GCE-LTER
ANNUAL REPORT OF ACTIVITIES,
Year One (2000-2001)
Award NSF OCE 99-82133

Project Administration

James Hollibaugh, Dept of Marine Sciences, UGA; Steven C. Pennings, UGA
Marine Institute

The GCE web site has been set up and is available online at http://gce-lter.marsci.uga.edu/lter/. Data sets from the Georgia Rivers LMER as well as new data from the LTER are being organized in the database associated with this web site. We have made presentations about the GCE LTER at local and coastal schools and to a meeting of the research coordinators from NOAA’s National Estuarine Research Reserve program. We have been interviewed by reporters from newspapers in Athens, Savannah and Jacksonville. We have established collaborative working relationships with other agencies (GA Department of Natural Resources, The Nature Conservancy, Sapelo Island National Estuarine Research Reserve, USGS). We have initiated a monitoring program at the head of tide on the Altamaha River and at 10 study sites within the saltmarsh/estuarine study domain. Scientists from our group are participating in LTER comparative studies of ground water, microbial diversity, and sediment organic matter. One of the senior scientists on the proposal, Dr. Deborah Bronk, moved from UGA to VIMS and is no longer part of the GCE-LTER.

Web Site and Database
Wade Sheldon, Department of Marine Sciences UGA

Overview. During this past year we acquired the necessary computer hardware and software to establish our data management system and World Wide Web presence. We are currently providing WWW, relational database, Matlab web server, and FTP services on our project server (dual-cpu Dell PowerEdge 2400 running Microsoft® Windows NT Server 4). We are also running analytical, mapping and application development software on a data management workstation (Dell Precision 420 running Windows 2000). This workstation is protected by firewall software and used for offline data storage and archival.

Most of the data management efforts during this year have been focused on technology and standards development. As of March 2001 we have established protocols for submitting, processing, and managing all categories of research data we proposed to
collect. These protocols are documented on our web site at http://gce-lter.marsci.uga.edu/lter/research/guide/gce-is.htm. Of particular note, we created a standard for storing tabular data sets as hierarchical, self-documenting Matlab data structures, and developed a suite of custom database-like query and analysis tools to work with these structures. We will use this technology to provide support for online data display, statistical analysis, and custom formatting using a web application interface.

We have also adopted a provisional metadata standard, based on the Ecological Society of America’s Future of Long-term Ecological Data 1995 report (http://gce-lter.marsci.uga.edu/lter/research/guide/metadata.htm). We are using a relational database (Microsoft® SQL Server) to store and manage project metadata. This database will support metadata cataloging and querying on our web site and will be used to generate printable metadata documentation. We will extend this database to add support for the proposed LTER metadata standard when it is released.

**Web Site.** We established an interim web site in July 2000 to provide background information on our project and personnel. In November 2000 we moved this site to our project web server (http://gce-lter.marsci.uga.edu/lter/) and augmented the site to include information about newly established study sites and ongoing research and educational activities. We have recently added links to new GCE publications and information about submitted monitoring data sets. This site received 67,945 hits from 1124 web visitors between December 2000 and March 2001.

We have also established a private project web site to foster information exchange within the GCE project. This site contains data submission forms, downloadable programs and files, and a project discussion board. Monitoring data sets and analytical tools will be added to this site in the near future.

**Database.** Four data sets have been submitted to the data manager from year one monitoring efforts:

- August 2000 Grasshopper Survey at 5 GCE LTER Sites (Steven Pennings)
- August 2000 Soil Organic Content Analysis for GCE LTER Permanent Plots at Sites 1-10 (Steven Pennings)
- October 2000 Plant Monitoring Survey for Permanent Plots at GCE LTER Sites 1-10 (Steven Pennings)
- October 2000 Fungal Biomass and Productivity at GCE LTER Sites 1-10 (Steven Newell)

These data sets have been formatted and processed, and will be published on the project web site as soon as data documentation is completed. We have also received preliminary data from our new weather monitoring stations at Butler Island and Meridian (USGS super station at Hudson Creek). This data is being evaluated for formatting and calibration, and more data from weather monitoring is expected soon.
We also established a bibliographic database to organize GCE publications. To date, citations for six journal articles and four conference presentations based on GCE research have been added. Citations will be regularly updated on the web site, and will be submitted to the LTER all-site bibliography when the database is redeployed.

In addition, we have produced a database of geographic information for all our primary sampling sites, and have submitted this information to the LTER Network for inclusion in the updated 2001 LTER Global Fiducial Location application. We have also obtained historic weather and hydrographic data sets from two monitoring locations on Sapelo Island (operated by University of Georgia Marine Institute and the Sapelo Island National Estuarine Research Reserve program). These data will be available to GCE researchers as soon as usage and attribution agreements are formalized. Acquisition of legacy Georgia Rivers LMER data and USGS discharge data for the Altamaha River is also planned for year 2.

