tom Chandler[1,2], Marj Aelion[1,2], Al Decho[1,2], Dan Tufford[2], Geoff Scott[2,3], Mike Fulton[2,3], and Tom Siewicki[2,3]
Belle W. Baruch Institute Baruch for Marine and Coastal Sciences, USC[1]
Norman J. Arnold School of Public Health, USC[2] and NOAA's Center for Coastal Environmental Health and Biomolecular Research[3]

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 Coastal Oceans Program/NOAA/Dept. of Commerce from 08/01/01though 07/31/02

<u>An evaluation of remote sensing and traditional surveying approaches for rapidly assessing the status and trends of oysters and adjacent marsh habitats</u>

Investigators: Drs. Loren Coen[1], David Bushek[2], Dwayne Porter[2], and Steve Schill[3], and Ray Haggerty[1].
South Carolina Department of Natural Resources, MRRI[1] and Baruch Marine Field Laboratory, USC[2], GeoMetrics Inc.[3]

The primary objective of this effort is a collaborative effort to evaluate a variety of remote sensing (ADAR, GeoVantage, Lidar, NAPP, Hyperspectral) and on-the-ground surveying approaches to rapidly assess status and eventually trends of oysters and adjacent marsh habitats using shellfish beds in Jones Creek and adjacent areas. Sites in Jones creek include the previously unsurveyed recreational-only State Shellfish Ground (S342) and a larger adjacent area that is part of the Baruch Grant area (G-344) originally surveyed in the 1990s fringing one side of Jones Creek. Secondary objectives include a cost-benefit analysis comparing the original survey methods developed by OFM in the1980s to those using a new surveying GPS unit. Also we will be comparing a portion of the Jones Creek's original survey data within the Baruch Grant area (G344) with our updated and resurveyed data.

With the recent acquisition of the Trimble GPS survey unit mentioned above, intertidal oyster reefs can be walked and simultaneously surveyed generating polygon areas with very accurate GPS. Attribute data (e.g., oyster spatial density codes – or "strata", matrix composition and depth, etc.) are then keyed into the touch pad in the field for rapid post-processing. This survey regimen will be repeated also at a subset of sites each year for current status and eventual trends and compared to remote sensing information. We will use these collected datasets for ground-truthing purposes in the evaluation of remote sensing technologies and their aerial imagery products for this area.

Previously, we conduced visual qualitative assessments of the recreational only State Shellfish Ground in January of 2002, using a modified protocol based on that used for the annual assessment of SC's commercial State Shellfish Grounds (S-342). An additional assessment category (reef density) was added to the original three (quantity, quality, and size) used to assess commercial grounds. In this assessment methodology, density refers to the spatial proximity of oyster clusters within oyster reefs, while quantity refers to the overall number and footprint of all reefs within the ground's boundaries (see attached S-342 boundary map). As with commercial assessments, the category of quality includes presence or absence of recent growth (white feathered edges), color or shade and relative thickness of live oysters' shell (dark gray-green vs. "sickly" paler gray), and the relative amount of recent mortality (visible, clean white interior shell surfaces on gaping and unhinged oyster shells). Size is the length in inches of the predominantly visible portion of oysters on the reefs (a visual "mode"). Each of these assessment categories are assigned a rating from1 to 5 ("poor" to "excellent"), and their scores averaged to yield an overall assessment score.

Increasing human activity in this area nearby development will inevitably impact oyster populations and adjacent tidal creek habitats. Development and utilization of more rapid, extensive and accurate population census methodologies will aid resource managers and policy makers in the more proactive management of marine resources in this and other portions of the state. They will also be more cost effective with a subset reevaluated in a more timely manner as remote sensing points to problem areas.
This project is supported by SCDNR, Saltwater Recreational Fisheries License Program, and NOAA-CICEET through September 2004.

## Using hyperspectral remote sensing to map and assess intertidal shellfish resources in the southeastern USA

Investigators: Jeffrey S. Vincent[1], Drs. Dwayne E. Porter [2,3], Loren Coen[4], Dave Bushek[3] and Steve Schill[5]
Department of Geography[1], Norman J. Arnold School of Public Heath[2], Baruch Marine Field Laboratory, USC[3], South Carolina Department of Natural Resources Marine Resources Research Institute[4], GeoMetrics, Inc[5]

Oyster resources in the southeastern USA are predominantly intertidal. Water clarity and tidal stage limit the use of passive remote sensing systems while shallow water limits the ability of sonar to accurately map beds and reefs. Oysters can be observed directly during low tide exposure, but inaccessibility and other problems make mapping these intertidal oyster resources difficult and tedious with questionable accuracy. Currently, maps are produced via a lengthy process of ground surveys and manual interpretation of aerial photographs, both of which are time-consuming and prone to human error. This project is developing a library of hyperspectral imagery to identify spectral end members of shellfish from in situ and remotely sensed (HyMAP) imagery. Preliminary results indicate separation in hyperspectral characteristics of oyster resources compared to surrounding habitats. Furthermore, HyMAP spectral end members show reasonable separation and similarity with in situ spectral end members. We will use these

spectral characteristics to classify and map the distribution and condition of intertidal shellfish resources. If successful, we will develop an automated mapping technique in a GIS environment that can be used by resource managers to obtain more timely information on the changing condition of oyster resources and better direct enhancement/restoration efforts. This research is funded in part by the Cooperative Institute for Coastal and Estuarine Environmental Technology, (CICEET).

