GCE-LTER
ANNUAL REPORT OF ACTIVITIES,
Year Five (2004-2005)
Award NSF OCE 99-82133

Project Management

Project Administration

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

Administrative responsibilities have included organizing the GCE annual meeting, participating in LTER network coordinating committee meetings, and dealing with accounting, reporting and supplementary and continuation funding paperwork. Hollibaugh and Pennings split Coordinating Committee responsibilities with Pennings attending the spring meeting in Santa Barbara, CA and Hollibaugh attending the summer meeting in Fairbanks, AK. Hollibaugh also participated in a workshop (Coco Beach, FL) organized by LNO to develop a series of Grand Challenge questions to guide network synthesis in the next decade of LTER research. Science oversight responsibilities involved coordinating the efforts of scientists in different aspects of the study, and negotiating agreements with different agencies to supplement monitoring efforts.

Our fourth year of Schoolyard LTER support provided an opportunity for teachers to participate in field research at the GCE-LTER site during the summer of 2004. Immediate supervision of the Schoolyard LTER is currently being provided by J.T. Hollibaugh, with the actual teacher training effort lead by Ms Trisha Hembree. Ms Hembree has been successful in augmenting the Schoolyard with funds from the Eisenhower Foundation.

Web Site, Database, and Information Management Activities

Wade Sheldon, Dept. of Marine Sciences, UGA

Overview

Information management activities this year were largely focused on strengthening existing support for LTER Network Information System initiatives, such as EML metadata, developing standards and software support for automatic synchronization of GCE metadata with the LTER Network Office and other metadata clearinghouses (NBII, KNB, SEEK Ecogrid), and supporting GCE investigators in data integration, analysis and synthesis projects. We also enhanced our IT infrastructure by acquiring a new database server and adding a network-attached RAID server to provide secure central storage and backup of GCE investigator data and to simplify data exchange and collaboration within subproject working groups.

Near-real-time Climate and Hydrographic Data

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 streamflow gauge (Altamaha River at Doctortown). Real-time data are finalized monthly, re-sampled to daily values and submitted to the LTER climate and hydrological databases (ClimDB and HydroDB), along with data from the manually operated NWS climate station on Sapelo Island.

Salinity, temperature and pressure data from moored hydrographic data loggers continue to be downloaded and processed on a bimonthly to quarterly basis. Provisional data and plots are provided to GCE investigators on the project web site within two days of acquisition, and finalized, quality-controlled data are added to the GCE Data Catalog at the end of each year to provide public access.

The GCE project also 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 52 USGS streamflow gauging stations are automatically harvested on a weekly basis for 10 LTER sites (AND, BES, 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.

Software Development

We have continued to improve on the GCE Data Toolbox for MATLAB software and offer a compiled version of this toolbox for public download on our web site (see http://gce-lter.marsci.uga.edu/lter/research/tools/data_toolbox.htm). Major new features were added this year to support data discovery and integration, including a comprehensive data indexing and search engine for performing metadata-based searches to identify data sets that meet a wide range of user-specified thematic, temporal, and geospatial criteria. All public data sets in the GCE Data Catalog and Data Portal web sites can be searched in addition to user-created or customized data sets stored in local directories; consequently, this tool serves both as an end-user data management tool and a remote data access client in addition to a search engine. Significant improvements were also made to data integration functions, allowing multiple related data sets stored in any number of directories to be merged into composite data sets in one step, with user-specified handling of metadata content, QA/QC flags and overlapping date ranges. Over 500 visitors downloaded the toolbox package this year (see download statistics below).

Support for EML Metadata

Support for EML 2.0, the new xml-based metadata standard adopted by the LTER Network in 2002, was significantly enhanced this year by adding EML support to the GCE taxonomic database. Standard and user-specified species lists can now be generated as stand-alone EML documents (in addition to HTML, text tables and CSV files) to support exchange of taxonomic information across LTER. Two different EML implementations were developed (i.e. list form and tree form) and submitted for consideration as a network-wide standard.

The GCE Information Manager (W. Sheldon) also headed a working group at the LTER Network Office (LNO) in May 2004 to establish best practices for LTER EML implementation. The best practices document and example schemas from this working group are currently under review by the LTER IM Committee, but all recommendations have already been implemented at GCE in the EML dynamically-generated for each data set in our public data catalog. We also provided logistical support to other LTER sites this year in implementing EML, including: Coweeta (CWT), Virginia Coast Reserve (VCR), Niwot Ridge (NWT) and Palmer Station (PAL).

In addition, W. Sheldon collaborated with LNO and NCEAS on development and testing of a specification for automatically harvesting EML documents from LTER sites for inclusion in the KNB Metacat repository (and therefore the distributed Metacat and Ecogrid networks). This 'Metacat Harvester' is now operational and 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 country. The USGS National Biological Information Infrastructure project has also adopted this specification to harvest EML for inclusion in the NBII metadata clearinghouse, and GCE is the first LTER site to become established as an NBII Clearinghouse node. All GCE metadata can now be searched using the NCEAS Morpho application, the KNB Metacat web interface (http://knb.ecoinformatics.org), 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 has enabled NCEAS and the KNB and SEEK projects 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 these projects.

