CURRENT RESEARCH PROJECTS

2001

Baruch Marine Field Laboratory (BMFL)

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

University of South Carolina

Baruch Institute

North Inlet - Winyah Bay
National Estuarine Research Reserve

Introduction

More than 522 scientific research projects and about 290 student theses and dissertations have been completed by Baruch Institute research associates since 1969. This work has resulted in the publication of more than 1252 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 86 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 supports 36 faculty, 21 technicians and 19 students as investigators on these projects. In addition, 29 faculty, 4 technicians , 4 students and 6 volunteers representing 21 other institutions participate as investigators. Dozens of other graduate and undergraduate students assist these investigators 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 which 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 attached map).

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 Dr. David Bushek 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.

LONG-TERM MONITORING AND RESEARCH

Long-term monitoring is essential for scientists to distinguish natural cycles that may span decades or more from anthropogenic impacts. This information allows scientists to develop hypotheses and design experiments to identify mechanisms that control the world around us. The BMFL has a long history of monitoring ecological change in a relatively pristine estuarine ecosystem. This work forms the backbone for many of the more elaborate studies described elsewhere in this document. In many cases, BMFL data sets are either the longest continuous data sets or the most comprehensive data sets available. Much of these data may be obtained via our web site 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.

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

Investigators: Dr. Drew Lohrer, Paul Kenny, and Mark Crane
Baruch Marine Laboratory, USC

An automated weather station with a computerized data acquisition system provides up-to-the-minute measurements of atmospheric and water column parameters. Wind speed, wind direction, air temperature, barometric pressure, solar radiation, and precipitation are measured with sensors mounted on a tower at the pier. Other sensors measure tidal height, conductivity, and water temperature beneath the pier. Records have been gathered for more than 12 years for most parameters and the data have been instrumental in determining how hourly, daily, weekly, seasonal, and annual variations in weather affect other ecosystem characteristics such as nutrient cycling, plant production, and the growth and migrations of animals. Visiting scientists can obtain up-to-date readings and monitor these parameters in real time from the main laboratory. New software may soon enable researchers to access these data in real time over the internet. The Oyster Landing site is also a National Weather Service installation. See map location no. 3

Water chemistry: long-term monitoring of tidal water from North Inlet Estuary

Investigators: William Johnson[1], Dr. L. Robert Gardner[3], Dr. James Morris[2], and Dr. Drew Lohrer[1]
Baruch Marine Laboratory[1], Dept. of Biol. Sci.[2] and Dept. of Geol. Sci.[3], USC

Water samples have been collected at various times and locations in the North Inlet Estuary since 1976. Daily collections from 1978 to 1993 have provided an understanding of how weather events, changes in sea level, and other physical factors affect concentrations of nitrogen, phosphorus, and organic compounds in the water column. Data are also collected for chlorophyll

(an indicator of microscopic plant production) and suspended sediment concentrations in the tidal creeks. In the summer of 1993, automatic samplers were deployed to collect water every two hours over 24 hr periods once every 20 days at two sites in North Inlet and one in Winyah Bay. More than 15 years of daily records are now complimented with finer scale (tidal and diel) measurements of the same parameters. Water chemistry data are incorporated into computer models in an attempt to explain long-term variations in other ecosystem processes such as plant and animal production. See map location no. 3 and 21.

Piloting new parameters for inclusion into the National Estuarine Research Reserve System Wide Monitoring Program – Part 2: Comparing field and laboratory fluorescence measurements as indicators of chlorophyll a levels in estuarine systems.

Investigators: Drs. Drew Lohrer and Dennis Allen
Baruch Marine Laboratory, USC

Data on the concentration, distribution and variability of chlorophyll (particularly chlorophyll a) within estuaries are useful as indices of system productivity and eutrophication. Several instruments are becoming available that allow constant monitoring of fluorescence in aquatic habitats. The National Estuarine Research Reserve (NERR) System has added the measurement of fluorescence as a biological parameter to its ongoing System Wide Monitoring Program (SWMP). The SWMP has been monitoring water physical and chemical parameters for several years at locations within each of the 25 NERR sites around the country and has recently begun measuring weather parameters at many of these Reserves. Approximately 10 of the NERR sites are participating in this pilot program to test the performance of a fluorescence probe on the YSI dataloggers currently being used to measure the water physical and chemical parameters. Where possible, probe measurements will be correlated with fluorescence data obtained from concurrent water samples taken at these same locations and processed using other analytical techniques. The data from all participating sites will be submitted to the North Inlet – Winyah Bay Reserve for consolidation and interpretation en route to producing a NERR system-level report concerning the fluorescence probe's performance under varying estuarine conditions. Funding for this research is being provided by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).

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

Investigators: Drs. Bruce Coull[1] and Robert Feller[2]
School of the Env[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 no. 11 and 12.

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

Investigators: Dr. James Morris and Warren Hankinson
Dept. of Biol. Sci. 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 which 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 no. 4 and 14.

Town Creek zooplankton program: 19 years of continuous monitoring

Investigators: Dr. Dennis M. Allen[1], Dr. Steve Stancyk[2], Paul Kenny[1], and Ginger Ogburn-Matthews[1]
Baruch Marine Laboratory[1], Dept. of Biol. Sci. 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; generally a high level of stability in species composition and relative abundance has been demonstrated. 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 no. 4.

Oyster Landing Basin seine collection program: long-term monitoring of fish, shrimp, and crab populations

Investigators: Ginger Ogburn-Matthews, Paul Kenny, and Dr. Dennis M. Allen
Baruch Marine Laboratory, USC

Relatively little is known about what and how natural factors affect the extent to which young-of-the-year animals use shallow marsh habitats. An understanding of natural variability in abundance, growth, and production rates is essential to evaluate and adjust human impacts on habitats and populations. Since 1983, we have made biweekly collections in the same tidal creek pool to determine seasonal and interannual variations in the abundance, biomass, and length distributions of animals using this nursery habitat. Seine samples have been processed for information which will provide insights into relationships between more than 60 species of fishes and decapod crustaceans and physical characteristics of the system. Although abundances of all species vary between seasons and years, their timing of arrival and departure from the nursery habitat and their rates of growth are very predictable. Estimates of secondary production indicate little year-to-year variation in total production, even though the individual species' contribution to total production may vary greatly. Our study in the undisturbed habitats of North Inlet Estuary affords a rare opportunity to understand these ecological processes. See map location no. 5.

Use of flooded marshes by migratory fishes and crustaceans

Investigator: Dr. Dennis Allen, Ginger Ogburn-Matthews, and Paul Kenny
Baruch Marine Laboratory, USC

The movement of a diverse assemblage of fishes, shrimps, and crabs into intertidal habitats with flooding tides is widely recognized, but quantitative information regarding the structure and dynamics of these migrations is scarce. In this study, the timing and magnitude of movement of fauna onto the vegetated marsh surface is measured by enclosing a one acre area of flooded marsh at high tide and determining the taxonomic and life stage composition of the nekton leaving the area with the ebbing tide. These monthly collections are paired with the long-term nekton seine collection at Oyster Landing. Together, these studies are revealing temporal and spatial partitioning of the use of the habitats and previously unsuspected relationships among the species sharing the nursery. Weather conditions, depth, and time of day influence the way the migratory fauna use the marsh. Collections from the flooded marsh have been made continually since 1995. See map location no. 5.

Settlement patterns of the Eastern Oyster in the North Inlet Estuary

Investigators: Paul Kenny and Dr. David Bushek
Baruch Marine 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 which influence the population. See map location no. 17.

Spatial and temporal patterns of Dermo disease in North Inlet

Investigators: Drs. David Bushek[1] and Dwayne Porter[2], Jennifer Keesee[1]and Brian Gray[2]
Baruch Marine Laboratory[1], Baruch Inst. USC and Global Information Processing Lab[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 of Dermo disease for oysters from mid-Atlantic and Gulf states are well known and have been positively correlated with temperature and salinity. The warm, high salinity waters of small bar-built estuaries of the southeast should provide favorable conditions for Dermo disease, yet epizootics are rare events. Spatial and temporal monitoring of *P. marinus* from throughout the North Inlet estuary shows a typical seasonal pattern of intensification and remission that is described from other regions, but intensities remain comparatively low. Using GIS and other spatial analytical tools we have determined that foci of infections are generally located within tidal nodes and other areas with high water residence times. Poor flushing of these areas may permit local intensification of the parasite resulting in higher infection intensities. These findings have implications for the siting of oyster culture grounds and efforts to restore oyster reefs. Continuing efforts are directed toward verifying this relationship and examining the causes of inter-annual variation by coupling these data with the long-term atmospheric and water quality data collected by other BMFL programs.

Invasive species monitoring programs to begin at NI-WB NERR.

Investigators: Dr. Andrew Lohrer[1], Rich Lehnert[1], Paul Kenny[1] and Mary Jo Hartman[2]
Baruch Marine Laboratory[1] and Marine Science Program[2], USC

Invasive species are a top threat to marine biodiversity and can have devastating ecological and economic consequences. Detailed biological monitoring of intertidal oyster reef habitat will be initiated at several sites in the North Inlet estuary in anticipation of the arrival of three brachyuran crab species (*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. A second invasive species monitoring program, which focuses on the invertebrate "fouling" community, will also be initiated at the NI-WB NERR this year as part of a concerted effort by the NERR system to understand the mechanisms and consequences of exotic species invasions. As is planned at several other NERRS sites (e.g., in Oregon, Southern California, and Rhode Island), settling plates will be suspended from floating platforms at three locations within the NI-WB NERR. These plates will be hung adjacent to dataloggers that measure water characteristics at Oyster Landing, Thousand Acre, and Debidue Creek. Patterns

of recruitment and community development of native and invasive epifaunal invertebrates will be analyzed and the data will be used in several related manipulative experiments.

Tide Level: long-term monitoring at Oyster Landing Pier

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

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

A satellite-linked tide gauge measures water level every six minutes and data are transmitted to NOAA's Geostationary Operational Environmental Satellites (GOES), making the data available on-line in near real-time. Six minute data can also be viewed in real-time from a computer interface at the Field Laboratory. 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 ±1mm, and the data it provides, aids in predicting tides, observing sea level rise, and modeling local phenomenon in North Inlet Estuary. This project will begin January 2001.

Sea Turtle Nest Monitoring on Debidue Beach/Hobcaw Barony

Investigators: Betsy Brabson[1], Debidue Beach Coordinator, Sarah Adams, Wendy Allen[2], Robin Baugn[1], Becky Ellin[2], Lisa Free[1], Judy Johnson[1], Dan Harkins[4], Julian Lewis[2], Carrie Lucas[3], Raphael Tymowski[2], Patti Varhol[1]
DeBordieu Colony[1], Baruch Marine Laboratory[2], Baruch Institute of Clemson University[3], other local communities[4]

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 has occurred, 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 which oversees the volunteer sea turtle program for the state.

Long-term monitoring of wading bird nesting on Pumpkinseed Island

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

In conjunction with the non-game species biologists of the SC Department of Natural Resources, we census wading bird nesting activity on Pumpkinseed Island located in the Mud Bay region of Winyah Bay. Following a tradition initiated in 1979 by Peter Frederick, Keith Bildstein, and associates, white ibis nest are counted or estimated in April-May of each year 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 the spring following Hurricane Hugo in September 1989. Numbers returned to about 2,000 pairs in 1992 and reached a high of 2,700 in 1993. About 200 white ibis nests occurred each year from 1996 and 2000. Large colonies have developed in the southern part of the state in recent years. Tri-colored herons, great egrets, and snowy egrets produced about 2,000 nests each year, and numbers of glossy ibis and tri-colored herons nests on Pumpkinseed are some of the highest in the state. See map location no. 19.