**Environmental Forcing Functions**

**Climate**
Daniela Di Iorio, Dept. of Marine Sciences, UGA

Within the GCE-LTER domain five meteorological stations, operated and maintained by various institutions, will be used to characterize the weather and climate over a large spatial scale. Three stations are located on Sapelo Island at Marsh Landing, Flume Dock and the Marine Institute. The Marine Institute maintains a National Weather Service station for daily min/max temperatures and precipitation, and data exists back to 1957. The Marsh Landing and Flume Dock stations measure various semi-hourly hydrological and hourly meteorological parameters, and data exists back to 1986. A fourth, new station is located on Hudson Creek in Meridian and is maintained by USGS. This station has been operational since October 2000 and provisional data on hydrological and meteorological parameters are acquired semi-hourly and hourly respectively. Finally, a fifth meteorological station, belonging to the SINERR program and made available for the GCE-LTER project, is located within the DNR Waterfowl Management Area on Butler Island. This station is not yet operational since the instrumentation is being serviced and calibrated. From all these stations we meet the level 0 and level 1 meteorological observation standards for LTER sites. However, we do not yet meet level 2 meteorology for inter-site comparisons and standardization purposes and so we will be working towards this objective. Meeting level 2 standards will require adding a total solar radiation sensor to one of the existing weather stations and acquiring wind data at 10 m.
Residence times in the Altamaha River Estuary
Merryl Alber, Dept. of Marine Sciences, University of Georgia

Changes in river discharge can result in fundamental changes in an estuary, in terms of both the estuarine residence time and salinity distribution, with consequent implications for the entire ecosystem. Our goal is to develop a simple model for estuarine residence time that builds on the classic box model method first developed by Officer. Classic box models use fixed and often arbitrarily-drawn box boundaries and steady-state river flow. However, the choice of box sizes can impact the model outcome and must be chosen with regard to river flow rate. Additionally, if non-steady state river flow rates are to be used then box boundaries must be allowed to vary in response to changes in flow. Our approach will use actual daily-varying river flow rates and allow box sizes to change in mid-run. We reported on the rationale behind these improvements, and the progress we have made towards developing a residence time model for the Altamaha River Estuary, Georgia at the GCE-LTER annual meeting. We have compiled historic data on salinity in the river and have developed the smoothed model input necessary to allow this flexibility. Information about freshwater residence time and the distribution of salt is especially important to develop in this system, as there is pressure to withdraw increased amounts of surface water from the river in order to meet the water demands of a growing coastal population.

Estuarine salinity regime
Jack Blanton, Skidaway Institute of Oceanography

Salinity Regime Studies. We have examined historical salinity data in the LTER domain in order to define the spatial scales of salinity variability and the relationship of salinity in the domain to Altamaha River discharge. The cruises examined include the most recent LMER cruise of September 2000 (Table 1).

Table 1. List of cruise data in the LTER domain that were examined to define temporal and spatial salinity fluctuations. LMER = Land Margin Ecosystem Research; CZM = Coastal Zone Management.

<table>
<thead>
<tr>
<th>Cruise</th>
<th>Date</th>
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<tbody>
<tr>
<td>LMER0</td>
<td>4-5 November 1994</td>
</tr>
<tr>
<td>LMER1</td>
<td>7 April, 17 April 1995</td>
</tr>
<tr>
<td>LMER2</td>
<td>16 October, 24 October, 28 October 1995</td>
</tr>
<tr>
<td>LMER3</td>
<td>16 July 1996</td>
</tr>
<tr>
<td>CZM</td>
<td>12 May 1999</td>
</tr>
<tr>
<td>CZM</td>
<td>24 June 1999</td>
</tr>
<tr>
<td>CZM</td>
<td>8 September 1999</td>
</tr>
<tr>
<td>CZM</td>
<td>4 April 2000</td>
</tr>
</tbody>
</table>
Lowest salinity is usually found in the southern-most corner of the LTER domain where Altamaha discharge enters the domain. This discharge creates extremely strong salinity gradients through Altamaha Sound and into the Intracoastal Waterway (ICW) behind Wolf Island. The extent of influence depends upon Altamaha discharge. When it is above average, brackish water lower than 20-25 PSU (practical salinity unit) can be found behind Sapelo Island. Usually, salinity in Doboy and Sapelo Sounds is higher than 25 PSU. During the drought of 1999 and 2000, salinity exceeded 30 PSU in north of Doboy Sound.