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

Investigators: Drs. Dwayne E. Porter[1,2], Tom Siewicki[2,3], Jeff Allen[4], Marj Aelion[1,2], and Heath Kelsey[2] and Sam Walker[2]
Belle W. Baruch Institute for Marine and Coastal Sciences[1] and The Norman J. Arnold School of Public Health[2], and NOAA's Center for Coastal Environmental Health and Biomolecular Research[3], and the Strom Thurmond Institute, Clemson University[4]

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

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

The South Carolina Department of Health and Environmental Control (DHEC) uses fecal coliform levels measured in surface waters to classify shellfish harvesting areas based on the Interstate Shellfish Sanitation Conference (ISSC) guidelines. Under the ISSC guidelines, shellfish harvesting areas can be classified as approved, conditionally approved, restricted, conditionally restricted, or prohibited based on the fecal coliform concentrations measured by DHEC. Shellfish in areas with high fecal coliform levels in the surface water are assumed to have potentially dangerous levels of fecal coliforms (and human pathogens) as well. However, fecal coliforms can be deposited in surface waters from both human and wildlife sources, and it may be important to differentiate between these sources. The transport of fecal coliforms to surface waters from human

sources and wildlife sources may be very different, and their differentiation could lead to changes in the classification of some shellfish harvesting areas. Additionally, if the prediction of fecal coliform from human and animal sources is possible using land use characteristics, it may be possible to develop a land use based classification system of harvesting areas.

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

Geographic Information Systems (GIS) are used to characterize various land uses within the study areas. Data from the fecal coliform classification are incorporated into the GIS to examine the spatial distribution of human and animal source fecal coliforms. Using the land use characterizations and the fecal coliform distribution, GIS and statistical procedures will be used to attempt to predict the fecal coliform levels from human and animal sources based on the land use characteristics. Specific land use characteristics characterized include septic tank density, population density, housing density, vegetation, impervious surfaces, sewage treatment outfalls, and stream locations and volumes. Additional variables include rainfall, salinity, temperature, and tidal fluctuation. Statistical procedures include kriging, multiple regression and logistic regression. This project is funded from 08/01/00-07/31/04 by the SC Sea Grant Consortium.

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

Investigators: Samuel P. Walker and Dr. Dwayne E. Porter
The Norman J. Arnold of the School of Public Health[1], and the Baruch Institute for Marine and Coastal Sciences [1,2]

The goal of this research is to evaluate an integrated approach combining in situ and remote sensing data collection techniques with digital image processing and geostatistical and statistical modeling to assess the distribution of invasive species in the North Inlet and ACE Basin estuaries. The project is funded through NOAA and the National Estuarine Research System Graduate Research Fellowship Program.

A multidisciplinary approach to quantify and model the transport and deposition of organic pollutants in coastal environments

Investigators: Drs. Miguel A. Goñi[1], George Voulgaris[1], Richard Styles[1], John Ferry[2], Dept. of Geological Sciences[1], USC, and Dept. of Chemistry and Biochemistry[2], USC

Two key issues directly affect the ability of environmental managers to assess the effects and mitigate the impacts of enhanced pollutant loadings in estuaries. One is the determination of the sources and mode of contaminant introduction in coastal areas. The second is the estimation of pollutant residence times in estuaries. Our research objectives are aimed to specifically address these two critical issues by conducting intensive sampling, analyses and modeling of the fluxes and compositions of PAHs in coordination with a suite of physical and chemical measurements of fluid flow and sediment dynamics. In order to accomplish this goal, we will first measure water flow, fractional suspended sediment concentrations, dissolved, colloid- and particle-bound PAHs concentrations along three transects in the upper mid-section of an impacted estuary (Winyah Bay, SC). We will measure the stable isotopic compositions of PAHs to infer their sources. Based on these data, we will calculate a contaminant budget for the study area, including fluxes across the boundaries and short-term pollutant deposition in bay sediments, in order to estimate the residence time of PAHs in this system. Finally, we will integrate these measurements into a 3-D model that will be applied to other environmental conditions and other estuaries within the state.

The research will provide diagnostic as well as predictive information on the transport, deposition and dispersion of contaminants in estuaries. We expect to improve our current risk assessment and risk management capabilities by incorporating the measured chemical and physical variables into a 3-dimensional water quality model similar to the Environmental Fluid Dynamics Code developed and implemented by EPA. The source of support is EPA/EPSCOR and the project starts and ends 7/1/01 – 6/31/02

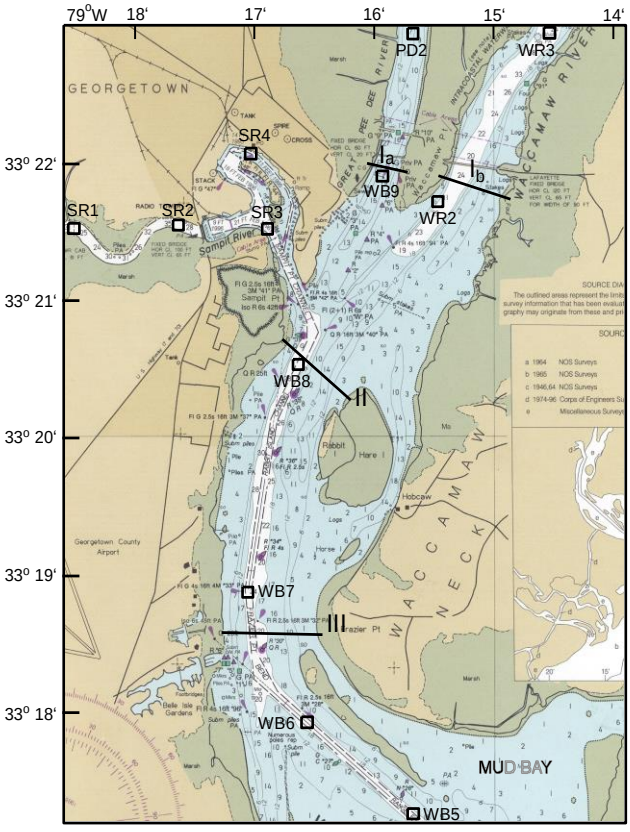


Fig. 1. Detailed map of the mid and upper reaches of Winyah Bay. Station locations of previous work are identified as well as the location of the proposed transects.