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.

At least two stations in the state/site network will be in the North inlet Estuary.

PHYSICAL AND BIOGEOCHEMICAL PROCESSES

The physical environment sets the stage for the development of a functioning ecosystem. Several researchers at the BMFL are interested in the physical aspects of coastal ecosystems and how they interact with the biology and chemistry that occurs in these dynamic areas. The following studies are providing a better understanding of the mechanisms that structure coastal ecosystems.

Groundwater dynamics at the forest-marsh boundary

Investigators: Dr. L. Robert Gardner
Dept. 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 3) 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 ground water 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.

Rainfall enhanced sediment mobility in a meotidal estuary

Investigator: Mwasi J. Mwamba
Dept. of Geological Sciences, USC

The North Inlet salt marsh system has been evolving under a regime of estuatic sea-level rise; importing sediment at a rate sufficient for its surface elevation to keep pace with the rising ocean (Vogel et al. 1996). It is within this context that the salt marsh system is characterized as a depositional environment. On the other hand, erosional processes in North Inlet have produced well-developed tidal channel networks.
Gardner and Bhon (1980) proposed that the higher order tidal creeks draining North Inlet were originally fresh water streams, however processes that control the initiation and evolution of lower order tributary tidal channels are not well constrained. Pestrong (1965) observed that the low order segments of tidal channels are morphologically similar to terrestrial channels. He reasoned that tide induced sheet flow over the salt marsh surface generated flow velocities that were adequate to erode cohesive sediment from the marsh surface. On the other hand, observations by Settlemyre and Gardner (1975) reveal that low-tide rainfall events could increase net sediment flux by 10 to 100 times. This observation is compelling since the total volume of fresh water flow at the North Inlet is negligible relative to salt water flows (Kjerfve pers. com. 1999), but fresh water flows resulting from direct precipitation onto the marsh surface may produce a two order of magnitude increase in sediment flux.

The cohesive forces that bind salt marsh sediment particles at the surface may control the sediment shear resistance to erosion (e.g. Mehta et al., 1989). The observations above indicate that pore water chemistry may control particle to particle cohesive forces. I hypothesize that low-tide rainfall events alter the pore water chemistry of salt marsh surface sediments, leading to a reduction in the shear resistance to erosion of the marsh surface, and a net increase in sediment flux. I propose to test this hypothesis through rainfall simulation experiments designed to vary the spray water salinity, intensity, and duration, as well as drop size. I will measure the flow depth, runoff and suspended sediment concentrations from a 3-ft x 9-ft plot to investigate how these parameters might control sediment flux. These experiments will allow me to quantify the relative importance of tidal driven erosion versus rainfall erosion on channel network evolution.

Tidal Creek Development in an East Coast salt marsh system

Investigator: Mary Kosko,
Dept. of Geological Sciences, USC

This project is designed to: (1) to characterize the processes controlling tidal creek network development and topography of the marsh surface (2) quantify tidal creek channel characteristics using parameters typically applied to terrestrial fluvial systems. (ie., width:depth

ratios, width:length ratios, contributing area:length,etc.) (3) determine the level of self-similarity which exists in tidal creek networks.
Data collection consists of a topographical survey of the surface of a marsh island in the mid-marsh at North Inlet. This will be accomplished using a Total Station and rods with prisms. This data will be used to construct contour maps for analysis of basin and channel characteristics. It is currently unclear how environmental factors such as sea-level rise, tidal prism changes, and other physical and biogenic processes interact to create the salt marsh surface and tidal creek networks. This study will lay the groundwork for future studies seeking to determine how sediment-sorbed contaminants or nutrients circulate throughout the marsh. The project is funded through the Department of Geological Sciences through May 2002

Measurements of Bi-directional Reflectance Distribution Function (BRDF) with Goniometer

Investigator: Steven R. Schill, Project Manager
NASA Affiliated Research Center (ARC)
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The purpose of my research will be to model the way light reflects off the top of smooth cordgrass so I can better map it using imagery acquired from an airplane. Cordgrass looks different depending on where the person is viewing it, and where the sun is positioned. This is called the Bi-directional Reflectance Distribution Function (BRDF). I will be using an instrument developed by NASA called a goniometer which records BRDF measurements at 66 different angles every hour. It will record every hour to document how the light reflectance changes as the sun moves across the horizon. In addition, I will document how differences in leaf-area-index, biomass, height, geometry, understory, and tide levels of the cordgrass, significantly affect the BRDF patterns. This is important because people can create better maps by using this information to calibrate and significantly improve the accuracy of the measurements made from remotely sensed data. I plan to collect these measurements in two different canopy structures based on field quadrant and ceptometer measurements: a) Sparse (approximately dry weight < 40 grams, height < 36 inches, and LAI < 1.0); (Osyterlanding site) c) Dense (approximately dry weight > 75 grams, height > 48 inches, and LAI > 2.0) (Goat island site) I expect to contribute to BRDF research by:
1. Establishing a BRDF database for Spartina alterniflora that will provide resource managers with insight into maintaining estuarine health that is threatened by impending urban sprawl,
2. Increasing the knowledge base on the effects of BRDF on vegetation with erectophile leaf orientation,
3. Documenting the effects of BRDF in intertidal environments,
4. Fulfilling the need among the BRDF community to increase in situ validation studies.

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], 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 habitat in cooperation with NERRS research coordinators and participating scientists across the country. The data base 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 data base 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 data base 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)

Fractional Sediment Flux and Flocculation in a Salt Marsh Channel

Investigator: Samuel Meyers
Marine Science Program, USC

The survival of coastal salt marshes is dependent upon their ability to accumulate sediment at a rate sufficient to keep pace with the rise of sea level. The North Inlet marsh system seems to be surviving despite studies that indicate a bias toward net sediment export. Traditionally, hourly and daily estimates of bulk suspended sediment flux have been determined by filtration and dry weight measurements. This study measures fractional suspended sediment flux over shorter time intervals of minutes, which will provide better resolution of net flux estimates. These measurements are compared to velocity readings to determine if there is a direct correlation between the amount of suspended sediment transported and the magnitude, and turbulence levels, of flood and ebb tide flow. The effects of flocculation have not been well documented for the North Inlet marsh, but are important in determining the mode of transportation for silt and clay sized particles. This study also examines the interaction between turbulence in tidal channels and flocculation in order to gain more insight into the sedimentary processes of the marsh.

Microbial transformation of atrazine and PAH contaminants in coastal sediments

Investigator: Dr. C. Marjorie Aelion
Department of Environmental Health Sciences and Marine Science Program, USC

This project is designed to determine the ability of bacteria in coastal sediments from three different land uses to degrade and transform atrazine, a commonly used pesticide. Atrazine, is phytotoxic but the production of microbial metabolites (compounds formed as microbes breakdown the atrazine) is rarely taken into account when determining the impact of atrazine on coastal environments. In general, the production of microbial metabolites in coastal sediments has not been well documented. This study is funded by NOAA and the USES project for the period, June 1, 1996-May 30, 2000. Sediment samples were collected from a relatively pristine site in North Inlet Estuary, an urbanized site in Murrells Inlet Estuary and near golf course adjacent to Pawley's Island, then incubated with 14C-radiolabeled atrazine in sediment microcosms. The aqueous and sediment fractions are extracted to measure the concentrations of atrazine and two microbially-produced metabolites, deethlyatrazine and deisopropylatrazine over time. A second project which continues to May 30, 2001 is similar to that above, but is looking for the microbial degradation (complete mineralization to CO2) of phenanthrene, a three-ringed PAH, at the three study locations. Indirect evidence of metabolite formation is determined by using a series of solvent extractions on the sediment. The 14C collected in the different solvents is quantified on a liquid scintillation counter, but the metabolites produced are not identified using gas chromatography / mass spectrometry . It appears that a significant portion of the added phenanthrene is mineralized, and a smaller portion is transformed into as of yet unknown metabolites that are subsequently sorbed onto organic matter associated with the sediment.

Investigation of the cycling of dissolved and particulate organic matter in coastal ecosystems

Investigator: Maria Teixeira
Dept. of Geological Science, USC

A critical aspect of this work is the isolation and chemical characterization of natural organic matter from different systems with contrasting anthropogenic impacts. My studies focus on North Inlet as a pristine system vs. Winyah Bay as a highly impacted one. I am also interested in the effect and controls of polycyclic aromatic hydrocarbons, PAHs, in aquatic environments. PAHs are ubiquitous environmental contaminants that have toxic characteristics and represent the largest class of suspected chemical carcinogens.

PAHs have natural sources such as vascular plant debris, coastal peat erosion and petrogenic sources. There are also anthropogenic sources from combustion of fossil fuels, petroleum spills and sewage. Direct discharges, urban and agricultural runoff, and groundwater flow deliver substantial quantities of PAHs to aquatic environments. Estuaries located in proximity to urban and industrial centers are major repositories of PAH compounds. But these are not the only places susceptible to PAH contamination. High concentrations of natural PAHs have been found in pristine areas also. PAHs can also enter aquatic environments through atmospheric deposition increasing their ability to contaminate many areas. A better understanding of the different sources of PAHs and how they interact with natural organic matter is an especially interesting question that I plan to investigate in my work. Aquatic environments, such as the coastal zone of South Carolina, with high dissolved and particulate organic loading, are an ideal place in which to study the interaction of man made contaminants with natural organic matter.

Non-point sources of dissolved organic matter to the ocean: groundwaters from coastal soils and sediments

Investigator: Dr. Miguel Goni
Dept. of Geol. Sci. and Marine Science Program, USC

The prinicipal question fueling this work is: What is the role of groundwater on the cycling of dissolved organic matter (DOM) in coastal ecosystems? This project is designed to determine (1) the sources and characteristics of groundwater DOM; (2) the seasonal dynamics of groundwater DOM production and transport; and (3) the impacts of groundwater DOM on the coastal ocean. Several analytical techniques, including tangential ultrafiltration, 13C NMR, and the novel combination of compound specific isotope analyses with CuO oxidation and pyrolysis, are used to quantitatively characterize DOM. Groundwater samples are collected from wells across Crabhaul Creek while surface samples are collected at various locations in North Inlet and offshore regions of the South Carolina coast. Our data suggest that groundwaters are important non-point sources of DOM to the coastal ocean. These observations also suggest that groundwater DOM is quantitatively and compositionally different than DOM from rivers (point-sources). Given the unavoidable impact of human development on our coasts, it is imperative to understand how the diffused flow of groundwater constituents affects the dynamics of carbon, nitrogen and other nutrients in coastal environments.

Sediment accretion in North Inlet salt marshes

Investigator: Dr. James Morris
Dept. 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.

Sediment Transport and Trapping in Estuaries, Southeastern United States

Investigator: Dr. Gail C. Kineke
Dept. of Geology and Geophysics, Boston College

This project has both a research and education component. The goal of the research is to examine sediment transport processes in three estuaries: Winyah Bay (SC), ACE

Basin (SC), and the Satilla River (GA). Each study focuses on the physical processes responsible for trapping sediments within the estuary. The three estuaries are chosen to address specific sediment transport processes necessary for understanding resuspension, trapping, and turbidity maximum related questions. In contrast to the other two, more pristine sites, Winyah Bay is highly impacted by human activity and the channel is regularly dredged. The focus of study will be the trapping of sediments as a result of frontal dynamics in the lower part of the estuary, downstream of where a traditional turbidity maximum usually occurs. The study in Winyah Bay also serves as the foundation for the education component of this project which introduces undergraduate students to research in estuarine processes through individualized and team projects. The study is being carried out through a combination of hydrographic surveys using an instrumented profiling tripod, CTDs, and optical sensors for both spatial and time-series observations, bottom sediment characterization using dual frequency echosounders, and bottom sediment sampling. Understanding transport and trapping of fine sediments in estuaries is critical for dredging-related issues and transport of many contaminants (heavy metals, PCBs, pesticides) which are frequently adsorbed on fine-grained particles. This project is funded by the National Science Foundation.