Coastal salinity also varies with river discharge. When the major rivers like Pee Dee, Savannah and Altamaha are at flood stage, coastal salinity beyond the sounds can go below 20-25 PSU. More typically, coastal salinity is in the high 20's to low 30's, but extreme low flow conditions like 1999 and 2000 raised coastal salinity to above 35 PSU. While these variations seem rather subtle, they raise problems in flushing models for which the end-member salinity value must be defined. Coastal salinity fluctuations on a several day time scale are primarily generated by wind stress.

Preliminary surveys using an acoustic Doppler current profiler (ADCP) were conducted last September, 2000, to quantify the net (tidally averaged) exchange of water across the entrances to Sapelo and Altamaha Sound. We found that the net flow across the entrance of Sapelo Sound shows inflow over most of the cross-section, with a narrow outflow zone along the southern flank. On the other hand, the data in Altamaha Sound (not yet fully analyzed) suggests just the opposite. Thus it appears that Sapelo Sound imports high salinity coastal water over most of its cross-section, while Altamaha Sound has a net outflow of lower salinity water to the ocean. (Large quantities of Altamaha water also flow south in the ICW and away from the LTER domain.)

Research during the first year suggests that channels having a tidal node (areas having low vertical mixing) can enhance water exchange along the channel. Such a channel connects Doboy and Altamaha Sound, along which the salinity distribution looks like a weakly mixed estuary. However, the low salinity buoyancy source (analogous to a river entering an estuary) pulses with the tide rather than slowly varying as river discharges usually do. The resulting 2-layer flow is hypothesized to serve as a conduit that passes low salinity water at the surface toward Doboy Sound and imports high salinity water along the bottom toward Altamaha Sound. Understanding the time-varying nature (both at the tidal period measured in hours) and longer periods (measured in days) of this and similar conduits is important to understanding the fluctuations in the salinity regime throughout the LTER domain.
Continuous Monitoring Network. This section summarizes the work of the salinity monitoring committee comprised of the following team members: J. Amft, K. Helm, D. Di Iorio, J. Blanton and S. Pennings. The long-term objective will be to document spatial and temporal variability of salinity and its relationship to water level. The committee primarily focused on the monitoring of physical parameters.

Nine sites were selected within the GCE-LTER domain for long-term measurements of conductivity, temperature and sub-surface pressure. (See ‘http://gce-lter.marsci.uga.edu/lter/sites/proposed_sites2.htm’ for site locations). Site selection was designed as a compromise to span the salinity gradient as well as the take advantage of existing physical structures (docks or pilings) for mounting instruments. It is also essential to have the long-term moorings near the marsh study areas of GCE-LTER investigators.

Sea-Bird Electronics, Inc. MicroCAT data loggers were selected as the best investment of capital equipment resources for the continuous monitoring network. These small self-contained instruments reliably record temperature and conductivity (from which salinity is calculated) for extended periods of up to 3 or 4 months. Sub-surface pressure was added to each MicroCAT as a physical monitoring parameter that provides valuable information about tidal forcing at the seaward sites and an indication of tidal distortion upstream. MicroCATs have the advantage of antifoulant protection of the conductivity cell, which is a necessity in areas of extreme biological fouling, such as the GCE-LTER domain.

Present funding constraints allowed the purchase of only seven MicroCATs with pressure sensors. Thus, initial focus will be at three longitudinal locations in each of three estuaries (Altamaha Sound, Doboy Sound, and Sapelo Sound). Instruments will be first installed at the 4 "corner" sites of the study area:

Site 1 SAP landward Eulonia dock (Sapelo River)  
Site 3 SAP seaward Coast Guard Marker 140 (Sapelo Sound)  
Site 7 ALT landward 2-Way Marina* (S. Altamaha River)  
Site 9 ALT seaward Coast Guard Marker 5 (Altamaha Sound)  

* or Hammersmith Cr.

The goal is to establish these four primary stations (as soon as possible) where extreme ranges in salinity are expected. Values at the interior sites are expected to fall in between those measured at the edges. We plan to eventually sample at all of the nine proposed monitoring sites; the probable deployment order will be Site 8 (ALT mid), Site 2 (SAP mid), Site 6 (DOB seaward) and Site 5 (DOB mid). Site 4 (DOB landward;
Meridian dock) is already outfitted as a SUPER station (measuring weather and hydrological parameters) maintained by the U.S. Geological Survey.

Instruments will initially be swapped about every 2 months, but the ultimate swapping schedule will depend on the degree of fouling and its affect on the quality/accuracy of the salinity record. MicroCAT salinity will be calibrated to a standard immediately after each deployment. The sample interval will be 30 minutes at all MicroCAT stations.

