CURRENT RESEARCH PROJECTS

1999 - 2000

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 505 scientific research projects and about 280 student theses and dissertations have been completed by Baruch Institute research associates since 1969. This work has resulted in the publication of more than 1200 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 92 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. A wide variety of basic and applied research is represented. 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). Although many other investigators presently use the Field Laboratory to support their studies, the list includes only those projects which make regular use of the site.

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://inlet.geol.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: Chris Aadland, Paul Kenny, Mark Crane, and Dr. Evan Chipouras
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. Evan Chipouras [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. Other analyses yield data on 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. Evan Chipouras[1], Dave Nemazie[2], et al.
Baruch Marine Laboratory, USC[1], Chesapeake Bay - Maryland National Estuarine Research Reserve[2]

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 is considering adding 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 23 NERR sites around the country and has recently begun measuring weather parameters at many of these Reserves. Approximately half of the NERR sites will be participating in this one-year pilot program to test the performance of a fluorescence probe developed by YSI that will couple directly to the 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 500 microns in size, comprise the meiofauna. The 25 year long meiofauna study represents the longest estuarine meiofauna time series in the world. Dozens of macrobenthos species, including a variety of worms and clams, are sieved, identified, and counted in replicated macrobenthos core samples. 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. See map location no. 11 and 12.

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

Investigators: Dr. James Morris and Robin Krest
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: 18 years of continuous monitoring

Investigators: Dr. Dennis M. Allen[1], Dr. Steve Stancyk[2], Paul Kenny[1], Chris Aadland[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, Chris Aadland, 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 contribution of individual species 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.

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], Dave White[3], Ben Jones[2] and Jennifer Keesee[1],
Baruch Marine Laboratory[1], Baruch Inst. USC and Global Information Processing Lab[2], and Marine Sci. Program[3], USC

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 on subtidal oysters are well known and have been correlated with temperature and salinity. The warm, high salinity waters of small bar-built estuaries of the southeast appear to 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 a relatively new geostatistical analysis (kriging) within a geographic information system (ARCINFO), hot spots of intensification have been identified and are 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. The accumulating temporal data is providing insight into inter-annual variation. Coupling these data with the long-term atmospheric and water quality data will highlight new associations and help to elucidate mechanisms that drive natural cycles of this important oyster pathogen.

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 nongame 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 1998. 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 Pumpkinssed are some of the highest in the state. See map location no. 19.

Sea Turtle Nest Monitoring on Debidue Beach/Hobcaw Barony

Investigators: Betsy Brabson[1], Debidue Beach Coordinator, Chris Aadland[2], Wendy Allen[2], Robin Baugn[1], Becky Ellin[2], Lisa Free[1], Dan Harkins[4], Jennifer Keesee[2], Carrie Lucas[3], Raphael Tymowski[2], Lucy Woodhouse[4]
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 are participating in the monitoring program this year. Volunteers walk the beach early in the morning during the nesting and hatching season, and 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.

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
Department of Geological Science, USC

The effects of fresh groundwater flow from upland forests on adjacent salt marshes, such as at North Inlet, are not yet well understood. We have installed bundles of piezometers at numerous stations along three forest-marsh transects across the Crabhaul Creek basin at the North Inlet National Estuarine Research Reserve site (map location 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.

The Distribution and Dynamics of Fiddler Crab Burrowing and its Effect on Salt Marsh Sediment Composition and Chemistry in a Southeastern Salt Marsh

Investigator: Barbara McCraith
Marine Science Program, USC

Fiddler crabs are one of the principal agents of bioturbation in salt marsh ecosystems. Burrowing activity can modify the physical, chemical, and biological properties of sediments. My study examined the effect of fiddler crab burrowing on sediment reworking, the distributions of ^{210}Pb and ^{137}Cs in salt marsh sediments, and the influence of fiddler crabs on the exchange of nitrogen metabolites in salt marsh systems. Fiddler crab burrow density and turnover rates were determined along a transect from the forest to the creek bank to North Inlet Estuary, S.C. Burrow density ranged from 40 to 300 burrows m^{-2} with highest densities at the creek bank. Sediment reworking rates ranged between 4×10^3 and $5.7 \times 10^4 cm^3 m^{-2} y^{-1}$. The distributions of excess ^{210}Pb and ^{137}Cs indicated that fiddler crab burrowing mixed the top 8 to 15 cm of sediment. Field measurements of burrow density, turnover, and size were used in a mathematical model to predict the effect of fiddler crab burrowing on ^{210} Pb profiles. Results suggested that fiddler crab burrowing determines sediment reworking rates and thus, strongly affects sediment composition. Additionally, my study demonstrated that fiddler crab burrows are sites of enhanced nitrification and that fiddler crab burrowing transports ammonium from anoxic sediment at depth to the surface where it may be used in primary production. These results clearly demonstrate that fiddler crab burrowing may be the primary controlling factor for nutrient availability, sediment structure, vegetative production, and remineralization in the salt marsh system.

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 systems 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, 2000 is similar to that above, but is looking for the microbial degradation (complete mineralization to CO2) of PAHs at the three study locations. Indirect evidence of metabolite formation is being collected, but so far the sediments have not been analyzed using gas chromatography or mass spectrometry to identify the metabolites produced.

Reactive Organic Carbon Flux and Cycling on a South Carolina Sandflat: The Role of Physical and Macrobiological Processes

Investigators: Anthony F. D'Andrea, Drs. Glenn R. Lopez and Robert C. Aller
Marine Sciences Research Center, State University of New York, Stony Brook

Sandflats are physically dominated, low-carbon environments supporting dense infaunal assemblages. This suggests that the flux of organic carbon is more important than standing stock concentrations in sands. Despite this implication, the role of sandy sediments in carbon flux and cycling in coastal systems is poorly understood. This study used a processes-oriented approach to identify and quantify the biological and physical processes most likely to control carbon flux and cycling on Debidue Shoal, a dynamic intertidal sandflat in the North Inlet estuary. Particles deposited on the sandflat are rapidly mixed deeper (mm d^{-1})into the sandflat. The sediment column is well oxygenated to 25cm and completely flushed within 2 hrs. The primary macrobiological activities most likely to significantly impact carbon flux include burrowing and feeding by the thallassinid shrimp *Callianassa major*, and the seasonal formation of dasyatid ray pits which act as sediment traps. The primary physical process operating in this system is tidally induced porewater movement in permeable intertidal sands, called porewater advection. This can increase the supply and decomposition of organic carbon, remove metabolic products, and could explain the low values of carbon measured in intertidal sands. Carbon fluxes measured for Debidue Shoal were high, particularly in the vicinity of *C. major* burrows, and are comparable to those measured for the muddy portions of the North Inlet estuary. At this point, the exact role of *C. major* fecal pellets is unclear, but our experiments indicate that these pellets are high in reactive carbon and could be an important food source for infauna. The results indicate that the interaction of macrobiological processes with the tidally-driven porewater flow plays a significant role in organic supply, decomposition, and preservation in this system. More importantly, this study emphasizes the importance of intertidal sands in carbon and nutrient cycles of estuarine systems.