BIOLOGY AND ECOLOGY

Factors affecting successful invasion by exotic species: role of species diversity, eutrophication, and predation

Investigators: Dr. Andrew Lohrer, Rich Lehnert, Mary Jo Hartman
Baruch Marine Laboratory, USC

Some investigators have reported positive relationships between native biodiversity and resistance to invasion by exotic species. Others have suggested the opposite, namely, that exotic species invade hotspots of native diversity. Most of the studies are observational and correlative (rather than experimental), leaving many potentially important factors uncontrolled. A series of field-based, manipulative experiments are planned to address this problem. The diversity of sessile invertebrate epifauna will be experimentally altered in patches of oyster shell habitat and the responses of several invasive species will be evaluated. Exotic species presently established in the North Inlet Estuary provide unique opportunities for study because of different life-history traits and/or trophic positions. For example, we predict that *Petrolisthes armatus* (a mobile, filter-feeding anomuran crab), *Ecteinascidia turbinata* (a sessile, filter-feeding tunicate), and *Charybdis hellerii* (a predatory brachyuran crab) will all respond differently to the same manipulations. The predatory crab may be attracted to treatments with high species diversity, whereas the filter-feeders may have less success in the presence of a diverse guild of competitors for food and space. The effects of predation by fish (a top down control on resources for sessile epifauna--i.e., available bare space) and eutrophication (a bottom up control on resource supply for filter-feeders) will also be incorporated into the design.

Distribution of an invasive anomuran decapod, *Petrolisthes armatus*, along the South Carolina coast from Charleston Harbor to Murrells Inlet

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

Invasive species can be both amazing and alarming in their ability to colonize and dominate new habitats. Numerous studies have demonstrated that invasive organisms can completely change an ecosystem once they have become established. Presently, there is an impressive invasion occurring on the east coast of the United States by the anomuran, *Petrolisthes armatus* (Gibbes, 1850). Preliminary studies using recruitment trays in Charleston Harbor have recorded juvenile densities of >18,000 m^2 (L. Coen, pers. comm). This is a project to further study the distribution and biology of *P. armatus* at sites on the South Carolina coast from Charleston Harbor north to Murrells Inlet. Transects will be run perpendicular and parallel to the shoreline from the shallow subtidal to the upper intertidal zone on selected oyster reefs or jetties. Sampling of *P. armatus* will be conducted by randomly selecting three 0.1 m^2 areas at each of three zones (subtidal, lower intertidal and upper intertidal) and collecting all *P. armatus* individuals. Other components of the oyster reef community will be quantified to determine whether *P. armatus* densities affect biodiversity. *P. armatus* has been found recently in the North Inlet NERR and in Murrells Inlet 20 miles north. *P. armatus* may be moving northward from Charleston, SC, and could become established in the North Inlet-Winyah Bay National Estuarine Research Reserve. This study will provide baseline information on the invasion, and will be used in the design of experiments to examine the influence of *P. armatus* on South Carolina oyster reefs. This project is funded by the NERR-GRF program for the period June 2000 to June 2001

RUI Creek Project: The role of oyster reefs in the structure and function of tidal creeks

Investigators: Drs. Richard Dame[3], Eric Koepfler[3], Dennis Allen[1], David Bushek[1], Don Edwards[2], Bjorn Kjerfve[4], Alan Lewitus[1], and Ms. Leah Gregory[3]
Baruch Marine Laboratory[1], Dept. of Statistics[2], USC,
Coastal Carolina University[3], Dept. Geol. Sci. and Mar. Sci. Prog[4]., USC

Oyster reefs interact with and modify both the biological and physical characteristics of tidal creek ecosystems by altering water flow, providing increased hard surface area for other organisms, filtering large amounts of particles including plankton and detritus, and increasing the recycling of materials. Through these and other activities, oyster reefs may strongly regulate the structural and functional nature of tidal creek systems. This project offers a multidisciplinary, integrated field and laboratory design to address the role of oyster reefs in regulating the structure and function of tidal creek systems. A statistically robust, replicated system design (BACI), consisting of eight tidal creeks, is being used to partition the biological and physical effects exerted by oyster reefs upon tidal creek biota. In phase one, oyster biomass was equalized among creeks and baseline data collected to characterize creeks and measure spatial and seasonal variability on numerous parameters including plankton, bacteria, motile animals, nutrient cycling, and metabolism. In phase two, the biotic influences of oysters is being examined by comparing creeks possessing oyster reefs with creeks in which oyster reefs have been carefully removed. Preliminary results indicate little system level effects from oyster

removal, but indicate that seasonal changes in nekton utilization may be important. This study has advanced the scientific understanding regarding the interaction between benthic filter feeding systems and the biological and physical components of tidal creeks. By coupling an undergraduate university, a research university, and a field laboratory this project also provides up-to-date and hands-on training for a number of excellent undergraduates and future scientists. We also receive a Research Experience for Undergraduates (REU) supplement from NSF for additional students during the summer period. See map location no. 15 and 16.

Influence of oyster reefs on the structure and productivity of microbial communities: a NSF CREEK Project Substudy.

Investigators: Drs. Alan Lewitus[1], Eric Koepfler[2], and Kenneth Hayes[1], and Mike Wetz[2],
Baruch Marine Laboratory, USC[1] and Coastal Carolina University[2]

North Inlet is characterized by dense oyster reef communities, which are thought to regulate microbial populations by their grazing and nutrient regenerative activities. It was hypothesized that the removal of oyster reefs would lead to an increase in the relative abundance of small phytoflagellates and primary productivity, based on the selective effects of oyster grazing and nutrient (particularly NH_4) production. The hypothesis is tested by a) monitoring nutrients and microbial food web structure in tidal creeks with vs. without oyster reefs, b) conducting bioassay experiments to compare the effects of substrate additions and grazing pressure in water from those creeks, and c) using flow-through flumes to examine the effect of live oysters on creek water microbial community structure at simulated tidal flow velocities. Analysis of pre-manipulation data (i.e. prior to oyster reef removal) indicates that, although physical variability among all creeks is pronounced, the seasonal patterns in the structure and regulation of phytoplankton communities are similar. For example, the transition from spring to summer is characterized by similar increases in the ratio of phytoflagellates:diatoms, decreases in the responses of phytoplankton to N additions, and increases in the effect of microzooplankton grazing on phytoplankton growth. Ongoing analyses of post-manipulation monitoring and experimental results will reveal whether oyster removal leads to a) a greater response to N enrichment (expected if oysters are indeed an important N source), and b) a greater effect of microzooplankton grazing (expected if oyster grazing on microzooplankton is important). This study is funded for the period July 1, 1995 to December 31, 1999

Acid-base and Blood Gas Measurements of Intertidal Oysters In situ

Investigator: Dr. Louis E. Burnett
Grice Marine Laboratory, University of Charleston, SC

The goal of this project is to determine the acid-base status and oxygen levels in the hemolymph of oysters exposed to air at high temperatures.
The oyster beds at the end of the pier at Oyster Landing near the Baruch Field Laboratory were monitored for tissue temperature, pH and oxygen. Hemolymph was sampled in situ from oysters in the field, while carefully measuring field conditions (i.e., ambient air temperature,

shell temperature, tissue temperature, duration of air exposure). Samples were transported on ice to the laboratory where they were analyzed for pH, total carbon dioxide and oxygen.
My students and I have been interested in the adaptive mechanisms oysters use to live in the extreme environmental conditions of the intertidal zone in South Carolina. From our studies we have learned that when oysters are exposed to the air during a low tide, they effectively close themselves off from the external environment. The shells of the oysters become an impenetrable barrier cutting the oyster off from the surrounding air. The limited stores of oxygen within the shell is the only effective source of oxygen and this supply is rapidly reduced. The carbon dioxide produced from the aerobic metabolism is trapped within the shells and this acidifies the oyster tissues, lowering the pH. Both the depletion of oxygen and the acidification of oyster tissues have profound effects on the animal's physiology.

The only thing that the oyster exchanges with its outside environment is heat. An air exposed oyster is at the mercy of the surrounding air temperatures and the radiation of the sun. Oysters exposed to the hot summer sun heat up rapidly, warming to temperatures up to 10^0C warmer than the ambient air. The increase in temperature accelerates the reduction of oxygen stores and the acidification of the internal tissues and produces a deeper acidosis.
These findings indicate that the natural patterns of emersion for South Carolina oysters produce conditions within the oyster resembling those what occur during another environmental extreme, a decline in ambient oxygen levels (hypoxia). My students and I have shown that the low oxygen that occurs within the tissues of the oyster and the extreme acid conditions that occur coincidentally with hypoxia can place oysters at risk to pathogenic infections. Thus, these types of measurements are important in understanding the mechanisms that can contribute to oyster mortality and oyster disease.

While we and other researchers at the Baruch Field Station have done a reasonably good job of documenting environmental extremes tolerated by oysters and the tissue conditions of oysters subjected to these extremes under laboratory conditions, we have not evaluated the tissue conditions that occur within the oysters in the field.
This project is supported by the Belle W. Baruch Foundation Visiting Scholars Program. Sampling was conducted in July 2000

Influence of metabolites from several types of estuarine algae on the filtration rates of *Crassostrea virginica* and *Geukensia demissa*

Investigators: Michael Wetz and Dr. Alan Lewitus
Baruch Marine Laboratory, USC

In recent years, a newly discovered red-tide forming dinoflagellate, *Scrippsiella carolinium*, has appeared in Bulls Bay and North Inlet, SC. There is anecdotal evidence that this organism may have deleterious effects on the health of shellfish. Due to an inability to culture the organism, though, no thorough bioassays have been conducted on shellfish. We intend to use previously published methods to examine the direct effects of *Scrippsiella carolinium* and also filtrates from it on the filtration rates of the oyster *Crassostrea virginica* and the ribbed mussel *Geukensia demissa*. Along with *Scrippsiella*, we will look at filtrates from several other types of microalgae common to North Inlet estuary. This study will provide indications as to whether or not *Scrippsiella* is harmful to shellfish, and on a broader scale will examine the importance of chemoreception on the feeding activity of two common estuarine bivalves.

Temporal variation in the grazing impact of the oyster *Crassostrea virginica* and microzooplankton in a salt marsh estuary

Investigators: Michael Wetz, Kenneth C. Hayes, and Dr. Alan Lewitus
Baruch Marine Laboratory, USC

In previous studies in which we examined the effects of oyster feeding activity on microbial community structure, we showed that: 1) oysters clearly preferred phototrophic nanoflagellates over heterotrophic nanoflagellates and 2) most oyster feeding takes place at flow velocities less than 15 cm/s. To study the influence of current velocity as well as seston composition and concentration (which changes over a tidal cycle) on oyster feeding, we will collect water samples from the mouth and back of two tidal creeks (≈125 to 150m long) bi-hourly over a complete tidal cycle and analyze them for plankton composition using epifluorescent microscopy and HPLC pigment analysis. Also, adult oysters will be deployed for short time periods (≈30 minutes) in the creeks, and after removal will have their stomach contents analyzed. This sampling regime will allow the quantification of grazing rates and food preference by oysters. Furthermore, microzooplankton grazing in the two creeks will be estimated using the dilution method.

