GCE Annual Report Fall 2007 – Research Findings

Context
The central paradigm of GCE-II is that variability in estuarine ecosystem processes is primarily mediated by the mixture of fresh and salt water flows across the coastal landscape. The project is focused on 5 main, inter-related questions:

Q1: *What are the long-term patterns of environmental forcing to the coastal zone?*

Q2: *How do the spatial and temporal patterns of biogeochemical processes, primary production, community dynamics, decomposition, and disturbance vary across the estuarine landscape, and how do they relate to environmental gradients?*

Q3: *What are the underlying mechanisms by which the freshwater-saltwater gradient drives ecosystem change along the longitudinal axis of an estuary?*

Q4: *What are the underlying mechanisms by which proximity of marshes to upland habitat drives ecosystem change along lateral gradients in the intertidal zone?*

Q5: *What is the relative importance of larval transport versus the conditions of the adult environment in determining community and genetic structure across both the longitudinal and lateral gradients of the estuarine landscape?*

Q1: *What are the long-term patterns of environmental forcing to the coastal zone?*

Climate signals
A. Burd (UGA) and J. Sheldon (UGA) have continued to investigate the effects of large-scale climate drivers on long-term data relevant to the GCE study area. They previously found that the Southern Oscillation Index (SOI) was not highly correlated (if at all) with monthly-averaged precipitation and river discharge data from the GCE region. They have continued these investigations by evaluating both the North Atlantic Oscillation Index (NAOI) and the Bermuda High Index (BHI). The NAOI is a prominent teleconnection pattern linking the East and West Atlantic associated with changes in the position of the North Atlantic jet stream and storm track. The index consists of a north-south dipole, with the southern pole spanning the North Atlantic between 35ºN and 40ºN. The BHI describes the east-west position of this southern pole and has been shown to influence weather in the southeastern U.S. more than the north-south NAOI.

Three-month standardized anomalies were formed of Altamaha River discharge, precipitation at two stations in its watershed, and one on the coast. These series were detrended and short-term autocorrelations were removed if necessary. These were compared with each other and the three climate indices (SOI, NAOI and BHI). During winter and spring, river discharge is more highly correlated with precipitation in the lower watershed than with that in the upper watershed. This pattern reverses during summer and fall. In winter, precipitation is correlated more with winter SOI than with other climate indices, but precipitation is only weakly correlated with the previous winter's SOI during other seasons. In spring, the BHI develops a strong correlation with coastal precipitation. This influence weakens somewhat during summer and fall but spreads to the Altamaha watershed (Figure 1). Fall precipitation is correlated with the spring NAOI as well as the fall BHI. At times, climate signals explain as much as 29% of the variability in local data.

This analysis is ongoing and will involve investigating in greater detail the relationships among the SOI, NAOI, BHI, Altamaha River discharge, and other climate data and indices relevant to the area. This work was presented at the biennial meeting of the Estuarine Research Federation.

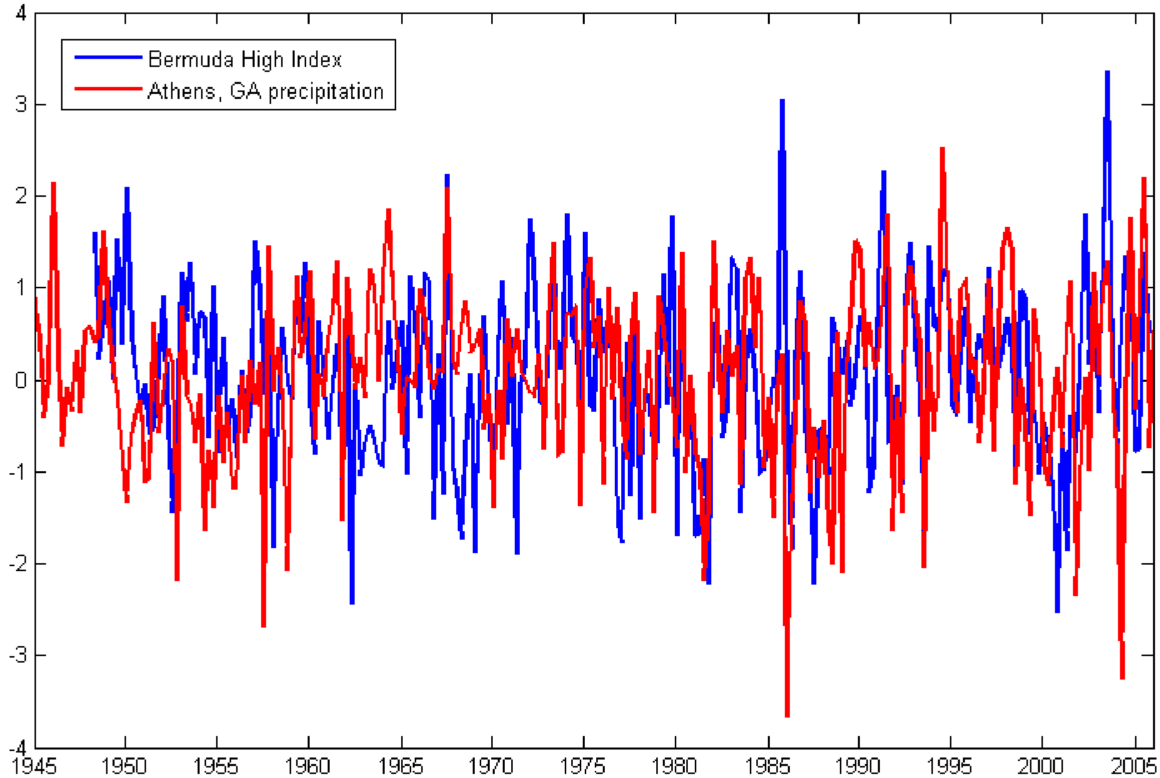

Figure 1. Time series of the Bermuda High Index and precipitation at Athens, GA.

Weather station

The fully automated climate data harvesting system (developed in November 2002 with supplemental NSF funding for ClimDB/HydroDB participants) continues to provide GCE participants with near-real-time data and plots from two climate stations (Marsh Landing on Sapelo Island and Hudson Creek/Meridian Landing) and one USGS stream flow gauge (Altamaha River at Doctortown), updated hourly. Real-time data are finalized monthly, re-sampled to daily values and submitted to the LTER climate and hydrological databases (ClimDB/HydroDB), along with data from the manually operated NWS climate station on Sapelo Island. In addition, near-real-time and historic data and plots from these and other relevant climate stations are also publicly accessible on the GCE Data Portal website (http://gce-lter.marsci.uga.edu/portal/).

We made one major change to our climate data harvesting system this year. The Sapelo Island NERR program received funding to upgrade monitoring stations on Sapelo Island to support near-real-time data access via GOES satellite telemetry. A new Campbell Scientific Instruments CR1000 data logger and satellite transmitter were installed on the Marsh Landing weather station (cooperatively funded by SINERR and GCE). We then began harvesting data from this station through the NOAA Hydro-meteorological Automated Data System (HADS) via the Internet instead of using telephone modems. This transition also required development of new data processing algorithms to convert highly normalized data streams retrieved from HADS to tabular data sets compatible with GCE data processing, quality control and analysis programs. Conversion of other SINERR weather stations and YSI sondes to support GOES telemetry is also planned; when complete, we will be able to use the same generalized data harvesting program to acquire and process near-real-time data from these stations as well.

Watershed inputs

M. Alber (UGA) and S. Schaefer (Ph.D. student, UGA) have developed complete nitrogen and phosphorus budgets for the watershed of the Altamaha River for 6 time points between 1954 and 2002 (Figure 2). Fertilizer tended to be the most important input of both N and P to the watershed, but net food and feed import increased in importance over time and was the dominant source of N input by 2002. When considered on a sub-watershed basis, fertilizer input tended to be highest in the middle portions of the watershed (Little Ocmulgee, Lower Ocmulgee and Lower Oconee sub-watersheds) whereas net food and feed imports were highest in the upper reaches (Upper Oconee and Upper Ocmulgee sub-watersheds). These findings are now in press (Schaefer and Alber 2007b).

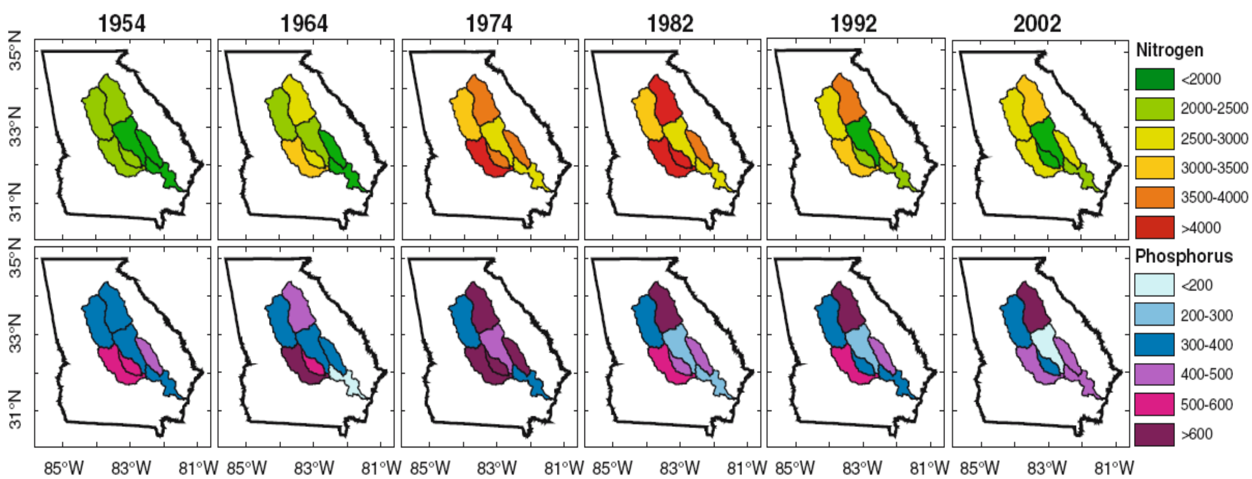

Figure 2. Spatial distribution of total inputs of N and P to sub-watersheds of the Altamaha River. All values in kg $km^{-2}yr^{-1}$. (Source: Schaefer and Alber 2007b).

River delivery of dissolved and suspended material

We continue to work with Jack Sandow (Altamaha Riverkeeper) to monitor nutrients in the river water entering our domain. The Joye lab (S. Joye, UGA) received a total of 90 river samples this past year (about 8 samples per month), for a total of about 497 since the GCE project began. Samples are analyzed to determine concentrations of DIN, DIP, DSi species, organics (DOC, DON, and DOP) and total suspended solids. A paper describing temporal variations in concentrations, estimates of nutrient and dissolved organic matter loading rates to the estuary, and an evaluation of the estuarine response is in review (Weston et al.) and another paper is in preparation.

Q2: *How do the spatial and temporal patterns of biogeochemical processes, primary production, community dynamics, decomposition, and disturbance vary across the estuarine landscape, and how do they relate to environmental gradients?*

Salinity structure

Long-term measurements of conductivity, temperature and sub-surface pressure are collected every 30 minutes at 8 moorings distributed across the GCE-LTER domain (see http://gce-lter.marsci.uga.edu/public/research/mon/sounds_creeks.htm). Mooring locations were chosen to span the salinity gradient as well as to take advantage of existing physical structures for mounting instruments. The moorings are located in transect regions used for GCE oceanographic surveys and long-term water column monitoring, and near to GCE-LTER marsh study sites. MicroCAT sondes are cleaned and inspected biweekly to minimize data loss due to fouling, and logged data are manually downloaded and processed on a bimonthly to quarterly basis by GCE field technicians (K. Helm, D. Saucedo, J. Shalack, UGA Marine Institute). Provisional data and plots are provided to GCE investigators on the project website within two days of acquisition, and finalized, quality-controlled data are added to the GCE Data Catalog (http://gce-lter.marsci.uga.edu/public/app/ data_catalog.asp) and GCE Data Portal (http://gce-lter.marsci.uga.edu/portal/) at the end of each year to provide public access.

Long-term water salinity and temperature monitoring at GCE provides critical insight into temporal and spatial patterns across the GCE domain. For example, in late 2006 the Southeast U.S. entered into severe hydrologic drought, which strengthened substantially in summer 2007. Discharge measurements from the Altamaha River gauge at Doctortown, GA, dropped to the lowest volumes recorded since USGS monitoring began in 1932. Consequently, salinities at GCE site 7 (Carrs Island, southwest of Sapelo), a historically freshwater site, regularly exceeded 5 PSU at high tide during summer 2007, whereas salinities at GCE site 3 in Sapelo Sound (northeast of Sapelo) remained above 30 PSU throughout the tidal cycle (i.e. near oceanic conditions). This represents a significant salinity shift compared to 2002-2003, comparable to the shift that occurred during the last hydrologic drought in 2001 (Figure 3). These data will help inform ongoing long-term studies of plant and invertebrate distributions and biomass as well as biogeochemical processes.

Patterns of dissolved and suspended material

The GCE sound surface water quality monitoring program transitioned from quarterly cruise sampling (during GCE-I) to monthly sampling during 2006-2007, the transition between GCE-I and GCE-II. Water samples were collected in April and November 2006 and then monthly starting in January 2007 (K. Helm, D. Saucedo, J. Shalack) and then analyzed at UGA (S. Joye). This monthly sampling program will be continued throughout GCE-II. During the past year, the Joye lab processed a total of 4800 samples from the monitoring cruises: 576 samples for determination of concentrations of dissolved inorganic nutrients (NO_2^-, NO_3^-, NH_4^+, HPO_4^{2-}, and $H_2SiO_4^{2-}$) and dissolved organics (DOC, TDN, DON, TDP, and DOP); 1440 chlorophyll *a* samples; and 1440 total suspended sediment and particulate CN samples. Blanks (10 blanks each per suite of analyses) were also collected and run as samples. These analyses are in various phases of completion.