Data Catalog Additions

Data submissions from both monitoring and directed study programs were similar to those in year 4, with 101 data sets added to the catalog or in the final stages of documentation for inclusion. GCE investigators have contributed a total of 280 documented data sets to date, 194 of which are currently accessible to the LTER and broader scientific community through our web-accessible public data catalog. This year we also became the first LTER site to develop support for automated metadata synchronization with the LNO/KNB Metacat repository, the NBII Metadata Clearinghouse, and the nascent SEEK Ecogrid Network (see EML Metadata section). These metadata-sharing collaborations dramatically increased the visibility and accessibility of GCE data and contributed to a 10-fold increase in data set downloads in Year 5 relative to Year 4. Detailed public data download statistics are provided below in the Web Site and Data Access Statistics section.

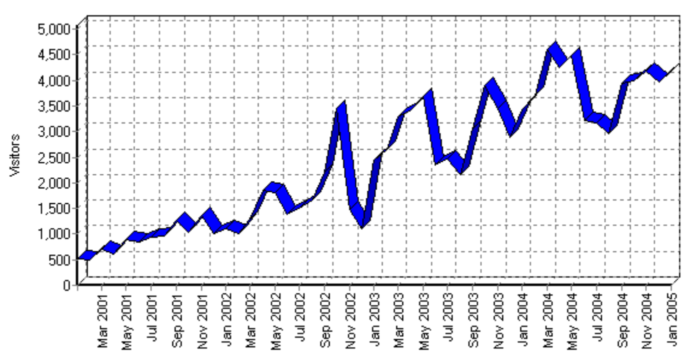
Web Site Additions

The project calendar web application developed last year to promote communication within the project was significantly enhanced this year to improve display of upcoming events. All GCE participants can add events to the calendar, and event details are stored in a relational database to support dynamic calendar generation and searching. Support for title text searching was also added to the interactive filter panel on the public data catalog to improve data discovery, and an enhanced data search engine is currently under development in parallel with efforts at LNO to develop a standard data query interface for the LTER network. As mentioned above, additional options to display species lists in various EML metadata formats were added to the taxonomic database to facilitate exchange of taxonomic information for systematics research.

Web Site and Data Access Statistics

GCE public web site statistics for Year 5 (filtered to remove all invalid requests and web indexing spiders) are listed to the right, and long-term web activity trends are illustrated in the figure below. Overall web activity in Year 5 was consistent with Year 4, with highest activity during the academic year and lowest during the summer months. Although most page requests originate in the U.S. (62.2%), requests were logged from 158 distinct countries and territories overall (based on Internet domain analysis).

Month	Hits	Visitors
Jan-04	54,603	3,440
Feb-04	94,625	3,711
Mar-04	62,335	4,611
Apr-04	67,933	4,246
May-04	62,228	4,475
Jun-04	44,617	3,225
Jul-04	49,325	3,167
Aug-04	40,436	2,963
Sep-04	48,942	3,942
Oct-04	42,599	3,994
Nov-04	47,310	4,176
Dec-04	43,786	3,965
Total	**658,739**	**45,915**



As in year 4, the software tools, data catalog, and taxonomic database pages were the most frequently requested web pages other than the home page.

Public downloads of GCE data sets in Year 5 are listed below. Note that many data sets from Year 3 and Year 4 efforts were not publicly accessible due to data release restrictions, and that downloads by GCE participants are not included. Unlike previous years, the majority of public data requests in Year 5 were brokered through the new LTER Network Office/KNB Project Metacat Server (see Support for EML Metadata above), so detailed end-user information is not currently available. Use of GCE data to test and demonstrate metadata-mediated applications under development by the SEEK project accounts for some of the Metacat-based requests. Educators and academic researchers submitted the majority of the 188 individual data requests to the GCE online catalog, similar to past years. Note that this activity represents a 10-fold increase in overall public data distribution relative to Year 4, and a 3-fold increase in individual data requests alone.

Year	Theme	Affiliation	Total
2004	Aquatic Invertebrate Ecology	Academic Research Program	15
		Educational Program (Post-secondary)	34
		LTER Network Office	369
		Other LTER Site	1
		Other/Unspecified	3
	Bacterial Productivity	Educational Program (Post-secondary)	3
		LTER Network Office	19
		Other/Unspecified	1
	Fungal Productivity	Government Agency	2
	General Nutrient Chemistry	Academic Research Program	2
		Educational Program (Post-secondary)	2
		Government Agency	1
		LTER Network Office	8
	Meteorology	Academic Research Program	13
		Educational Program (Post-secondary)	5
		Government Agency	6
		International LTER Site	1
		LTER Network Office	2
	Organic Matter/Decomposition	Academic Research Program	1
		Educational Program (Post-secondary)	1
		LTER Network Office	17
		Other LTER Site	1
		Other/Unspecified	2
	Physical Oceanography	Academic Research Program	12
		Educational Program (Post-secondary)	11
		Government Agency	3
		International LTER Site	1
		LTER Network Office	17
		Other LTER Site	5
		Other/Unspecified	18
	Phytoplankton Productivity	Academic Research Program	4
		Educational Program (Post-secondary)	2
		LTER Network Office	23
		Other/Unspecified	6
	Plant Ecology	Academic Research Program	3
		Educational Program (Post-secondary)	7
		Government Agency	4
		Other LTER Site	3
		Other/Unspecified	3
	Pore-water Chemistry	Academic Research Program	1
	Terrestrial Insect Ecology	Academic Research Program	2
		Educational Program (Post-secondary)	5
		Government Agency	4
		LTER Network Office	4
	All Themes	**All Affiliations**	**647**

Public downloads of the GCE Data Toolbox for MATLAB (software for metadata-based analysis, visualization, transformation and management of ecological data, including all GCE data sets) during year 5 are listed to the right.