Whereas the grazing properties of oysters have been examined in laboratory or mesocosm experimental systems, the proposed study uses a novel and ecologically relevant approach in determining the impact of oyster reefs on plankton community structure in a natural setting. The results on grazing rates and preference will enhance our understanding of the role of oyster reefs in regulating microbial food web structure and ecosystem production.

Relationships between oyster reefs and nekton within small intertidal creeks: a NSF CREEK Project Substudy

Investigators: Drs. Dennis M. Allen[1] and David Bushek[1], Leah Gregory[2] and Brian Milan[2]
Baruch Marine Laboratory, USC[1] and Coastal Carolina University[2]

As one of the substudies associated with the NSF CREEK Project, this effort focuses on the relationship between oyster reefs in small intertidal creeks and the fishes and motile macroinvertebrates which occupy the habitat. During representative tidal cycles and seasons, changes in the composition, abundance, biomass, and length frequencies of all nekton were measured at each of the eight study creeks. Similarities and differences in fauna among creeks with similar oyster biomass/tide volume ratios were established before oysters were removed from four of the eight creeks in the winter of 1998. Relationships between creek geomorphology and nekton densities/composition that were demonstrated for the pre-manipulation year persisted following oyster removal. Some creeks consistently support up to ten times more biomass per cubic meter than other creeks. Information generated in this study will be useful in the future management and restoration of intertidal creek habitat Undergraduate students from Coastal Carolina University participate in the research program.

Fish Community Associated with Subtidal Oyster Shell

Investigators: Richard Lehnert and Dr. Dennis M. Allen
Marine Science Program, USC and Baruch Marine Laboratory, USC

The value of subtidal shell bottoms has been underestimated as essential nursery habitat for many ecologically and economically important species. Ongoing research in Town Creek, North Inlet has shown that a distinct community of decapods and fishes is associated with this substrate. This study is designed to sample subtidal habitat with 1-m2 trays that are filled with substrate matching the surrounding bottom. After a set soak period, the contents of the trays are analyzed for species diversity, abundance, and length frequency analysis. The relative importance of subtidal oyster shell compared to other subtidal substrates (sand and mud) as essential habitat for nekton is not known. Work during summer 2000 will include comparisons of tray catches with sand and shell substrates as well as comparisons with intertidal tray sets. This project started in May 1998 with a tentative end date of Fall 2000, and support is being provided by the USC Marine Science Program and the Baruch Marine Field Lab.

Strong site fidelity of juvenile pinfish (Lagodon rhomboids) in salt marsh creeks

Investigators: Michael Potthoff[1] and Dr. Dennis Allen[2]
Coastal Carolina University[1], Baruch Marine Laboratory[2]

Field experiments are being conducted to determine subtidal and intertidal distribution patterns of juvenile pinfish (Lagodon rhomboids) in the North Inlet Estuary, SC. During summer 1999, mark and recapture experiments were conducted at four locations within a salt marsh creek. Pinfish were marked with site and week specific finclips. Recapture from the same sites, and the absence of cross over from one location to another indicated strong site fidelity. In addition, pinfish initially marked in the subtidal zone were shown to venture into adjacent intertidal creeks at high tide, possibly to increase foraging opportunities. These results suggest that recruiting pinfish tend to select and remain in the same location throughout their first summer. In another set of experiments in summer 2000, marked pinfish were shown to remain within 40 meters of their original marking sites for periods of up to two months. Maintenance of intertidal and subtidal home ranges may minimize intraspecific competition and increase avoidance of migratory predators.

Microhabitat preferences and interactions between grass shrimp and mummichogs

Investigators: Beth Brost[1], Drs. Dennis Allen[2], and Rob Young[1],
Coastal Carolina University[1], and Baruch Marine Laboratory[2]

This study examined animal-habitat relations in the North Inlet Estuary. Habitat choices for fishes and shrimp are vast and they vary in structural composition and accessibility. To better assess estuarine resource quality and its relationship to the animals that inhabit these areas,

it is important to understand patterns and factors affecting habitat use. We hypothesized that individual bottom type preference by two common salt marsh animals, *Palaemonetes* spp. (grass shrimp) and *Fundulus heteroclitus* (mummichogs), would change as a result of interactions between them. A microcosm experiment tank (MET) was used to quantify the relative use of sandy mud and shelly rubble substrates. In single species tests with both sandy mud and shelly rubble, neither grass shrimp nor mummichogs demonstrated a preference. However, in experiments using the same bottom types with both species present, grass shrimp showed a significant preference for shelly bottom. This change in behavior is perhaps in response to disturbance by mummichogs. Unlike grass shrimp, mummichogs did not change preference with the addition of another species. Subsequent experiments are testing whether shrimp responses vary with the size of mummichogs. Other experiments will test the shrimps response to only the scent of the fish.

Salt Marsh Mesocosm

Investigators: Drs. James Morris[1] and Bob Gardner[2]
Dept. of Biol. Sci[1]., and Dept. of Geol. Sci[2]., USC

A series of salt marsh mesocosms are being constructed 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) will be filled with inorganic sediment and planted with cuttings of *Spartina alterniflora*. The sediment surface will have a slope of approximately 20 cm/10 m. A computer-controlled pump will simulate the spring and neap diurnal tides. Experiments will begin in 2000 and continue indefinitely. 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

Ecological Role and Habitat Utilization Patterns of Bottlenose Dolphins in the North Inlet Estuary and Adjacent Waters

Investigator: Dr. Rob Young, Assistant Professor
Dept of Marine Science, Coastal Carolina University

This project began in September, 1997 and seeks to identify resident and/or transient (migratory) populations of bottlenose dolphins in the North Inlet system and to identify their patterns of habitat utilization. This information is used to model the trophic role of dolphins within the system (in terms of the proportion of total primary production required to support the resident dolphins) and to model the potential impact of dolphins upon prey populations. Video photography and image capture are used to identify and catalog individual dolphins based on the shape of the dorsal fin. Resightings of individuals are used to identify resident individuals and to correlate habitat use patterns with various physical and temporal parameters. Bioenergetic models are then used to estimate the ecological role of dolphins within the system. The research is conducted in the North Inlet creek system, Winyah Bay, and adjacent waters. Current bottlenose dolphin research efforts along the east coast are focused on the relative importance of,

and the amount of interaction between, resident, seasonally resident, and migratory populations. This information has a direct impact on population estimates and on the population management response to major events (such as a die-off) which may affect only a portion of the total dolphin population. In addition, this particular study represents a unique opportunity to model the ecological role of an apex predator upon a complex marine ecosystem.

Age, growth, reproduction and population structure of the blacknose shark *(Carcharhinus acronotus)* in the Western North Atlantic Ocean

Investigator: Trey Driggers
Marine Science Program, USC

The blacknose shark ranges from Virginia to Brazil in the western Atlantic, including the Caribbean Sea and the Gulf of Mexico. Although blacknose sharks are abundant in the coastal waters of the southeastern United States, the biology of this species is poorly understood. To effectively manage fisheries, accurate and reliable information regarding the age composition, growth rate, reproduction, and population genetics of each species within the fishery is required. For management strategies to properly address these crucial issues, the best possible biological data must be provided to those charged with establishing regulations for the recreational and commercial sectors. Blacknose sharks are being collected from South Carolina coastal waters off of Charleston, Georgetown, and Little River with longline gear. The purpose of this investigation is to examine the life history of this shark and thus provide vital information necessary for effective management.

An Experimental Assessment of Habitat Quality in Coastal Marine Environments

Investigator: Dr. Keith Walters
Dept. of Biol. Middle TN State University, TN

The similarity and quality of major estuarine habitats are being investigated in a series of growth and survival experiments. Invertebrate species naturally present in one or more estuarine habitats were marked-released and/or caged within adjacent mudflat, oyster reef and saltmarsh sites at multiple tidal creek locations in the North Inlet Estuarine Research Reserve, SC. Marked and caged invertebrates also were placed at an additional location within the anthropogenicaly impacted Murrells Inlet. Currently over 500 marsh periwinkles, *Littorina irrorata*, and 150 ribbed mussels, *Geukensia demissa*, have been sized, wet weighed and either marked-released or caged at the various locations. Growth and survival of the experimental organisms will be monitored throughout 1999/00. Additional species and/or locations will be added to the experiment as time permits. Actual differences in the growth and survival of the experimental snails and mussels, minus any cage or other confounding effects, should reflect differences in the quality of the various estuarine habitats. Results will provide data critical to assessing habitat value and establishing sound habitat management practices in Southeastern estuaries.

Assimilation efficiency of juvenile penaeid shrimp

Investigators: Dr. Bob Feller and Jessica Stephen
Marine Science Program, USC

This study will examine the relationship between food quality and feeding, both in the laboratory and in the field. Juvenile penaeid shrimp will be allowed to ingest feeds that vary in their protein, carbohydrate, and fiber content. Measurements of gut passage time, gut passage rate, growth, and nitrogen and carbon assimilation efficiency will be made. It is hypothesized that as gut passage times increase or as gut passage rate decreases, assimilation efficiencies will increase. There may be a narrow range of food quality that promotes good growth while the least amount of food is wasted (= not assimilated during gut passage). Knowledge of the relationships between food quality and growth will enable shrimp growers to produce a crop with lower feed costs and less damage to water quality from excess feeding. It is anticipated that laboratory results will accurately reflect field results. Studies will be conducted in the vicinity of Oyster Landing in North Inlet and in a local shrimp pond. This study is sponsored by the SC Sea Grant Consortium (NOAA).

Chemically mediated interactions in a sedimentary assemblage.

Investigators: Drs. Charles R. Lovell, Sarah Woodin, David Lincoln, and students
Dept. of Biol. Sci., 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 no. 7. This project has been supported by NSF, ONR, and EPA.

Predator deterrency of biogenic bromophenols—from individual benefits to chemical refugia

Investigators: Deirdre Edwards and Dr. Sarah Woodin
Dept. of Biol. Sci. and Marine Science Program, USC

Many polychaete and hemichordate worms produce brominated hydrocarbons. 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 recruitment cues, allelopathic chemicals, and as predator deterrents. Areas where the sediments are appreciably contaminated by these compounds can act as chemical refuges from predation. Many of the worms that produce these compounds are very

small (< 5cm in length). They do not appreciably contaminate the surrounding sediment, yet they are commonly found throughout temperate infaunal communities. In a series of laboratory and field experiements in the wet lab and at Oyster Landing, 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 hydrocarbons affect infaunal community structure. This project is currently funded by NSF.

Molecular genetic analysis of strains of the oyster parasite *Perkinsus marinus*

Investigators: Drs. David Bushek[1] and Kim Reece[2], and Karen Hudson[2].
Baruch Marine Laboratory, USC[1] and Virginia Institute of Marine Science[2]

The protozoan oyster parasite *Perkinsus marinus* causes Dermo disease in oysters from Maine to Texas. We developed eight molecular genetic markers that can distinguish strains of *P. marinus*. Isolates of *P. marinus* were obtained from 76 oysters collected from Massachusetts to Texas, cloned and screened with the eight markers. Results have demonstrated that *P. marinus* is diploid (contains two sets of chromosomes), that individual oysters may be infected with more than one strain, and that three distinct clades exist (northeast, southeast and Gulf). Despite the 6,561 possible combinations of genes at the eight loci examined, only 13 distinct genotypes were observed. Greatest strain diversity occurred in the southeast, lowest in the Gulf and isolates in the northeast were generally closely related. This last finding suggests that the recent northeast range expansion probably spread from the same region. Additional knowledge of the population genetic structure will help identify mechanisms of dispersal, provide a means to evaluate the effectiveness of management strategies designed to reduce the spread of various parasite strains, and provide a mechanism to enforce management regulations. In the future, we plan to relate genotypes to levels of virulence.