The seven MicroCATs were recently delivered to Ken Helm, who (with assistance from Julie Amft) is in the process of developing procedures for MicroCAT set-up and data uploading procedures. Julie Amft and Ken Helm will work with GCE-LTER Data Manager, Wade Sheldon, to submit the appropriate monitoring data to the private GCE-LTER web site as soon as possible. The private web site allows all GCE-LTER participants and authorized guests access to the GCE Information System. The data will eventually be posted for other GCE_LTER investigators at ‘http://gce-riv.marsci.uga.edu/’.

**Groundwater hydrology and geophysical site assessment**

**Carolyn Ruppel, Georgia Tech**

Groundwater studies provide a fundamental link between the chemical, biological, and physical processes occurring at the land/ocean margin. The hydrology and geophysics component of the LTER study focuses on the processes and factors that control and perturb groundwater flow and the three-dimensional distribution of fresh, transitional, and seawater at multiple spatial and temporal scales. The objectives of groundwater research in the GCE include: 1) constraining the distribution of fresh, transitional, and saline groundwater; 2) quantifying freshwater flux into the marsh and its impact on marsh communities; 3) determining the response of upland and submarsh aquifer units to variable forcings such as tidal, barometric, and anthropogenic perturbations; and 4) monitor the flux of dissolved constituents across the porous-open water interface. This research uses builds on baseline results accumulated for Sapelo Island and St. Simons Island under NOAA- and USGS-sponsored studies we have conducted since 1997.

In Year 1, our research has included reconnaissance of landward and barrier island sites within GCE and preliminary geophysical characterization of selected sites (North Sapelo River site, Visitors’ Center site, North Sapelo Island site, Moses Hammock site, and Dean’s Creek site). We have also extended our analyses of hydrogeologic properties to include sediment samples of creek bank and marsh facies along existing monitoring well transects at 2 barrier island focus sites. Using indirect methods (analyses of tidal pumping and permeameter tests) in existing upland well networks, we constrain the distribution of bulk hydrogeologic properties across the upland-marsh system. To confirm apparent variability in hydraulic conductivity between upland and marsh sediments, we have sampled and tested marsh sediments using standard soils
and permeameter tests in the laboratory. From our preliminary hydrogeologic results we have developed a conceptual model of the groundwater flow regime.

Noninvasive geophysical surveys using both DC resistivity and terrain conductivity methods have been conducted at the Visitors' Center, North Sapelo Island, Moses Hammock, and Deans Creek sites. These initial surveys reveal a high degree of variability in both the horizontal and vertical distribution of saline waters in the subsurface. In addition to constraining the bulk nature of subsurface media at each site, comprehensive geophysical surveys were conducted to identify areas that are more representative of margin processes, to ensure that monitoring well installations at these sites constrain the degree of variability, but also sample "normal" areas. The Visitors' Center and North Sapelo sites have been chosen for the initial installation of monitoring wells. In addition, the existing well network at the Moses Hammock site has been extended marshward toward the LTER focus site in the marsh by the addition of three new piezometers and three multi-level sampling wells. We have also developed plans to install monitoring well networks in creek banks, levees, and marsh muds and to instrument these sites to record time-series of fundamental physical and chemical properties. Much of the instrumentation will occur in the first few months of Year 2 of the project.

Future research involves the use of direct methods to constrain the scales of heterogeneity in marsh sediments and to quantify the magnitude and variability of groundwater discharge. Essential to this phase of the research is the completion of monitoring well installations at selected sites and the implementation of marsh based instrumentation including downhole pressure, temperature, and conductivity logging. These data may be used indirectly to constrain the response of the aquifer to multi-frequency forcing and directly by collaborating researchers to assess the nature of transport across the porous-open water interface. Temporal variations in the bulk salinity of aquifer systems will be constrained by repeated geophysical surveys at selected sites.

**River delivery of dissolved and suspended material**  
James T. Hollibaugh, University of Georgia

We have begun monitoring riverine loading of a variety of materials to the GCE study area with the goals of developing rating curves that can be used in subsequent geochemical modeling and of obtaining background data needed for other studies. For example, we hope to use major ion composition to reconstruct the paleosalinity regime of the Altamaha estuary based on the composition of buried oyster shells. Samples are collected 1-2 times per week near the main USGS gauging station on the Altamaha River at Jesup by a collaborator (Mr. Jack Sandow). Quarterly samples taken at or near the confluence of the main tributaries of the Atlamaha will help us attribute loadings to different subwatersheds. At present, samples are collected for determining dissolved and particulate C, N, P and Si, total suspended material, total alkalinity, dissolved
inorganic carbon and major ion composition. Water temperature is measured at the same time. We hope to begin measuring pesticide loading to the estuary in the future.