Year	Affiliation	Total
2004	Academic Research Program	177
	Educational Program (K-12)	24
	Educational Program (Post-secondary)	72
	Environmental Advocacy Group	12
	Government Agency	27
	International LTER Site	11
	Other LTER Site	6
	Other/Unspecified	214
	Total:	**543**

Annual Meeting

We conducted our fifth GCE-LTER annual meeting in February, 2005, in Athens Georgia. We presented and discussed our results to date and solicited feedback from our scientific advisory committee: Iris Anderson (VIMS/VCR), Jack Gallagher (U. Del), Chuck Hopkinson (MBL/PIE), George Jackson (TAMU), Jane Caffrey (UWF) and Wim Kimmerer (SFSU). A major focus of this meeting was discussing our renewal proposal.

Environmental Forcing Functions

Salinity Regime

Daniela Di Iorio, Dept. of Marine Sciences, UGA; Jack Blanton, Skidaway Institute Of Oceanography

The GCE-LTER monitoring program at fixed locations plus the quarterly shipboard sampling has documented that freshwater discharge enters the southern region from the Altamaha while salty coastal water is always present along the ocean boundary. Tidal mixing of the salt and freshwater end members creates a continuum of salinity gradients that change at various time and space scales.

The three adjacent estuaries (Altamaha, Doboy, and Sapelo Sounds) display dramatically different salinity patterns and degrees of riverine influence over distances as short as 30 km. Altamaha Sound is strongly river dominated and encompasses a complex delta made up of low islands, marshes and tributaries. Its discharge varies over annual and inter-annual cycles and is typically less than 400m/s during low flow but can exceed 3000m/s during high flow. Drought conditions from 1999-2001 resulted in low discharge values and uncommonly high salinities. Extremely strong salinity gradients (2 PSU/km) are common in the Altamaha estuary, especially during high discharge periods.

The two sounds to the north of the Altamaha have relatively unobstructed connections to the sea. Low salinity water from the Altamaha River is transported into Doboy Sound through the Intracoastal Waterway (ICW), marsh channels and via the coastal ocean. The Altamaha's effect on Doboy is apparently directly related to its discharge. Sapelo Sound, at the northern edge of the study area, receives minimal freshwater input (from precipitation, groundwater or local runoff). The highest salinities of the LTER domain are found in Sapelo Sound because it is farthest from the Altamaha River freshwater source. Even Sapelo Sound has reduced salinity when Altamaha discharge is maximal.

Since 2002, there has been a gradual recovery to lower salinity as the prolonged drought in the Southeast ended. Rainfall events in the drainage basin and locally have strengthened the freshwater source from the Altamaha system. Salinity decreased throughout the year at all of the GCE monitoring locations, especially after August 2002. The farthest upstream station on the Altamaha River has basically returned to a constant near-zero salinity since October 2002.

Spatial salinity patterns are revealed in the annual statistics for the 8 monitoring sites (Table 1). Not surprisingly, the seaward stations (Sites 3, 6 and 9) had the highest salinities, and became relatively fresher toward Altamaha Sound. The greatest variabilities in salinity were recorded at Sites 1 and 9, while very little fluctuation occurred at Site 3 (saltiest) and Site 7 (freshest).

Table 1: GCELTER annual statistics for salinity (Year 2002). Questionable values were excluded. Abbreviations in the table are: SAP = Sapelo River estuary; DOB = Doboy Sound; ALT = Altamaha River estuary. Units are in PSU.

Site	Station	Min	Max	Mean	SD	% good
1	SAP landward	0.07	32.45	13.20	10.55	63
2	SAP middle	18.36	33.99	29.12	2.80	82
3	SAP seaward	25.77	34.56	31.74	1.49	100
4	DOB landward	11.69	32.01	25.76	3.42	90
6	DOB seaward	22.21	34.47	29.06	2.28	72
7	ALT landward	0.05	10.53	0.25	0.49	98
8	ALT middle	0.06	29.61	5.18	5.17	92
9	ALT seaward	0.19	34.11	18.45	8.55	82

In summary, at the end of the drought in 2002, the Upper Altamaha estuary returned to fresh conditions. Salinity also decreased in Doboy Sound and even Sapelo Sound in response to the sustained large pulse of freshwater into the system.