Ecological factors influencing epizootics of the oyster parasite *Perkinsus marinus*

Investigators: Drs. David Bushek[1], Richard Dame[2] and Loren Coen[3], Nancy Hadley[3] and Alan J. Erskine[1]
Baruch Marine Laboratory[1],USC, Dept. of Mar. Sci., Coastal Carolina University[2] and SCDNR Marine Resources Research Institute[3]

Mechanisms triggering epizootics or outbreaks of *Perkinsus marinus* are poorly understood. Temperature and salinity are clearly important factors that influence spatial and temporal patterns with both high temperature and high salinity favoring parasite proliferation. In light of this relationship, it is surprising that *P. marinus* is not a persistent problem in the relatively warm, high salinity estuaries of South Carolina. In addition to temperature and salinity, tidal flushing, host recruitment rates, high temperatures, and dispersal distance have all been invoked to help explain what causes an epizootic. To gain a better understanding, we deployed hatchery-reared disease-free oysters in eight tidal creeks, four of which had native oysters removed. Parasites were found in disease-free oysters within two weeks regardless of location in a creek or whether or not native oysters had been removed. These data appear to

indicate that the parasite is well distributed and broadly dispersed in the North Inlet Estuary. These data are being used to help develop a transmission model for *P. marinus*.

The Role of Oyster Reefs in the Source-Sink Dynamics and Transmission of the oyster parasite, *Perkinsus marinus*

Investigators: Rebecca Ellin[1], Drs. Dave Bushek[2], Alan Decho[3], Stephen Stancyk[1], and Ray Torres[4]
Marine Science Program, USC[1], Baruch Marine Laboratory[2], USC, Dept. of Environmental Health Sciences[3], USC, Dept. of Geology[4], USC

Perkinsus marinus, a protozoan endoparasite, is the causative agent of Dermo disease in the Eastern oyster, *Crassostrea virginica*. This disease poses an important challenge to estuarine management, as *P. marinus* is responsible for oyster mortalities from Maine to Mexico. Much research has been conducted on the *C. virginica-P. marinus* relationship, however, the mechanics of planktonic transmission remain poorly understood. Oysters can serve as either a source by releasing *P. marinus* into the water column or a sink by filtering *P. marinus* from the water column. To address this role, planktonic *P. marinus* concentrations will be quantified from water samples collected over two tidal cycles monthly for one year at the mouths and ends of four creeks involved in the NSF Creek Study, two creeks with oysters and two without oysters. This will allow for examination of seasonal changes and influences of creek hydrology on planktonic *P. marinus* concentrations and the role of oysters on these populations by comparing creeks with and without oysters. Determination of the basic ecology of planktonic *P. marinus* and the parasite's interactions with the host oyster and estuarine environment will allow for more comprehensive management decisions with regard to sustaining and restoring oyster populations affected by *P. marinus*. The NERR-GRF program, South Carolina Sea Grant, and USC Marine Science Program fund this research.

The Caribbean Oyster: Genetic Resource for American Oyster Culture?

Investigators: Drs. Dave Bushek[1] and John Scarpa[2]
Baruch Marine Laboratory[1], USC, and Harbor Branch Oceanographic Insitute[2]

Seafood workers of the Gulf states have experienced unemployment and under-employment due to the decline of resources and seasonality of the eastern oyster fishery (*Crassostrea virginica*). Overharvesting, adverse environmental conditions and disease have resulted in substantial declines in oyster landings. Although the decline of the American oyster industry has been caused by a number of factors, Dermo disease has proven to be a formidable natural problem since it was described in the Gulf of Mexico over forty years ago. Although variations in oyster resistance to Dermo have been demonstrated, resistance levels are low. Additional genetic resources for disease resistance may be found in closely related species, such as the Caribbean oyster, *C. rhizophorae*. Dermo causing parasites have been identified from Caribbean oysters, but Dermo related mortalities have apparently not been problematic for this oyster. The Caribbean oyster could be resistant or conditions in the Caribbean may inhibit the disease or the parasite strains in the Caribean may not be virulent. This project is testing the relative resistance of the Caribbean oyster to Dermo. If resistant to Dermo the next step will be

to identify mechanisms of resistance and, if genetically based, transfer that resistance to the eastern oyster via hybridization and selective backcrossing or genetic engineering. This work is supported by the National Sea Grant Gulf Oyster Industry Program.

Brittlestar population studies: use of skeletal growth rings as markers

Investigators: Stephen Stancyk[1] and William Dobson[2]
Marine Science Program, USC and Dept. of Biol. [1], Appalachian State University[2]

Large populations of brittlestars which live in sediments in the North Inlet Estuary have been the subject 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 no. 8.

Brittlestar regeneration/calcification studies: The effects of arm and disc loss on reproductive effort of Amphipholis gracillima.

Investigators: Stephen Stancyk and Traci Heincelman
Dept. of Biol. and Marine Science Program, USC

Large populations of brittlestars which live in sediments in the North Inlet Estuary have been the subject of many physiological studies over the past decade. The primary objective of the present study is to determine the effects of arm and/or disc loss on reproduction by Amphipholis gracillima. Pieces of tissue are removed from brittlestars in February (beginning of gametogenesis) and May (middle of gametogenesis). Animals are replaced in the field in plastic cores to allow regeneration under natural conditions. In early July (time of first spawning), experimental and field control animals are collected. Gonads are excised, sectioned and stained for assessment of oocyte numbers and diameters. Comparison of experimental with control animals allows determination of how much reproduction is lost due to tissue loss in these burrowing brittlestars. This information will help elucidate environmental effects, particularly predation, on brittlestar reproduction. See map location no. 8.

Population dynamics of rhizosphere nitrogen fixing bacterial assemblages.

Investigators: Dr. Charles R. Lovell, and Kitt Bagwell
Dept. of Biological Sciences and Marine Science Program, USC

This project examines nitrogen fixing bacterial (NFB) assemblages associated with the smooth cordgrass, Spartina *alterniflora*, and the environmental stresses and plant host characteristics affecting them. Stress factor gradients in salt marshes result in a transition from highly productive tall form *Spartina* at the banks of tidal creeks to less productive short form plants at higher elevations. Differences in abundance and activity rhizosphere NFB, which contribute nitrogen to *Spartina*, may also be explained by these stress gradients and by host plant responses to them. Field *Spartina* 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 defined the NFB assemblages of tall and short *Spartina* and explored some of their responses to changing environmental parameters. Current studies examine quantitative responses of specific NFB species to experimental 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 *Spartina* and its microflora. Parallel studies will be launched at the Plum Island Sound LTER site and at Sapelo Island to allow the generality of results from North Inlet to be assessed for most of the Atlantic coast range of *Spartina alterniflora*. See map location 14. This project is supported by the National Science Foundation (1994-2002, so far).

Microbial food web structure/function in North Inlet

Investigators: Drs. Alan Lewitus[1] and Eric Koepfler[2],
Baruch Marine Laboratory, USC[1] and Coastal Carolina University[2]

This study examines the seasonal variability in microbial food web dynamics in North Inlet. In particular, we are focusing on the influence of two factors important to regulating microbial food web structure; nutrient supply and grazing pressure. Our protocol is to incubate natural samples in treatments designed to differentiate between nutrient and grazing effects (e.g. ammonium or glycine addition; prokaryotic vs. eukaryotic inhibitors; dilution), and follow time-course changes in chlorophyll, bacterial numbers, and phytoplankton community composition (HPLC, microscopy). We are finding pronounced seasonal differences in microbial food web structure, and the response of bacteria and phytoplankton to nutrient additions and grazer effects. For example, the summer phytoplankton bloom is marked by a "microbial loop" structure featuring the dominance of phytoflagellates whose population growth is limited by microzooplanktonic grazing and light, but not inorganic nutrients. In contrast, phytoplankton growth (mostly diatoms) is controlled by nutrient supply (ammonium) in the winter. The results are useful in understanding the flow and regulation of material and energy through southeastern salt marsh estuarine ecosystems. This study is from 1994 to present (ongoing).

Use of dissolved organic nitrogen by North Inlet phytoplankton during the summer bloom.

Investigators: Dr. Alan Lewitus[1], Dr. Eric Koepfler[2], and Ryan Pigg[2],
Baruch Marine Laboratory, USC[1] and Coastal Carolina University[2]

North Inlet is a shallow, turbid salt marsh estuary where a summer phytoplankton bloom occurs that is composed primarily of nanoflagellates. Grazing and light-limitation are important

regulatory factors for bloom formation, and nitrogen does not limit phytoplankton population growth, as evidenced by the ineffectiveness of ammonium in stimulating biomass production in bioassay experiments. In contrast, glycine greatly stimulated community chlorophyll concentrations and the abundances of all phytoplankton size-fractions, but primarily the nano- and picoplankton. Comparisons of phytoplankton physiological responses to dissolved organic nitrogen (DON) enrichment in the presence or absence of antibiotics suggested that the stimulatory effect of DON on phytoplankton growth resulted from both direct uptake of the organic substrate (e.g., the nanoplankton) and indirectly through bacterial breakdown (e.g., microplanktonic diatoms). Because phytoplankton growth was light-limited, but not nitrogen-limited, during the bloom, we hypothesize that the stimulatory response to glycine is due its use as a respiratory substrate. The net stimulation of phytoplankton by additions of glycine or other organic substrates stresses the need to consider DOM supply and flux on the regulation of primary productivity in North Inlet and similar salt marsh estuaries. This study is funded since 1994 and is ongoing.

The influence of sediment chemistry on dinoflagellate benthic stages in a North Inlet tidal creek

Investigators: Kenneth C. Hayes and Alan J. Lewitus
Baruch Marine Laboratory, USC and SC DNR / Marine Resources Research Institute

This project examines the influence of sediment and water column properties on the distribution of the planktonic community at the Clambank Bridge site in North Inlet. This is a site where the dinoflagellates *Pfiesteria piscicida* and *P. shumwayae* have been confirmed, as well as the red tide forming *Scrippsiella carolinium*. All three of these dinoflagellates can form benthic resting and active cyst stages, and therefore can settle to the sediment surface until conditions are optimal for growth. This site is highly affected by episodic rain events, and rapid salinity and nutrient (e.g. DOM, NH4, NO3) changes can occur over the course of a tidal cycle. This site is also characterized by low abundance of filter feeders, which are potentially important grazers of dinoflagellates. Sampling occurs twice a week from late March to early October, and weekly for all other months. Surface and pore water samples are collected for plankton analysis (microscopy), pigment analysis (Chlorophyll a and HPLC), and nutrient analysis (NH4, Si, NO3, OP, DON, DOP, TDN, TDP, TN, TP, DOC, DIC). Sediment samples are also brought back to the lab for isolation and culturing of dinoflagellates and other plankton. Water quality is continuously monitored using YSIs.

Physiological ecology of the red tide dinoflagellate, *Scrippsiella carolinium*

Investigators: Bonnie M. Willis[1] and Dr. Alan J. Lewitus[2]
Marine Science Program[1] and Baruch Marine Laboratory[2], USC

Scrippsiella carolinium is a new species of dinoflagellate responsible for red tides in several South Carolina estuaries in spring 1998, 1999, and 2000 (the first red tides reported to be localized to SC estuaries). 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 *Scrippsiella*'s physiological responses (growth, photosynthetic properties) to DOM and inorganic nutrient enrichment (nutrient addition bioassays), and its ability to take up these compounds (Michaelis-Menton kinetics using radiolabeled substrates, microscopic evaluation of uptake of fluorescently-labeled carbohydrates, and exoenzyme activity measurements). The results will enhance our understanding of the potential role of DOM in stimulating red tide formation by *Scrippsiella*.