Phosphorus Biogeochemistry in Intertidal Wetlands of South Carolina

Investigator: P.V. Sundareshwar
Dept. of Biol. Sci., USC

Nutrient limitation of primary production is a function of relative nutrient solubility. Unlike nitrogen, phosphorus has limited solubility and is cycled between the biotic and abiotic sinks and sources within the sediment matrix of a wetland. Although nitrogen is generally known to limit primary production at the mouth of estuaries, phosphorus is limiting at the fresh water end. There is no consensus on the mechanisms that control these changes in nutrient status. We have observed trends in phosphorus biogeochemistry along the Cooper River and in North Inlet salt marshes that can explain the switch from phosphorus limitation to nitrogen limitation of primary production and raise the possibility of, hitherto unreported, differential nutrient limitation among trophic groups within an ecosystem. We have examined the relative status of the fresh, brackish, and salt marsh on the Cooper River with respect to phosphorus availability, the distribution of phosphorus among different chemical pools (by a combination of 31P-NMR and chemical fractionation techniques), and the P binding capacity of wetland sediments. The salt marshes on the Cooper River are relatively enriched in nutrients. For

instance, the porewater concentrations of dissolved reactive phosphorus (DRP) increase along the salinity gradient on the Cooper River. In contrast, the pristine salt marshes at North Inlet support low concentration of porewater DRP. The relatively higher fertility of Cooper River salt marsh appears to be a function of site-specific sediment characteristics and anthropogenic influence

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

Investigators: 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 volume change and accretion in a salt marsh

Investigator: Dr. James Morris
Dept. of Biol. Sci. 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 to be 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.

BIOLOGY AND ECOLOGY

Use of flooded marshes by migratory fishes and crustaceans

Investigator: Dr. Dennis Allen, Ginger Ogburn-Matthews, Chris Aadland, 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.. See map location no. 5.

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. In phase two, the influence of oyster reef dams upon creek flow and water residence time will be addressed. This study will advance 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

Influence of the American oyster, *Crassostrea virginica,* on microbial community structure

Investigators: Michael Wetz[1], Dr. Alan Lewitus[2], Dr. Eric Koepfler[1], and Kenneth Hayes[2]. Marine Science Dept., Coastal Carolina University[1], Baruch Marine Laboratory, USC[2],

Oysters filter tremendous volumes of water and can therefore significantly impact planktonic microbial communities. Few studies have examined the grazing impact of *Crassostrea virginica* on natural assemblages of phytoplankton. We examined ciliate, heterotrophic flagellate, and phototrophic flagellate abundances monthly from March through July, 1998, in eight tidal creeks of the North Inlet estuary, four of which had oyster reefs removed. Significant spatial and temporal differences were observed for the microzooplankton, some of which involved the influence of oyster reefs on the microbial community. For example, during July, phototrophic nanoflagellate abundances were significantly greater in creeks without oysters than in creeks with oysters, indicating that the oysters were selectively grazing the phototrophic nanoflagellates. This finding has led to the implementation of several seasonal flume studies,

with the purpose of examining the impact of oysters on microbial community structure. Presently, we are examining nanoflagellate, ciliate, diatom, bacteria, and cyanobacteria abundances as they pass over a simulated oyster reef. We will also examine chlorophyll and nutrient concentrations. This study has received funding from the NSF- CREEK project, the marine science department of Coastal Carolina University, and the Honors Program of Coastal Carolina University.

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

Investigators: Drs. Dennis M. Allen[1], David Bushek[1], and 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 are 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.

An artificial creek mesocosm: testing fish and motile macroinvertebrate preferences for bottom composition and topography

Investigators: Brian Milan[2], and Drs. Dennis M. Allen[1] and Rob Young[2]
Baruch Marine Laboratory, USC[1] and Coastal Carolina University[2]

The composition of fish and motile macroinvertebrate assemblages using intertidal habitats varies considerably across the estuary. Preliminary observations suggest that differences in the relative abundance of animals in different intertidal creeks and pools may be related to bottom characteristics. We have constructed a mesocosm in which eight 1.8 m^2 sections of bottom are covered with one of two sediment sediment types (e.g. mud, mud with live oysters). The size, depth, and water flow patterns of the artificial creeks are comparable to those in the field. In the experiments, test animals are released into the creeks and are given time to explore the options. After several hours, the eight buried nets are lifted to isolate animals associated with the different sediment types. The study compliments the CREEK project sampling which has demonstrated relationships between the occurrence of certain species and bottom types within natural creeks. The artificial creek mesocosm is a prototype that will be upgraded in the development of the new tidal mesocosm complex recently funded by NSF.

Fish Community Associated with Subtidal Oyster Shell

Investigators: Richard Lehnert[1] and Dr. Dennis M. Allen[2]
Marine Science Program[1], USC and Baruch Marine Laboratory[2], USC

Adjacent to intertidal oyster reefs is a subtidal habitat which is relatively under-studied in the southeast. It consists of shell that originates from the intertidal oyster reefs. The relative importance of subtidal oyster shell compared to other subtidal substrates (sand and mud) as essential habitat for nekton is not known. Ongoing research in Town Creek, North Inlet has shown that a distinct community of decapods and fishes is associated with this substrate. The study is designed to sample subtidal habitat with 1 m^2 trays, filled with substrate matching the surrounding bottom. After a set soak period, the contents of the trays are analyzed for species diversity, abundance, weight, and length frequency analysis. As expected the study has shown distinct seasonal changes in the community structure of this habitat. This project started in May 1998 with a tentative end date of May 2000, and support is being provided by the USC Marine Science Program and the Baruch Marine Field Lab.

Pre-dredge Characterization of Fauna and Subtidal Habitat Type in Upper Debidue Creek, North Inlet SC.