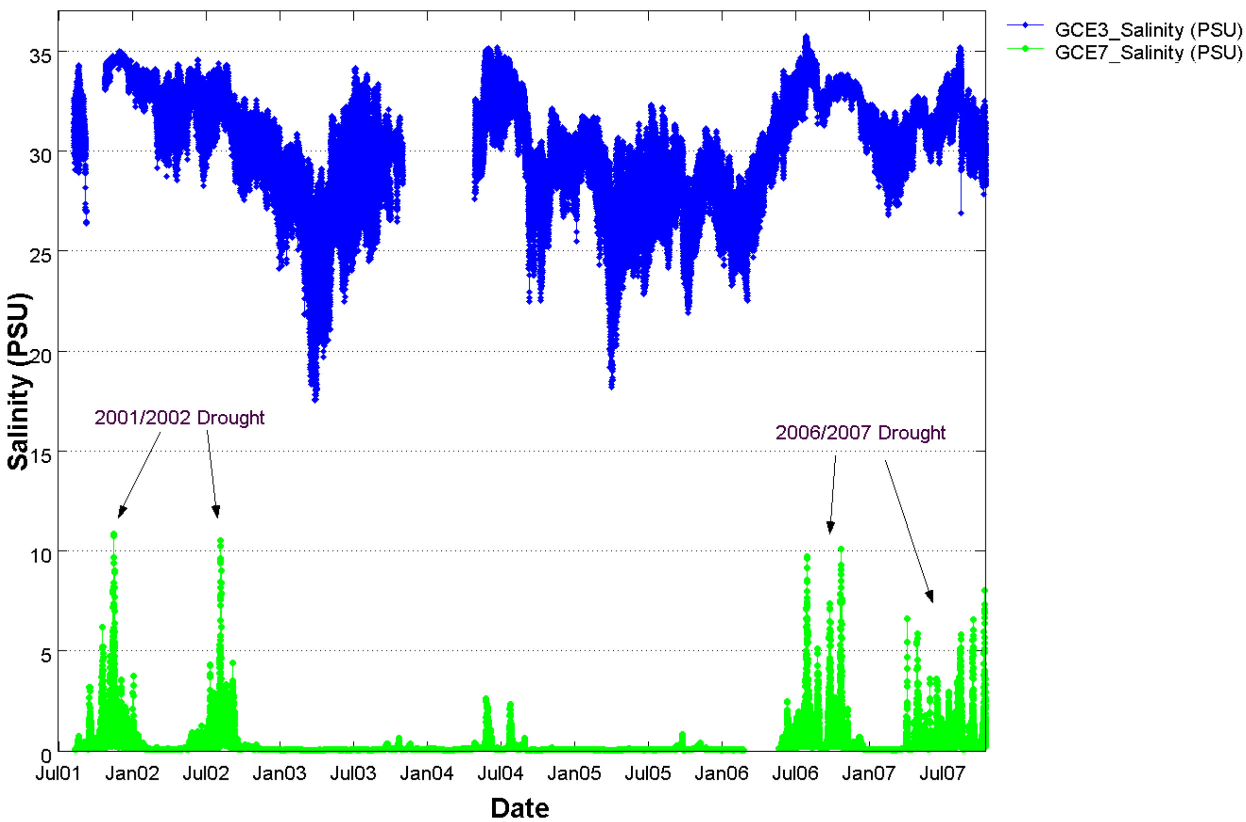

Figure 3. Long-term salinity observations at GCE3 (North Sapelo) and GCE7 (Carrs Island).

As observed in past years, spatial and temporal variations among the study sites were apparent. The highest NO_x concentrations were present in Altamaha Sound at GCE 7 and 8. No significant differences in NO_x concentration were observed between surface and bottom water samples at any of the stations. In Altahama Sound, NO_x concentrations usually exceeded NH_4 concentration whereas in Doboy and Sapelo Sounds, concentrations of NH_4 usually exceeded NO_x. DOC concentrations were highest in Sapelo Sound, followed by Doboy and Altamaha Sounds.

The groundwater wells within the GCE domain (Moses Hammock and Visitor Center) were sampled five times during the past year by the Joye lab. Approximately 50 samples per trip were collected for a total of ~250 samples. Two papers are in preparation describing the results of the Moses Hammock groundwater biogeochemistry data.

Soil processes

We continue to measure vertical accretion and sedimentation using sedimentation-erosion tables (SETs) and feldspar marker layers to evaluate the effects of freshwater pulsing on long-term stability of tidal marshes. We measure changes in marsh surface elevation and sediment deposition every six months at the ten GCE study domain sites and at three sites of a directed study on Dean Creek.

C. Craft (IU) published a study (Craft 2007) that compared the soil properties of marshes in the GCE study site. Marshes along the Altamaha River estuary experience much lower salinities than those along Sapelo and Doboy Sounds, have higher proportions of organic carbon and nitrogen in the soil, and are increasing in elevation at a faster rate than those in saltier areas. He found that these disparities were not because of differences in plant growth at the study sites, but were instead due to the fact that decomposition is slower in fresher water so more organic material can accumulate. The study compared the Georgia results with those from studies in marshes throughout the U.S. and found that most patterns were general. Increases in elevation were related to freshwater input in all areas, as was soil nitrogen. These results were highlighted in the Georgia Coastal Resources Division Newsletter, The Georgia Sound.

Plant dynamics

S. Pennings (UH) and his lab continue to monitor plant biomass to test the hypothesis that end-of-year biomass varies as a function of 1) freshwater discharge from the Altamaha River and 2) average sea level. In 2000 they set up permanent plots at all 10 GCE monitoring sites. Plots were established at creek-bank and mid-marsh zones (8 plots/zone/site). An additional zone (high marsh *Juncus*) was established at site 10 in 2005 to increase replication of sites with *Juncus*. Plants were non-destructively monitored (stem counts, heights, flowering status) in October of every year from 2000 to 2007. Soil organic content was measured by ashing cores collected adjacent to each plot in October 2000. Stem samples were taken adjacent to plots in 2002, measured, dried and weighed, in order to generate regression relationships between height and mass. Plots are also proving useful in documenting spatial and temporal variations in disturbance from physical (wrack) and biotic (grazing) sources.

In a separate experiment, Pennings is testing the hypothesis that annual variation in marsh plant species composition is driven by variation in rainfall. Salt marsh vegetation often consists of discrete stands with abrupt borders between different species or associations. He has monitored mid-summer plant composition at permanent plots on 3 types of vegetation borders (*Spartina alterniflora-Juncus roemerianus*, *S. alterniflora*-meadow, meadow-*J. roemerianus*), at two sites each, since 1996. Vegetation composition in these plots is dynamic and appears to be related to variation in rainfall, although more years of data will be needed to test this hypothesis rigorously.

Pennings is also conducting parallel experiments in GA and AL to examine 1) how rapidly marsh vegetation can recover from disturbance, and 2) the role of competition in secondary succession. In 3 vegetation zones (*S. alterniflora*-meadow border, meadow-*J. roemerianus* border, *J. roemerianus* zone) at each of 2 marshes in each state, replicate 3 x 3 m plots were cleared using herbicide and clipping and maintained free of vegetation for 2 years. Control plots were marked but unmanipulated. In 2000 individual plots were divided into two or four sub-plots, depending on the diversity of the vegetation in each zone, with one sub-plot allowed to recover without further manipulation and the other sub-plot(s) treated by periodically removing 1 or 2 dominant plant species occurring in each zone. To date, succession has been fastest in plots on the *S. alterniflora*-meadow border, which have already converged on control plot values, and slowest in the *J. roemerianus* plots, which are still early in the successional trajectory. Removal treatments indicate that competition plays a strong role in mediating the composition of the vegetation in each zone.

Amy Kunza (MS student, UH) compared marsh plant diversity in replicate marshes in GA and TX. Results suggest that TX marshes are more diverse at the scale of individual plots and individual sites, but the marsh plant species pool of TX is not greater than that of GA. Thus, the nature of the interactions among plants, or between plants and the abiotic environment, differs in these two geographic regions. A manuscript based on this work will be submitted in late 2007.

Animal dynamics

Our annual monitoring of mollusk, crab, and infaunal populations at all ten GCE sites continued in 2007, under the direction of D. Bishop (UGA). One of the striking patterns since monitoring began in 2000 is that densities of the periwinkle snail, *Littoraria irrorata*, are lower in the Altamaha than in the other sounds (Figure 4). This may be a result of the inability of larvae to recruit upstream, or else reduced survival of the new recruits. Work being planned in this grant cycle will attempt to differentiate between these two alternatives (see Q5, below).

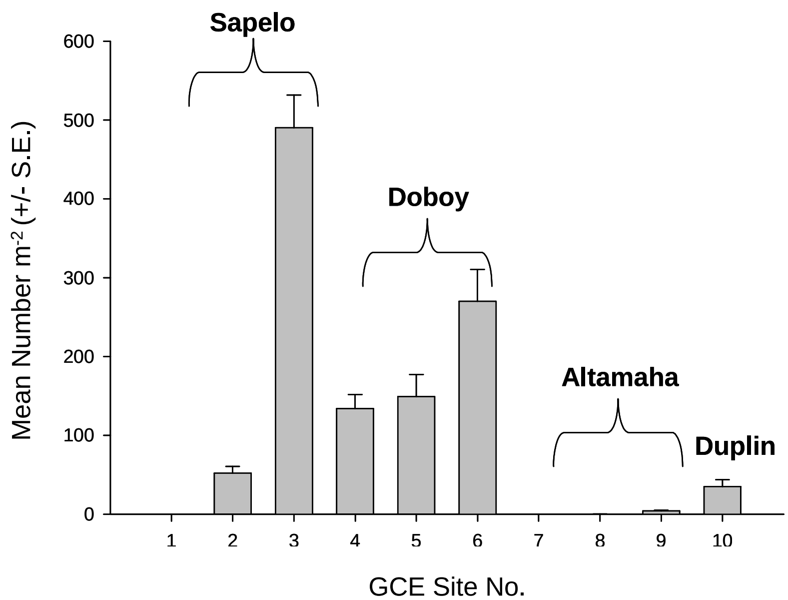

Figure 4. Mean number of snails observed at GCE mid-marsh monitoring sites, 2000-2006.

D. Bishop continues his work on invasive species, including annual monitoring of the green porcelain crab (*Petrolisthes armatus*). He has confirmed the presence of an invasive barnacle (*Megabalanus coccopoma*) on buoys in Sapelo and Doboy Sounds and has identified an isopod (*Paradella dianae*) that has not been previously recorded in Georgia. This work is included in a statewide management plan for invasive species being developed by UGA Marine Extension.

S. Pennings is testing the hypothesis that grasshopper abundance varies among sites and years as a function of site characteristics and angiosperm production. Grasshoppers were visually counted on transects (mid-marsh, 8-10/site) at the 10 GCE monitoring sites in each August from 2000 to 2007. Grasshopper populations were dominated by two common taxa. Densities differed more than ten-fold among sites. The rank-order of sites was similar among years, suggesting that some sites consistently supported high grasshopper populations and other sites consistently supported low populations. Expanded monitoring at 30 sites in 2003 indicated that grasshoppers were common at sites with extensive adjacent upland, but were absent at mid-estuary sites that had extensive *Spartina* zones but lacked upland habitats.

Chuan-Kai Ho (PhD student, UH) also tested the hypothesis that an omnivorous crab would have strong top-down control on an arthropod food web on the shrub *Iva frutescens*. It is generally believed that the diverse and reticulate interactions promoted by omnivory will tend to reduce strong trophic cascades. In both laboratory and field experiments, however, crabs suppressed both predator and herbivore populations, releasing plants from herbivore pressure and promoting plant performance. A manuscript based on this work is in press in *Ecology*.

B. Silliman (UF) has worked to assess population densities of the American alligator on Sapelo Island. He and his student have taken tissue samples from over 80 individuals to assess the level of connectivity between these predator populations and marine food sources.

Duplin River estuary

We continue our focus on the Duplin River estuary, including our work on construction of a high-resolution digital elevation model (DEM) for the system, led by J.Blanton (SkIO) in collaboration with F. Andrade (Univ. of Lisbon), M. Adelaide Ferreira (IMAR-Marine Laboratory, Portugal) and J. Amft (SkIO). They completed the classification and analysis of a series of 7 aerial passes over the Duplin River at 1hr intervals, covering low water (LW) to high water (HW). For each pass, a total of eight images were obtained on infrared (IR) film. The photographs were processed to yield the water surface area as a function of time. Subsurface pressure gages deployed along the tidal creek were used to determine the vertical reference level for the corresponding flooded area. The analyses of these images were used to construct curves relating flooded area to water level (Figure 5).