**Human impacts on the Altamaha watershed, GIS**

Alice Chalmers

We have obtained the most recent GIS coverages of McIntosh County for hydrology, roads, railroads, airports, and hypsometry; we also have land use/land cover for 1979, 1989 and 1996 for both McIntosh County and for the entire Altamaha watershed. New land use/land cover for the county and the whole state of Georgia will be publicly available in June, at which time the watershed coverage will be assembled. Color infra-red aerial photographs of McIntosh County taken in 1989 and 1999 are being purchased, scanned and geo-referenced. These will be available for reference and detailed analysis of wetland vegetation. These resources plus other related projects on land use change in the coastal area that I am working on will give us a good understanding of large-scale changes in land use in the Altamaha watershed, and will allow a more detailed analysis of changes in the coastal uplands and wetlands of the study area. All of these GIS coverages will be available on the GCE-LTER web site.

Although Georgia is working on detailed digital soils data, it is not yet available for McIntosh county or for significant portions of the Altamaha watershed. To supplement the STATSGO digital soils data that is currently available, the existing soils map of McIntosh County is being digitized to supplement the similarly digitized soils map of Sapelo Island.

Satellite imagery of the study area is available from 1996 and 1997. Images from the 1970s and imagery from 2000 will be added to the database during the coming year as part of a related research project.

ERDAS Imagine, ArcInfo and ArcView software are available for use by project researchers. Eventually, we plan to make ArcView and ArcExplorer projects with images and GIS coverages of the study area available for download on the web site.

A runoff model that was used in the Satilla watershed during the Georgia Rivers LMER project is being parameterized for the Altamaha using the latest land use, weather and river discharge data. At present the nutrient and discharge data from the USGS and LTER monitoring stations near Doctortown on the Altamaha will be used in the model. Related work that I have done with Merryl Alber, Dick Wiegert and Jack Blanton has indicated that more detailed studies of sub-watersheds is needed to understand the relationships between land use changes and river discharge.

**Responses of Estuarine Processes to Environmental Forcing**
Biogeochemistry
Samantha Joye, Dept of Marine Sciences, UGA

Sediment biogeochemical processes are being examined in intertidal habitats at LTER stations 6 and 10. In the first year of work, surface and groundwater from non-vegetated habitats (mudflats and tidal creeks) has been collected on four occasions, either from permanent monitoring wells or from points at depth (using a drive point piezometer and peristaltic pump). Geochemical characterization of study sites consisted of the quantification of surface and pore water nutrient concentration, physical properties (temperature, salinity, porosity, etc.) and solid phase characterization (CHN). We conducted two 6-8 week pore water equilibration chamber incubations (summer, winter) to obtain detailed profiles of dissolved pore water constituents (hereafter, these data are referred to as "peeper" profiles). Rates of benthic metabolism, net photosynthesis and denitrification were determined using flow-through incubations and membrane inlet mass spectrometry (for dissolved gases). Concentrations of other constituents were also determined on flow-through chamber samples. Gross photosynthetic rates were determined using standard microelectrode techniques. Potential denitrification rates were determined using the acetylene block technique. These data can be used to improve comprehensive geochemical models describing interactions between benthic production and denitrification.

We are still in the process of analyzing and interpreting the pore water data we have collected. However, clear differences in rates of sediment metabolism and denitrification were observed in flux incubations. Denitrification rates are always higher in dark incubated cores; in fact, significant rates of N\textsubscript{2} uptake (e.g., N\textsubscript{2} fixation) in illuminated cores have been observed. Denitrification rates at Stations 10 and 6 were similar (40 µmol N\textsubscript{2} m\textsuperscript{-2} h\textsuperscript{-1}). Oxygen uptake was higher in the dark at St. 10 (-3 vs. -1.3 mmol O\textsubscript{2} m\textsuperscript{-2} h\textsuperscript{-1}) but rates of light and dark O\textsubscript{2} consumption were similar at St. 6 (~ -4 mmol O\textsubscript{2} m\textsuperscript{-2} h\textsuperscript{-1}). Rates of gross primary production were similar at both sites (12 mmol O\textsubscript{2} m\textsuperscript{-2} h\textsuperscript{-1}). At both stations, NH\textsubscript{4} uptake was observed under light and dark conditions (~ -4 µmol NH\textsubscript{4} m\textsuperscript{-2} h\textsuperscript{-1}). Under dark conditions, benthic effluxes of N\textsubscript{2} (gas) always exceeded rates of NH\textsubscript{4} efflux in the dark (by a factor of 10) suggesting that a large fraction of regenerated N is lost from the system. However, rates of N efflux is significantly lower under illuminated, relative to dark, conditions, suggesting that benthic microalgae efficiently trap and retain N in the system when exposed to natural diel cycles.