Investigators: Richard Lehnert[1] and Dr. Dennis M. Allen[2]
Marine Science Program[1], and Baruch Marine Laboratory[2], USC

Both dredging activity and boat traffic remove and accelerate the break down of subtidal oyster shell. This topic has immediate relevance to North Inlet because of proposed maintenance dredging in Upper Debidue Creek. The most likely result of dredging activity will be the removal of complex shell substrate, and replacement by sand or mud. Bi-weekly habitat tray and seine collections will be used to characterize the fauna of Debidue Creek. A detailed study of the creek bottom will also be undertaken to determine the relative percentages of the different bottom types, oysters/shell, sand, or mud. The information gained through this project should enable managers to make more informed decisions concerning which procedures and precautions are appropriate during dredging operations. This study is being supported by the NERR-GRF program and will run from June 1999 to June 2000.

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 mesocosms (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 1999 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 effect 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.

Long-Line Survey of Sharks of Winyah Bay and Nearby Waters

Investigators: Dr. Daniel C. Abel
Marine Science and Biology Depts. Coastal Carolina University

Recent surveys of sharks along the southeast coast have shown decline in several species, e.g. sandbar and dusky sharks. These and other sharks inhabit coastal waters and/or estuaries, and use the latter as nurseries. We are undertaking a long-term long-line study to survey the sharks of Winyah Bay and nearby waters; to determine which sharks use the Bay as a nursery; to understand habitat selection in selected species in the Bay; and to examine pollutant load in Bay sharks. We will thus understand more about the life history, diversity, abundance, and seasonality of sharks in Winyah Bay. Detailed information arising from this study will contribute to a greater understanding of the health of this group along the southeast coast.

Reproductive strategies of the blacknose shark, *Carcharhinus acronotus*

Investigator: Trey Driggers
Marine Science Program, USC

Forty of the approximately 390 species of sharks in the world are caught in the targeted shark fishery and as bycatch in other fisheries along the southeastern coast of the United States. Sharks are highly susceptible to overfishing because of their low fecundity, late onset of maturation, and slow growth. As a result, many shark populations are declining and stronger management initiatives are being proposed. The blacknose shark, *Carcharhinus acronotus*, is one of the most common sharks in South Carolina's coastal waters from June through November. We have been collecting blacknose sharks from South Carolina waters for the past year using longline fishing gear and will continue to do so through the summer of 2000. The purpose of this study is to investigate the reproductive strategies of this species of shark and gain information on growth rates, age at first maturity, fecundity, and longevity. An additional component of this study is the investigation of the population structure of these sharks throughout their range. With assistance from other institutions, blacknose sharks will be collected from the coastal waters of Brazil, Georgia and Florida, as well as the Gulf of Mexico. These data will allow us to determine if there is one interbreeding population or if separate populations exist. Comparisons of life-history information between blacknose sharks occupying different regions will also be made.

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.

International research project on flatfish ecology I. Ecology and life history of the fringed flounder, *Etropus crossotus.*

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

The abundance of some species of smaller sized flatfishes indicate that they may represent significant elements in the epibenthic community in estuaries and near shore waters of the southeast US. The fringed flounder, *Etropus crossotus*, is one of the most common smaller flatfishes found in South Carolina but little is known about its age and growth. The maximum reported total length is 16.9 cm, but individuals are rarely longer than 15 cm, and their wet weight is seldom more than 40 g. The age of fish can be determined by counting layers of calcium carbonate are deposited daily on its otoliths -- calcified structures located in the inner ear of bony fishes. From otoliths, we have determined that most adult fringed flounder have a maximum expected life span of about 14.5 months, with no differences in life span or growth between sexes. Back-calculated hatch dates, catches of young juveniles, and histological information indicated a long spawning season from March through October. The typical life history pattern is one of relatively rapid growth in the first months, with sexual maturity reached in about 6 to 9 months at a length of about 8cm. The adult fish typically live through only one spawning season and individuals hatched early in the spawning season are potentially capable of producing eggs in that growth season. This short life span is unusual for flatfishes and has not been previously described. As a result and because reproduction occurs over several months,, growth patterns deduced from the increase in mean size of the population cannot be used to estimate growth rates of individuals. Experimental data are being collected to help understand relationships between factors that affect growth of juvenile *E.crossotus* in South Carolina estuarine nursery areas. We will use the relationship between otolith growth and somatic growth to estimate recent growth rates in fish caught in the field.

The potential role of environmental heterogeneity in behavioral osmoregulation by juvenile estuarine-dependent fishes.

Investigator: Dr. Evan Chipouras
Baruch Marine Laboratory, USC

Results of field and laboratory studies demonstrate that the body-fluid osmotic concentrations of juvenile striped mullet (*Mugil cephalus*) and some other estuarine-dependent species are much more variable than expected. The observed pattern of internal osmotic concentrations and concurrent metabolic responses under changing environmental salinity suggest that these organisms may not alter physiological osmoregulatory mechanisms unless an environmental change persists for several hours. Rather, these organisms may exploit the temporal and spatial salinity heterogeneity found in many estuarine systems to osmoregulate in the same fashion as some ectotherms achieve thermoregulation by shuttling between areas that are thermally different. This hypothesis is being tested at the BMFL using an experimental paradigm that employs vertical salinity gradients established in mesocosms. White and striped mullet of different age/size classes are adapted to one of several different levels of constant salinity for several days. Fixed- and random-interval sampling procedures are used to compare

the behavior of fishes transferred to enclosures with vertical gradients with that of fishes transferred to enclosures with a uniform salinity. The observed behavioral differences are expected to be a function of both the magnitude of the salinity difference between the adaptation and test enclosures and the magnitude of the salinity difference between the layers in the stratified enclosures. These differences are expected to reflect, in part, the status of the physiological osmoregulatory mechanisms at the time of transfer between the adaptation and test conditions. If these organisms are capable of exploiting environmental salinity heterogeneity to achieve regulation, then the relationships between the mobile capabilities of these fishes during ontogeny and the structure of temporal and spatial environmental salinity distributions may be important determinants of estuarine habitat value.

The effect of salinity on the growth and development of larval estuarine dependent fishes

Investigators: Dr. V. Pernell Lewis
Dept. of Biol. Sci. and Marine Science Program, USC

Salinity may be a major environmental factor influencing the utilization of estuaries by larval fishes. The goal of this study is to examine the role of salinity in determining the distribution of larval fishes within the estuary. The energetics of growth in three different salinities (2, 12 and 35 ppt) for three common species (Atlantic menhaden, spot, and southern flounder) will be determined. Metabolic rates, proximate composition, and growth rates will be among the primary variables measured to assess the effect of salinity on these larval fish. Their distribution in Winyah Bay and North Inlet will also be determined relative to salinity zones. Salinity preference will be determined in the laboratory using a salinity gradient test.