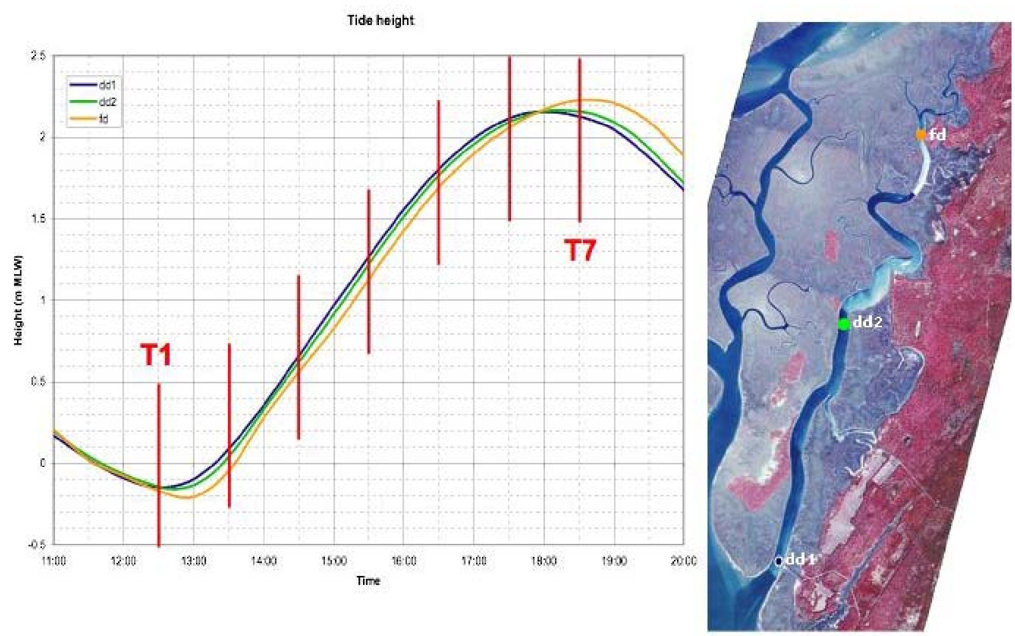

Figure 5. Water level curves for 15 April 2004 along the axis of the Duplin River. The red vertical lines (T1 through T7) show the times of each aerial pass. The locations of the three curves are shown in the image on the right. Water level at a given time varies within 0.1 m over a distance of 7 km, so water surface is assumed to be horizontal over the 2min duration of a single pass of the airplane. Data courtesy of Dr. Daniela Di Iorio (UGA) and the LTER monitoring network.

The hypsometric curves produced from this analysis (Figure 6) have a consistent pattern of growth in water level versus time based on following the evolution of water area during a flood tide. Eleven of 16 prisms show relatively slow growth rates and small initial volumes. The largest tidal prisms are found for Polygon 1 (Barn Creek) and Polygon 5 (Marsh along the east fork north of Hunt Camp). Careful study of the individual hypsometric curves as well as those describing the growth in water volume is likely to reveal morphological details throughout the Duplin River intertidal area that would be relevant to the distribution of plants and animals as well as residence time of water. Numerical models of water circulation in the river may simulate tidal currents more accurately by incorporating the DEM into their model grids.

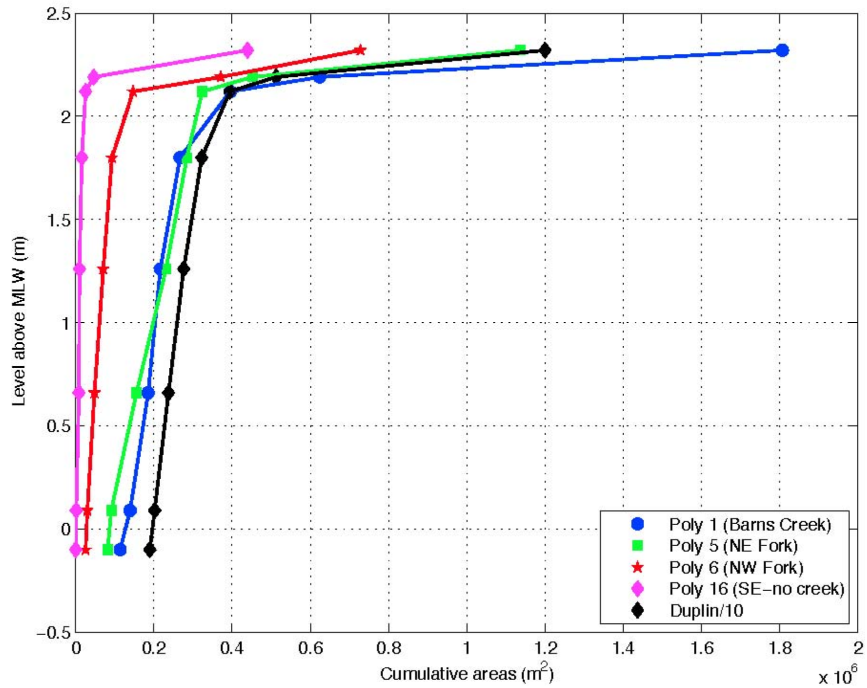

Figure 6. A comparison of hypsometric curves for four polygons with one for the total drainage area. The final line segment in each plot connects water depths and areas from 2.19 to 2.30 meters. The area at 2.19 m references the largest water area calculated for the final overflight (T7). The area at 2.30 m (the water level of the NOAA published mean spring HHW) references the total polygon area. Areas for the total Duplin tidal watershed have been divided by ten to scale that curve with the polygons.

Additional analyses of the Duplin River involve the development of heat budgets by D. Di Iorio (UGA) and P. McKay (Ph.D. student, UGA). They have found a pronounced change in characteristics between the lower and the upper segments. The lower Duplin is dominated by tidal processes with cool, salty water being brought in on each flood tide thus temporarily suppressing the along-channel temperature gradient and mixing cool water up the channel. Short period temperature cycles are predominately at M2 tidal frequencies. In contrast, the upper Duplin is fresher and warmer, presumably reflecting the influence of ground water input, the shallow nature of these waters and the greater extent of intertidal marshes and side creeks.

Direct atmospheric fluxes play a minor roll in controlling the temperature cycle in the Duplin, accounting for a mere two percent of the observed temperature storage in the lower Duplin and twelve percent in the upper Duplin. The presence of a strong S1 solar signal in the temperature cycles in the upper, and even in the lower, Duplin is indicative of the strong diel temperature signal embedded in the residual term. This term is presumably due to lateral advection of heat due to flows through the marsh and side creeks. This lateral advection constitutes a very significant, though ungauged, source of heat which accounts for 63 percent of the observed heat storage in the upper Duplin and a still significant 33 percent in the lower Duplin. Tidal advection of heat is a major factor in both the lower and upper Duplin, accounting for 65 percent of the observed heat storage in the tidally dominated lower Duplin and a still significant 25 percent in the more isolated upper Duplin.

D. Di Iorio and P. McKay have also calculated centerline salt fluxes, which show the effect of tidal correlations in pumping salt upstream and maintaining the along-channel salinity gradient. In the lower Duplin, upstream tidal salt fluxes ranged between 0 and 2 PSU m s^{-1}, with higher values at spring tide. The fluxes can be expressed as a diffusion coefficient acting on the along-channel residual salinity gradient. In the lower Duplin, this coefficient, K_x, varies between 150 and 600 m^2 s^{-1} on a spring/neap cycle with higher values on spring tide. In the upper Duplin, upstream salt fluxes are much lower than in the lower Duplin and range between 0 and 0.05 PSU m s^{-1}, again with higher values on spring tide. The along-channel salinity gradient reverses sign, being positive (salty towards the mouth) on spring tide and negative (salty towards the head) on neap tide. This is believed to be due to the interaction between tidal energy and ground water pumping in the region between the upper and lower Duplin and represents an unusual class of a reversing estuary.

In addition to the above projects, J. Schalles (Creighton) has continued his analysis of the hyperspectral airborne imagery of the area that was acquired in June 2006. Five plant species were consistently abundant and mapped using Spectral Angle Mapper and several other classifiers in the ENVI software package. Spectral libraries were constructed for each class using atmospherically corrected AISA spectra from reference plots and delineated stands. The dominant species, *Spartina alterniflora*, was divided into 3 size groups for classifications. Biomass ranged from 0 (salt pans) to about 5 kg m^{-2} dry wt (tall *Spartina* stands), with an average biomass of 1.22 kg m^{-2}. Several alternative vegetation indices were compared to NDVI and found superior in accounting for biomass patterns. This work was presented at the Estuarine Research Federation meeting in November.

The data set that was collected in order to groundtruth the hyperspectral imagery included information on soil traits (salinity, water content, organic content), plant community traits (species composition and richness, biomass by species, canopy height), the chlorophyll content of *Spartina alterniflora,* and the abundance of the most common invertebrates (the snails *Littoraria* and *Melampus* and the bivalve *Geukensia*). Oyster abundance was estimated visually. In collaboration with Alana Lynes (MS student, UH), S. Pennings is using this data set to explore patterns of plant community assembly in Georgia marshes.

Finally, we continue to evaluate the thermal IR imagery that was collected to provide information on potential inflow of groundwater to the area. S. Joye and M. Alber worked to identify paired sites (those with evidence of groundwater and nearby controls) that were sampled in summer 2007 for nutrient analysis of porewater. A total of 9 paired sites were sampled for DOC and TDN.

Cross-site comparisons

M. Alber and S. Schaefer applied the N budgeting methodology developed for the International SCOPE Nitrogen project to 12 watersheds in the southeastern U.S, and compared them with estimates of N export for 16 watersheds in the northeastern U.S. They found that average N export was only 9% of input in southeastern watersheds, suggesting the need for downward revision of global estimates. The proportion of N exported was significantly related to average watershed temperature (% N export = $58.41e^{-0.11*\text{temperature}}$; R^2=0.76), with lower proportionate nitrogen export in warmer watersheds. In addition, we identified a threshold in proportionate N export at 38°N latitude that corresponds to a reported break-point in the rate of denitrification at 10-12°C. They hypothesize that temperature, by regulating denitrification, results in increased proportionate N export at higher latitudes. This work was published as a “Synthesis and Emerging Ideas” paper in *Biogeochemistry* (Schaefer and Alber 2007a).

J. Lyons (Ph.D. student, UGA), worked with J.T. Hollibaugh (UGA) and M. Alber on the ascomycete fungal communities on *Spartina* spp. in the U.S. She used terminal restriction fragment length polymorphism (T-RFLP) analysis of 18S-to-28S internal transcribed spacer (ITS) region to compare the ascomycete communities on two *Spartina* species (*S. alterniflora* and *S. patens*) that co-occur in salt marshes on the east coast of the U.S. (Georgia, North Carolina, New York, and Massachusetts). Amplicons representing *Phaeosphaeria spartinicola* were recorded on 94% of all *S. alterniflora* samples but on only 75% of *S. patens*, and represented a significantly different (p=.006) percent average coverage of 47 and 21% on the chromatograms, respectively. Samples of *S. patens* yielded a higher number of total (eight) and of unique (three) T-RFs than did *S. alterniflora* (six total, one unique). If T-RFs are used as a measure of diversity, then that on *S. patens* is significantly higher than that on *S. alterniflora*. Similar results were also seen on the two species sampled in Gulf coast marshes. This work is now being written up for publication.

S. Pennings has been involved in several efforts to compare plant-herbivore interactions across latitudinal gradients. The work involves comparative studies of multiple sites, including 3 LTER sites and a number of NERR sites. Feeding preference experiments indicate that most marsh plants are more palatable at high latitudes (New England) than at low latitudes (e.g., GA). This variation is correlated with latitudinal differences in toughness, nitrogen content and chemistry, and is constitutive rather than induced. He is testing the hypothesis that herbivore pressure is greater at low latitudes, and that this could be one selective pressure on plant palatability. Chuan-Kai Ho (PhD student, UH) is testing the hypothesis that high-latitude plants are better food for herbivores than low-latitude plants by conducting growth experiments in the greenhouse. Preliminary results support this hypothesis, but suggest that the results may vary among feeding guilds.

Pennings also worked with Elizabeth Wason (undergraduate, UH) to collect grasshoppers from the *Spartina alterniflora* zone of multiple sites along the Atlantic Coast of the US from FL to ME to examine latitudinal variation in salt marsh grasshopper species composition. They focused on tettigoniid grasshoppers, which dominate the collections. Two species (*Orchelimum* *fidicinium* and *Conocephalus spartinae*) make up >90% of all the individuals collected. *Conocephalus* dominates the northern collections and *Orchelimum* the southern collections. An additional 5 species are present but rare. Elizabeth Wason completed a senior honors thesis at UH based on this work. A manuscript based on this work has been submitted.

Q3: *What are the underlying mechanisms by which the freshwater-saltwater gradient drives ecosystem change along the longitudinal axis of an estuary?*

Much of the monitoring data, described above under Q2, can be used to look at long-term changes along the longitudinal axis of the estuary in response to changes in river inflow and climate. There also continues to be interest in the potential application of the SqueezeBox modeling approach (developed by J. Sheldon and M. Alber) as a way to estimate mixing time scales (such as residence time) to compare the relative susceptibility of estuaries to nutrient loading. J. Sheldon completed a review of the box modeling approaches currently used by the Land-Ocean Interactions in the Coastal Zone (LOICZ; Gordon et al. 1996) program to develop nutrient budgets for estuaries, and is participating in a working group that will inform planned upgrades to that methodology.

S. Pennings and Hongyu Guo (PhD student, UH) are examining the factors creating plant community structure along the estuarine salinity gradient. They have sampled plant biomass and diversity at replicate fresh, brackish and marine tidal marshes. They are currently conducting a series of transplant experiments to explain the patterns of composition, diversity and productivity that they have documented.

We are planning specific manipulations to address this question as a directed project starting in Year 3. However, leveraged funding from an EPA grant (PD-C. Craft, co-PIs S. Pennings and S. Joye) is currently supporting a study that involves sampling along the salinity gradient of three rivers along the Georgia coast, the Altamaha, Satilla and Ogeechee, at freshwater, brackish and fully marine sites. The goal of the project is to examine how ecosystem services related to disturbance regulation (shoreline protection), gas exchange (CH_4 and CO_2 fluxes), soil formation (C sequestration), nutrient regeneration (N, P retention) and waste treatment (denitrification, sediment deposition) vary as a function of salinity.

Q4: *What are the underlying mechanisms by which proximity of marshes to upland habitat drives ecosystem change along lateral gradients in the intertidal zone?*

The physical and biological processes associated with coastal marsh hammocks are a major focus of GCE-II. Marsh hammocks are small islands surrounded by marshlands or tidal creeks and nested between the mainland and larger barrier islands. There are approximately 1,670 marsh hammocks in coastal Georgia, ranging in size from less than a hectare to tens of hectares. Most are remnants of high ground of either Pleistocene (1,110 hammocks) or Holocene (294) age, but there are also man-made hammocks that have developed from dredge spoil or ballast stones (265). We hypothesize that uplands of different size (ranging from small to large hammocks to mainlands) will support a different extent of upland marsh, and that hammocks of different elevation will have different associated marsh plant and invertebrate communities.