Plant Production
Steve Pennings, UGA Marine Institute

I am monitoring end-of-year plant biomass annually to test the hypothesis that biomass varies as a function of discharge from the Altamaha and average sea level. In 2000 we set up permanent plots at all 10 LTER monitoring sites. Plots were established at creek-bank and mid-marsh sites (8 plots/zone/site). Plants were non-destructively monitored (stem counts, heights, flowering status) in October 2000. This monitoring will be repeated annually to document year-to-year changes in plant biomass that result from changes in salinity regime and/or sea level. Soil organic content was measured by
ashing cores collected adjacent to each plot in October 2000. In 2001 we will harvest a
range of stems from outside the plots to construct relationships between stem height and biomass that will allow us to convert our non-destructive measurements into biomass estimates.

**Fungal Crop**  
*Steve Newell, UGA Marine Institute*

Lignocellulolysis-supported growth by ascomycetous fungi within standing-dead shoots is a major form of microbial secondary production in saltmarshes. I will measure living-fungal crop and sexual productivity in samples collected at the same time as those taken for plant production (previous paragraph), at all of the ten stations in the GCE/LTER monitoring framework. Ancillary data in the fungal monitoring will be organic density (mg/cm$^2$ of leaf area) and ash content. The data for autumn 2000 is on the GCE website. There are hints in the data suggesting that degree of freshwater influence is negatively correlated with size of living-fungal crop, but the differences among stations were not pronounced enough to permit more than very tentative conclusions. I was surprised to find that the marshgrasses of the least salty sites (*Spartina cynosuroides* and *Zizaniopsis miliacea*) exhibited either very low or zero ascospore expulsion -- my methods probably need alteration for these sites.

**Plant Community Ecology**  
*Merryl Alber, Dept of Marine Sciences, UGA; Steve Pennings, UGA Marine Institute*

We are testing the hypothesis that variation in freshwater and marine influences determines plant community structure. We hypothesize that the distribution of *Spartina alterniflora* and *S. cynosuroides* along the estuary is mediated by physical stress (limiting the down-stream distribution of *S. cynosuroides*) and competition (limiting the up-stream distribution of *S. alterniflora*). We have established transplant and thinning experiments in the field to test this hypothesis.

We further hypothesize that the relative dominance at particular marsh sites of different marsh plants is mediated by differences among sites in average salinity, salinity variability, and flooding regime. In the first year of the project we established 55 study sites within the LTER domain, and began to monitor soil salinities every month in 3 zones at each site. We also surveyed the vertical and horizontal distributions of the major vegetation zones at each site. Results to date indicate that 1) pore water salinity is correlated across the three marsh zones, but pore water salinity is not correlated with the salinity of the water in adjacent creeks, and 2) the relative abundances of *Spartina cynosuroides*, *S. alterniflora* and *Juncus roemerianus* are correlated with pore water salinity, but there is a great deal of scatter in the relationships. In the coming year we will continue to measure salinity and will also measure flooding frequency and range at each site. We are seeking external funding to explore the mechanisms producing these correlative relationships.
Phenotypic and genetic variation in salt marsh plant species
Lisa Donovan, Botany Department, UGA

Salt marsh plants have broad ranges in phenotypes and live across broad ranges in environmental factors. In three studies, we have begun to investigate plant strategies that may have evolved in response to the heterogeneity of the marsh environment: phenotypic plasticity, microscale genetic differentiation and clonal integration. The first study, done on Sapelo Island, looked at the relationships between plant phenotypes and soil characteristics (salinity, water content, and ash content) in natural populations of twelve salt marsh species. Salinity significantly predicted height in 8 out of 12 species, water content predicted height in 6 out of 12 species and ash content predicted height in 3 out of 12 species (Richards and Donovan 2000). This descriptive study shows that plants express a broad range of phenotypes in response to environmental factors in salt marshes. The second study, done in the controlled environment of a greenhouse, explored the basis of that phenotypic variation. We exposed Borrichia frutescens populations from high salt and low salt areas of the marsh (seeds started in greenhouse) to high and low salinity treatments. The high salt population showed less of a reduction in height (p=0.04) than the low salt population, potentially indicating local adaptation. However, leaf area, leaf number and gas exchange characters showed similar plastic responses and no differentiation between plants from both high and low salt parents. These results suggest some traits are differentiating, while others are plastic. The third study, a preliminary survey of allozyme diversity in Spartina alterniflora, revealed that clone size in Spartina is not as large as we anticipated. Thus, clonal integration appears to be less important than the alternative strategies of local adaptation and plasticity. Future studies will include 1) further description of clone size with nuclear markers 2) distribution of specific genotypes or alleles along environmental gradients in both Spartina alterniflora and Borrichia frutescens, and 3) testing for local adaptation with reciprocal transplants in the field and greenhouse.