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

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

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

Differential gene expression in *Fundulus heteroclitus* due to the environmental metal, hexavalent chromium

Investigators: Drs. Jonathan Roling and William Baldwin
Biological Sciences, University of Texas at El Paso

Changes in gene expression are useful biomarkers that can provide information about the health of an organism, its ability to adapt to its surroundings, and specific pathways or effects of toxicants. Furthermore, gene expression can be used to monitor an organism's exposure to a toxicant, provide an early warning that an ecosystem is exposed to harmful chemicals, or indicate whether remediation of a polluted area is successful. The purpose of this study is to build a microarray to be used as a reliable biomarker of exposure and effect for hexavalent chromium in the abundant estuarine minnow, *Fundulus heteroclitus*.

Chromium is discharged during steel production and is the dominant toxicant found at several metal-contaminated estuarine Superfund sites around the United States, including Shipyard Creek in Charleston, SC and Seavey Island in Kittery, ME. Laboratory experiments will be performed first to determine differential gene expression caused by only hexavalent chromium. First, one month growth studies will be performed with juveniles according to EPA protocols and a NOEC and LOEC will be determined. Adults will then be exposed to Cr(VI) for 7-days at the NOEC, the LOEC and an environmentally relevant level. Preliminary experiments indicate that adults will probably be exposed to 0.1, 1.5 and 3.0 mg/L Cr(VI) as $CrO_3$. Subtractive hybridization will be performed between controls and each of the three groups to isolate sequences differentially expressed by Cr(VI).

*Fundulus* will be collected at Shipyard Creek and a reference site at North Inlet, National Estuarine Research Reserve and Belle Baruch Institute of Marine Biology. Subtractive hybridization will be performed to determine changes in gene expression at

the Superfund site. However, significant differences may occur because of genetic variation or chronic acclimation at Shipyard Creek compared to 7 days of laboratory exposure; therefore, North Inlet *Fundulus* will be transported to Shipyard Creek for 7-day cage studies and subtractive hybridization performed. This experiment should help bridge the gap between field studies and laboratory studies. All of the differentially expressed sequences isolated during the subtractive hybridization from the caged studies, the field studies, and the laboratory studies will be used to make a microarray. The microarray will be used to confirm differential expression in the laboratory, and then will be used in the field and cage studies to determine whether similar genes are altered in these studies as in the laboratory studies. Furthermore, we hope to correlate changes in gene expression to exposure levels and body burdens of Cr(VI) in the field caught and laboratory exposed *Fundulus*. By identifying epigenetic responses in *Fundulus heteroclitus* caused by Cr(VI), monitoring estuarine systems for bioavailable toxicant can be assessed without tedious analytical procedures that do not reflect bioavailability or valency. The long-term goal is to create an array that can be used to indicate potential exposure effects of chromium (and in the future other chemicals) to *Fundulus*, in order to monitor the health and recovery of our nation's estuaries.

Impact of various management strategies and boat wakes on oyster bed condition and recovery rates

Investigators: Drs. Loren Coen[1] and David Bushek[2], and Nancy Hadley[1] and Ray Haggerty[1].
South Carolina Department of Natural Resources[1] and Baruch Marine Field Laboratory, USC[2]

Our overall objective was to evaluate the impact oyster harvesting and die-offs have on intertidal oyster reef habitat and associated resource by: (1) examining recruitment, growth, and survival of oyster spat as an indicator of recovery and recruitment potential and (2) following recovery of manipulated sites after 'simulated' harvesting and/or major population die-offs. In 2000-2001 a boat wake-impacts pilot study to assess impacts on shell planting and associated marsh erosion impacts (Myer et al. 1996, 1997, Chose 1999, Coen and Fisher 2002, Grizzle et al. 1990, 2002). Finally we are synthesizing and integrating the data collected into recommendations and guidance for managing the State's oyster resources.

The approach was to identify paired oyster reefs that are similar in size, oyster populations, and environmental conditions. Various management/harvesting practices were simulated at one of the paired sites (~10 m); the other member of the pair (~10 m) was used as a control. We then monitor recruitment, growth, condition, and survival of oysters and the kinds and abundances of other living resources associated with oyster habitat annually following the simulated harvesting and die-offs. We followed the above 'managed/harvested' areas for approximately 3 years (1998-2001) to evaluate recruitment/recovery of significant harvestable (adult) oysters (>3" SL).

Our examination of the impact of boat wakes in tidal creeks and their interaction with shell replenishment stability and development is already providing the DNR with

information on the impact harvesting levels, boat wake and die-offs have on habitat quality, resource 'sustainability' and resource recovery. A recent study in North Carolina suggests that both intertidal oyster and clam harvesting negatively impacts both habitats and resources (Lenihan and Micheli, 2000). We are also using information to direct and improve restoration and management of the state's shellfish and adjacent fringing marsh habitats. We have presented the results at several national/international meetings with several papers in prep. We have already been using the information for several current Marine Recreational Fisheries License Programs related to oyster monitoring and restoration, including our SCORE community restoration work. We have received funding also to continue related work on intertidal oyster reefs in Florida (L. Walters et al. 2002-2003).

Funds were provided by SCDNR, the Marine Recreational Fisheries Stamp Program and SC Sea Grant Consortium.

Related Papers:

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Coen, L. D., and A. Fischer, 2002. Managing the future if South Carolina's oysters: an experimental approach to evaluating current harvesting practices and boat wake impacts. Journal of Shellfish Research 21:894.

Grizzle, R.E. 1990. Distribution and abundance of *Crassostrea virginica* (Gmelin, 1791) (eastern oyster) and *Mercenaria* spp. (quahogs) in a coastal lagoon. Journal of Shellfish Research 9: 347-358.

Grizzle, R.E., J.R., Adams, and L.J. Walters, 2002. Historical changes in intertidal oyster (*Crassostrea virginica*) reefs in a Florida lagoon potentially related to boating activities. Journal of Shellfish Research 21:749-756

Lenihan, H. S., and F. Micheli, 2000. Biological effects of shellfish harvesting on oyster reefs: resolving a fishery conflict by ecological experimentation. Fishery Bulletin 98:86-95.