The hammock project began in summer 2007 under the direction of M. Alber and C. Alexander (SkIO). A team of technicians, graduate and undergraduate students did a broad survey of hammocks representing a range of sizes (Table 1) and origin (20 each of Pleistocene and Holocene origin; 9 dredge spoil islands; 6 ballast stone islands; 4 mainland transects; see Figure 7). They used GIS and field methods to characterize each site in terms of its geomorphology, stratigraphy, water table characteristics, flora and fauna (Table 2). Field surveys at each hammock involved circumnavigating the hammock with a real-time sub-meter GPS to delineate the extent of the upper marsh. Transects were conducted at six locations around the perimeter of each hammock to determine the slope and profile (e.g., relative elevation) using traditional surveying techniques (i.e., rod and level). Surficial sediment was sampled along each transect to characterize trends in grain size (i.e., for permeability) and carbon content of soils. At each of the six transect locations, flora and fauna were surveyed using standardized GCE protocols in 0.5 m^2 quadrats set up 2.5 m from the upland edge. Plant species, shoot height (to the nearest cm) and flowering status were recorded; epifauna were counted and measured for size frequency information. Stratigraphy and water table height were determined at the top of one of the transects (n = 1 per hammock) using a 25-cm throw hand auger. Water was sampled for salinity and nutrient analysis (DOC, TDN).

Table 1. Size classes of hammocks sampled in the GCE domain, 2007.

Size Class	*Area (ha)*	*Number Sampled*
I	< 1	28
II	1-3	13
III	3-6	6
IV	6-10	4
V	10-15	2
VI	15-20	0
VII	> 20	2

The data collected from this effort are now being input into both GIS and Access to develop a synchronized database. The data will be used to characterize hammocks and explore relationships among a series of independent (i.e. upland physical characteristics) and dependent (i.e. marsh biodiversity, plant and animal distributions) variables.

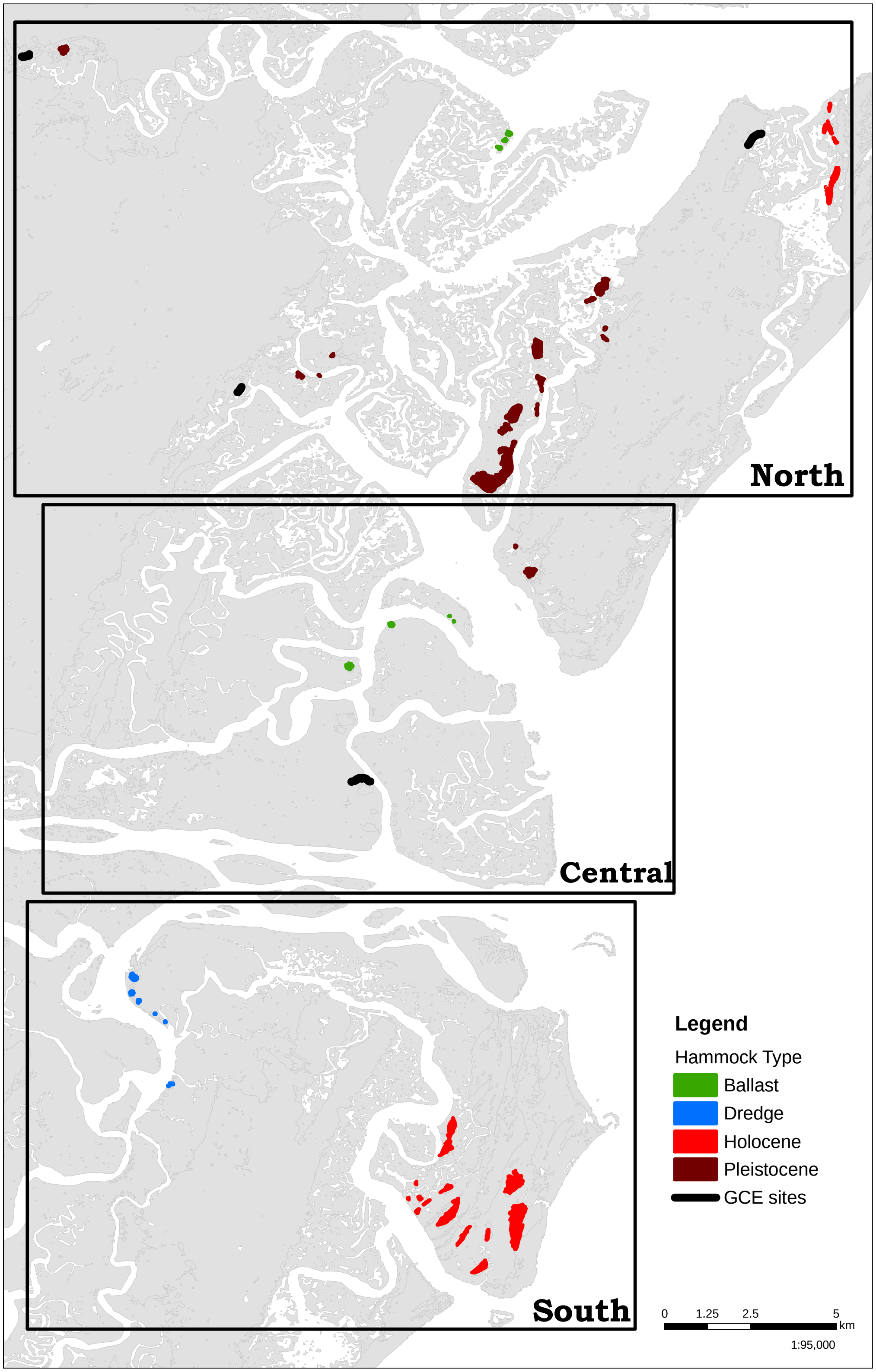

Figure 7. Marsh hammock and mainland sites sampled in summer 2007.

Table 2. Variables, methodology and sampling strategy for hammock survey.

Independent variables	**Methodology**	**Sampling strategy**
Upland Area	GIS (ARCGIS 9.1)	Hammocks selected to cover a broad range of size classes and origins
Upland Elevation (Maximum, Avg); slope of upland/marsh interface	Standard surveying equipment	Transect from marsh to upland at 6 locations evenly distributed around hammock
Water table height, measurements of surficial aquifer	Soil augur	Augur to water level, water sampled for measurements of salinity, DOC, TDN.
Surficial sediment type across hammock; hammock stratigraphy	Manual surficial sampling and auger core	Transect across hammock into marsh; vertical boring
Dependent variables		
Extent of upland and mid-marsh	Distance to *Spartina* edge	GPS circumnavigation of each site, augmented by 6 transects per hammock and aerial photography/GIS
Vegetation in upland marsh (including relative amounts of *Juncus, Borrichia*)	Standard GCE-LTER methods	0.5 m^2 quadrats per hammock, located 2.5 m from upland edge at 6 transect sites
Upland marsh benthic invertebrate diversity and abundance	Standard GCE-LTER methods	Same as above
Terrestrial-dependent herbivores (marsh grasshoppers, deer)	Abundance and damage scores for marsh grasshoppers; direct counts, tracks, and droppings for deer	Visual observations along transect from upland to creek conducted at 6 transect sites
Vertebrate presence Terrestrial-dependent animals (i.e. birds, raccoons, deer)	Observations of tracks, scat, nests, direct counts, other indicators	Same as above

Q5: *What is the relative importance of larval transport versus the conditions of the adult environment in determining community and genetic structure across both the longitudinal and lateral gradients of the estuarine landscape?*

One of the goals of this portion of the project is to determine whether the invertebrate species distributions seen within the GCE domain are the result of recruitment dynamics or post-recruitment responses to habitat suitability (physical and biological constraints). In late summer and early fall, D. Bishop designed and tested field gear needed to assess recruitment rates of several of the aquatic species that have not been previously surveyed. For the barnacle, *Chthamalus fragilis*, a series of five PVC poles with Safe-T-Walk® tape attached were distributed on the creek banks at nine of the ten regular GCE monitoring sites. We recorded settlement of *C. fragilis* at GCE #2, #3, and #10. These are very encouraging results since the test was done so late in the recruitment season. For *Petrolisthes armatus* and other oyster reef species, we set out a series of bags constructed of Vexar® plastic mesh filled with oyster cultch. These bags were suspended on PVC poles set into either mud or oyster reef substrate at approximately the mid-intertidal near Marsh Landing. Many of the species collected will be the same as those found in our monitoring of oyster reef fauna associated with the *P. armatus* population dynamics study we have conducted since 2002. These bags are scheduled to be retrieved in late November or early December, 2007. B. Silliman has focused on perfecting recruitment traps for marsh invertebrates (snails, mussels, barnacles). He has found that a combination of potted *Spartina* plots and bricks acts to capture all of the important species. Deployment of all gear is planned for early spring and will continue through the summer of 2008 to coincide with the peak recruitment times of species of interest.

J. Wares (UGA) is conducting a genetic survey of GCE sites. Extant microsatellite loci were optimized for use in the oyster *Crassostrea*; novel microsatellite markers were developed for use in fiddler crabs (genus *Uca*). His initial results indicate a statistically significant trend in diversity across community, with highest diversity at “open ocean” sites. An ongoing analysis will determine the best model for relating pattern of diversity to ecological observations. This sampling has been expanded to other LTER marsh sites on the Atlantic coast to gain contextual data for gene flow and recruitment studies. A possible genetic cline in mtDNA was noted for *Chthamalus fragilis* between GCE and the Florida Keys.

Project Management

GCE administration

Day-to-day project administration is shared by Alber and Pennings, with support from the GCE Executive Committee (Hollibaugh, Joye, Sheldon, Burd). Project management involves submitting supplementary proposals, overseeing the core budget (including setting up subcontracts, approving purchase orders, travel, etc.), taking care of routine reporting, supervising core project personnel and writing letters of support for collaborative projects. We also continue to provide GCE support for leveraged projects.

We conducted our annual GCE-LTER meeting in February 2007, in Athens, GA, during which we provided an overview of recent research results and discussed new research planned for the GCE-II grant. The meeting was attended by the following members of our scientific advisory committee: Iris Anderson (VIMS/VCR), George Jackson (TAMU), Wim Kimmerer (SFSU), Cathy Pringle (UGA) and Mark Hay (Georgia Tech). Jane Caffrey (UWF) was unable to attend the meeting but continues to serve on the committee.

Pennings continued administrative duties related to field efforts, including supervising field technicians at Sapelo Island and overseeing repair and maintenance of boats and field instruments. He also oversees the GCE Schoolyard LTER, which provided an opportunity for teachers to participate in field research during the summer of 2007. The actual teacher training effort is led by Dr. Trisha Hembree (Hull Middle School, GA).

Network interactions

GCE scientists are also active at the network level. S. Pennings serves on the LTER Executive Board, and W. Sheldon (UGA) served on the mid-term review panel for the MCR LTER site. Both M. Alber and A. Burd attended the LTER Science Council Meeting in Portland, OR (5/07), and A. Burd continues to collaborate with the Climate Trends Discovery Group started at that meeting. M. Alber participated in the planning grant meeting in Athens, GA (4/07) as well as the Ecosystem Services workshop held prior to the Science Council Meeting. She also co-authored a paper for a special issue of *Frontiers* about continental-scale research (Hopkinson et al., submitted). This grew out of a coordinated effort by coastal sites to establish a network of observational towers aimed at understanding and forecasting the effects of sea level rise and intense windstorms.

S. Pennings is a member of an LTER cross-site synthesis group examining whether the traits of plant species can predict different responses by different taxa in fertilization experiments. This work will enhance our ability to predict the impacts of anthropogenic inputs of nitrogen into natural systems. The group has published three manuscripts based on this work, one in PNAS, and have two additional manuscripts submitted for publication. J.T. Hollibaugh participated in the recent workshop, “Catalyzing Cross-Site Comparisons of Microbial Diversity and Function.”

In order to support the new Trends Book effort in LTER, the GCE contributed interpretive graphs depicting long-term increases in sea-level on the Georgia Coast and NO_x concentration in the Altamaha River Estuary. We also contributed long-term data sets on sea-level, climate (air temperature and precipitation), and river discharge to represent long-term trends observed in the GCE domain. These data sets were also added to the GCE Data Catalog (at daily, monthly and annual aggregations) to provide comprehensive EML metadata, which is necessary for the dynamic Trends database that is under development.

We also have a strong presence in terms of information management, through the activities of W. Sheldon. Over the past year he has served the network in the following capacities:

- Elected to co-chair the LTER Network Information System Advisory Committee in May 2007.
- Co-leader of an LTER working group to define quality control standards for derived environmental data products, in collaboration with other LTER sites, CUAHSI, SEEK and the Canopy Databank Project.
- Chair of two working group sessions on quality control for streaming sensor data at the 2007 LTER Information Managers Meeting in San Jose, California. As part of this, he developed and managed a dynamic website to support the meeting (http://gce-lter.marsci.uga.edu/lter_im/2007/)
- Collaborated with Barrie Collins at the Coweeta LTER site to establish near-real-time harvesting of streamflow data from 4 USGS gauges near the CWT field site, using data processing software developed at GCE (http://coweeta.ecology.uga.edu/ecology/hydrologic_data/hydrologic_data.html)
- The GCE project continues to host the USGS Data Harvesting Service for HydroDB (see http://gce-lter.marsci.uga.edu/lter/research/tools/usgs_harvester.htm). Data from 57 USGS stream flow gauging stations are automatically harvested on a weekly basis for 11 LTER sites (AND, BES, CWT, FCE, GCE, KBS, KNZ, LUQ, NTL, PIE, SBC) and one USFS site. Recent provisional and finalized data are automatically acquired, standardized, quality-checked, formatted, and uploaded to HydroDB to provide the LTER community with the best available stream flow and precipitation data for synthetic research at no cost to individual site research programs.