Residence times in the Altamaha River Estuary

Merryl Alber and Joan Sheldon, Dept. of Marine Sciences, University of Georgia

Ongoing work includes continued development of the SqueezeBox model for the Altamaha River estuary. We completed a recalibration that extends the operational range of discharge to include both drought and flood observations. We are using the improved model to compare the relative responses of the salinity and transit times of the Altamaha with those of the Ogeechee estuary to changes in river flow. This work will be presented at the spring meeting of the Georgia Water Resources Conference. We are starting a project funded by the Coastal Resources Division of Georgia DNR to add non-conservative tracers (including nutrients) to the model. J. Sheldon gave several presentations of the model this year, including one to an invited workshop sponsored by NOS/NOAA. We have also recently completed a theoretical paper on the calculation of turnover times in estuaries.

Circulation and biogeochemical fluxes in the Duplin River

Jack Blanton, Skidaway Institute of Oceanography; Daniela Di Iorio, Dept. of Marine Sciences, UGA

GCE-LTER PIs participated in a study of the exchange processes between a large tidal creek and its adjacent intertidal areas. The study focused on the time period of 12-21 August 2003, a time when metabolic activity in the study area was at its annual maximum. High resolution sampling of geochemical variables was undertaken to see if changes could be detected between water that goes onto the marsh and that which comes off. Results through 2004 are summarized here.

Exchange processes between intertidal areas and tidal creeks

The intertidal topography of the area was determined from a series of 7 infrared aerial images of the Duplin River, taken at 1hr intervals during the flood phase of the tide (Fig. 1). Spectrum North Carolina, Inc conducted the aircraft mission. The images had a pixel resolution of 1 m^2, and analysis of each image yielded 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.

We defined 17 polygons within the intertidal area of the Duplin River (Fig. 2) by measuring coordinates of the connecting creeks, using *GCE Mapping Toolbox* (written by Wade Sheldon http://gce-lter.marsci.uga.edu/lter/research/tools/it_development.htm). The implied assumption for each polygon is that no water crosses the drainage boundaries. While some cross-boundary transport may occur at extreme high tides, the volumes involved are quite small compared to the creek fluxes draining the intertidal areas.

Estimates of the low water and high water areas of each polygon are being used to estimate the relative magnitude of tidal water storage in various parts of the Duplin intertidal area. Moreover, these data are furnishing storage volume estimates for use in a hydrodynamic model mesh that will include idealized representations of the intertidal water area.