Meyer, D.L., E.C. Townsend; P.L. Murphy, 1996. Final report for the project "The Evaluation of restored wetlands and enhancement methods for existing restorations". NMFS, SEFSC, Beaufort Lab, NC., 115 pp + append.

Meyer, D.L., E.C. Townsend; G.W. Thayer, 1997. Stabilization and erosion control value of oyster cultch for intertidal marsh. Restoration Ecology 5, 93-99.

Walters, L.J., L.D. Coen, and R.E. Grizzle, FL Sea Grant, 2002-2003 funded. Impact of boat wakes on the eastern oyster *Crassostrea virginica* in the southeastern United States: maximizing sustainability and restoration.

<u>Impacts of selected contaminants on Perkinsus marinus</u>

Investigators: Drs. David Bushek[1], Dwayne Porter[12]
Baruch Marine Field Laboratory[1], The Norman J. Arnold School of Public Health[2]; USC

The protozoan parasite *Perkinsus marinus*, which causes Dermo disease in oysters, is transmitted through the water as a free-living stage. During this period it is exposed directly to any contaminants that are present in the water. Studies of host-parasite interactions often assume that pollutants negatively impact the host, making it more susceptible to parasites and disease. The results of such work are often equivocal because the impacts of pollutants on the parasite are often not examined. As part of NOAA's USES project, this study is examining the effects of pollutants that are commonly found in South Carolina estuaries on *P. marinus*.

Using the National Estuarine Research Reserve System platform to prevent and control invasions by exotic decapod crabs.

Investigators: Dr. David Bushek and Mary Jo Hartman, BMFL and NI-WB NERR
Dr. Drew Lohrer, National Institute of Water And Atmospheric Research, New Zealand
Dr. Maurice Crawford, NOAA Estuarine Reserves Division
Dr. Steve Rumrill, South Slough NERR
Dr. Kerstin Wasson, Elkhorn Slough NERR

Non-indigenous species are introduced to U.S. estuaries on a daily basis and are considered a potent economic and ecological threat to the coastal zone. This project takes advantage of the National Estuarine Research Reserve System network to establish a proactive surveillance and management program for invasive decapod crabs at four northwestern and five southeastern NERR sites. The focus on invasions by decapod crabs is relevant, as several species have established breeding populations along both the Atlantic and Pacific coasts of the U.S. A web site is being created to disseminate findings and raise awareness in addition to flyers, identification cards and other means of distributing information. A major means of disseminating the information to managers is inclusion of results into the NERRs Coastal Training Program and its Coastal Decision Maker Workshops. This is a pilot project for an unprecedented effort within the Reserve System that aims to encourage a nationally coordinated System-Wide Invasions Prevention and Control Program. This project is funded by NOAA's Aquatic Nuisance Species Task Force: July 2002 – June 2003

Estuary-Net Project - National Estuarine Research Reserve System

Investigators: Beth Thomas and Julian Lewis
Baruch Marine Field Laboratory, USC

Estuary-Net is a volunteer water quality monitoring project developed by the National Estuarine Research Reserve System to educate high school students and others about the importance of healthy water quality and the value of watersheds and estuaries. It includes a complete curriculum with both classroom and field activities that provide a hands-on approach for investigating non-point source pollution and its impacts on

estuaries. Teams of students from local school districts work with Reserve staff to design a sample plan, survey waterways near their schools, and share their collected data through the Estuary-Net web site: http://inlet.geol.sc.edu/estnet.html. Participating schools work closely with the Reserve's Education Coordinator and receive an introductory classroom visit highlighting the Reserve System, the Estuary-Net project, and instruction on monitoring equipment and sampling protocols for a variety of sampling variables. The schools then begin their site monitoring and data collection and report their findings via the data directory on the website. Follow-up visits and seasonal sampling summaries are also provided.

Education Activities - National Estuarine Research Reserve System

Investigators: Beth Thomas and Julian Lewis
Baruch Marine Field Laboratory, USC

Educational activities that integrate findings from research are offered throughout the year. Baruch lecture series provide an informal means for people to learn about ongoing research programs at the coast. Other regular offerings include open houses and the Fishes of North Inlet Estuary program whereby participants help Reserve scientists sample and process collections of fishes, shrimps and crabs made on a bi-weekly basis. Contact the Reserve for a schedule of events at (843) 546-6219 or visit the Baruch Institute's Web Site at: www.baruch.sc.edu

Coastal training program for decision-makers

Investigators: Wendy Allen, Jeff Pollack, Laura Schmidt, and Beth Thomas
Baruch Marine Field Laboratory, USC

The North Inlet – Winyah Bay NERR has been offering workshops on coastal issues for decision-makers for several years in cooperation with the ACE Basin NERR and the SC Office of Ocean and Coastal Resources Management (SC-OCRM). This has been part of a nation-wide effort among Reserves to provide the latest scientific information and technology to people involved in making decisions that affect coastal resources. These efforts have evolved into a Coastal Training Program (CTP) that most of the 25 NERR sites are implementing this year. The North Inlet – Winyah Bay NERR is working with the ACE Basin NERR, SC-OCRM, the SC Sea Grant Consortium, the NOAA Coastal Services Center and other partners to implement training programs based on identified needs of decision-makers in local coastal communities.

## The National Estuarine Research Reserve System Centralized Data Management Office

Investigators: Dr. Dwayne E. Porter[1,2], Tammy Small[1], Ashly Norman[1], Danna Dowdy[1] and Nick Stines[1]
Belle W. Baruch Baruch Institute for Marine and Coastal Sciences and the Baruch Marine Field Lab, USC[1], and The Norman J. Arnold School of Public Health[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, biodiversity monitoring, and land-use and habitat change analysis.

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

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

Investigator: Drs. Renae Brodie and Marcel Reichert
Marine Science Program and Dept of Biological Sciences, USC

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

Settlement Distribution of Pre-Adult Fiddler Crabs (*Uca* spp.)