Resistance of benthic microalgae to haloaromatic toxicity.

Investigators: Dr. Charles Lovell[1], Dr. Alan Lewitus[2], Yung Pin Chen[1], and Dr. Niels Eriksen[3], Dept. of Biol. Sci.[1], Baruch Marine Laboratory[2], USC, and Odense University, Denmark[3]

Among the sediment biota chronically exposed to haloaromatic compounds in nearshore environments are the benthic microalgae (BMA). BMA are highly productive and an important carbon source for estuarine food webs. They also constitute an important link in benthic nutrient cycles, and stabilize soft sediments through their production of exopolymers. Any significant negative impact of haloaromatic compounds on these organisms could have serious consequences for nearshore ecosystem function. However, a previous study showed no impact of biogenic sediment contamination by 4-bromophenol, 2,4-dibromophenol, and 2,4,6-tribromophenol on distributions of BMA biomass or on levels of BMA primary productivity (Steward et al. 1992). The underlying mechanism(s) supporting this resistance is not understood, but may involve degradation of halophenols. We have examined a ubiquitous marine diatom, *Thalassiosira sp.*, for its capacity to degrade halophenols. The specific activities of halophenol-degrading enzymes in *Thalassiosira sp.* were consistent with the capacity to use aromatic compounds as supplemental carbon sources, and in fact exceeded those found in some bacteria that demonstrably utilize various aromatic compounds as their sole carbon source for growth. This capacity to degrade halophenols and various other aromatic compounds, if broadly distributed among diatom species, provides a viable explanation for the resistance of benthic microalgae to haloaromatic contamination in nearshore sediments. This project is funded from 1997 to the present and is supported by the EPA.

Colonization of man-made surfaces in the marine environment.

Investigators: Dr. Charles R. Lovell, and Hongyue Dang
Dept. 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 are now tracking the seasonal dynamics of these primary colonists and determining their interactions with other types of organisms. In some biofilm systems, the primary colonists 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.

Effect of urbanization on iron bioavailability to phytoplankton: A USES project substudy.

Investigators: Dr. Alan Lewitus[1], Dr. Tomo Kawaguchi[2], Dr. Jack Ditullio[3], and Jennfier Keesee[1]
Baruch Marine Laboratory,[1] Dept. Env. Health Sci.[2], USC and College of Charleston[3]

Iron is an essential growth requirement for phytoplankton. Although iron is generally abundant in coastal regions, only limited fractions can be assimilated by phytoplankton because bioavailable iron species are highly unstable in oxygenated seawater. One way in which iron bioavailability can be enhanced is by chelation to dissolved organic matter (DOM). We hypothesized that urbanization-associated deforestation in Murrells Inlet caused a reduction of iron bioavailability to estuarine phytoplankton by decreasing the supply of forest-derived DOM (i.e. the iron chelation source). To test the hypothesis, we are comparing Murrells Inlet with North Inlet, a forested estuary. We found sharply lower concentrations of bio-available iron and a higher potential for iron limitation in phytoplankton communities in the urbanized Murrells Inlet estuary, consistent with our hypothesis. The results suggest that organically-bound iron produced by coastal forests plays an important role in maintaining iron bioavailability to phytoplankton, and therefore the potential effect of forest clearing on the quality and quantity of stream dissolved organic material should be an important consideration in coastal zone management strategies. This study is funded from 1996-present.

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

Investigators: Drs. Alan Lewitus[1], Allen Southerland[2], Alan Decho[2], Gary Kleppel[2], and Jennfier Keesee[1]
Baruch Marine Laboratory[1], and Dept. Env. Health Sci.[2], USC

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. β-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.

CISNet: A molecular- to landscape-scale monitoring of estuarine eutrophication

Investigators: Drs. James Morris[1], Madilyn Fletcher[2], John Jensen[3], Alan Lewitus[4], Peter Noble[2], Dwayne Porter[5], and Raphael Tymowski[4]
Dept. of Biol. Sci.[1], Baruch Institute[2], Dept. of Geography[3], Baruch Marine Laboratory[4], and Dept. Env. Health Sci.[5], USC

Eutrophication of our coastal waters as a result of increasing coastal development is a major threat to fisheries and recreational uses, and poses a significant human health risk. Monitoring research will be conducted at North Inlet that enhances and extends the long-term, intensive monitoring program (LTER; NERR) of this oligotrophic (e.g. low nutrient) estuary. Similar measurements will be obtained from the ACE Basin, a system characterized by much higher nutrient levels. Ongoing data collection will be linked with novel measurements of phytoplankton and bacterial community structure, made possible by advances in molecular biology and analytical chemistry, and to remotely sensed indices of wetland productivity and change at the landscape-scale. Comparison of the relationship between nutrient and food web dynamics in these estuarine systems with extremely different nutrient loading patterns will lead to a greater understanding of the effects of eutrophication on the structure and function of estuaries. This study is funded from 1999-present.

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

Investigators: Dr. Alan Lewitus[1], Dr. JoAnn Burkholder[2], Howard Glasgow[2], Kenneth Hayes[1], and Bonnie Willis[1]
Baruch Marine Laboratory, USC[1] and North Carolina State University[2]

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 which 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 1995-present.

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], Kenneth Hayes[1], Bonnie Willis[1], Ivy Collins[1], Scott Gransden[1], Dr. JoAnn Burkholder[2], Howard Glasgow[2], and Dr. Patricia Glibert[3]. Baruch Marine Laboratory, USC[1], North Carolina State University[2], and Horn Point Laboratory, University of Maryland[3].

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.

Fish kill/lesion event response: The South Carolina Task Group on Toxic Algae.

Investigators: Dr. Alan Lewitus, Kenneth Hayes and several others from SC. Baruch Marine Laboratory, USC.

Given the growing recognition that *Pfiesteria piscicida* was a problem in NC and MD with respect to ecosystem and human health, its discovery in North Inlet in 1997, and its potential link to the fish lesion problems in Bushy Park and elsewhere, 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 was organized by Rick DeVoe (SC Sea Grant Consortium) and includes representatives from USC, SC DHEC, SC DNR, NOAA/NOS, Clemson University, MUSC, USGS, and Charleston VA

Medical Center. One of the first accomplishments of the group was to implement a program to monitor for *P. piscicida* (ECOHAB-funded) and respond to fish kills or lesion events in the summer of 1998 (CDC grant to SC DHEC), with particularly emphasis on the Bushy Park region, the site of recurrent menhaden lesion occurrence. From July-October, 1998, we analyzed water samples from several fish kill or lesion events throughout SC (in collaboration with SC DHEC and SC DNR). Presumptive *Pfiesteria* abundances were consistently low compared to NC areas impacted by the dinoflagellate, with 62 and 34 cell/ml in two Hilton Head samples, but < 15 cell/ml in all other samples. Thus, evidence linking *Pfiesteria* to SC fish events was lacking. This proactive program is ongoing, with plans to continually expand research efforts in environmental and human health surveillance. This project is funded for the period 1998-present.

Accelerated Research in Biofouling Control

Investigators: Wes Johnson[2], Susan Hauswaldt[2], Drs. Peter Noble[1], Wally Scrivens[3] and Madilyn Fletcher[1],
Mar. Sci. Prog., USC[2], Baruch Institute, USC[1] and Chemistry Dept., USC[3]

The primary goal of this study is to develop novel approaches for control of microbial fouling by (1) developing fouling resistant surfaces from highly defined organic surfaces, and (2) applying molecular and microscopic methods to characterize composition and succession in biofilms on materials with different surface functional groups. Briefly we are (1) characterizing the adherence of marine microbes to different types and combinations of self-assembled monolayers (SAMs) constructed from alkanethiols, (2) screening test surfaces for resistance to bacterial attachment (microscopy, image analyses), and (3) characterizing adherent microbial communities (e.g., stable low molecular weight rRNA analysis, PCE/DGGE of 16S rRNA.
The work is conducted at the Baruch Marine Field Laboratory and University of South Carolina (Columbia). The study will provide information on the initial adherence of microbial communities to test surfaces and addresses the question: Do different types of microbes attach to specific types (e.g., hydrophilic vs. hydrophobic) of surfaces? The study is funded by University Research Initiative Program for Combat Readiness, US Dept. of Defense/Office of Naval Research. The study period for this project is June, 1997-May, 2000

Estuarine eutrophication and microbial community compositions.

Investigators: Wes Johnson[1], and Drs. James Morris[2], Peter Noble[3] and Madilyn Fletcher[3]
Marine Sci. Program[1], Dept. of Biol. Sci.[2], and Baruch Institute[3], USC

This project examines the effects of increased nutrient-loading (nitrogen and phosphate) on microbial community compostion. Microbial compositions of sediment communities will be determined by amplifying 16S rRNA using polymerase chain reaction (PCR) and separating the amplified products using denaturing gel electrophoresis (DGGE). The study will be conducted at the Baruch Marine Field Laboratory and University of South Carolina (Columbia). Comparison of the sampling sites will enable us to determine if there are differences in the microbial community structure as a function of the nutrient amendments (nutrient-loading). 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 Sept., 1999-Aug., 2002

Microbial genomes compared by a back-propagating neural network and cluster analysis of tetranucleotide frequencies.

Investigators: Drs. Peter Noble and Jonas S. Almeida
Baruch Institute, USC

This study examines the heterogeneity among and between different genomes, to determine the true relatedness of regions of genomes which would otherwise appear to be similar due to biases associated with DNA replication and repair systems, DNA restriction/modification enzyme systems, and coding preferences. Training a back-propagating neural network to recognize the oligonucleotide frequencies of sections of genome DNA, and using the trained neural network to compare different sections of microbial genomes. The research will be conducted at the Baruch Institute, University of South Carolina (Columbia). The significance of this study is to determine the underlying structure/function of genomes which presumably will provide an better understanding of how genomes evolve. The study is funded by NSF from Dec., 1998-June 2000.

Novel mathematical approaches for determining ecosystem structure and dynamics.

Investigators: Drs. Peter Noble[1], Jonas S. Almeida[1], Alan Lewitus[2], and Madilyn Fletcher[1]
Baruch Institute[1], and Baruch Marine Laboratory, USC[2]

This study is designed to investigate the complexity and the dynamic properties (dimensionality, entropy and instability) of North Inlet estuary using physical and nutrient data from the LTER database (1981-1993), to determine the relationship between the dynamic properties and the marine microbial community (e.g., phytoplankton/bacteria/microeukaryotes), and to develop unifying measures for characterizing the dynamic properties of ecosystems. The work is being done at the Baruch Institute, University of South Carolina (Columbia). The significance of this research is its potential for development of new physical concepts for understanding the dynamic behavior of natural ecosystems. The study is funded by EPA/NOAA/NASA, CISNET: Molecular to Landscape-Scale Monitoring of Estuarine Eutrophication and NSF (SGER) July 1st, 2000-June 30th, 2001.

Interspecific competition among some salt marsh perennials in South Carolina

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

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 no. 14 and 20.