Feeding of post-larval white shrimp, *Penaeus setiferus*

Investigators: Dr. Robert Feller and Orinna Clark
Dept. of Biol. Sci. and Marine Science Program, USC

Our objective is to define and quantify the diet of young shrimp when they first take up a life style of living and feeding on the muddy floor of the estuarine nursery grounds. It is hypothesized that small bottom-dwelling invertebrates less than one millimeter long form the bulk of the diet at this stage of the shrimp's life history. As they grow, their diet probably shifts to larger bottom-dwelling prey. Immunoassays may be used to examine shrimp gut contents and test this hypothesis of dependence on meiofaunal sized prey.

Production, degradation, and biotic effects of noxious chemicals generated by some benthic invertebrates

Investigators: Kevin Fielman, and Drs. Sarah Woodin, Charles Lovell, David Lincoln and Pernell Lewis.
Dept. of Biol. Sci. and Marine Science Program, USC

Measurements of the production and degradation of bromophenols, noxious organic compounds which affect other animals, are being made in Debidue Creek. The chemicals are produced by polychaete and acorn worms. Field and laboratory experiments are being conducted to determine the effects of these biogenic compounds on the recruitment of invertebrates (settlement of planktonic larvae to the contaminated sediments), predation by fishes, and migration/mortality of adult infauna. Additional studies are characterizing the responses of populations of bacteria to the presence of the chemicals around the worm burrows. In addition the dehalogenases of the bacteria associated with the worms as well as dehalogenases of the worms themselves are being characterized. These compounds are similar to another group of compounds (chlorophenols) released by pulp mills and other industries. The studies will reveal how estuarine organisms react to long-term exposures to contaminants of these types. See map location no. 7. This project was initiated with NSF funding and is currently funded by the EPA.

Molecular ecology of biohalogenation and dehalogenation

Investigators: Kevin Fielman, Dr. David Lincoln, and Dr. Sarah Woodin
Dept. of Biol. Sci. and Marine Science Program, USC

Halogenated aromatic compounds are important pollutants in a variety of industrial processes. Similar compounds are also produced naturally by a wide variety of marine organisms. We are examining the extent to which the capacity of organisms to produce and degrade naturally-occurring halogenated organic compounds determines the biological impact of pollutants in marine benthic communities. DNA probes developed from common worm species which contain high concentrations of halogenase and/or dehalogenase will be used to compare the potential for halophenol metabolism of organisms at three sites: one with native worm species which produce large quantities of bromophenols, a nearby site which has substantial chlorophenol contamination from sulfate-process paper pulp mill effluent, and a control site lacking halophenols. These studies will allow us to assess the activities and potentials for halogenases and dehalogenases to influence benthic community species composition and enable us to determine if these characters are important determinants of organism survival and persistence in polluted habitats. See map location no. 7.

Larval Settlement Responses to Diffusionally Released Sulfide, Glucose and Bacterial Growth Media

Investigator: Dr. Dan Rittschof, Baruch Visiting Investigator, 1999
Duke University Marine Laboratory, Beaufort NC

The purpose of this project is to explore the role of chemical cues in directing colonization of habitat by organisms living in low energy estuarine creeks. A variety of compounds were diffusionally released from cold polymerized and diffusionally loaded alginate gels. Gels were surrounded with a pourous habitat (kitchen scrubbing pads) into which organisms could burrow. After 1 to 3 day exposures, pads were removed from arrays and colonizers collected by washing the pads with fresh water, sieving immediately and preserving in rose bengal, salt water and formalin. Gels released from 0.4 micromoles to about 0.04 micromoles of chemicals per square centimeter per minute. At this time, the preserved samples are being sorted.

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 and DNA denaturing gradient gel electrophoresis studies are providing 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 and EPA.

Marine microbial biofilms: A structuring matrix for microbial processes and transformations

Investigators: Dr. Alan W. Decho
Dept. Env. Health Sci. and Marine Science program, USC

The formation of biofilms constitutes a requisite step for colonization and/or biofouling of surfaces by macroorganisms such as barnacles, oysters, etc. Biofilms consist of microbial cells surrounded by a matrix of large mucous molecules (exopolymers). These polymers stabilize the attachment of microorganisms to surfaces and afford protective and sorptive properties to the cells. Ongoing biofilm studies are geared in three basic process and environmental directions: (1) Sorption studies are examining how exopolymers may bind dissolved nutrients and localize microbial extracellular enzyme activities close to cells; (2) The protective effects of exopolymers in binding, concentrating, and detoxifying metals and organic contaminants are being examined;

and (3) Applied studies are examining the role of specific biofilms in mediating the settlement and metamorphosis of oyster larvae.

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

Investigators: Drs. David Bushek[1] and Kim Reece[2], Karen Hudson[2], Carla Beals[1]and Sarah Bashaw[1].
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 are trying to determine the distribution of different strains to better understand the mechanisms of its dispersal. Isolates of *P. marinus* have been collected and cloned from throughout the parasite's distribution. DNA is then extracted from the clones and several loci screened to distinguish different strains. Results to date have demonstrated *that P. marinus* is diploid (contains two sets of chromosomes), that individual oysters may be infected with more than one strain, that three distinct clades exist (northeast, southeast and Gulf), with greatest strain diversity in the southeast, and that isolates from a recent northern range expansion (the northeast clade) are closely related. This last finding suggests that the 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.

Preventing Transmission of the oyster parasite *Perkinsus marinus*

Investigators: Dr. David Bushek[1], William Anderson[2], Tom Howell[3]
Baruch Marine Laboratory, USC[1] and SCDNR Office of Fisheries Management[2],
Spinney Creek Shellfish, Inc.[3]

The protozoan oyster pathogen *Perkinsus marinus* is a major problem for oyster stock enhancement, management, restoration, and aquaculture efforts because it can cause extensive oyster mortality. Transport of oysters for commerce, research or personal consumption can facilitate dispersal of the parasite. For example, we have found the parasite on tissues that have remained attached to shell discarded by restaurants and packing houses that was destined for replanting beds at sites in different regions from where it originated. Similarly, effluent from packing houses, depuration plants or wet storage facilities (all of which may obtain oysters from distant sources) may contain viable parasites. If these waters or shell make their way back to local estuaries, the parasites may survive and spread to local oyster populations. We have been testing shell from various sources to estimate the magnitude of this problem, and are conducting laboratory studies to develop treatment methods to kill the parasite before shell or effluents reach estuarine waters.

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 Connecticut to Texas. 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. Flume experiments will further investigate the relationships between planktonic *P. marinus* concentrations, oyster infection intensities, and flow velocities. 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.