Investigators: Matthew Behum and Dr. Renae Brodie,
Marine Science Program and Dept of Biological Sciences, USC

This project will examine at which stage do pre-adult *Uca* pugnax and *Uca* pugilator segregate to their adult adult habitats. In the field, it is evident that adult U. pugilator frequent "open" habitat (such as new oyster beds), while adult U. pugnax frequent *Spartina* habitat. My research will aim at testing this null hypothesis that pre-adult *U. Pugnax* and *U. pugilator* settle randomly upon introduction from the estuary. From mid-May to late August, I will be sampling for pre-adult *Uca* biweekly. Two days during the sampling periods *Uca* will be collected along transects where *Spartina* and 'open habitat' meet. *Uca* will be spoon collected in stations moving into both the S*partina* and open habitat directions. Through RFCP analysis in the laboratory, and assuming rejection of ($H_O$), I will be able to determine if both species immeadiately separate to adult habitats ($H_1$); if both first segregate to *Spartina* ($H_2$), or if both first segregate to open habitat ($H_3$).

Salinity Flucuations and Post-Settlement Effects on *Uca Pugnax*, *U. pugilator* and *U. minax*

Investigators: Jenice Emord and Dr. Renae Brodie
Marine Science Program and Dept of Biological Sciences, USC

The goal of this study is to further investigate how salinity differences act as a cue for when and where *Uca* megalopae settle, as well as looking at how salinity changes affect newly settles crabs in the area. In addition to looking at salinity gradients, we are interested in how fast changing salinity fluxes affect the newly settled juvenile crabs. A storm event would precipitate a fast change in the salinity of the environment. A few sites that we will sample are small channels and would have a rather fast response to changes in salinity. We will then compare these sites to a more buffered site, such as a river, and see how settlement has affected the population dynamics of the juveniles and the adults in the different areas. Sampling will occur twice a week at each site. In total, 4 sites are being used; a wooded area, 1000 acre and the Clambank Road Bridge. Morgan Park in Georgetown is the large buffered site.

Effect of Microenvironment on Distribution of *Ilyanassa obsoleta* in a South Carolina Tidal Creek

Investigator: Maxine Henry
Marine Science Program, USC

I have developed a mechanistic model of thermal energy fluxes for *Ilyanassa obsoletea and littorina littorea,* and this summer, I plan to ground truth these models using live snails and physical models. I will also investigate the spatial variability of the

creek's bottom and sides from a thermal viewpoint to see if it is possible for such variability to affect the distribution of *I. Obsolete* individuals.

A weather station in Bly Creek (see map location #4) will be set up to record free-stream environmental parameter data at intervals of less than 5 minutes. Smaller data loggers will also be used to collect microclimate data and mode/snail temperatures. A grid pattern across a small portion of small portion Bly Creek will be set up to map spatial variability and snail individuals over time. Smaller data loggers deployed on the substrate will record microenvironment conditions.

In conclusion, I will link spatial variability and the scale at which it occurs in a tidal creek benthic environment. In addition, I will link the spatial variability measurements to the mechanistic mode; and begin making hypotheses about organismal response to thermal variability in soft sediments, and global climate change.

Estimating body temperature of the Atlantic Ribbed Mussel, *Geukensia demissa* in the field.

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

The goal of this study is to accurately estimate the body temperature of *Geukensia demissa* at a number of thermally distinct habitats in the field. Empty mussels shells are filled with silicone, which has similar thermal properties to mussel body tissue. An iButton temperature data logger is placed into the shell at a fixed location, and estimated body temperature readings are recorded every 20 minutes. There are four field sites (described below), and six mussels are placed at each site: 2 small (4-6 cm shell length), 2 medium (6-8 cm shell length) and 2 large (8-10 cm shell length).

The mussel models have been placed at four field sites along Oyster Landing. Site 1 is located within the oyster reef at the end of Oyster Landing pier (see map location #3). The mussels are attached to the oyster shells with cement, and they are exposed to the environment above the substrate. The other three sites are located in the salt marsh near Oyster Landing. In all three sites, the mussels are buried within the soft sediment. The small mussels are buried to be flush with the sediment surface, the medium mussel extend above the sediment surface 1-2 cm and the large mussels extend above the sediment surface more than 2 cm. The sites vary in tidal height, vegetation, amount of sunlight, and amount of standing water during low tide. Site 2 is in the highest part of the marsh, with sandy substrate, no vegetation (a great deal of sunlight), very little immersion time, and little to no standing water during low tide. Site 3 is along the edge of the *Spartina alterniflora* zone, and therefore, it is slightly shaded. The substrate is less sandy and there are almost always pools of water during low tide. The tidal height is intermediate compared to Site 2. Site 4 is the lowest tidal height, and therefore, this site has the greatest amount of immersion time. Also, it is completely located within the *Spartina alterniflora* zone, and it is very shaded. The substrate is muddy with an intermediate amount of standing water during low tide.

In the past, the majority of field research involving body temperature has assumed that mussel body temperature is equal to air temperature during low tide and water

temperature during high tide. However, recent studies have indicated that there are many factors, including air temperature, that influence the body temperature of intertidal invertebrates during low tide. This study is significant in that it attempts to predict body temperature in the field more accurately than previous studies.
This project is supported by a NSF grant to Dr. Brian Helmuth through 2003.

Blue crab recruitment to Winyah Bay; the role of the estuarine plume

Investigators: Dr. Dennis M. Allen[1], Dr. Martin Posey[2], and Paul D. Kenny[1]
Baruch Marine Field Laboratory, USC[1]
Center for Marine Science, Univ. of North Carolina at Wilmington[2]

Macrozooplankton collections along a transect from inside the Winyah Bay jetties to the sea buoy several kilometers offshore will provide information about the timing and magnitude of larval blue crab migrations. Blue crabs spawn near the mouth of the estuary, young larvae move to deep water tens of miles offshore, and late developmental stages (megalopae) return to the estuary in late summer and fall. Simultaneous collections of megalopae in the Cape Fear Estuary, NC will be compared to those from Winyah Bay in an effort to determine regional differences in recruitment patterns. Remotely sensed and shipboard measurements of physical conditions, especially ocean currents, will be used to interpret the patterns. Sampling multiple levels of the water column on either side of the turbid estuarine plume will characterize the role of this edge in aggregating and attracting larvae. The project seeks to understand the mechanisms of recruitment for multiple species of blue crabs, penaeid shrimps, and fishes that use the estuary as a nursery area.