HUMAN IMPACTS: HABITAT ALTERATION, POLLUTION, AND MANAGEMENT

Urbanization and Southeastern Estuarine Systems (USES)

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], Hank McKellar[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]
Baruch Institute, USC[1], Dept. of Env. Health Sci., 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:

1. to delineate the impact of multiple stresses resulting from urbanization on high-salinity estuaries; and
2. 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. Several of the sub-studies are

described elsewhere in this document. For more information on the USES project, please visit our Web presentation at http://www.baruch.sc.edu/usesweb/useshome.html. This project is funded through Sea Grant/NOAA/Dept. of Commerce for the period 1 July 2000 – 30 June 2001.

Modeling fecal coliform levels from human sources based on land use characteristics in Murrells Inlet, SC

Investigators: Heath Kelsey[2], Dr. Dwayne E. Porter[1,2], Dr. Geoff Scott[2,4], Dr. Tom Siewicki[2,4], and Dr. Jim Hussey[2]
Baruch Institute[1], Dept. of Env. Health Sci. [2], and Department of Statistics[3], USC, and NOAA's Center for Coastal Environmental Health and Biomolecular Research[4]

This project seeks to predict human source fecal coliform contamination in the surface waters of Murrells Inlet, 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 such as septic tanks and high population densities.

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 Murrells Inlet area. 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 as part of the USES project through Sea Grant/NOAA/Dept. of Commerce for the period 1 July 2000 – 30 June 2001.

Watershed analysis and nutrient loading

Investigators: Drs. Hank McKellar and Dan Tufford
Department of Environmental Health Sciences, USC

This project is a component of the USES research program that's related to watershed/stream nutrient runoff. The project is designed to quantify patterns of nutrient runoff from small coastal watersheds. We are currently sampling a spectrum of 12 coastal streams over a range of land uses and hyrologic conditions. Monthly grab samples are analyzed for total nitrogen and phosphorus, plus dissolved organic fractions and dissolved inorganic components (ammonia, nitrate/nitrite, o-phosphate). The freshwater stream inputs to Oyster Creek and Bly Creek (The other locations are in Murrell's Inlet). Information on patterns of nutrient transport in coastal streams will be incorporated into developing models of land use and water quality. Such models will be useful in issues of land use planning and management in coastal areas. This project is funded through NOAA for the period June, 1990 – May, 2000

Identification of Metal-Responsive Genes from the Mummichog *Fundulus heteroclitus* by Differential Display

Investigators: Nikki Maples and Dr. L. J. Bain
Department of Environmental Toxicology, Clemson University

Shipyard Creek is an estuarine site near Charleston, South Carolina that has been adversely impacted with numerous heavy metals, with the dominant contaminant at the site being chromium. We are using mummichogs (*Fundulus heteroclitus*) as an indicator species to study the chronic effects of metal contamination on organisms at this site. As there are few suitable biomarkers to monitor exposure to chromium, we used differential display reverse transcription-polymerase chain reaction (DD RT-PCR) to examine the effects of chromium on these fish. DD RT-PCR is a technique that permits us to examine hundreds of genes at the same time in the livers of these fish exposed to metals. We captured fish from the North Inlet National Estuarine Research Reserve and exposed them in the laboratory to three different concentrations of trivalent chromium, and compared their pattern of gene expression to mummichogs collected from Shipyard Creek. Differences in RNA expression between exposed and unexposed fish were then confirmed by Northern blots. We have found several differentially expressed genes in the fish exposed to chromium, which include a putative sodium channel protein and a putative DNA helicase. We hope to use the differentially expressed genes as biomonitoring probes to assess contaminant exposure of mummichogs at other sites.

The spatial and temporal trends in water quality and phytoplankton community composition in an urbanized estuary and non-urbanized estuary

Investigators: David White[1,3], Dr. Dwayne E. Porter [1,2,3], Dr. Alan Lewitus[1,2,3]
USC's [1]Baruch Institute for Marine Biology and Coastal Research, [2]The School of Public Health, and [3]Marine Science Program

This research examines North Inlet (NI), and Murrells Inlet (MI), SC, for spatial gradients in nutrients, phytoplankton biomass, and phytoplankton community composition in relation to land use and land cover. Both estuaries are high salinity, shallow, tidally dominated systems that are similar in structure and function. However, MI is affected by non-point source pollution, whereas NI is relatively unimpacted anthropogenically. The research objectives are to: (1) provide an analysis of eutrophication and its influence on biomass and phytoplankton composition; (2) examine the relationship between nutrient ratios and community structure; and (3) utilize Geographic Information Systems (GIS) to correlate the spatial relationships among land use and land cover, eutrophication, phytoplankton community composition, and biomass. This research will address the effects of non-point source pollution on estuarine ecosystems and mechanisms for sustaining resources within estuarine ecosystems by examining the role of land use and land cover in non-point source pollution in its relation to phytoplankton biomass and community structure. This project is funded by a NOAA NERRS Graduate Research Fellowship awarded to David White for the period of 1 June 2000 – 31 May 2001.

DNA damage in marine invertebrates exposed to natural and anthropogenic stressors.

Investigators: Michel L. Gielazyn[1], Drs. Stephen E. Stancyk[1,2], Amy H. Ringwood[3], and Walter Piegorsch[4]
Marine Science Program[1], Department of Biological Sciences[2], USC, SCDNR Marine Resources Research Institute[3], Department of Statistics[4], USC.

Contaminants are introduced into marine environments via rivers, land runoff, direct application, or from the atmosphere. Exposure to these pollutants coupled with natural stressors can result in decreased growth, fecundity, and/or survivorship for exposed organisms. Biomarkers can be used to identify cellular level effects of stress, which range from depletion of compounds that protect the cell, such as glutathione, to direct damage of DNA. The primary focus of our current research is examining DNA damage in invertebrates as a result of exposure to both natural and anthropogenic stressors. We are using single cell gel electrophoresis, or the comet assay, to detect DNA damage in different tissues. Currently, we are primarily working on oysters from Charleston Harbor, but we are also collecting the brittlestar, *Amphipholis gracillima*, from North Inlet and adapting the comet assay for use with tissues from this organism. Our future research will be concerned with assessing the practicality of using of the comet assay, in combination with other biomarkers, in marine habitats for environmental monitoring. See map location 8.

CISNet: Molecular to landscape-scale monitoring of estuarine eutrophication (Remote Sensing component)

Investigators: Drs. Dwayne E. Porter[1,2] and J.R. Jensen[3]
Baruch Institute[1], Dept. of Env. Health Sci[2], and Department of Geography[3], USC

Chlorophyll-a is highly absorbent of radiation in the spectral range of 630-690 nm and reflective in the range of 760-900 nm. Previous attempts to estimate biomass from remote images have met with limited success in part because the concentration of chlorophyll in leaf tissues is not constant. Instead, chl-a concentration in tissue varies with phenology and with nutrition. However, since photosynthetic rate and chl-a concentration are directly related, chl-a concentration is actually a more sensitive indicator of the condition of higher plants than biomass and should be investigated as an index of stress. We have hypothesized therefore that at a landscape-scale, remote sensing of the concentration of chlorophyll in emergent wetland vegetation will provide a quantitative index of the wetland condition. During the first two years (1999, 2000) we will develop a model to assess the functional condition, as measured by chlorophyll content in emergent vegetation, of the *Spartina*-dominated coastal wetland. For the subsequent year, this model will be applied to the study site and we will monitor changes in the estuary. This project is funded by EPA from 1 January 1999 – 31 December 2001.

CISNet: A molecular- to landscape-scale monitoring of estuarine eutrophication

Investigators: Drs. James Morris[1], Madilyn Fletcher[2], John Jensen[3], Alan Lewitus[4], Peter Noble[2], Dwayne Porter[5], and Raphael Tymowski[4]
Dept. of Biol. Sci.[1], Baruch Institute[2], Dept. of Geography[3], Baruch Marine Laboratory[4], and Dept. Env. Health Sci.[3], USC

Eutrophication of our coastal waters as a result of increasing coastal development is a major threat to fisheries and recreational uses, and poses a significant human health risk. Monitoring research will be conducted at North Inlet that enhances and extends the long-term, intensive monitoring program (LTER; NERR) of this oligotrophic (e.g. low nutrient) estuary. Similar measurements will be obtained from the ACE Basin, a system characterized by much higher nutrient levels. Ongoing data collection will be linked with novel measurements of phytoplankton and bacterial community structure, made possible by advances in molecular biology and analytical chemistry, and to remotely sensed indices of wetland productivity and change at the landscape-scale. Comparison of the relationship between nutrient and food web dynamics in these estuarine systems with extremely different nutrient loading patterns will lead to a better understanding of the effects of eutrophication on the structure and function of estuaries. This study is funded from 1999-present.

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

Investigators: Drs. D.E. Porter, J.R. Jensen[2], Cassandra Coombs[3] and Jeff Allen[4]

Department of Env. Health Sci[1]., Geographic Information Processing Laboratory, Baruch Institute[1], Dept. of Geoghraphy[2], USC, College of Charleston[3], Strom Thurmond Inst., Clemson[4]

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:

1. Can remote sensing methods be used to measure the health of the wetlands using LAI (leaf area index) and biomass
2. Can we assess pattern ecological succession in wetland environments using remotely sensed data?
3. Can natural and anthropogenic factors that influence marsh erosion rates be quantified?
4. What is the amount of wetlands loss?
5. What is the greatest contributor to wetland erosion?

This study is funded by NASA for the period 04/01/97 – 03/31/01

Habitat utilization and growth of juvenile flounder, with emphasis on the ecology and life history of the fringed flounder, Etropus crossotus.

Investigators: Marcel Reichert, Dr. John Mark Dean & Dr. Robert Feller
Marine Science Program, USC

Habitat alteration is considered the greatest long-term threat to marine fisheries productivity, but there is a lack of direct information on the interaction of habitat utilization and recruitment of juvenile fish in the estuarine nursery grounds. This information is important for resource managers and can be used in policy development and implementation. This study, part of an international cooperative project of the University of South Carolina, Louisiana State University, and the Netherlands Institute for Sea Research. From July 1993 through August 1998, quantitative monthly sampling has been conducted to determine the species distribution, abundance, and age structure of juvenile flatfish populations in the North Inlet and Winyah Bay area. Distribution and abundance of various flatfish species are analyzed to provide information on the habitat utilization of these species. Growth of selected species is examined on the basis of information extracted from the otoliths. We will use this information to estimate the growth of juvenile flatfish and compare this information on maximum growth rates available in the literature or from growth experiments. Increment formation in the otoliths were validated, and growth rates were determined in laboratory experiments for the fringed flounder (see above). In the fall of 1999 we expect to resume the monthly sampling of juvenile flatfish. Pending funding, additional experimental work is planned to provide similar information for other species.

This project is funded by the Baruch Institute.

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 David Whitaker[1]
South Carolina Department of Natural Resources[1] and Baruch Marine Laboratory, USC[2]

Fishing Stamp purchasers and commercial fisherman utilize the state's oyster and clam resources as a fishery. We currently have little quantitative information on how long it takes heavily fished areas that undergo annual and significant harvesting or areas hit with large die-offs to regain the productivity and ecological value as nursery habitat for functionally important fishes. This information is critical to the development of effective oyster management strategies. Recent concerns have also arisen regarding the impact of boat wake disturbance on tidal creek habitats, including oyster reefs. This study will evaluate the impacts of oyster harvesting, oyster die-offs and boat wakes on the stability and recovery of oyster reefs. To accomplish this objective we are (1) examining recruitment, growth, and survival of oyster spat as an indicator of recovery and recruitment potential on shell repletion and natural sites and then (2) following recovery of manipulated sites after 'simulated' harvesting, repletion, and/or major population die-offs and finally (3) examining the impact of boat wakes in tidal creeks and their interaction with shell replenishment stability and development. This work will build upon ongoing oyster studies by MRRI staff, in conjunction with researchers at USC's Baruch Lab. This study will provide scientists and research managers with information on the impact harvesting levels, boat wakes and die-offs have on habitat quality, resource 'sustainability' and resource recovery.