Benthic invertebrates
Merryl Alber and Dale Bishop, UGA Dept of Marine Sciences

Benthic invertebrates are being monitored twice per year. In October 2000, we completed our initial sampling of the 10 GCE monitoring sites. We could not sample inside the permanent vegetation plots described above due to the partly destructive nature of our sampling methods, so the animal sampling areas were located several meters away from each plot. A 0.5 m² quadrat was positioned around the bases of the marsh plants, and epifauna, litter fauna, and macroinfauna were collected for preservation (70% ethanol and Rose Bengal stain) and processing. Epifauna were collected from the marsh plants and bare marsh surface; litter was washed and sieved (0.5 mm-mesh sieve) to remove associated fauna; macroinfauna was sampled by taking a 5 cm wide by 10 cm deep core and then washed and sieved as above. This sampling regime resulted in 160 samples each of epifauna, litter fauna, and macroinfauna (10 sites x 2 marsh zones x 8 plots). Processing of the samples is ongoing, but we are sorting fauna by taxon for enumeration, and selected taxa are being measured to assess size frequency distributions. In addition to the faunal data, we are recording
sediment temperature, litter dry mass and core organic material dry mass and volume. In the spring sampling effort, we will also measure sediment salinity. These environmental variables may be useful in explaining fauna distribution patterns.

Prior to the initial monitoring period, we took faunal surveys in the Altamaha and Satilla Rivers in October 1999 and July 2000 that will be useful for comparison to current samples. For example, Georgia suffered the worst year of a three-year drought from October 1999 to October 2000, which resulted in greatly elevated salinities in the estuary. Comparing our October 1999 and October 2000 data sets has indicated shifts in population distributions, community composition patterns and size distributions, which may be due to salinity effects on recruitment and survival.

**Grasshopper abundance**  
Steven Pennings, University of Georgia Marine Institute

I am testing the hypothesis that grasshopper abundances vary between years as a function of angiosperm production. Grasshoppers were visually counted on transects (mid-marsh, 10/site) at 5 of the 10 LTER monitoring sites in August 2000. Densities differed ten-fold among sites. Grasshoppers will be counted in both creek-bank and mid-marsh zones at all sites in 2001 and following years. Factors contributing to the dramatic variation among sites will be explored in future work.

**Microbial decomposer consortia**  
Mary Ann Moran, James T. Hollibaugh, Robert Hodson, Dept of Marine Sciences, UGA; Steven Newell, UGA Marine Institute

In the intertidal salt marshes of the Georgia coast, both bacteria and ascomycetous fungi play critical roles in decomposition of Spartina alterniflora and other lignin-rich detritus. This project brings together fungal and bacterial microbial ecologists to examine the interactions between fungi and bacteria in the salt marsh decomposition. Both molecular biological and culturing approaches are being used to describe the decomposer communities and examine spatial and temporal patterns in community composition. Fungal communities (characterized by sequencing and T-RFLP analysis of internal transcribed spacer regions) are dominated by a relatively few species clusters, most of which have been brought into culture. Bacterial communities (characterized by sequencing and T-RFLP analysis of 16S rRNA genes) are more diverse, and many of the major taxa are not present in companion culture collections. Both the bacterial and ascomycete fungal communities present on decomposing vascular plant material show low spatial variability but clear seasonal shifts. Studies of functional genes of potential importance in bacterial-fungal interactions are also underway. Sequences of bacterial ring cleavage dioxygenases and ascomycete laccases, two enzymes involved in the breakdown of aromatic components of vascular plant material, are being retrieved from cultured organisms and from DNA extracted directly from decomposing plant material. The next stages of the project will include studies of bacterial chitinases and will involve manipulative studies designed to examine direct interactions between bacterial and fungal decomposer groups.
**Estuarine respiration**  
Wei-Jun Cai, Dept of Marine Sciences

We have surveyed CO$_2$ parameters ($p$CO$_2$, pH, total alkalinity (TA) and total dissolved carbon dioxide (DIC)) and O$_2$ in the three areas of GCE site. $p$CO$_2$ levels are all very high in these areas (1000 to 3000 uatm), presumably due to net decomposition over carbon fixation, though other geochemical explanations are being investigated. We are in the process of calculating gas fluxes based on wind speed information. We have also started a monitoring program for CO$_2$ parameters in the Duplin River, a blind creek adjacent to Sapelo Island that is surrounded by marsh. We plan to estimate net marsh metabolism from CO$_2$ parameters collected between flooding and ebbing conditions. TA and DIC are also measured in the Altamaha River at the head of tide to characterize loading to the coastal zone.