Information Management

Overview

Information Management at the GCE site is led by W. Sheldon. The major focus of our IM efforts during the past year has been on expanding the GCE information system to support the new research activities in the GCE-II study plan, particularly spatial data analysis and mapping (GIS). We hired a full-time assistant IM / spatial data manager and greatly expanded our IT infrastructure to accommodate large volumes of geospatial data. We also upgraded the GCE website and web applications to support the latest web standards (e.g XML, XHTML) and technologies (e.g. Ajax), and developed new web-accessible databases to provide access to GCE project news and announcements as well as a searchable archive of documents, GIS data products, imagery (e.g. maps, organism photos, site photos), and other resources.

Spatial data management and GIS

We established a Geographic Information System (GIS) lab on Sapelo Island in June 2006 (in collaboration with the Sapelo Island NERR and UGA Marine Institute) to improve access to spatial data resources for both GCE scientists and other investigators working on Sapelo. SINERR research staff are providing baseline GIS data and support to researchers and students on Sapelo, and GCE IM staff are providing hardware, software and network support for the facility. We are currently working with SINERR to establish an Internet-accessible clearinghouse for Sapelo-related GIS data and imagery.

We hired a full-time assistant information manager / GIS specialist at UGA in January 2007 (K. Meehan, recently replaced by J. Carpenter), and expanded our server storage capacity to accommodate large volumes of spatial data. Our first task was to create several geographic databases for the project using ESRI ArcGIS SDE to provide centralized, version-controlled access to relevant GIS data for GCE researchers and students. To date we have acquired both vector and raster datasets for areas throughout Georgia with an emphasis along the coast and especially our primary GCE-LTER sampling sites. Our GIS databases include boundary, infrastructure, and hydrology datasets as well as topographic maps, satellite images, digital elevation models, land use/land cover classifications, and color infrared and digital ortho-photographs. We are currently providing centralized access to:

- Georgia Rivers LMER data: estuary features (soil, hydrology, tides)
- NOAA Electronic Navigational Charts
- GA boundaries (physiographic, coastlines, conservation areas, elevation contours)
- GA hydrology (groundwater recharge, rivers and corridors)
- GA infrastructure (roads)
- Sapelo Island data and imagery (2003 color infrared photography, natural areas, trails, and infrastructure)
- 2001 USGS National Land Cover Dataset
- 2005 National Agriculture Imagery Program digital orthophotography
- GCE-LTER geographic information (sampling locations, transects, GPS coordinates, site boundaries)

We also purchased a high resolution, differentially-corrected field GPS unit (Trimble GeoXH, with sub-foot accuracy) for use in GCE marsh studies, to compliment the high precision GPS equipment already installed on boats used for GCE research. We are currently in the process of collecting higher precision geo-location information for all established GCE sampling sites and permanent plots in order to register legacy GCE marsh-oriented data sets in the GIS to support spatial analysis.

Website development

W. Sheldon performed a complete redesign of all GCE websites and web-based database applications this year to improve overall appearance and functionality, as well as to support the latest web standards (e.g XML, XHTML) and technologies (e.g. Ajax). The new website brings together information from the original public website as well as the private project website and GCE Data Portal to provide more uniform access to all web-accessible resources from a common menu and navigation structure. The new website is currently undergoing review by GCE participants, and will be available to the public in late 2007.

As part of the redesign, we developed a new web-accessible database for managing project news and announcements, which will allow GCE participants to directly post news items on the website with automatic content expiration and archiving. We also developed a generalized file archive database to improve management of all GCE documents (e.g. reports, protocols, governance), general GIS data files, imagery (e.g. maps, organism photos, site photos, etc.), and other static files. The database supports file versioning and thumbnail images, and is dynamically linked to the taxonomic database and GCE bibliography to support comprehensive searching for online files and imagery. A search form and dynamic browse interface are available on the new website to search for files by type, category, theme, contents and author (http://gce-lter.marsci.uga.edu/public/app/resource_search.asp). In addition, we developed a new dynamic news page, which automatically draws information from several web-accessible databases to display current calendar events, announcements, and recent data catalog and file archive additions on the website (http://gce-lter.marsci.uga.edu/public/app/news.asp).

Software development

We have continued to enhance the GCE Data Toolbox for MATLAB software and offer a compiled version of this toolbox for public download on our website (see http://gce-lter.marsci.uga.edu/lter/research/tools/data_toolbox.htm). This software can be used to search and download data from the GCE Data Catalog and GCE Data Portal as well as import data from various sources, and then perform metadata-based analysis, transformation, integration and visualization. Significant improvements were made in data integration and quality control functions this year, allowing multiple related data sets stored in any number of directories to be merged or joined to create composite data sets, complete with detailed metadata and QA/QC flags. Users can also retrieve data from any USGS or ClimDB/HydroDB station directly over the Internet, using either command-line functions or graphical dialogs, and then integrate these data with GCE data sets or their own data in real time. Nearly 700 web visitors downloaded the toolbox package over the past year, with 2668 total downloads since release in July 2002.

EML metadata

We comprehensively support the XML-based EML 2.0 metadata standard adopted by LTER in all GCE databases, allowing us to dynamically generate EML for all data sets in our catalog as well as species lists, personnel entries and bibliographic citations. GCE was the first LTER site to fully support EML 2, and our rapid implementation has facilitated adoption of this standard across LTER and aided in development of EML-based applications at LNO, NCEAS and NBII. Our EML implementation is still among the most comprehensive in LTER, supporting metadata-mediated data access and integration (Level 5 in the EML Best Practices guidelines, a document created by a working group chaired by W. Sheldon in 2004).

We also continue to collaborate with LNO, NCEAS and NBII on development and testing of specifications for automatically harvesting EML documents from LTER sites for inclusion in the LNO Metacat repository (and therefore the distributed Metacat and Ecogrid networks). GCE EML documents are automatically added or updated in the LNO Metacat server on a weekly basis, and then synchronized to other Metacat servers across the world. GCE EML is also harvested weekly for inclusion in the NBII metadata clearinghouse. As a result, GCE metadata can be searched using the NCEAS Morpho application, the LNO Data Catalog (http://metacat.lternet.edu/query/), the NBII Mercury search engine (http://mercury.ornl.gov/nbii/), and the Ecogrid network being developed by the SEEK project. Corresponding data tables can also be automatically retrieved by these external systems using connection information in the metadata, with data access logged by the GCE database. In addition, the comprehensive EML implementation and support for automated data streaming developed at GCE continues to enable NCEAS and the SEEK project to prototype, test and demonstrate EML-based data analysis and workflow tools, such as Kepler (http://seek.ecoinformatics.org), using realistic ecological data sets, significantly aiding their development work.

We are planning to provide complete EML for new spatial data sets as they are added to the GCE catalog. We are collaborating with other GIS experts across LTER to adapt existing XSLT style-sheets for converting ESRI XML metadata to EML for GCE use, and we are developing extensions to our existing relational databases to support management, online distribution, and access logging for GIS data products just as for tabular data products.

Website and data access statistics

GCE public website access statistics for June 2006 to Oct 2007 and long-term web activity trends are illustrated in Table 3 and Figure 8, below. Web visits peak during the academic year (~7000 visits per month) and drop during the summer months (~5000 visits). Over 312,000 distinct visits have been logged on the GCE website since its introduction in December 2000, accounting for nearly 1 million page views and over 4 million hits. Although most page requests originate in the U.S. (61%), requests were logged from 194 distinct countries and territories overall (based on Internet domain analysis). GCE software tools, data catalog, and taxonomic database pages were the most frequently requested web pages other than the home page over the past year.

Table 3. GCE website access from November 2006 through October 2007, filtered to remove all invalid requests, errors and web indexing spiders.

Month	Hits	Page Views	Visitors
Nov-06	72,835	18,835	7,087
Dec-06	56,611	13,424	5,788
Jan-07	64,749	14,905	6,422
Feb-07	57,679	12,679	5,460
Mar-07	64,530	15,070	6,359
Apr-07	53,726	12,145	5,804
May-07	68,161	21,082	6,427
Jun-07	45,173	10,743	5,472
Jul-07	55,007	16,264	4,962
Aug-07	44,903	11,819	4,854
Sep-07	46,953	10,003	5,271
Oct-07	58,784	16,212	6,330
Total	**689,111**	**173,181**	**70,236**

Public downloads of GCE data sets from Fall 2001 to Fall 2007 are listed below (Table 4), broken down by data set theme and user affiliation. Note that downloads by GCE participants are not currently tracked, due to open data access policies within the project. The majority of public data requests in 2006-2007 were made by individual web visitors or GCE Toolbox users, unlike 2004 in which most requests were brokered through external catalogs, such as the LNO Metacat server (i.e. due to extensive use of GCE data to test and demonstrate metadata-mediated applications under development by the SEEK project). Data requests over the past year were fairly evenly split among academic researchers, educational professionals, government agencies, and users of external metadata catalogs.

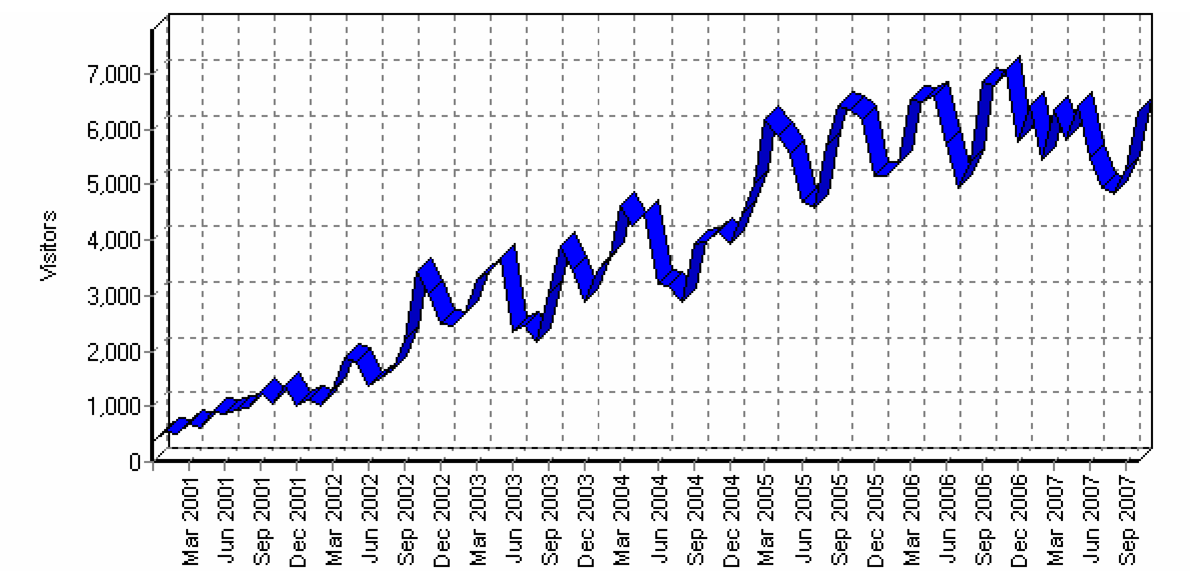

Figure 8. GCE website access over time based on web log analysis, excluding web indexing spiders.

Table 4. Downloads of GCE data by theme and user affiliation.

Theme	2001	2002	2003	2004	2005	2006	2007	AllYears
Algal Productivity	0	0	0	0	1	13	9	23
Aquatic Invertebrate Ecology	0	0	12	137	110	94	93	446
Bacterial Productivity	0	0	4	15	36	16	38	109
Chemistry	0	0	0	0	6	2	7	15
Fungal Productivity	0	2	1	1	13	1	3	21
General Nutrient Chemistry	0	7	5	8	31	11	8	70
Geology	0	0	0	0	0	2	17	19
Hydrography	0	0	0	0	4	6	4	14
Meteorology	12	27	8	20	22	13	29	131
Organic Matter/Decomposition	0	5	1	13	17	12	27	75
Physical Oceanography	0	2	2	54	312	128	78	576
Phytoplankton Productivity	0	0	1	17	42	20	5	85
Plant Ecology	0	13	9	19	97	28	22	188
Pore-water Chemistry	0	0	0	2	8	4	4	18
Real-time Climate	0	0	0	4	78	29	38	149
Terrestrial Insect Ecology	4	7	3	12	15	27	28	96
Various (custom file)	0	0	0	0	1	5	12	18
All Themes	**16**	**63**	**46**	**302**	**793**	**411**	**422**	**2053**

Affiliation	2001	2002	2003	2004	2005	2006	2007	AllYears
Academic Research Program	5	15	15	45	146	104	153	483
Ed. Program (K-12)	0	7	2	0	36	5	1	51
Ed. Program (Post-secondary)	4	12	1	50	129	76	102	374
Environmental Advocacy Group	0	1	0	0	0	3	1	5
Government Agency	6	1	0	19	210	26	9	271
International LTER Site	0	0	0	2	1	1	4	8
LTER Network Office (Metacat)	0	0	2	148	166	131	102	549
Other LTER Site	1	12	16	10	29	29	1	98
Other/Unspecified	0	15	10	28	76	36	49	214
All Affiliations	**16**	**63**	**46**	**302**	**793**	**411**	**422**	**2053**

Research and Education Activities

- Supported partnerships to maintain continuous data from National Atmospheric Deposition Program station (GA33), National Weather Service COOP station (097808), USGS water quality monitoring station (022035975; Hudson Creek at Meridian Landing).
- Continued long-term monitoring of hydrologic variables (temperature, conductivity, salinity), water quality (river, estuary and groundwater nutrients), plant and animal populations and ecosystem processes (flora and fauna surveys, sediment elevation).
- Continued measurement and analysis of environmental forcing functions (climate, watershed nutrients, riverine input); spatial and temporal patterns of water, soil, plant and animal dynamics in relation to environmental gradients; cross-site comparisons of nutrient input, microbial decomposition and plant-animal interactions.
- Completed a directed study of the Duplin River watershed, including construction of a high resolution digital elevation model and analysis of hyperspectral imagery to map marsh plant biomass and productivity.
- Initiated a directed study of marsh hammocks, including surveys of 54 hammocks to characterize each site in terms of its geomorphology, stratigraphy, water table characteristics, flora and fauna Two REU students and several additional undergraduates were part of the field team.
- Operated a comprehensive data and information management program that provides online access to near real-time and long-term environmental data, publications and presentations, species lists, personnel information and other products from GCE research and educational activities.
- Established a GIS infrastructure to provide GPS data and geospatial analysis and management for GCE research.
- Administered the GCE Schoolyard program, which involved one nine-day workshop in the summer and two three-day conferences of all participants during the academic year.
- Continued to provide outreach to coastal managers through partial support of the Georgia Coastal Research Council (www.gcrc.uga.edu/), which acts to facilitate interactions between scientists and managers, synthesize technical information, and coordinate research efforts on emerging coastal resource issues for the state of Georgia.