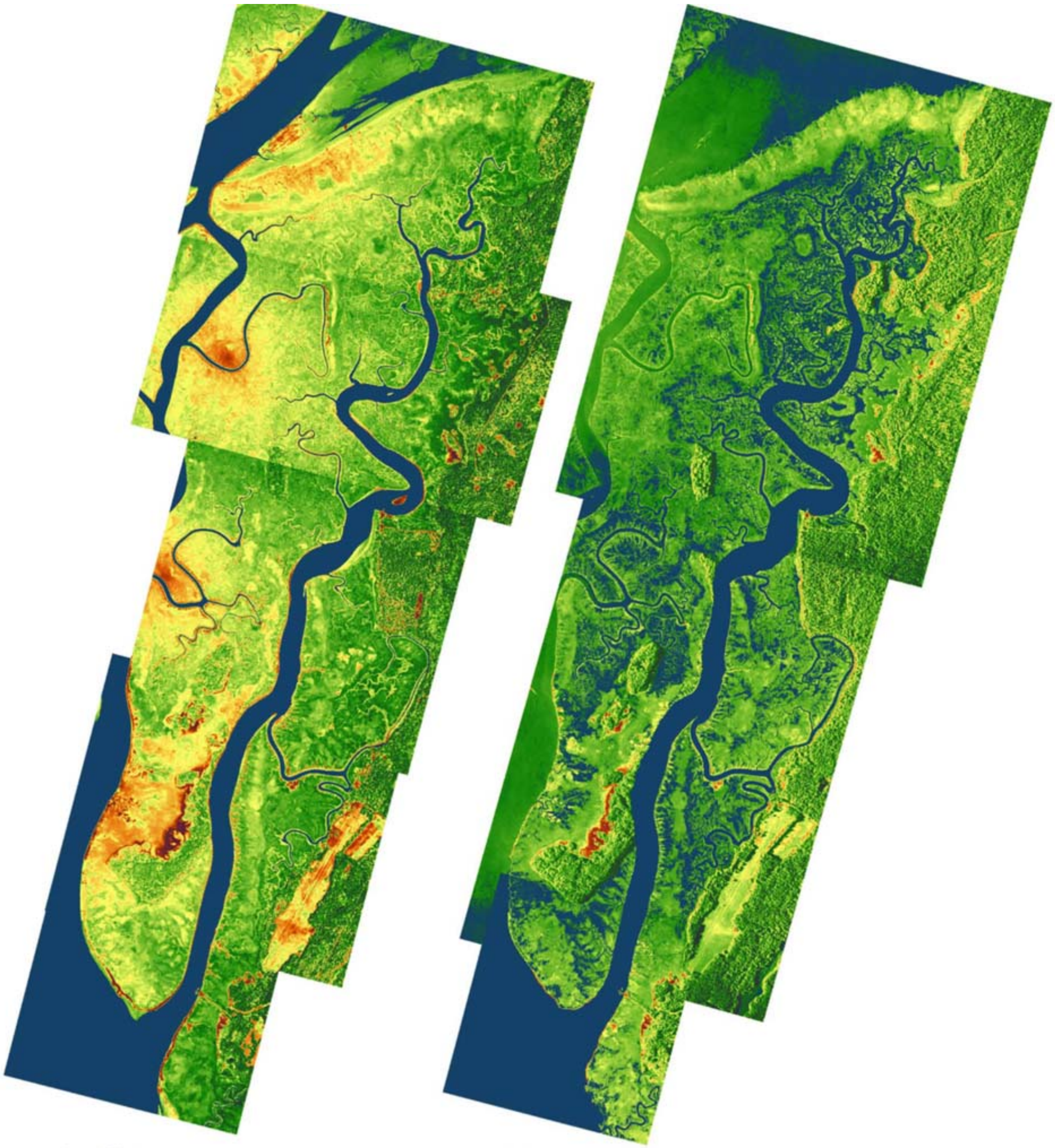


Figure 1: *Aerial images of the Duplin River showing the distribution of low water (left) and high water (right).*

Modeling experiments are being designed to simulate processes controlling the dynamics of the Duplin River and its interaction with the intertidal areas. The goal is to quantify salt transport and diffusion parameters in the area. The TELEMAC model was chosen for this study, a flow model based on finite element techniques developed by the Laboratoire National d'Hydraulique (EDF -Paris). The nature of the finite element mesh

allows the fitting of various sized elements within a specified boundary, permitting high resolution in areas of increased bed slope or narrow channels and low resolution in areas where detail is not required. This particular feature makes the model ideal for incorporating the complex boundary and topography of the Duplin River.
Data from the “Directed Study” of August 2003 are being used to validate this model. Measurements from Station GCE 6 (Doboy Sound) furnish the boundary condition at the river mouth, while measurements from stations 1, 2, 3, 4 and 5 in DUPLEX I furnish data for model validation.

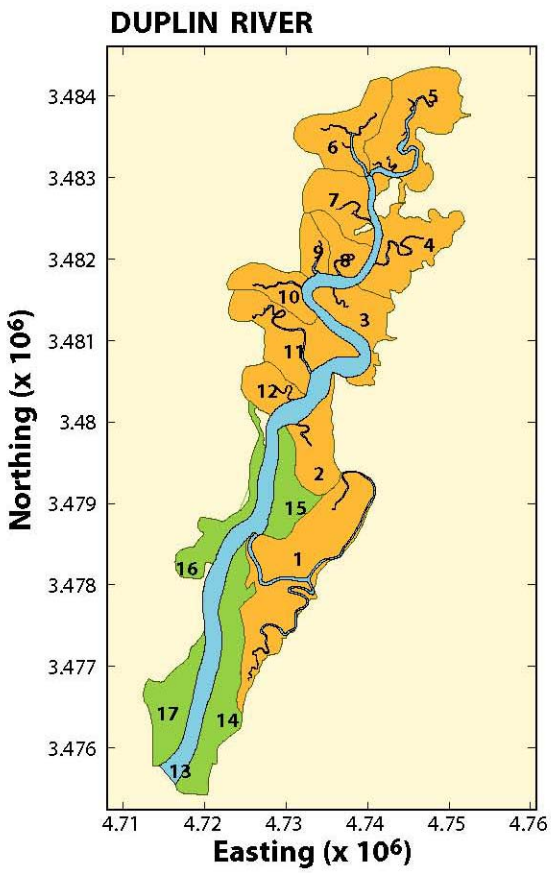


Figure 2: *The definition of tidal tributaries to the Duplin River, described as polygons.*

Energy dissipation in the Duplin River

Using data from instruments moored during DUPLEX I, we estimated energy dissipation at each station using the following equation (Taylor, 1919):

$$D = - < \rho C_d [U^2]^{\frac{3}{2}} >$$

where the bracket pair <> represent the average over an integral number of M2 cycles, C_d is a drag coefficient and U is the tidal velocity. We use C_d =0.002, a representative value for one of the coastal plain estuaries in Georgia (Seim et al., 2002). The results for each station are summarized for the M2, M4 and M6 tidal constituents (Table 2).