**Annual Meeting**

We held the first GCE-LTER annual meeting in March, 2001. We presented and discussed our results to date, received feedback from our scientific advisory committee: Iris Anderson (VIMS/VCR), Jack Gallagher (U. Del), Chuck Hopkinson (MBL/PIE), George Jackson (TAMU), Jane Caffrey (UWF) and Wim Kimmerer (SFSU).

**Education and Human Resources**

**UGA.** LTER funding supported 2 post-doctoral associates (Dale Bishop and Wade Sheldon), 8 graduate students (Erin Biers, Alison Buchan, Justine Lyons, William Porubsky, Christina Richards, Merrilee Thoresen, Susan White, Amanda Wrona), 3 technicians (Joan Sheldon, Chris Smith, Ed Sheppard) and 3 undergraduates (Sarah Fisher, Gretchen Goodbody, Maria Pickering) in the past year.

**UGAMI.** LTER funds have provided support for two technicians at the Marine Institute: Tracy Buck, Ken Helm. We have requested supplemental funding through the LTER program to support 3 REU students in the coming year, and to begin an LTER schoolyard program.

**GA Tech.** The project supported a Ph.D. student (Greg Schultz) and an undergraduate assistant (Patrick Fulton). Funding for a full-time undergraduate summer researcher is pending from the REU program. Related research on redox zonation of a surficial aquifer system was started by an MS student under the auspices of a USGS grant and will be completed this summer under LTER sponsorship.
Partially in conjunction with this grant, Ruppel has involved undergraduates in her required Environmental Field Methods class at Georgia Tech in LTER well installations, baseline geophysical and geochemical surveys at an LTER focus site, and related scientific studies. Information about the Fall 2000 course is available on the GCE web site, with reports and graphics linked off http://hydrate.eas.gatech.edu/nsfcdcouse/

**SkIO.** The grant supported one technician (Julie Amft).

**Outreach**

- "Georgia Coastal Ecosystems LTER", presented to the Research Coordinators of the National Estuarine Research Reserve System by Steve Pennings (UGAMI), Sapelo Island, March 2001.


- “Hydrologic geophysical methods to constrain GW flux into marshes” collaboration between C Ruppel and PIE and VCR personnel.

- C. Ruppel's undergraduate Environmental Field Methods class installed monitoring wells for the LTER project, see:

  - http://hydrate.eas.gatech.edu/eas4420/

**Publications**

**Peer-reviewed Journals**


Presentations


Newell, SY. 2000. Patterns and fate of fungal productivity in saltmarshes. INTECOL 2000, the Millenium Wetlands Symposium of the International Association for Ecology, Quebec City, Canada, August 2000.


Richards, CL Richards, SN White, MA Mcguire, SJ Franks and LA Donovan Evidence for local adaptation along a salinity gradient in a salt marsh perennial. ESA 2001 abstract.
Ruppel, C.  Groundwater exchanges in GCE marshes. Marine Biological Lab (PIE group), March 2001


Schultz, G. and C. Ruppel, Groundwater flow and transport at the island-estuary boundary, Sapelo Island, Georgia. LTER All-Scientists' Meeting, August 2000.


Additional Funding

- Mary Ann Moran (UGA Dept Marine Sciences) and collaborators obtained funding for an NSF Microbial Observatory Project. This 5-year project is focusing on describing the bacterial communities within the estuarine systems in the LTER domain, and the work will complement the microbial studies of the GCE-LTER.

- Rick Lovell at the University of South Carolina is funded by NSF/OCE to examine by DNA technology N2-fixing bacterial biodiversity in the rhizosphere of smooth cordgrass. He is using LTER station 6 as one of his field sites and collaborating with Newell and Moran so that his data will complement (and vice versa) the Decomposer Consortia Experiments

- Linda Blum and Aaron Mills (University of Virginia, Department of Environmental Sciences) (VCR) "The Relative Importance of Organic Material vs. Local Environmental Conditions on Microbial Decomposer Communities", DEB-
This project will compare sediment microbial diversities (bacteria: 16S rDNA fingerprinting; fungi: ITS rDNA fingerprinting) at several coastal-marsh LTER sites, focusing on the high marsh just marshward of the terrestrial boundary.