Training and Development

GCE Schoolyard Program

The GCE Schoolyard program (P. Hembree, Hull Middle School) included a nine-day workshop in the summer; two three-day conferences of all participants during the academic year; and support of the teachers through monitored email discussions and e-mentoring. Participating teachers also receive books and classroom supplies, including lab-ware specifically made for young children, water proof field notebooks, identification guides, Brock scopes, water quality kits; student-friendly cameras to document biological events on campus and in the classroom, macro invertebrate traps, and large amounts of do-it-yourself materials such as PVC pipes and window screening.

Teachers work with different LTER investigators over the course of the program. This past summer, S. Pennings and three graduate students provided teacher in-service training in field ecology methods; D. Bishop led a project in which the teachers designed and conducted a field experiment to examine predation rates on Littoraria in dieback and natural marsh areas; teachers worked in the field with personnel from C. Craft and B. Silliman's labs to survey birds and sample alligator tissue for isotope analysis; M. Alber met with teachers to discuss the GCE children's book.

Undergraduate education

The GCE supported two REU interns as part of the hammock project this past summer: Caitlin Yeagar (UGA) and Abby Cramer (Georgia Southern University). Both students are now continuing their projects as directed research at their respective institutions. Caitlin Yeagar, working with M. Alber, is using a GIS to analyze the GPS data she helped to collect this summer. She is interested in determining whether there is a predictive relationship between the edge of the hammock, as mapped on the ground, and the edge as determined by aerial photography. This correction is important as most hammocks are not assessed on the ground and there is controversy as to how much upland area is available to develop in these areas. Abby Cramer is working under the direction of Clark Alexander to perform a detailed analysis of down-core textural changes in auger cores collected from all hammocks, to determine the variability and composition of sediments making up Holocene, Pleistocene, Dredge Spoil and Ballast Stone Islands.

Two graduating seniors also participated in the hammock project this summer. One of them, Jonathan Pahlas, is now enrolled in an M.S. program at UGA (working with S. Joye). The other, Nathan McTigue, is now applying to graduate school. He recently contacted us to state the following: I think often about the summer's work, and how much I really enjoyed it. It was so gratifying to finally get my nose out of the books and do some field work. Although the books are important, I had so much fun participating in the 'doing' part of science. By about the beginning of July, I had a totally new and improved understanding of the word 'ecology.' I really only understood that which I previously learned (the books) by the doing (the field). On top of that, the amount of data we collected this summer is just awesome. Maybe I have a skewed opinion since I've never worked in the field like that before, but I'm impressed by us. Anyway, thanks for the experience.'

Other activities for undergraduates:

- T. Kennemer, an REU student from 2006, continued research on the LTER and had a poster presentation on his work at the Southeastern Estuarine Research Federation. He was also an author on a poster at the Estuarine Research Federation meeting.
- J. Wares is conducting cross-site genetic surveys of animals at GCE, VCR and PIE LTER sites using mitochondrial COI sequencing (specimen collection and laboratory work included an REU student who gained her first exposure to salt marsh ecological research).

- Elizabeth Wason (undergraduate, UH) completed a senior honors thesis based on her work on grasshoppers with S. Pennings. A manuscript based on this work has been submitted.
- A. Burd includes GCE data in his undergraduate 'Biological Oceanography' course.

Graduate education

Graduate students are an integral part of the research at the GCE LTER. There are currently a total of 24 students from 5 institutions engaged in LTER activities. Over the past year, three LTER students have completed their degrees:

- Amy Kunza (M.S., Univ. of Houston), Patterns of plant diversity in two salt marsh regions.
- Sylvia Schaefer (M.S., Univ. of Georgia), Nutrient budgets for watersheds on the southeastern Atlantic coast of the United States: temporal and spatial variation.
- Justine Lyons (Ph.D., Univ. of Georgia), Molecular description of ascomycete fungal communities on Spartina spp. in the U.S.

Graduate students have also been authors on numerous publications that have resulted from this work.

Other activities for graduate students:

- Burd includes GCE data in his graduate level 'Quantitative Methods in Marine Science' course

Other Training

- W. Sheldon conducted a workshop on quality control for derived data in February 2007 at the Jornada LTER site in Las Cruces, NM, in collaboration with Don Henshaw (AND) and Ken Ramsey (JRN)

Outreach Activities:

The GCE continues to provide outreach to coastal managers through partial support of the Georgia Coastal Research Council (GCRC). Over the past year, core activities of the GCRC have included maintaining the GCRC listserv (137 registered users); significantly upgrading the GCRC website (www.gcrc.uga.edu, now logging more than 2000 page views per month); identifying and enlisting 17 new members; helping to plan the Coastal Incentive Grant Colloquium; and organizing Coastal Georgia Colloquium '06, which brought together 56 of Georgia's coastal resource managers and scientists, representing 10 academic units and nine government agencies. Technical synthesis activities included providing technical support for two series of stakeholder meetings convened by CRD (one to examine the permitting criteria for marinas and community docks and the other to create rules for development in the coastal uplands permitted under the Coastal Marshlands Protection Act); preparing a literature review of impervious surfaces (for the coastal upland stakeholder group); reviewing a vegetative buffers document that was submitted to the EPD by the River Basin Center; synthesizing information on stormwater control measures for CRD to distribute to the Board of Natural Resources; providing input for a CRD presentation to a legislative committee on the potential effects of desalinization on the salt marsh; and responding to information requests related to restoration of salt marshes and oyster reefs. Our focus area activities have involved ongoing coordination of marsh dieback monitoring efforts throughout the coast, including sampling two sites and maintaining the coastwide dataset. We have now converted the dataset to a more robust database format and have done preliminary analysis of this information in anticipation of writing a complete synthesis paper.

In addition, the GCRC is the lead organization on a (separately funded) Sea Grant project to develop a regional research plan for the South Atlantic states. As part of this process we will establish charter membership in a South Atlantic Coastal Research Council (modeled after the GCRC) such that, once the final, approved plan is implemented, mechanisms will be in place to ensure the transfer of technology and information to the appropriate end users.

Technical Summaries:

- Impervious Surfaces: Review of Recent Literature. M. Alber and C. Tilburg. Literature synthesis prepared for the Georgia DNR Uplands Stakeholder Workgroup (2006)
- Stormwater Treatment in Coastal Areas. J. Flory and M. Alber. Literature synthesis provided to the Board of the Georgia Dept. of Natural Resources (2007)
- Climate Change: Research, Management Implications and Information Gaps. J. Flory and M. Alber. Literature synthesis provided to the Georgia Dept. of Natural Resources Coastal Resources Division (2007)

Media Coverage:

- 10/07 'Drought, what drought?' The Savannah Morning News. Interviewed regarding linkage between dieback and drought.
- 6/07 'Drought attacking marsh grass' The Brunswick News - GCRC named in article, credited with research. M. Alber interviewed.
- 9/06 'Southeast may be joining the hypoxia club.' Coastal and Estuarine Science News 29 (4). http://erf.org/cesn/ Article featuring Verity et al. paper in Estuaries and Coasts.
- 9/06 'New England salt marshes losing vibrant grasses.' National Public Radio. Alber interviewed for background for a story about marsh dieback in New England.
- 7/06 'Cause sought as marshes turn into barren flats' Boston Globe. Alber interviewed to discuss marsh dieback in the southeast and New England

Web/Internet Site

URL(s): http://gce-lter.marsci.uga.edu/
Description: This is the primary website for the GCE LTER project. It is used to provide access to project information, research findings, data, publications, and other products.

Other Specific Products

Product Type: Software (or netware)

Product Description: GCE Data Toolbox, MATLAB-based software for metadata-based analysis, visualization, transformation and management of ecological data sets
Sharing Information: The software package is publicly distributed on the GCE web site (http://gce-lter.marsci.uga.edu/public/im/tools/toolbox_download.htm)

Product Type: Data or databases
Product Description: GCE Taxonomic Database, providing WWW access to taxonomic and habitat information, photos, and links to data for plant and invertebrate species present in the GCE study domain.
Sharing Information: The database can be accessed and searched from the GCE public web site (http://gce-lter.marsci.uga.edu/public/app/all_species_lists.asp)

Product Type: Data or databases
Product Description: GCE Data Catalog, providing access to over 300 accessioned data sets from GCE research accompanied by comprehensive EML metadata
Sharing Information: The data catalog is publicly accessible on the GCE web site (http://gce-lter.marsci.uga.edu/public/app/data_catalog.asp)

Product Type: Data or databases
Product Description: GCE Data Portal, providing access to data from GCE monitoring partners and public agencies in consistent formats optimized for comparison and synthesis?
Sharing Information: The data portal is available on the public GCE web site at http://gce-lter.marsci.uga.edu/portal/monitoring.htm

Product Type: Data or databases
Product Description: GCE Bibliographic Database, providing access to publications and presentations from research on Sapelo Island and the Georgia coast from 1955 to the present. Includes all publications from GCE LTER, Georgia Rivers LMER, and UGA Marine institute libraries.
Sharing Information: The database is available to the public on the GCE web site (http://gce-lter.marsci.uga.edu/public/app/biblio_query.asp)

Product Type: Data or databases
Product Description: GCE Bibliographic Database, providing access to publications and presentations from research on Sapelo Island and the Georgia coast from 1955 to the present. Includes all publications from GCE LTER, Georgia Rivers LMER, and UGA Marine institute libraries.
Sharing Information: The database is available to the public on the GCE web site (http://gce-lter.marsci.uga.edu/public/app/biblio_query.asp)

Contributions Contributions within Discipline

Thirty-one papers, eleven book chapters, and numerous presentations and other communications were entered into the GCE bibliography this year. They cover a broad range of topics, including soil processes (e.g. Craft 2007), microbial interactions (e.g. Cong et al. 2007), plant ecology (e.g. Pennings et al. 2007), nutrient cycling (e.g. Joye and Anderson 2007), water chemistry (e.g. Biers and Moran 2007), and physical oceanography (e.g. Di Iorio and Kang 2007). Our research program has examined a variety of estuarine processes at spatial scales ranging from individual plots (Ho and Pennings, in press) to the South Atlantic Bight (Jiang et al., in review) to the entire Atlantic Coast (e.g. Schaefer and Alber 2007). A review of recent results can be found under 'Research Findings', and a complete list of publications can be found at http://gce-nas.marsci.uga.edu/public/app/biblio_query.asp

Contributions to Other Disciplines

The GCE is an interdisciplinary program, with biologists, geologists, chemists, and physicists engaged as PIs on the project. This past year we have added two anthropologists to our team: Dr. Elizabeth Reitz at UGA specializes in the identification of vertebrate remains in the southeastern U.S. Victor Thompson, an archeologist at Univ. of West Florida, was able to collect preliminary data to assess the usage of marsh hammocks played in the economy of the pre-contact inhabitants. Dr. Thompson led an archaeological team from the University of West Florida and the University of Georgia to institute a systematic survey of six marsh island/hammocks during the spring and summer of 2007. The survey included shovel test probes at every 20 meters over the entire area and shell ground probing (accomplished with a 1/2 inch diameter solid metal probe) every 5 meters to detect for buried shell. They were able to find evidence of human occupation of the hammocks, including oyster shell middens. We are now interested in exploring this further to determine how the presence of humans may have affected the plant community in the area.

Contributions to Human Resource Development

The GCE engages graduate and undergraduate students, post-docs, technicians and scientists from multiple institutions. We also have international collaborations: J. Blanton worked with F. Andrade (Univ. of Lisbon) and M. Adelaide Ferreira (IMAR-Marine Laboratory, Portugal) on development of the Sapelo Island DEM model; S. Pennings collaborated with M. Zimmer (Christian-Albrechts-Universitõt, Germany), who brought a group of students to the field site in summer 2007 to collect data on invertebrate detritivores.
GCE scientists regularly give seminars and public presentations, contribute articles to newsletters and other popular publications, and talk to the media about coastal issues. Our Schoolyard program brings K-12 teachers to the field site.?