Modeling the impacts of anthropogenic and physiographic influences on grass shrimp in localized salt marsh estuaries

Investigators: James Daugomah[3], Dr. Dwayne E. Porter[1], Dr. Geoff Scott[3], Dr. Don Edwards[2]
Baruch Institute[1], Dept. of Statistics[2], USC and Southeast Fisheries Science Center-Charleston Laboratory National Marine Fisheries Service, NOAA[3]

The complexity and severity of ecological impacts associated with coastal growth demands that resource managers explore new spatial analytical techniques combined with multi-disciplinary scientific expertise for proactive coastal zone management. Arising from these environmental concerns and the identified need for adequate databases and integrated models, an ongoing long-term study of the impacts of urbanization on localized coastal estuaries of the southeastern United States was initiated in 1990. A goal of the Urbanization and Southeastern Estuarine Systems (USES) study is to examine the role of Geographic Information Processing (GIP) to integrate data and scientific expertise for the identification, assessment, and modeling of anthropogenic and physiographic relationships within coastal estuaries. This goal is being achieved through the implementation and utilization of a multi-agency Geographic Information System (GIS) and the development and validation of spatially explicit models. This work involves spatial modeling efforts that incorporate land use and land cover characteristics with fisheries data to assess and predict the impacts of anthropogenic and natural influences on key species that inhabit critical estuarine habitats. A spatial assessment of two small, high-salinity estuaries suggests that upland development adjacent to critical estuarine habitat limits the population size and distribution of adult and larval grass shrimp (*Palaemonetes pugio*). Modeled

spatial distributions of adult populations suggest estuarine "deserts" -- wetlands and stream reaches adjacent to commercial and residential land use void of natant fauna. This approach is being developed for coastal resource managers to predict the impact of proposed landscape modifications prior to occurrence of changes. This project is funded as part of the USES project through Sea Grant/NOAA/Dept. of Commerce for the period 1 July 2000 – 30 June 2001.

Impacts of Urbanization on Dermo Disease in Oysters

Investigators: Drs. David Bushek[1], Dwayne Porter[2], Don Edwards[3], and Dave White[4], Jennifer Keesee[1]
Baruch Marine Laboratory[1] and Baruch Institute, USC[2]; Dept. of Statistics[3] and Marine Science Program, USC[4]

The spatial and temporal patterns of Dermo disease in the undeveloped North Inlet Estuary are being compared with patterns in the Murrells Inlet Estuary, a similar but developed system. Both systems show typical seasonal patterns of infection and remission with intensification occurring over the summer to a peak in the late fall. An outbreak or unusual intensification of the disease occurred in the developed system during the 1996 seasonal peak, but both systems have responded similarly to events such as El Nino and La Nina since then. Incorporation of the data into a GIS data base has identified hot spots of intensification that appear each year within each system, but appear to be associated with different phenomena in the different systems. In Murrells Inlet, highest intensities are associated with areas that have been more extensively developed and the waterways that are most frequently traveled by boaters. In North Inlet, hot spots are associated with tidal nodes and areas that are poorly flushed. Monitoring is continuing to verify these patterns and experiments are being developed to test hypotheses about potential cause and effect relationships. This project is funded as part of the USES project through Sea Grant/NOAA/Dept. of Commerce for the period 1 July 2000 – 30 June 2001

EDUCATIONAL AND SERVICE PROJECTS

An important objective of the Baruch Marine Field Laboratory is to link the research conducted at the field station with the education of students at different stages of their careers, various agencies that need the information for management decisions and the general public to increase awareness. Most of the projects described above make undergraduate and graduate students key participants of the investigations. The following projects enhance these efforts and also reach out directly to agency officials, K-12 students and teachers, and the general public.

Marine information processing applications in marine science undergraduate laboratories

Investigators: Drs. Bjorn Kjerfve[1,3], Stephen E. Stancyk[1,3] and Dwayne E. Porter[1,2,3]

USC's [1]Baruch Institute for Marine Biology and Coastal Research and [2]The School of Public Health, and the [3]Marine Science Program

We have been funded to improve the teaching of marine and coastal sciences to students by acquiring the infrastructure necessary to integrate information processing (IP) technologies into graduate and undergraduate curriculums. Building on the expertise of USC in teaching the techniques of GIS and remote sensing, we will be providing students interested in marine and coastal issues hands-on experience utilizing IP tools in lecture and lab settings. This new facility will include an HRPT satellite receiving system, computer software and hardware necessary for processing marine and coastal data, and field-capable instruments including laptops, radiometers, ceptometers, and GPS units. Developed courses will extensively utilize the resources of the Baruch Marine Field Lab and the long-term environmental databases maintained by the Baruch Institute. Particular attention will be paid to applied coastal zone management issues relevant to the NERRS program. These experiences will help graduates become better prepared to enter the job market and participate in solving complex environmental and societal problems. This project was originally funded by the NSF with supporting funds from the College of Science and Mathematics at USC.

Continuing support of the National Estuarine Research Reserve System Centralized Data Management Office

Investigators: Dr. Dwayne E. Porter[1,2], M. Crane[1], T. Small[1], and A. Norman[1]
USC's [1]Baruch Institute for Marine Biology and Coastal Research and [2]The School of Public Health

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:

(1) estuarine water quality monitoring,
(2) biodiversity monitoring, and
(3) 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. For more information on this project, please visit the CDMO's web presentation at http://inlet.geol.sc.edu/cdmohome.html. This project is funded by SCDHEC/OCRM/NOAA for the period 1 September 1999 - present.

Development of a GIS-based Database Management Program to Characterize Sources and Effects of Natural Parameters and Anthropogenic Impacts to Coastal Ecosystems

Investigators: Drs. Dwayne E. Porter[1,2], Tom Siewicki[2,3], Jeff Allen[4], Marj Aelion[1,2], and Dan Tufford[2]
USC's [1]Baruch Institute for Marine Biology and Coastal Research and [2]The School of Public Health, and [3]NOAA's Center for Coastal Environmental Health and Biomolecular Research, and the [4]Strom Thurmond Institute, Clemson University

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. For more information on the LU-CES project, please visit our Web presentation at:
http://www.baruch.sc.edu/luces2/luces/LUCES_1.HTML.
This project is funded through Sea Grant/NOAA/Dept. of Commerce for the period 1 August 2000 – 31 July 2004.

Estuary-Net Project - National Estuarine Research Reserve System

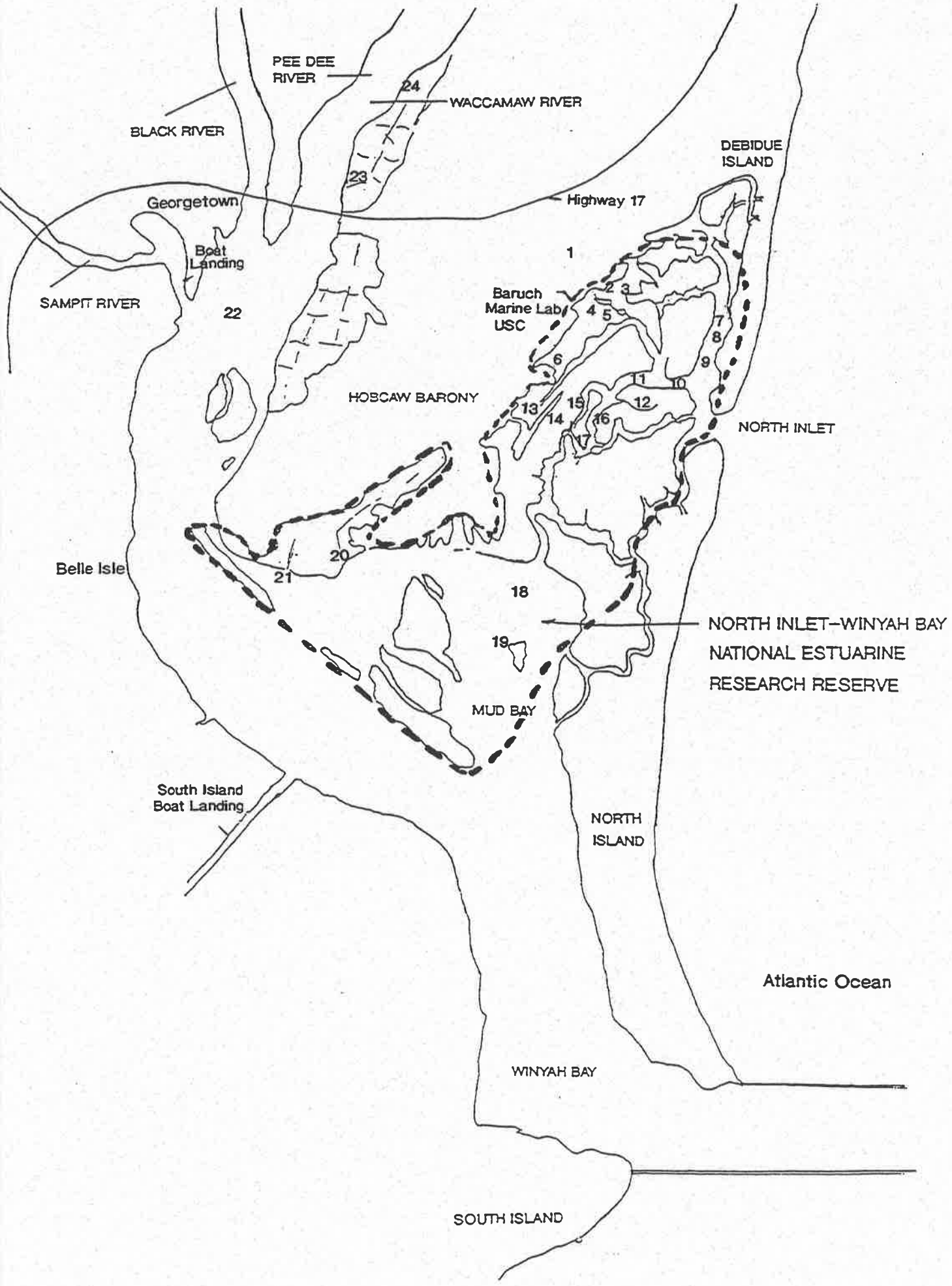
Investigators: Wendy Allen and Beth Thomas
Baruch Marine Laboratory, USC

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 instructional materials 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 results with other Estuary-Net participants around the country through the Estuary-Net web site: http://inlet.geol.sc.edu/estnet.html.

Education Activities - National Estuarine Research Reserve System

Investigators: Wendy Allen and Beth Thomas
Baruch Marine Laboratory, USC

Educational activities that integrate findings from research are offered throughout the year. Marsh-side chats 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. Workshops on current coastal issues are also offered for decision-makers. 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


PEE DEE RIVER
24
WACCAMAW RIVER
BLACK RIVER
DEBIDUE ISLAND
23
Georgetown
Highway 17
Boat Landing
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SAMPIT RIVER
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Baruch Marine Lab USC
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HOSCAW BARONY
NORTH INLET
20
Belle Isle
21
18
NORTH INLET–WINYAH BAY NATIONAL ESTUARINE RESEARCH RESERVE
19
MUD BAY
South Island Boat Landing
NORTH ISLAND
Atlantic Ocean
WINYAH BAY
SOUTH ISLAND