Brittlestar population studies: use of skeletal growth rings as markers

Investigators: Justin McAlister[1], and Drs. 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 variable water motion on the regeneration of central vertebral ossicles of the infaunal brittlestar Hemipholis elongata.

Investigators: Justin McAlister and Dr. Stephen Stancyk
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 wave stress on the regeneration of brittlestar ossicles. Previous research has indicated that brittlestars are quite plastic in their allocation of materials during regeneration. To assess this phenomenon, regenerating animals are subjected to continuous random water motion, i.e. physical stress, in laboratory aquaria. Scanning Electron Microscopy (SEM) and image analysis computer software will be used to characterize ossicle morphology and to allow for enumeration of 'coarse-pored' and 'fine-pored' stereom growth rings. The proposed methodology should help establish an explicit analysis regarding the mechanism of calcification in the central vertebral ossicle. This information will help elucidate environmental effects on brittlestar growth. See map location no. 8.

Symbiosis of the pea crab with two polychaete worms

Investigators: Michael Grove and Dr. Sarah Woodin
Dept. of Biol. Sci., USC

Symbiotic relationships between the pea crab, *Pinnixa chaetopterana* and its host polychaetes *Chaetopterus variopedatus* and *Amphitrite ornata* are being investigated on tidal flats in Debidue Creek. Growth rates of the animals are being measured in the field and in the lab and correlated with acoustic Doppler flow probe measurements which quantify the effects of

the crabs on the hosts' pumping activity. Crabs have been shown to locate new hosts by responding to conspecific odors. Frequent movement between hosts is necessitated by high host mortality as indicated by long-term mapping of host populations. The final phase of the work will investigate the genetic relationships of crab populations occupying tubes of the two host species. This work will be useful in understanding evolutionary trends in marine symbiosis. See map location no. 9.

Evolutionary history of diapause in harpacticoid copepods

Investigators: Regina Wetzer[1] and Dr. Bruce C. Coull[2]
Marine Science Program[1], USC and School of the Environment.[2]

The harpacticoid copepod, *Heteropsyllus nunni* Coull, originally described from North Inlet, is one of two marine harpacticoid species that undergoes diapause by adult encystment. Adult encystment has otherwise only been recognized in freshwater members of the family *Cletodidae*. Two possible explanations account for the presence of diapause in marine species: (a) diapause is the result of adaptation (natural selection) to the environment, or (b) diapause is a remnant of phylogenetic history. Phylogenetic inferences based on morphological data will clarify important controversies and species assignments. Comparative methods will then allow us to ascertain the evolution of adult encystment in closely related families and determine whether diapause in marine copepods is the result of natural selection or phylogeny.

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.

Phytoplankton use of dissolved organic matter to supplement energy requirements

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

Dissolved organic matter (DOM) can have a pronounced effect on phytoplankton growth and photosynthetic properties. Two factors generally thought to be important determinants of the potential for DOM uptake by phytoplankton are irradiance and DOM type. In turbid estuaries, light (i.e. energy) availability to phytoplankton can be limiting, suggesting that the use of DOM as an alternative energy source may be beneficial for phytoplankton growth or survival. This study tests the hypothesis that phytoplankton can use DOM to supplement energy requirements under light-limiting conditions. Our objectives are to determine the physiological responses (growth, photosynthetic properties, adenylate content) of DOM use, and DOM uptake potential (Michaelis-Menton parameters) of axenic phytoplankton cultures grown under conditions varying in growth irradiance and organic substrate type (varying in oxidation state, a reflection of energy potential). The results will enhance our understanding of the potential role of DOM in controlling primary production in light-restricted, organic-rich estuaries.

Chemotaxis in a marine cryptophyte: Behavioral plasticity in response to amino acids and nitrate

Investigators: Eunjung Lee[1], Dr. Alan Lewitus[2], and Dr. Richard Zimmer-Faust[3],
UCLA[1], Baruch Marine Laboratory [2], and Dept of Biol[3], USC

The behavioral responses of *Chroomonas sp.*, a small (3 μm diameter) cryptophyte, to amino acids, ammonium, or nitrate were investigated by computer-assisted video motion analysis. *Chroomonas sp.* exhibited chemotactic behavior consistent with that of some bacteria (i.e. a change in tumbling frequency but not swimming speed), but this response varied with growth nutritional condition and chemical stimulant tested. Cells grown with glycine as the sole nitrogen source exhibited significant reductions in tumbling frequency in response to glutamate, methionine, alanine, or aspartate at concentrations as low as 0.1 μM, but not to other amino acids, ammonium, or nitrate at comparable concentrations. In contrast to glycine-grown cultures, nitrate-grown cells did not significantly change motility properties in response to any amino acid tested or ammonium, but did reduce tumbling frequency in response to 1 μM nitrate. It is hypothesized that chemotaxis is inducible in *Chroomonas sp.*, and regulated by the nutritional environment (i.e. when nitrate is not available, cells become chemotactic towards alternative nitrogen sources such as amino acids). The observed behavioral responses to amino acids supplied at 0.1 μM suggests that *Chroomonas sp.* may exhibit chemotaxis to organic nitrogen sources under natural conditions when inorganic nitrogen is limiting, supporting the viewpoint that DON use by phytoplankton may be an ecologically relevant process. This project is funded from 1995-1999

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.

The role of alternative respiration in phytoplankton.

Investigators: Drs. Alan Lewitus[1] and Niels Eriksen[2]
Baruch Marine Laboratory, USC[1], Odense University, Denmark[2]

In the variable estuarine environment, phytoplankton frequently experience shifts in resource availability that affect intracellular energy levels. When conditions lead to energy overproduction (e.g. the transition from dark [night] to bright [day] light), phytoplankton use a variety of metabolic processes to get rid of the excess energy. One such energy-dissipating mechanism is alternative respiration. In higher plants, the alternative oxidase (AOX), the terminal oxidase in alternative respiration, is thought to allow carbon flow through glycolysis and the citric acid cycle when cellular energy levels are high. In phytoplankton, information is lacking on the taxonomic distribution and metabolic properties of the AOX. We used cyanide resistant respiration to indicate the presence of the AOX, and the AOX inhibitors, salicylhydroxamic acid (SHAM) and propyl gallate (PG), to estimate the relative activity and capacity of the AOX in axenic cultures of 6 estuarine phytoplankton species. The presence of the AOX in five of the six marine phytoplankton species tested suggests that the AOX is widespread among phytoplankton. Furthermore, the pronounced AOX inhibitor effects in stationary phase (nutrient-limited) cultures compared to linearly growing cultures implies that the AOX contributes substantially to oxygen and carbon cycling in many species of phytoplankton during nutrient deficiency. This project is funded from 1994-1999

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 University 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[2]
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 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], Dr. Peter Noble[1], M. Caroline Roper[2] and Dr. Madilyn Fletcher[1]
Mar. Sci. Prog., USC[2], and Baruch Institute, USC[1]

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, (2) to determine the true relatedness of regions of genomes which would otherwise appear to 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 (2) 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-Nov., 1999.