Expression of Phase II enzymes in estuarine fish species.

Investigators: Peter van den Hurk, Kristen Gaworecki,
Environmental Toxicology Program, Clemson University

This research project focuses on Phase II, conjugating enzymes in fish species. These enzymes are important in the breakdown and excretion of endogenous compounds like testosterone, estrogen, thyroid hormones and bilirubin. But they are also instrumental in the breakdown of unwanted compounds that enter the system through food and respiratory organs. In the medical realm these enzymes are of importance because they mediate the disposition of therapeutic drugs, hence the name “drug metabolizing enzymes”, but the same enzymes are active in detoxification pathways when animals are exposed to natural toxins and environmental pollutants.

We have been studying these enzymes, and specifically the sulfotransferases and UDP-glucuronosyltransferases, for a couple of years. We are in the process of generating monoclonal antibodies for these enzymes, and we have studied the catalytic activity and expression in channel catfish (*Ictalurus punctatus*), and recently in mummichog (*Fundulus heteroclitus*). Results of inhibition studies with hydroxylated PCBs in catfish

were published last year. All these experiments point at considerable differences between mammalian and lower vertebrate forms of these enzymes. And very recent results show even larger differences between catfish and mummichog, the last one not expressing sulfotransferases at all. This has large consequences for this species: if one enzyme is not expressed, it's physiological role has to be taken over by the other enzyme. We want to investigate why these species differences exist, and therefore we will investigate a suite of different fish species to find out if the differential expression of these enzymes is linked to phylogenetic differences, or ecological differences (fresh water species, marine, estuarine, herbivores, omnivores, predators).

Fish will be collected in the vicinity of the Baruch Marine Field Lab, using different collecting techniques (beach seine, cast net, otter trawl). Collected fish are transported to the Field lab on ice, where livers and gills are dissected and stored in liquid nitrogen. At our Pendleton facility the tissues will be homogenized, separated in subcellular fractions and analyzed for enzyme expression and activity by electrophoresis, Western blotting and standardized enzyme activity assays.The project is supported by Clemson University E&G funding.

## Long-Term Studies

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

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

Investigators: Virginia Ogburn-Matthews[1], Dr. David Bushek[1], and Dr. L. Robert Gardner[2]
Baruch Marine Laboratory[1] and Department of Geological Sciences[2], USC

Partners: Tom Mero, Chief (NOAA/NOS/OPSD) and Lewis Lapine, Director (SC Geodetic Survey)

Source of Support: National Science Foundation, NOAA/NOS/OPSD, and SC Geodetic Survey

Begin and End Date of database: May 2001 to present (ongoing)
(missing data during July 2002-Feb2003)

Goals, Objectives, and Significance: The tide gauge measures water level in reference to MLLW at Crabhaul Creek (Oyster Landing Pier) every six minutes. The data are transmitted to NOAA via NOAA's Geostationary Operational Environmental Satellites (GOES), making the data available on-line in near real-time (three hour delay). Visit the NOAA tides online site at http://tidesonline.nos.noaa.gov/geographic.html for North Inlet's data. The gauge is part of the NOS's National Water Level Observation Network (NWLON); NOS oversees all data management. The tide gauge's base datum is referenced to the North American Vertical Datum of 1988 (NAVD88). This state-of-the art tide gauge is accurate to +/-3 mm with a resolution of +/-1 mm, and the data it provides, aids in predicting tides, observing sea level rise, and modeling local phenomenon in North Inlet Estuary. See map location #3..

Long-term zooplankton time series: tracking and interpretting 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], and Ginger Ogburn-Matthews[1]
Baruch Marine Field Laboratory and NI-WB NERR[1], Department of Biological Sciences and Marine Science Program[2], USC

Collections have been made at the same location, stage of tide, and time of day using the same sampling technique every two weeks since 1981. Oblique tows with 153 micron mesh nets collect copepod and small invertebrate larvae, and 365 micron epibenthic sled collections take larval fishes, shrimps, and crabs and other large zooplankton species. Seasonal and interannual changes in abundance and species composition of the assemblages are documented and correlated to fluctuations in the physical characteristics of the estuary. These data sets are among the most complete and longest running in the world. They reveal rates and directions of change in an undisturbed estuarine ecosystem. A high level of stability in species composition and relative

abundance has been demonstrated over the period, but effects of extended periods of low salinity such as those that occur in the winter-spring seasons of ENSO (El Nino) events are apparent. Since many of the zooplankton species are developmental stages of larger animals, the study provides indications of the reproductive and potential recruitment success of several commercially and/or recreationally important species. See map location #1.

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

Investigators: Dr. Dennis Allen, Ginger Ogburn-Matthews, Paul Kenny, Tracy Buck
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 1996-2002 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. This information is providing a foundation for the development of new experimental approaches to understanding habitat requirements and interactions among co-occurring tidal migrants. Results have implications for the management of marsh creeks and watersheds proximal to nursery habitat. See map location #5

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

Long term monitoring project: began September, 1997

This project 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 and to model the potential impact of dolphins upon prey populations. 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 small number of resident dolphins regularly using the North Inlet

system (on average, less than 10 in any given season) consume a significant proportion of the prey fish populations (9.1 to 14.2 metric tons per year) and utilize between 3 and 7% of the annual primary production in North Inlet. 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.
Source of support: Subcontract to the grant, "Contributions to the Biology of the red drum, *Sciaenops ocellatus*, in South Carolina," an Unaligned Management Project funded by the National Marine Fisheries Service (PI - Charlie Wenner, SCDNR), and the Georgetown Environmental Protection Society
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