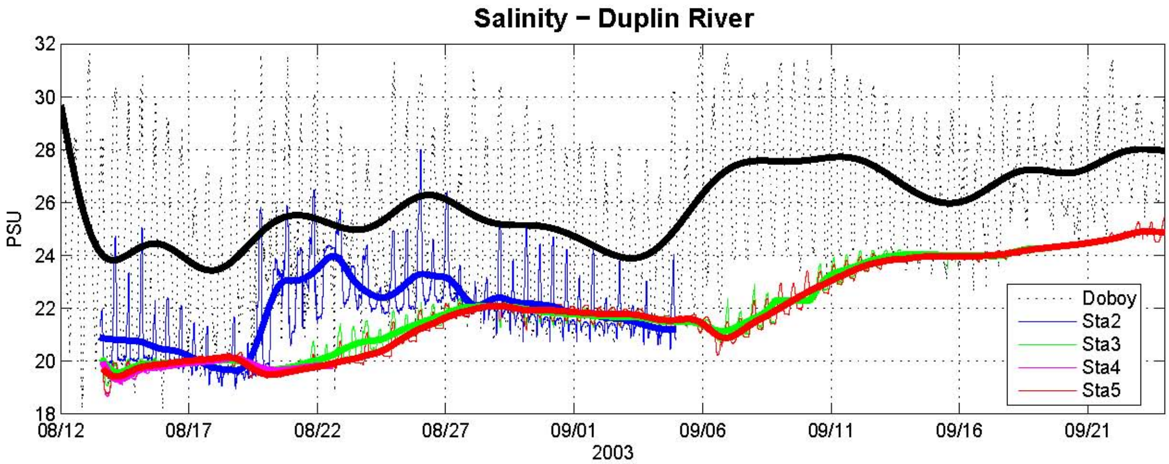
Dissipation estimates (Table 2) suggest that most of the tidal energy is dissipated near the mouth. Station 1 dissipation is greater by an order of magnitude than at the other stations. Most of the dissipation can be accounted for by the M2 tide, but the increasing energy of the overtides from the mouth to the head can add from 17% (near the mouth) to 63% (Station 5).

Table 2: *Dissipation of tidal energy in the Duplin River by M2, M4 and M6 tidal constituents [*W/m^2*] using Equation 1 and* C_d = 0.002*. The rightmost column is the ratio of M2+M4+M6 to M2 alone.*

Station	M2	M2+M4	M2+M4+M6	Ratio
1	0.153	0.174	0.179	1.17
2	0.017	0.020	0.020	1.18
3	0.030	0.038	0.039	1.32
4	0.018	0.022	0.023	1.29
5	0.013	0.021	0.022	1.63

The maximum dissipation of 0.18 W/m^s (Table 2) occurs in the lower Duplin River. This suggests that tidal mixing is significantly greater there than farther upstream. Even so, the dissipation rate is an order of magnitude smaller than values of about 1 W/m^s for the Satilla River (Seim et al, in prep) and 2-4 W/m^s for Coos Bay, Oregon (Blanton, 1969). The small dissipation rate in the Duplin River may be characteristic of relatively short tidal creeks. The correlation ηu for a large tidal creek tributary to the Satilla (White Oak Creek) is only 0.08 m/s which is of the same order as the correlations in the Duplin. This suggests that “closed” tidal creeks have conditions closer to a standing wave and thus dissipate less energy than the more “open” coastal plain estuaries where the tidal wave can propagate farther upstream (Blanton et al., 2002).

The maxima in energy dissipation found between Stations 1 and 2 of the DUPLEX I experiment is consistent with the temporal distribution of salinity at the various moorings (Fig. 3). The large gradient observed at Station 2 signifies that the mixing to that point preserves the salinity differences between Duplin River and Doboy Sound. At Stations 3 and 5, these differences have been smeared out so that the tidal advection of the salinity gradient was relatively small. A manuscript based on this work is being prepared for submission to *Estuaries.*



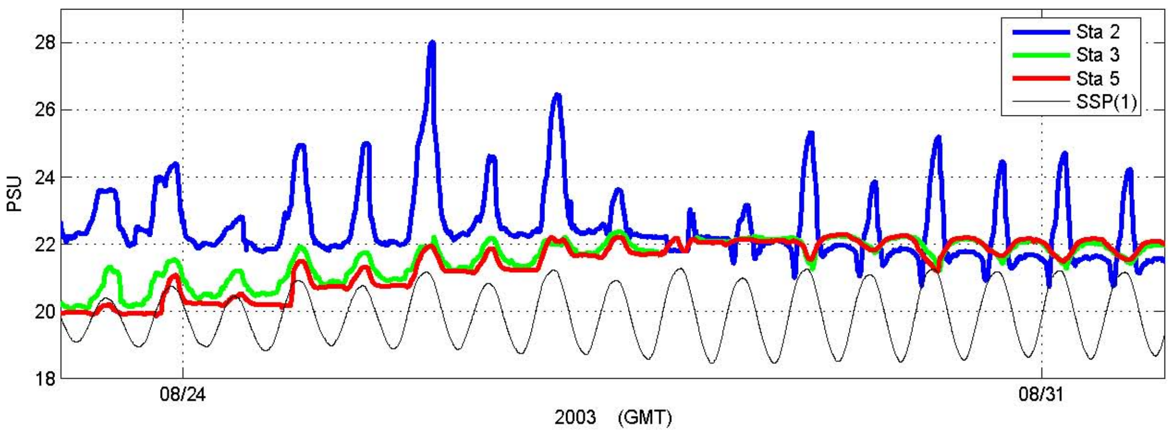


Figure 3: Salinity regime in the Duplin. Top panel: Salinity changes over 1.5 month. The heavy lines denote the data after applying a 40hr low-pass filter to remove tides. Bottom panel: Snapshot over one week showing trapping of a water mass. The black subsurface pressure line in this plot shows the phase of the tide.