Biocomplexity: The relationship between marine microbial community compositions and environmental parameters in marine estuaries.

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 complexity and the dynamic properties (dimensionality, entropy and instability) of North Inlet estuary using physical and nutrient data from the LTER database (1981-1993), (2) to determine the relationship between the dynamic properties and the marine microbial community (e.g., phytoplankton/bacteria/microeukaryotes), and (3) to develop unifying measures for characterizing the dynamic properties of ecosystems. Development of easy-to-use mathematical programs that calculate the dynamic properties and complexity of ecosystems, and (2) application of mathematical concepts (borrowed from physical sciences) to ecological phenomena. 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 (pending).

An investigation into the trophic ecology of the deposit-feeding, burrowing brittlestar *Microphiopholis gracillima*

Investigators: Dionne Hoskins
Marine Science Program, USC

Bacterial exopolymer secretions (EPS) often form dense mats (biofilms) at the sediment/water interface which may be consumed in significant amounts by benthic infauna. The burrowing brittlestar *Microphiopholis gracillima* is known to feed on small organics at the surface. This study, divided into three phases, will determine the typical feeding behavior of

Microphiopholis, exploring the depth of its feeding activity in sediments, its food preference, and the role of bacterial exopolymers in its diet. In Phase I, food is presented at discrete depths. Subsequent gut analysis will reveal if feeding has taken place and should establish a feeding depth range. Phase II experiments will introduce different food types in the feeding range determined in Phase II. In Phase III, toxins will be placed in the feeding area for trophic transfer studies. Brittlestars are expected to feed throughout the sediment column and to consume significant quantities of bacterial exopolymers in addition to a variety of other detrital organics. Evidence to support these hypotheses may substantiate additional theories involving the ability of the microbial community to pass pollutants to higher trophic levels through biofilms.

Microbe-deposit feeder interactions in estuarine mud

Investigators: Dionne Hoskins and Dr. Stephen E. Stancyk
Marine Science Program, USC

Bacterial exopolymer secretions (EPS) often form dense mats (biofilms) at the sediment/water interface which may be consumed in significant amounts by benthic infauna. The burrowing brittlestar *Microphiopholis gracillima* is known to feed on small organic particles at the surface. This study will determine the role of bacterial exopolymers in the diet of *Microphiopholis*. EPS are heterpolysaccharidic in nature so any assimilator of them must have enzymes capable of degrading complex sugars. Experiments will examine classes of enzymes possessed by ophiuroids with emphasis placed on carbohydrases. Brittlestars are expected to consume significant quantities of bacterial exopolymers in addition to a variety of other detrital organics. Evidence to support these hypotheses may substantiate additional theories involving the ability of the microbial community to pass pollutants to higher trophic levels through biofilms. The enzymes assays will assess the ability of brittlestars to digest EPS and ultimately the role of toxins in microbe-deposit feeder interactions.

Why animals form groups: predation defense vs. foraging success in fiddler crabs.

Investigators: Steven Viscido and Dr. David Wethey
Dept. of Biol. Sci., and Baruch Inst. USC

Anyone who has walked around the tidal creeks in North Inlet has probably observed vast "armies" of fiddler crabs wandering through the marsh. Two common explanations for why these animals join such aggregations are that their members experience either (1) a decreased danger of predation, or (2) an improved ability to locate food. To test these hypotheses, we are observing fiddler crab flocks in the creek beside the road to Oyster Landing. To date, our results show that flock formation peaks when predators are least likely to be present, and that flock members are more likely to be killed by predators than individuals who remain alone near their burrow. Additionally, many shore birds prefer to attack crabs in flocks. On the other hand, flocks form in areas with the highest food levels. Therefore, flock membership appears to represent a trade-off between the potential cost of being killed by a predator and the potential benefit of improved foraging success.

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, Tom Siewicki, David Bushek, Mike Fulton, Alan Lewitus, Alan Decho, Dan Tufford, Hank McKellar, Marge Aelion, Geoff Scott, John Vernberg, Winona Vernberg , Gary Kleppel, Tom Chandler, and Wayne Beam
USC's Baruch Institute for Marine Biology and Coastal Research and The School of Public Health, and NOAA's Center for Coastal Environmental Health and Biomolecular Research

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. This project was funded through Sea Grant/NOAA/Dept. of Commerce for the period 06/01/99 – 05/31/00

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

The relationship between carbon and nutrient dynamics in intertidal marshes and surface water quality in impacted and non-impacted regions of South Carolina Estuaries. Jun 97'-Jun 00'.

Investigators: Christopher T. Nietch[1] and James T. Morris[2]
Marine Science Program[1], and Dept. of Biol. Sci., USC[2]

We are studying relationships among estuarine water chemistry/quality, tidal marsh pore water chemistry, marsh productivity, and land-use. Surface water and pore water samples are collected monthly for analysis of nutrients (N and P) and microbial metabolic indicators (H2S, SO4, DIC, and CH4), plants are harvested, and sediment and plant CO2 gas exchange is monitored in 15 marsh sites located in the Edisto River, Cooper River, and Winyah Bay/North Inlet Estuaries.

These estuaries differ in their degree of anthropogenic influence and magnitude of freshwater inflow. We hypothesize that the physiological ecology of marsh vegetation will correlate with sediment biogeochemistry, which, in turn, interacts with surface water chemistry and landscape characteristics. For instance, in this project we have established that marshes in the brackish region of the river-dominated estuaries (Cooper and Edisto Rivers) support significantly higher primary production than their freshwater and saltwater marsh counter-parts. This appears to be a function of lower salinity stress and higher fertility (more balanced concentrations of ammonium and soluble reactive phosphorus) as bound nutrients in freshwater inflow are released in the brackish mixing zone of the estuary. On an estuarine-wide scale, our observations indicate that marshes in the Edisto River are more fertile than those of the Cooper River, even though the Cooper River Estuary is more urbanized. Nutrients in the marshes of North Inlet are much lower than in marshes of the river-dominated estuaries. Combined, these results lead to the hypothesis that watershed size is an important determinant of estuarine fertility. This project is supported by a NOAA/NERR graduate fellowship awarded to Christopher T. Nietch.