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

Investigators: Jennifer Keesee, Tracy Buck, and Dr. Chris Buzelli
Baruch Marine Field Laboratory, USC

A fully functional meteorological station (a National Weather Service installation) is positioned on a pier that extends over the tidal marsh in North Inlet Estuary. Wind speed, wind direction, air temperature, barometric pressure, solar radiation, and precipitation are measured with sensors mounted on a tower at the pier. A computerized data acquisition system provides regular uploads of data to the laboratory via a short haul modem. The public can obtain up-to-date readings and monitor our weather data in real time from the main laboratory or over the Internet. Records have been gathered for more than 12 years for most parameters. See map location # 3

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

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

Source of Support: NOAA/Coastal Services Center, Charleston

Begin and End Date of Project: August 1, 2002 to present (ongoing)

Baruch Institute has many valuable ecological and environmental coastal long-term databases that date from the late 1970s through the 1990s that are not readily accessible to the public and researchers. Technology and information management has changed dramatically just in the last 5 years with the growth and availability of the Internet. The goal of this project is to verify, rescue, organize, archive, and disseminate

each database and its documentation (metadata) in a variety of forms (paper, Compact Disk (CD), and web).

First the data and the documentation for each database is assessed. All data are graphed, verified, and documented for missing data and outliers. All previous documentation, programs, summary data, and processed files are organized and documented. After the data are verified error-free, final graphics are created, and exported in a .jpg format. All documentation is verified with the data, and summarized in a standardized form, using the Federal Geospatial Data Committee (FGDC)/National Biological Information Infrastructure (NBII) format. All raw datasheets are scanned and saved as .jpg formatted images. Raw data images, processed data (including programs and earlier documentation), and final data are archived to a CD. All final data, metadata, and graphics are printed out; these hardcopy versions along with the CDs are placed in a 3-ring binder notebook that is kept in the computer lab at the Baruch Marine Field Laboratory. The final data, graphics, and metadata are also posted to Baruch's Website (http://links.baruch.sc.edu/data/) and the metadata is posted to Baruch's Isite Node that is registered with the NOAA CSC (http://www.csc.noaa.gov/CID/), NBII (http://mercury.ornl.gov/nbii/), and FGDC (http://clearinghouse2.fgdc.gov/) clearinghouses.

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

Investigators: Tracy Buck, Dr Chris Buzelli
Baruch Marine Field Laboratory, USC

Using YSI data loggers deployed to four tidal creeks within the NI-WB Reserve boundaries, we collect information about the physical parameters of our estuarine waters every half-hour, every day, all year long. The YSI instruments are calibrated and deployed according to strict protocols. Those protocols were agreed upon by the NERR System and are adhered to nation wide. Furthermore, detailed metadata records are kept and data are sent to a Centralized Data Management Office for quality assurance and quality control. The parameters measured include: temperature, salinity, depth, pH, dissolved oxygen, and turbidity. See map location #'s 6A,B, 3, 2C for datalogger deployment locations.

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

Investigators: William Johnson[1], Drs. Chris Buzelli[1], Bob Gardner[3], Jim Morris[2], and Tracy Buck[1]
Baruch Marine Field Laboratory[1], Department of Biological Sciences [2], and Department of Geological Sciences[3], USC

Chemical analyses of NI-WB estuarine water samples began in the late 1970's. Since 1993, ISCO automated water sampling devices have been used to collect water samples at regular intervals over 2 complete tidal cycles. Once every 20 days, the ISCO samplers take a sample at predicted low tide and then sample every 2 hours and 4 minutes for a period of 24:48 (hr:min). With more than 150 such deployments now logged at multiple sites, baseline water chemistry is fairly well understood at this Reserve. The chemical analyses performed produce data on suspended solids, dissolved organic carbon, total nitrogen, ammonium, nitrate-nitrite, total phosphorus, orthophosphate, and chlorophyll *a*. At present, the water chemistry data are collected from the same four locations where YSI dataloggers record complementary environmental data (see above). Efforts to merge and synthesize these separate data sets are presently underway. See map location #'s 6A,B, 3, 2C.

National Atmospheric Deposition Program (NADP)

Investigators: Jennifer Keesee , Dr. Chris Buzelli
Baruch Marine Filed Laboratory, USC

The North Inlet – Winyah Bay NERR has established a precipitation chemistry monitoring site in North Inlet Estuary and now collects atmospheric deposition data according to NADP/National Trends Network (NTN) protocols. The work is made possible by the USEPA National Estuary Program and the SC Department of Health and Environmental Control. This partnership was formed because of the desire to better represent coastal areas in our nation's deposition monitoring networks and because the NI-WB Reserve wants to better understand the atmospheric deposition of nutrients and pollutants into an otherwise pristine marsh system. The collection instruments consist of a recording rain gauge and event recorder, an analytical balance, a pH meter, and a conductance meter and cell. Samples are collected and analyzed in accordance with the analytical chemistry contract with the Program. See map location #3

Decapod monitoring in an intertidal oyster reef system (Oyster Landing)

Investigators: Dr. Drew Lohrer[1] and Mary Jo Hartman[2]
NIWA Laboratory, New Zealand, and Marine Science Program[2], USC

Decapods are monitored quarterly in an intertidal oyster reef habitat at Oyster Landing. This monitoring effort was initiated to track the invasion of North Inlet Estuary by *Petrolisthes armatus*, a subtropical anomuran crab not seen in North Inlet prior to 1998. Additionally, the arrival of other invasive crabs is anticipated (e.g., *Hemigrapsus sanguineus*--a Japanese shore crab currently spreading south from North Carolina, *Charybdis hellerii*--an Indo-Pacfic crab spreading north from Florida, and *Hemigrapsus penicillatus*--a Japanese shore crab currently invading oyster reef habitats in Europe). Monitoring will allow detection of these species shortly following their arrival and may improve the odds of eradication should that course of action be chosen. Monitoring will

also provide baseline data from which to calculate impacts of these aliens should they become established. See map location #3