Transport and Salt Fluxes

This work is carried out by an UGA PhD candidate Mr. Paul McKay. During DUPLEX, continuous transects over a 13 hour tidal cycle in the upper Duplin estuary between experimental stations 3, 4 and 5, were carried out with a 1200 kHz ADCP (see Figure 4a). Both spring and neap tidal cycles were sampled and the mean transport was calculated as a function of time (Figure 4b) and as a function of location. Net transport varied between 200 and 400 m^3/s. Over the 13 h period the transport (as well as the depth averaged flow) varied from the M2 lunar tidal cycle, with the later part of the ebbing tide slowing faster than the lunar-predicted tide. This characteristic was consistent for the three cross sections studied. Non-linear interaction of the M2 tide with the shallow depths result in the overtides (M4 and M6) described earlier but this does not completely account for this flood/ebb asymmetry observed. Averaging over the 13 hour cycle resulted in a net transport of flow that is less than $0.001 m^3/s$ indicating essentially no net advective flow in the upper Duplin River estuary despite the deviations from the tidally predicted flow. Since averaging is only over 13 hours there are certainly some errors introduced in this measurement. Since the M2 tide is the dominant forcing as described earlier we will proceed next by analyzing the residual for any significant transport.

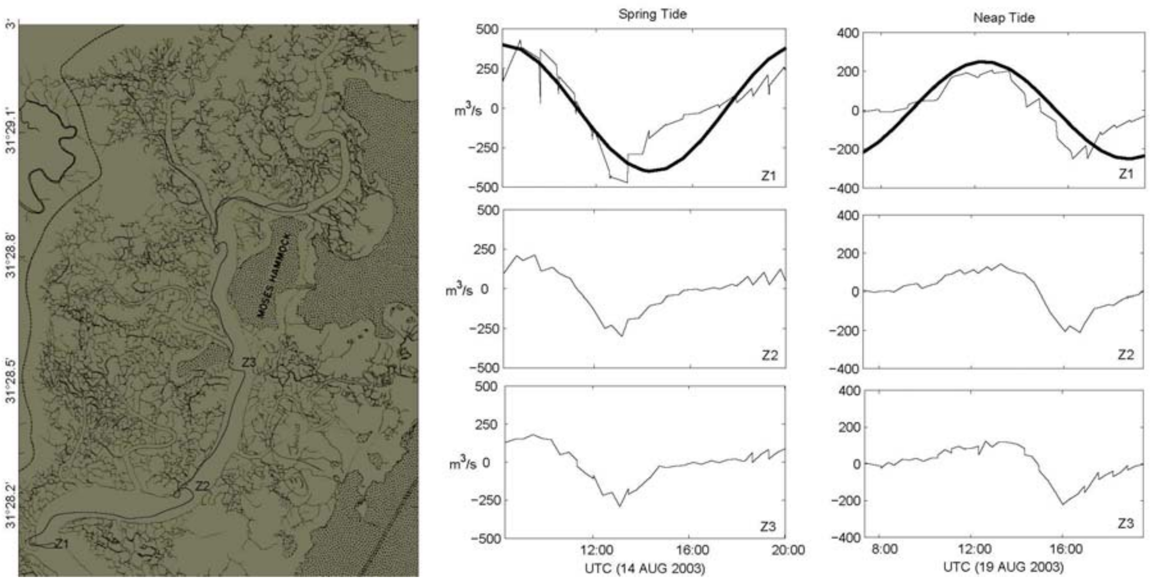


Figure 4: a) Map of the Duplin showing the location of the cross channel transects. b) Volume transport taken for each cross section in the upper Duplin River during spring (left) and neap (right) tides. Superimposed on the upper plots is the best fit M2 tidal signal.

The moored data set at Dup01, 02 and 03 in the lower Duplin River provided an opportunity to explore the mean residual and tidally varying properties of the flow and salinity in terms of salt fluxes by advection versus tidal pumping (see Figure 5). At each of the moorings a net advective flow from the estuary was measured which is contrary to the estimation of transport in the upper Duplin. As a result, a strong advective salt flux was obtained which dominates over the tidal pumping term. The tidal pumping salt flux would be 0 if the tide acts purely as a standing wave in the estuary with a 90 deg phase shift between the current and salinity time series. However, a positive amount (primarily during neap tides) implies that water flowing in on flood has a higher salinity than that flowing out. A larger negative amount (primarily during spring tides) implies that water flowing out on ebb has a higher salinity than that flowing in. These changes in the tidally varying salinity indicate that tidal mixing and interactions with the tidal marshes play a role in altering the salinity regime.

During spring 2004 a second experiment was carried out in the lower Duplin River. This data will be used to compare with the 2003 summer measurements of the derived salt fluxes described previously. In addition the flow data and tidal height measurements can be used for comparison to the coincident aerial infrared images of the Duplin River. Analysis of this data set is ongoing.