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

Investigators: David White[1], Dr. Alan Lewitus[2], Jennifer Keesee[2], Dr. Dwyane Porter [3&4]
Marine Science Program[1], Baruch Marine Laboratory[2], Department of Environmental Health Sciences[3], Geographic Information Processing Laboratory, Baruch Institute[4], USC

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 was funded by the Slocum-Lunz Foundation, Marine Science Program, USC and the Urbanization and Southeastern Estuarine Systems (USES) program for the period, July 1998 - January 2000

Meiofaunal microcosms to detect pollution

Investigators: Drs. G. Thomas Chandler[1] and B.C. Coull[2]
Dept. of Env. Health Sci. [1], School of the Env.[2], USC

Microcosms of entire meiofaunal communities are collected in North Inlet mud and transported to the laboratory in Columbia. Selected microcosms are dosed with contaminants and total community structure response is monitored. Cultured harpacticoid copepods are added to certain contaminated microcosms and their population success monitored. The goal is to determine how contaminants alter community structure so that we may better understand contaminant effects and also detect contamination problems via changes in community structure.

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.

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

Investigators: Drs. D.E. Porter[1] and J.R. Jensen[2]
Department of Env. Health Sci[1]., Geographic Information Processing Laboratory, Baruch Institute[1], Dept. of Geoghraphy[2] , USC

Chlorophyll-a is highly absorbent of radiation in the range of Landsat Thematic Mapper spectral band 3 (630-690 nm) and reflective in spectral band 4 (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 year (1999) 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 two years, this model will be applied to the study site and we will monitor changes in the estuary. This project is funded by EPA Jan 99 - Dec 01.

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

Prototype development of a GIS-based Web presentation for spatial analysis and promoting increased awareness of fish consumption advisories in support of the Lake Hartwell fish and turtle survey/exposure investigation

Investigator: Dr. Dwayne E. Porter
Department of Env. Health Sci. and Baruch Institute, USC

The South Carolina Department of Health and Environmental Control (DHEC) periodically issues and reissues health advisories to make the public aware that short- and long-term health risks sometimes exist from consuming fish, turtles and shellfish from some waterbodies. Fish consumption advisories are in effect for nearly 30 South Carolina rivers and lakes because of concerns for contamination from mercury, radionuclides and polychlorinated biphenyls (PCBs). In the coastal zone of South Carolina, shellfish beds are sometimes closed to recreational and

commercial harvest because of unacceptable fecal coliform levels. This project will develop a GIS-based Web interface to allow users to spatially query waterbodies in SC to identify the existence of fish consumption advisories. Using more detailed data available for Lake Hartwell, it will demonstrate the utility of GIS and the Web for promoting increased awareness of specific fish consumption concerns related to various areas of the lake. This project is funded by SCDHEC for the period 05/18/99 – 12/31/99.

International Research Project on Flatfish Ecology II. Habitat utilization and growth of juvenile flatfish.

Investigators: Marcel Reichert & Dr. John Mark Dean.
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 Institute, 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], and Ben Jones[1]
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 (*Paleomenetes 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.

Dynamics of feeding and egg production of the copepod *Acartia tonsa* at North Inlet and Murrell's Inlet

Investigator: Dr. G.S. Kleppel
Dept. of Env. Health Sciences, USC

Acartia tonsa is one of the dominant copepods in the estuaries of South Carolina. The productivity of this important species has been shown to be affected by variations in water quality, particularly as resultant from eutrophication and other factors that influence the food web. This project is evaluating the composition of the diet of *A. tonsa*, both in terms of the

kinds of phytoplankton and protozoa eaten and the rates of nutrient (protein, lipid and carbohydrate) assimilation by the copepod at stations in North and Murrells Inlets which are, respectively, more pristine and more suburbanized. The investigation also focuses on the egg production of *A. tonsa*; some of the key links between diet and production will be identified. Ultimately, the information produced by this project will contribute to the understanding of how suburban development affects secondary production in southeastern estuarine systems.

Impacts of Urbanization on Dermo Disease in Oysters

Investigators: Drs. David Bushek[1], Dwayne Porter[2], Don Edwards[3], and Dave White[4], Ben Jones[2], 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.

Kriging in estuaries

Investigators: Drs. Dwayne E. Porter[1], Dave White[1], Ben Jones[1] and Don Edwards[2]
Baruch Institute[1], and Dept of Statistics[2], USC

Geostatistical models are becoming an essential tool for understanding the spatial distribution of biological and chemical species in estuaries. These methods can construct statistically optimal predictions for data at unobserved locations using a relatively small, spatially explicit sample. The prediction at any given location is a weighted average of the sample values, where the weights depend on the distances between the sample sites and target locations. For most geostatistical settings, distances are computed using Euclidean distances, i.e. "as the crow flies". For measurements made in estuarine streams, however, intuition suggests that distances between sites should be measured in-stream, i.e. "as the fish swims". This study has been evaluating the relative accuracy of various kriging methods for predicting contaminant levels and water quality conditions in North Inlet and Murrells Inlet.

Hydrophobic organic contaminants in rivers and estuaries: colloidal phases

Investigators: Todd Cowan and Dr. Tim Shaw
Dept. of Chem. and Biochem. and Marine Science Program, USC

Current sampling schemes fail to distinguish hydrophobic organic contaminants distributed between the dissolved and colloidal phases. It has been postulated that descriptions of the "speciation" of hydrophobic compounds in natural waters should include not only dissolved and particulate fractions but also a component sorbed to a colloidal fraction. Significance of this colloidal material to the fate of contaminants depends on the following factors: (a) identity and concentration of colloidal matter; (b) nature of the interaction between contaminants and colloidal matter; and (c) mobility of colloidal matter in an aqueous environment. We plan to evaluate the contribution of the colloidal phase fate and transport of organic contaminants by measuring partition coefficients for the particulate and colloidal phases in Winyah Bay and the rivers that feed it. In addition, we plan to characterize any changes in each phase as it experiences an increase in the salinity of its environment. It is postulated that this may be a possible sink or capturing mechanism for organic contaminants in Winyah Bay. See map location no. 22.

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], Stephen E. Stancyk[2] and D.E. Porter[3]
Dept of Geol. Sci[1]., Marine Science Program[2], Department of Env. Health Sci[1].,
Geographic Information Processing Laboratory, Baruch Institute[3], USC

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 is funded by the NSF for the period 09/01/98 – 08/31/00

Sediment Transport and Trapping in Estuaries, Southeastern United States

Investigator: Dr. Gail C. Kineke
Department 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.