Contributions to Resources for Research and Education

The GCE web site provides public access to information and data from decades of research on Sapelo Island and the Georgia coast for scientists, educators, students, policy makers and the general public. Over 312,000 visits from 194 distinct countries and territories have been logged on the GCE web site since its introduction in December 2000, accounting for over 1 million page views. More than 70,000 visits to the GCE web site were logged over the past year alone. Web-accessible GCE resources include:

- A searchable data catalog that provides access to over 300 data sets from core GCE research activities, accompanied by comprehensive EML metadata (http://gce-lter.marsci.uga.edu/public/app/data_catalog.asp)?
- A data portal web site that provides access to near-real-time and historic data sets and plots from GCE, SINERR, USGS, NWS and NADP monitoring programs (http://gce-lter.marsci.uga.edu/portal/monitoring.htm)
- A taxonomic database that provides access to information, photographs and data for hundreds of plant and invertebrate species present at the GCE study site, with links to ITIS database entries (http://gce-lter.marsci.uga.edu/public/app/all_species_lists.asp)
- A searchable bibliographic database, providing access to over 1500 publications and presentations from GCE, Georgia Rivers LMER, and UGA Marine Institute research at Sapelo Island and the Georgia coast since 1955 (http://gce-lter.marsci.uga.edu/public/app/biblio_query.asp)
- A personnel database, providing information on GCE investigators, staff, students and affiliates, including research expertise and links to data contributions and publications (http://gce-lter.marsci.uga.edu/public/app/personnel.asp)?
- The GCE Data Toolbox for MATLAB, a comprehensive software package for metadata-based analysis, quality control, visualization, transformation and management of ecological data sets (http://gce-lter.marsci.uga.edu/public/im/tools/data_toolbox.htm)?
- The GCE Schoolyard program provides critical in-service training for K-12 educators in field ecology, allowing them to work side-by-side with scientists in the field and bring lessons and actual research data back to the classroom to enhance science education at their schools. From 2000 to 2006, 45 teachers participated in one or more sessions of the GCE S-LTER program, representing 106 teacher slots and a collective impact on 9100 students. We have also written a children's book about the salt marsh that is currently under consideration at UGA press.

Contributions Beyond Science and Engineering

The GCE outreach is served by partial support of the Georgia Coastal Research Council (GCRC, www.gcrc.uga.edu). Over the past year the GCRC has responded to requests from the state to synthesize information on various issues, ranging from stormwater runoff to climate change research. The GCRC also serves as a liaison for coastal research. For example, we were recently contacted by a consultant interested in initiating a marsh restoration project in coastal Georgia and were able to provide the names and contact information for several affiliates with appropriate expertise for this activity. GCRC staff also served as technical advisors in two series of stakeholder meetings convened by the state: one to examine the permitting criteria for marinas and community docks and the other to create rules for waterfront development permitted under the Coastal Marshlands Protection Act. GCRC representatives attended the meeting.

Publications and Presentations

Journal Articles

Bertness, M. D. and Silliman, B.R. Human Disturbance Driven Consumer Control of Salt Marshes - When Dogma Bites. Conservation Biology. (in press)

Biers, E.J., Zepp, R.G. and Moran, M.A. 2007. The role of nitrogen in chromophoric and fluorescent dissolved organic matter formation. Marine Chemistry. 103:46–60. doi:10.1016/j.marchem.2006.06.003

Cai, W.-J., Dai, M. and Wang, Y. 2006. Air-sea exchange of carbon dioxide in ocean margins: A province-based synthesis. Geophysical Research Letters. 33:L12603. doi:10.1029/2006GL026219.

Clark, C.M., Cleland, E.E., Collins, S.L., Fargione, J.E., Gough L., Gross, K.L., Pennings, S.C., Suding, K.N., Grace, J.B. 2007. Environmental and plant community determinants of species loss following nitrogen enrichment. Ecology Letters, 10:596-607

Craft, C.B. 2007. Freshwater input structures soil properties, vertical accretion, and nutrient accumulation of Georgia and U.S. tidal marshes. Limnology & Oceanography. 52(3):1220-1230.

Di Iorio, D. and Kang, K. 2007. Variations of turbulent flow with river discharge in the Altamaha River Estuary, Georgia. Journal of Geophysical Research - Oceans. 112, C05016, doi:10.1029/2006JC003763.

Dong, Y., Moran, M.A. and Guerrero, S. 2007. Exploring marine bacterial diversity in coastal Georgia salt marshes using DNA technology. The American Biology Teacher. (in press)

Frost, J.W., Schleicher, T. and Craft, C. (in review). Nitrogen limits primary and secondary production in a Georgia (USA) tidal freshwater marsh. Wetlands.

Gustafson, D.J., Kilheffer, J. and Silliman, B.R. 2006. Relative impacts of Littoraria irrorata and Prokelisia marginata on Spartina alterniflora. Estuaries. 26:639-644.

Ho, C.K. and Pennings, S.C. Consequences of omnivory for trophic interactions on a salt-marsh shrub. Ecology. (in press)

Hopkinson, C., Lugo, A., Alber, M., Covich, A. and Van Bloem, S.J. Understanding and forecasting the effects of sea level rise and intense windstorms on coastal and upland ecosystems: the need for a continental-scale network of observatories. Frontiers in Ecology. (in review)

Jiang, L., Cai, W.-J. and Wang, Y. A comparative study of carbon dioxide degassing in riverine and non-riverine estuaries. Limnology & Oceanography. (in review)

Jiang, L.-Q., Cai, W.-J., Wang, Y., Wanninkhof, R., and Lüger, H. Air-sea CO2 fluxes on the US South Atlantic Bight: Spatial and temporal variability. Journal of Geophysical Research-Ocean. (in revision)

Krull, K. and Craft, C.B. Ecosystem development of a newly emerged tidal marsh, Sapelo Island, Georgia USA. Wetlands. (In review)

McFarlin, C.R., Brewer, J.S., Buck, T.L., Pennings, S.C. (in review). Impact of fertilization on salt marsh food webs.

McKay, P. and Di Iorio, D. Heat Budget for a shallow, sinuous salt marsh estuary. Continental Shelf Research. (in review)

Moore, W.S., Blanton, J.O. and Joye, S.B. 2006. Estimates of flushing times, submarine groundwater discharge, and nutrient fluxes to Okatee Estuary, South Carolina. Journal of Geophysical Research. 111(C09006), doi:10.1029/2005JC003041.

Mou, X., Hodson, R.E. and Moran, M.A. 2007. Bacterioplankton assemblages transforming dissolved organic compounds in coastal seawater. Environmental Microbiology. 9:2025–2037. doi:10.1111/j.1462-2920.2007.01318

Mou, X., Moran, M.A., Stepansuskas, R., González, J.M. and Hodson, R.E. 2005. Culture-independent identification of bacterioplankton involved in DMSP transformations by flow cytometric cell sorting and subsequent molecular analyses. Applied and Environmental Microbiology. 71:1405-1416.

Pennings, S.C., Zimmer, M., Dias, N., Sprung, M., Davé, N., Ho, C.-K., Kunza, A., McFarlin, C., Mews, M., Pfauder, A. and Salgado, C. 2007. Latitudinal variation in plant-herbivore interactions in European salt marshes. Oikos. 116:543-549.

Poretsky, R.S., Bano, N., Buchan, A., LeCleir, G., Kleikemper, J., Pickering, M., Pate, W.M., Moran, M.A. and Hollibaugh, J.T. 2005. Analysis of microbial gene transcripts in environmental samples. Applied and Environmental Microbiology. 71: 4121-4126.

Porubsky, W.P., Velasquez, L. and Joye, S.B. Nutrient replete benthic microalgae as a source of labile dissolved organic carbon to coastal waters. Estuaries and Coasts. (in review)

Porubsky, W.P., Weston, N.B. and Joye, S.B. Benthic primary production and the fate of inorganic nitrogen in intertidal sediments. Estuarine Coastal and Shelf Science. (in review)

Schaefer, S.C. and Alber, M. 2007. Temperature controls a latitudinal gradient in the proportion of waterhsed nitrogren exported to coastal ecosystems. Biogeochemistry. 85:333-346.

Schaefer, S.C. and Alber, M.A. 2007. Temporal and spatial trends in nitrogen and phosphorus inputs to the watershed of the Altamaha River, Georgia, USA. Biogeochemistry. (in press)

Verity, P.G., Alber, M. and Bricker, S.B. 2006. Development of Hypoxia in Well-mixed Subtropical Estuaries in the Southeastern USA. Estuaries and Coasts, 29(4):665–673.

Wason, E.L. and Pennings, S.C. (in review). Grasshopper (Orthoptera: Tettigoniidae) species composition across latitude in Atlantic Coast salt marshes. Estuaries and Coasts.

Weston, N.B., Dixon, R.E. and Joye, S.B. 2006. Microbial and geochemical ramifications of salinity intrusion into tidal freshwater sediments. Journal of Geophysical Research. 111(G01009):doi:10.1029/2005JG000071.

Weston, N.B., Hollibaugh, J.T. and Joye, S.B. The Altamaha River Watershed: Thirty Years of Nutrient and Organic Carbon Loading Data from Sub-watersheds. Water Research. (in review)

Weston, N.B., Porubsky, W.P., Samarkin, V., MacAvoy, S., Erickson, M. and Joye, S.B. 2006. Pore water stoichiometry of terminal metabolic products, sulfate, and dissolved organic carbon and nitrogen in intertidal creek-bank sediments. Biogeochemistry. 77:375-408.

Wrona, A.M., Batzer, D., Alber, M. and Sharitz, R.R. 2007. Savannah River, Georgia: Science to support adaptive implementation of environmental flows to a large coastal river, floodplain, and estuary. Water Resources Impact. 9(4):21-24.

Books and Book Sections

Broomberg, K. and Silliman, B.R. Patterns of salt marsh loss within coastal regions of North America: pre-settlement to present. In Silliman, B.R., Grosholtz, T. and Bertness, M.D. (editors). Salt Marshes Under Global Siege. University of California Press. (accepted)

Broome, S.W. and Craft, C.B. Tidal marsh creation. In Perillo, G.M.E., Wolanski, E., Cahoon, D. and Brinson, M.M. (eds.). Coastal Wetlands. Elsevier. (in review)

Craft, C., Bertram, J. and Broome, S. Restoration of coastal zones. In Jorgensen, S.E. (ed.). Ecologicial Engineering. Elsevier, New York. (in press)

Joye, S.B. and Anderson, I. 2007. Nitrogen Cycling in Estuarine and Nearshore Sediments. In: Capone, D., Bronk, D., Carpenter, E. and Mulholland, M. (Eds). Nitrogen in the Marine Environment. Springer Verlag. (in press)

Joye, S.B., Cook, P. and de Beer, D. 2007. The biogeochemistry of tidal flats. In: Perillo, G.M., Wolanski, E., Cahoon, D. and Brinson, M. (Eds). Coastal Wetlands: An Integrated Ecosystem Approach. Elsevier. (in press)

Newell, S.Y., Lyons, J.I. and Moran, M.A. 2007. A saltmarsh decomposition system and its ascomycetous laccase genes. Pages 357-370 in: Gadd, G., Dyer, P. and Watkinson, S., eds. Fungi in the Environment. Cambridge University Press, Cambridge, UK.

Osgood, D. and Silliman, B.R. From climate change to snails: potential causes of salt marsh die-back along the U.S. Eastern Seaboard and Gulf Coasts. In Silliman, B.R., Grosholtz, T. and Bertness, M.D. (editors). Salt Marshes Under Global Siege. University of California Press. (accepted)

Schultz, G., Ruppel, C. and Fulton, P. 2007. Integrating hydrologic and geophysical data to constrain coastal surficial aquifer processes at multiple spatial and temporal scales. Pages 161-182 in Hyndman, D.W., Day-Lewis, F.D. and Singha, K., eds. Subsurface Hydrology: Data Integration for Properties and Processes. American Geophysical Union Geophysical Monograph, Series Volume 171 (doi: 10.1029/171GM13).

Sharitz, R.R. and Pennings, S.C. 2006. Development of wetland plant communities. Pages 177-241 in: Batzer, D.P. and Sharitz, R.R. (eds.). Ecology of freshwater and estuarine wetlands. University of California Press, Berkeley.

Silliman, B.R., Bertness, M.D. and Thomsen, M. Top-down control and human intensification of consumer pressure in U.S. southern salt marshes. In Silliman, B.R., Grosholtz, T. and Bertness, M.D. (editors). Salt Marshes Under Global Siege. University of California Press. (accepted)

Silliman, B.R., Grosholtz, T. and Bertness, M.D. A synthesis of anthropogenic impacts on salt marshes. In Silliman, B.R., Grosholtz, T. and Bertness, M.D. (editors). Salt Marshes Under Global Siege. University of California Press. (accepted)

Conference Proceedings (Published Papers and Abstracts)

Henshaw, D.L., Sheldon, W.M., Remillard, S.M. and Kotwica, K. 2006. ClimDB/HydroDB: A web harvester and data warehouse approach to building a cross-site climate and hydrology database. Proceedings of the 7th International Conference on Hydroscience and Engineering (ICHE 2006). Michael Piasecki and College of Engineering, Drexel University, Philadelphia, USA.

Theses and Dissertations

Kunza, A.E. 2006. Patterns of plant diversity in two salt marsh regions. Master of Science Thesis, University of Houston, Houston, Texas. 70pp.

Lyons, J.I. 2007. Molecular description of ascomycete fungal communities on Spartina spp. in the U.S. Ph.D. Dissertation, University of Georgia, Athens, Georgia. (in press)

Schaefer, S.C. 2006 Nutrient budgets for watersheds on the southeastern Atlantic coast of the United States: temporal and spatial variation. M.S. Thesis, University of Georgia, Athens, Georgia, 105 pp.

Conference Posters and Presentations

Alber, M. 2006. Presentation: CSI Ecology: Salt marsh dieback in Georgia. University of Georgia Department of Geology, Athens, Georgia.

Alber, M. 2006. Presentation: Losses of foundation species and the consequences for ecosystem structure and function. Working group at the LTER All Scientists Meeting, September 20-24, 2006. Estes Park, Colorado.

Alber, M. 2006. Presentation: Salt marsh dieback in Georgia. Sudden wetland dieback meeting, May 24, 2006, Wellfleet, Massachussetts.