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

Investigators: Drs. Bruce Coull[1] and Robert Feller[2]
School of the Environment[1] and Marine Science Program[2], USC

Regular (biweekly or monthly) collections of two size fractions of animals which live in the sand or mud have been made at the same locations in the North Inlet Estuary since 1972 (meiofauna) and 1981 (macrofauna). Small invertebrates, less than 0.5 mm in size, comprise the meiofauna. The meiofauna study is the longest estuarine meiofauna time-series in the world. Although collections of both meiofauna and macrobenthos continue to be collected, sample processing has lagged behind. Although these benthic communities contain hundreds of different species, only dominant taxa are identified regularly. The meiofauna are dominated by nematodes and harpacticoid copepods, while the macrobenthos consists mostly of polychaete and oligochaete worms, bivalves, and small crustaceans. Both size groups of organisms demonstrate annual cycles of abundance, peaking in winter. Simultaneous measurements of physical conditions in the water, sediment, and air help investigators to determine causes of variations over time. Data from undisturbed North Inlet habitats provide a baseline to which other areas, including contaminated areas, can be compared. These studies also provide an opportunity to examine the recruitment dynamics of soft-bottom benthos. See map location # 7

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

Investigators: Dr. James Morris and Warren Hankinson
Department of Biological Sciences and Marine Science Program, 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 allows for estimates of growth and primary production rates. Manipulative field experiments and long-term measurements of abiotic conditions including pore water salinity are providing insights into factors that affect production. Large monthly and interannual variations in the amount of organic material produced by the cordgrass are related to such factors as sea level and precipitation patterns. See map location #'s 3 and 8

Settlement patterns of the eastern oyster in the North Inlet Estuary

Investigators: Paul Kenny and Dr. David Bushek
Baruch Marine Field Laboratory, USC

Oyster reefs are important structural and functional components of the estuarine ecosystem. They provide food, shelter, and biological filtration. Patterns of oyster larvae settlement and their relationships to biotic and abiotic characteristics of the estuary have been studied since 1982. This long-term investigation involves collecting and counting recently metamorphosed oysters on settlement plates. The plates are suspended in vertical arrays next to intertidal oyster reefs. Biweekly processing has provided information about seasonal and interannual variation in settlement success. Although the timing and duration of the settlement season are stable among years, large fluctuations in abundance are typical. Such information allows us to monitor the condition of the oyster resource and determine natural factors that influence the population. See map location # 9

Monitoring coastal wetland change and modeling ecosystem health in South Carolina using advances in remote sensing digital image processing.

Investigators: Drs. Dwayne E. Porter[1,2], J.R. Jensen[3], Cassandra Coombs[4] and Jeff Allen[5]
Belle W. Baruch Baruch Institute for Marine and Coastal Sciences[1] and The Norman J. Arnold School of Public Health[2], Department of Geography, USC[3], Department of Geology,USC[4]., College of Charleston[5], and the Strom Thurmond Institute, Clemson University[5]

As part of the remote sensing team, we support NASA's strategic enterprise in Mission to Planet Earth by examining natural and human induced environmental change. Working with researchers from the College of Charleston, Clemson University and NOAA's Coastal Services Center, we are conducting remote sensing/change detection of wetland ecosystems in South Carolina. We have been, and are, in the process of collecting in situ data and correlating it with various remotely sensed data. Our goal is to produce biophysical distribution maps and quantitative modeling of an ecosystem's health. Specifically, the questions we, as a team, have posed include the following:
Can remote sensing methods be used to measure the health of the wetlands using LAI (leaf area index) and biomass?
Can we assess pattern ecological succession in wetland environments using remotely sensed data?
Can natural and anthropogenic factors that influence marsh erosion rates be quantified?
What is the amount of wetlands loss?
What is the greatest contributor to wetland erosion?
This project is funded from 04/01/97 – 03/31/03 by NASA

Sea turtle nest monitoring on Debidue Beach/Hobcaw Barony

Investigators: Betsy Brabson[1] and Robin Baugn[1] (Debidue Beach Coordinators), Wendy Allen[2], Tracy Buck[2], Jennifer Keesee[2], Ashly Norman[2], Raphael Tymowski[2], and other volunteers
DeBordieu Colony[1], 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 and the Baruch Institute of Clemson, 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, including Hobcaw, plus the middle and north sections, typically accounts for 30-50% of all nests in the region which includes 13 different beach areas. A final report summarizing nesting activity and success for the SCUTE region is prepared and submitted to the South Carolina Department of Natural Resources that oversees the volunteer sea turtle program for the state. See map location #1

South Carolina Estuarine and Coastal Assessment Program

Investigators: Drs. R. F. Van Dolah and D. E. Chestnut
South Carolina Department of Natural Resources

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, will provide 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 will be 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 2003. 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. See map location #11

Wadin bird nesting on Pumpkinseed Island: 1979-2003

Investigators: Dr. Dennis M. Allen[1], Dr. Keith Bildstein[2], and Wendy Allen[1]
Baruch Marine Field Laboratory, USC[1], Hawk Mountain Sanctuary Association[2]

Numbers of nesting wading birds are counted or estimated each spring and early summer to determine numbers of birds returning to the historically large colony. An average of 7,000 pairs occupied the island each year through the 1980's, but not a single pair nested in the spring following Hurricane Hugo (September 1989). About 2,000 pairs nested in 1992 and numbers reached a high of 2,700 in 1993. Numbers decreased each year to a low of about 200 in 1999. In 2001, more than 500 pairs of white ibis used the island and scattered clusters of nests on the south and west quadrants of the island marked the first time since 1989 that these areas were used. More white ibis returned in 2002 and almost all nesting was in the southwest portion of the rookery. Tri-colored herons, great egrets, and snowy egrets also use the island and have produced about 2,000 nests in recent decades. Until Sprong 2003, the numbers of glossy ibis and tri-colored herons nests on Pumpkinseed have been some of the highest in the state. See map location #9

# Research Locations in North Inlet