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

Investigators: Dr. Dwayne Porter[1], R. Clutter[2], M. Crane[2], T. Smalls[2], G. Ogburn-Matthews[2] and J. Jefferson[3]
Department of Env. Health Sci[1]. Geographic Information Processing Laboratory, Baruch Institute[1], Baruch Marine Laboratory[2], Baruch Institute[3] USC

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 22 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. This project is funded by SCDHEC/OCRM/NOAA for the period 9/1/96 – Present.

A Spatial Data Assessment for LU-CES

Investigators: Drs.D.E. Porter, Tom. Siewicki[2], Jeff Allen[3], Don Edwards[4] and Bill Michener[5]
Department of Env. Health Sci[1]., Geographic Information Processing Laboratory, Baruch Institute[1], NOAA's Center for Coastal Environmental Health and Biomolecular Research, Charleston[2], Strom Thurmond Institute, Clemson[3], Dept. of Stat. USC[4], Jones Ecological Research Cent. Ga[5]

This project began in November, 1997 and is ongoing. 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 (NOAA Coastal Committee 1995).
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.

Estuary-Net Project - National Estuarine Research Reserve System

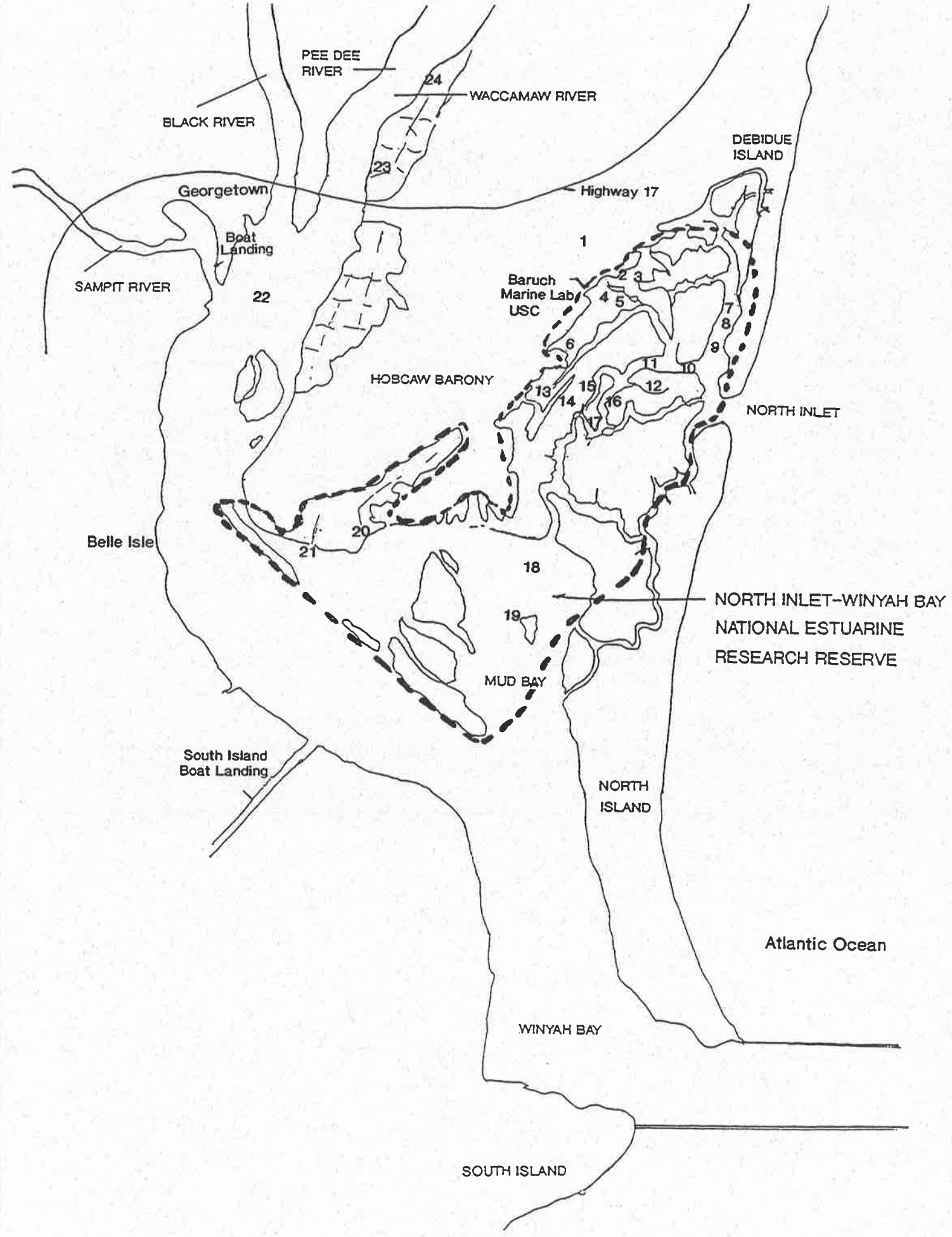
Investigators: Wendy Allen and Beth Thomas
Baruch Marine Laboratory, USC

Estuary-Net is a national educational telecommunications project that investigates non-point source pollution and supports watershed management. Education materials were created for this project by Wells National Estuarine Research Reserve (NERR) in Maine to provide a framework through which high school classrooms and volunteer groups become researchers for their community in its effort to solve watershed management problems. Instructional units are inquiry-based, experiential, learning-style sensitive, interdisciplinary, and relevant. Activities are designed for grade eight to adult. High school students conduct hands-on investigations in the classroom and field to learn about water quality in their watersheds and estuaries. Classes form partnerships and share collected information with each other, researchers at participating NERR sites across the US, local officials, and state coastal zone management programs through the Internet (http://inlet.geol.sc.edu/estnet.html). The teams also work towards solving non-point source pollution problems in their regions. Students gain an understanding of their connection to and the importance of estuaries, and the impact upland activities have on these ecosystems.

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 field lab. Members of the public can participate in a long-term study of the fishes of North Inlet on a monthly basis. Popular Coastal Ecology Classes for children are also offered each summer. Contact the Reserve for a schedule of events at (843 546-3623), or on 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
1
SAMPIT RIVER
22
Baruch
Marine Lab
USC
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Belle Isle
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NORTH INLET-WINYAH BAY
NATIONAL ESTUARINE
RESEARCH RESERVE
19
MUD BAY
South Island
Boat Landing
NORTH
ISLAND
Atlantic Ocean
WINYAH BAY
SOUTH ISLAND