Alber, M. 2006. Presentation: The Georgia Coastal Research Council - Project overview. Coastal Incentive Grant Colloquium, October 2006, Savannah, Georgia.

Alber, M. and Sheldon, J.E. 2006. Calculating estuary turnover times during non-steady-state conditions using freshwater fraction techniques. Southeastern Estuarine Research Society meeting, Ponte Vedra Beach, Florida.

Alber, M. and Sheldon, J.E. 2006. Presentation: Simple tools for assessing coastal systems: can we get there from here? Coastal Observing Systems Workshop, LTER All Scientists Meeting, September 20-24, 2006, Estes Park Colorado.

Alber, M., Mackinnon, J., Hurley, D. and Curran, M.C. 2007. Presentation: Salt Marsh Dieback in Georgia. Estuarine Research Federations 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Collins, S.L., Suding, K.N., Cleland, E.E., Batty, M., Pennings, S.C., Gross, K.L., Grace, J.S., Gough, L., Fargione, J.E., Clark, C.M. Presentation: Rank clocks and plant community dynamics. Joint Ecological Society of America / Society for Ecological Restoration 2007 Meeting, August 5-10, 2007, San Jose, CA.

Craft, C., Clough, J., Ehman, J. and Park, R. 2007. Presentation: Effects of accelerated sea level rise on biogeochemical cycles of tidal marshes of the southeast U.S. coast: a landscape simulation. 10th International Symposium on Wetland Biogeochemistry, April 1-4 2007, Annapolis, Maryland.

Craft, C., Clough, J., Ehman, J. and Park, R. 2007. Presentation: Effects of accelerated sea level rise on C, N and P retention by tidal marshes: a landscape simulation. 2nd International Symposium on Wetland Pollution Dynamics and Control (WETPOL), September 16-20 2007, University of Tartu, Tartu, Estonia.

Craft, C.B. 2007. Keynote presentation: Tidal marshes and climate change. 2nd International Symposium on Wetland Pollution Dynamics and Control (WETPOL), September 16-20 2007, University of Tartu, Tartu, Estonia.

Craft, C.B. and Krull, K. 2006. Presentation: Ecosystem development of a newly emerged tidal marsh. 6th International Workshop on Nutrient Cycling and retention in Natural and Constructed Wetlands, May 31-June 4, 2006, Trebon, Czech Republic.

Craft, C.B. and Krull, K. 2007. Presentation: Ecosystem development of a newly emerged tidal marsh: a model for evaluating "success" of created and restored marshes. Society of Wetland Scientists 27th International Conference, July 9-14, 2006, Cairnes, Australia.

First, M. 2005. Georgia Coastal Ecosystems Long-Term Ecological Research (GCE-LTER) Site Review. LTER Graduate Student Collaborative Research Symposium. Andrews Experimental Research Forest, April 2005, Blue River, Oregon.

First, M. and Hollibaugh, J.T. 2006. Presentation: Temporal and spatial patterns of benthic microbial communities in a subtropical salt marsh (Sapelo Island, GA). Long Term Ecological Research Network All-Scientists Meeting, September 20-24, 2006, Estes Park, Colorado.

First, M.R. 2006. Presentation: Benthic microbial food webs: daily and yearly variations and short cuts in the microbial loop. University of Georgia Marine Science Graduate Student Seminar Series, August, 2006, University of Georgia, Athens, Georgia.

First, M.R. and Hollibaugh, J.T. 2006. Diel monitoring of sediment bacteria and protists in a subtropical tidal creek, Sapelo Island, Georgia. ASLO Summer Meeting, June 2006, Victoria, British Colombia.

First, M.R. and Hollibaugh, J.T. 2007. Presentation: Direct uptake of high molecular weight dissolved organic carbon by benthic ciliates. ASLO Aquatic Sciences Meeting, February 2007, Santa Fe, New Mexico.

Hester, M.W., Mendelssohn, I.A., Alber, M. and Joye, S.B. 2007. Presentation: Climate-Linked Alteration of Ecosystem Services in Tidal Salt Marshes of Georgia and Louisiana: Preliminary Findings. Estuarine Research Federations 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Ho, C.-K. and Pennings, S. C. Presentation: Preference and performance in plant-herbivore interactions across latitude. 91st Annual Meeting of the Ecological Society of America. August 6-11, 2006, Memphis, Tennessee, USA.

Ho, C.-K. and Pennings, S.C. 2007. Presentation: Bergmann¡'s Rule and latitudinal variation in herbivore body size. Joint Ecological Society of America / Society for Ecological Restoration 2007 Meeting, August 5-10, 2007, San Jose, California, USA.

Hollibaugh, J.T. and Alber, M. 2006. Presentation: Georgia's Coast - Past, present, and future. Georgia Certified Court Reporters Class, September 2006, St. Simons, Georgia.

Hollibaugh, J.T. and Ransom, B. 2007. Presentation: Comparison of fish species reveals major differences in the composition of gut microflora. ERF 2007, 4-8 November 2007, Providence, Rhode Island.

Johnson, H.E. 2007. Presentation: Screening of Fosmid Library of Environmental Genomic DNA from Sapelo Island. Center for Undergraduate Research Opportunities Symposium, April 9, 2007, University of Georgia, Athens, Georgia.

Joye, S.B., Hunter, K.S., Bernier, M., Craft, C. 2007. Presentation: Salinity-driven patterns in sediment biogeochemistry and microbial activity in Georgia coastal estuaries. 10th International Symposium on the Biogeochemistry of Wetlands, 1-4 April 2007, Annapolis, Maryland.

Kenemer, B., McFarlin, C. and Alber, M. 2006. Poster: Fiddler Crabs Dig It: A Study of Burrow Dynamics in a Salt Marsh. Fall 2006 Meeting of the Southeastern Estuarine Research Society, October 19-21, 2006, Savannah, Georgia.

Kunza, A.E. and Pennings, S.C. 2006. Poster: Patterns of plant diversity in two salt marsh regions. Long Term Ecological Research Network All-Scientists Meeting, September 20-24, 2006, Estes Park, Colorado.

Lyons, J., Alber, M. and Hollibaugh, J.T. 2006. Poster: Molecular comparison of ascomycete fungal communities on Spartina species found along the east, west, and Gulf coasts of the U.S. LTER All Scientists Meeting, September 20-24, 2006, Estes Park, Colorado.

Lyons, J.I., Alber, M. and Hollibaugh, J.T. 2006. Poster: Molecular comparison of ascomycete fungal communities on Spartina species found along the east, west, and Gulf coasts of the U.S. Southeastern Estuarine Research Society. March 30-April 1, 2006, St. Augustine, Florida.

McFarlin, C., Ogburn, M. and Alber, M. 2006. Poster: The recent status and trends of two Georgia marsh dieback sites. Spring 2006 Meeting of the Southeastern Estuarine Research Society, March 30-April 1, 2006, St. Augustine, Florida.

McFarlin, C.R., Kenemer, B., Alber, M., Hester, M.W. and Bishop, T.D. 2007. Poster: A Comparison of Dieback Effects on Salt Marsh Invertebrates in Georgia and Louisiana. Estuarine Research Federations 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

McKay, P. and Di Iorio, D. 2006. Presentation: Salt and heat fluxes in a sinuous, macrotidal salt channel in the south Atlantic Bight. AGU Ocean Sciences Meeting, February 2006, Honolulu, Hawaii.

Pennings, S.C. 2006. Presentation: Plant community response to nitrogen enrichment: results from a cross-site synthesis. Long Term Ecological Research Network All-Scientists Meeting, September 20-24, 2006, Estes Park, Colorado.

Pennings, S.C. 2006. Presentation: Sea-level rise and ecosystem services of tidal marshes. Sea-level rise, hurricanes, and the future of our coasts. Sigma Xi Meeting,Texas A&M University, March 30, 2006.

Pennings, S.C., Ho, C.-K., Salgado, C., Wieski, K., Dave, N., Kunza, A.E., Wason, E.L. 2007. Presentation: Latitudinal variation in herbivore pressure in Atlantic Coast salt marshes. Joint Ecological Society of America / Society for Ecological Restoration 2007 Meeting, August 5-10, 2007, San Jose, CA.

Porubsky, W.P., Meile, C. and Joye, S.B. 2006. Poster: Nutrient dynamics in the hammock subsurface: The impact of flow and reactions on coastal groundwater biogeochemistry. Academy of the Environment Meeting, October 2006, Athens, Georgia.

Porubsky, W.P., Meile, C. and Joye, S.B. 2007. Poster: Variations in groundwater biogeochemistry and flow on Moses Hammock (Sapelo Island, GA): Field measurements, laboratory assays, and modeling. American Society of Limnology and Oceanography 2007 Aquatic Sciences Meeting, 4-9 February 2007, Santa Fe, New Mexico.

Porubsky, W.P., Meile, C. and Joye, S.B. 2007. Presentation: Using field measurements, laboratory assays and modeling to examine flow conditions and variations in groundwater biogeochemistry. Estuarine Research Federation 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Robinson, J.D., Cozad, M. and Wares, J.P. 2007. Presentation: Population structure of salt marsh invertebrates from the GCE-LTER. Benthic Ecology Meeting, March 21-25 2007, Atlanta, Georgia, USA.

Schaefer, S. and Alber, M. 2006. Nutrient inputs to the Altamaha River Watershed, 1954-2002. Southeastern Estuarine Research Society, Savannah, Georgia.

Schaefer, S. and Alber, M. 2006. Poster: Temperature response of denitrification drives a latitudinal gradient in coastal export. LTER All Scientists Meeting, September 20-24, 2006, Estes Park, Colorado.

Schaefer, S.C. and Alber, M. 2006. Presentation: A latitudinal gradient in the percentage of net anthropogenic nitrogen input exported to Atlantic coast rivers. Estuaries session. Semi-annual meeting of the Southeastern Estuarine Research Societ, March 31-April 1, 2006, St. Augustine, Florida.

Schaefer, S.C. and Alber, M. 2007. Presentation: Temperature as a Control on Proportional Nitrogen Export to Coastal Ecosystems: An application of the SCOPE nitrogen budgeting method. Estuarine Research Federations 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Schalles, J., Hladik, C., Whitehurst, L. and Merani, P. 2006. Poster: Hyperspectral imaging of wetlands and estuarine waters of National Estuarine Research Reserves in the Southeastern and Mid-Atlantic Regions of the United States. Shallow Water Optics. Ocean Optics XVIII, The Oceanographic Society, October 9-13, 2006, Montreal, Quebec, Canada.

Schalles, J.F., Hladik, C.M., Volkmer, M. and Saucedo, D.F. 2007. Presentation: Geospatial Mapping of Species and Biomass in Georgia Salt Marshes using AISA Airborne Hyperspectral Imagery. Estuarine Research Federation 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Seay, J.E., Bishop, T.D. and Tilburg, C.E. 2006. Poster: Spatial and temporal variations of fiddler crab (Uca spp.) larval abundance in a Georgia estuary. Southeastern Estuarine Research Society Spring 2007 Meeting, 30 March - 1 April 2006, St. Augustine, Florida.

Seay, J.E., Bishop, T.D. and Tilburg, C.E. 2006. Poster: Spatial and temporal variations of Porcelain Crab larval abundance in a Georgia Estuary. Southeastern Estuarine Research Society Fall 2006 Meeting, 19 October - 21 October 2006, Savannah, Georgia.

Segarra, K., Samarkin, V. and Joye, S.B. 2007. Presentation: Temperature driven variations in terminal metabolism in methanogenic freshwater sedments. Estuarine Research Federation 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Sheldon, J.E. and Burd, A. 2007. Poster: Detecting climate signals in river discharge and precipitation data for the central Georgia coast. 2007 AERS/SEERS Meeting, March 15-17, 2007, Pine Knoll Shores, NC.

Sheldon, J.E. and Burd, A.B. 2007. Presentation: Seasonal Effects of the Southern Oscillation and Bermuda High on Freshwater Delivery to Coastal Georgia, U.S.A. Estuarine Research Federation 2007 Annual Meeting, 4-8 November 2007, Providence, Rhode Island.

Sheldon, W.M and Remillard, S. 2006. Poster: Software tools for automated synthesis of LTER, USGS and NOAA climate and hydrologic data. Long Term Ecological Research Network All-Scientists Meeting, September 20-24, 2006, Estes Park, Colorado.

Sheldon, W.M. 2007. Presentation: Synthesis of incomplete and qualified data using the GCE Data Toolbox. Workshop to define quality management standards for data completeness in derived data products, January 31-February 1, 2007, Jornada Experimental Range, Las Cruces, New Mexico.

Wason, E.L. and Pennings, S.C. 2007. Poster: Gradients of grasshopper species composition and size in Atlantic Coast salt marshes. Joint Ecological Society of America / Society for Ecological Restoration 2007 Meeting, August 5-10, 2007, San Jose, CA.

Whigham, D.F., Barendregt, A., Craft, C. and Neubauer, S. 2007. Climate change consequences for tidal freshwater wetlands at the east and west coast of the Atlantic. International Association of Landscape Ecology, July 8-12 2007, World Congress, Wageningen, The Netherlands.

Newsletter and Newspaper Articles

Georgia Coastal Research Council. 2007. Research Summary: On the shoulders of giant plants. Georgia Sound Newsletter. 13(3):1.

Sheldon, W. 2006. Mining and Integrating Data from ClimDB and USGS using the GCE Data Toolbox. DataBits: An electronic newsletter for Information Managers, Spring 2006 issue. Long Term Ecological Research Network, Albuquerque, NM.

Sheldon, W. 2007. Practical Distributed Computing Approach for Web Enabling Processor-intensive Programs. DataBits: An electronic newsletter for Information Managers, Spring 2007 issue. Long Term Ecological Research Network, Albuquerque, NM.