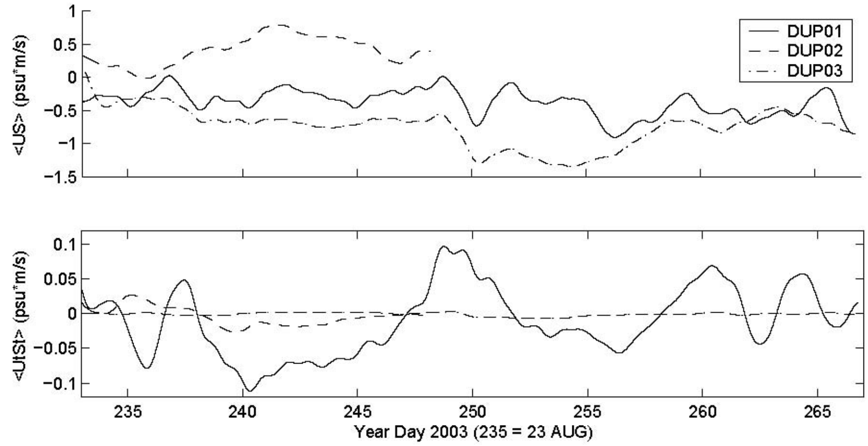


Figure 5: The advective (upper) and tidal pumping (lower) salt fluxes in the lower Duplin estuary.

Modes of sea level fluctuations in the GCE-LTER domain

Rochelle Randall, an REU mathematics major at Savannah State University, is examining the manner in which sea level fluctuates in the GCE-LTER domain at frequencies smaller than tidal (subtidal). The analyses are based on calculation of empirical orthogonal functions of a spring and autumn time series from the “corner” monitoring stations of the GCE-LTER domain: GCE1 and GCE3 (Sapelo River and Sound), GCE7 and GCE9 (Altamaha River and Sound). These data were correlated with wind stress data from the adjacent continental shelf at the Grays Reef buoy.

The analysis of all six variables (4 sea level stations plus 2 orthogonal components of wind stress) indicated remarkably consistent variance in the first three modes from spring and autumn data sets. More than 70% of Mode 1 is associated with covarying wind stress and water level; about 17% is associated with Mode 2; less than 10% is associated with Mode 3.

Mode 1 eigenvectors have the same algebraic sign for the four water level stations and are opposite the sign of the along-shelf stress. The vectors are remarkably close to the same magnitude, providing strong evidence that alongshore wind stress is the primary variable forcing subtidal water level fluctuations throughout the GCE-LTER domain.

The EOF analyses also indicated that water level was only marginally affected by cross-shelf winds, with onshore winds associated with a weak response of rising sea level. While the correlation was weak, the analyses suggest that the landward stations (GCE1 and GCE7) were affected most by landward wind stress.

In a separate empirical orthogonal function analysis confined to the 4 water level stations, more than 90% of the variability was the simultaneous rise and fall of sea level at all four stations. Mode 1 eigenvectors have the same algebraic sign and are remarkably close to the same magnitude. This mode indicates that more than 90% of the variance consisted of the simultaneous rise and fall of sea level at all four stations. As indicated above, this mode is driven by the alongshore component of wind stress on the continental shelf. Mode 2 eigenvalues and eigenvectors suggest that only between 4% and 6% of the variance is associated rising water levels at some stations while levels simultaneously fall at others. There was no consistent pattern for the the spring and autumn data sets.

Sources of turbulent energy in the Altamaha River

This work is carried out by an UGA PhD candidate Mr. KiRyong Kang. Analysis of turbulence in the Altamaha River estuary, during two different river discharge rates, has shown that there are three main sources (see Figure 6 of turbulent kinetic energy: shear production, buoyancy (also a sink of energy) and waves. Shear production is by far the most dominant source of TKE which is primarily greater during the ebb tide because of the net advective flow causing a greater shear. The Altamaha River is a compressed estuary which has an along channel density gradient of $2x10^{-3}kg/m^4$. Straining of this horizontal density gradient by the shear produces an advective buoyancy flux which can act as a source of TKE during flood and a sink of energy on ebb. The strong stratified conditions on ebb stabilize the flow and the well mixed conditions on flood occur because of advected buoyancy induced mixing. Flood/ebb asymmetries in the wave field occurs because of ebb shoaling and wave-current interactions (Kang and Di Iorio, 2004). The oscillatory boundary layer that develops when waves propagate during flood and high water enhances the bottom drag felt by the current flow leading to an hydraulic roughness that oscillates with the tidal cycle. This effect can increase the turbulent kinetic energy and will be shown by one dimensional model results with the general ocean turbulence model (GOTM).

Quarterly monitoring of salinity, temperature and water level

Quarterly sampling of water column properties were carried out during March, May, September, and December 2004. Profiles of salinity during March corresponded just after a peak in discharge for the Altamaha River. As a result, the Altamaha River sampling showed fresh conditions over the whole domain during low water and the head of tide occurring at Altamaha +06 during high water. Doboy Sound, which is connected to the Altamaha River via the Intracoastal Waterway, also showed a strong along channel salinity gradient during low water (10 psu change over 12 km). The upper reaches of Sapelo Sound showed freshening as a result of enhanced precipitation. During May, discharge was weak and hence salinities over the whole domain were increased for both low and high water. September showed the effects of hurricanes that inundated the southeast. River discharge and precipitation was greater during this time than in Feb/Mar and resulted in freshening throughout the whole domain. Sapelo Sound and its upper reaches were strongly affected by the precipitation level causing the mean salinity to be its lowest level for 2004 during this time. By December precipitation and discharge levels decreased showing more oceanic influence throughout the domain.

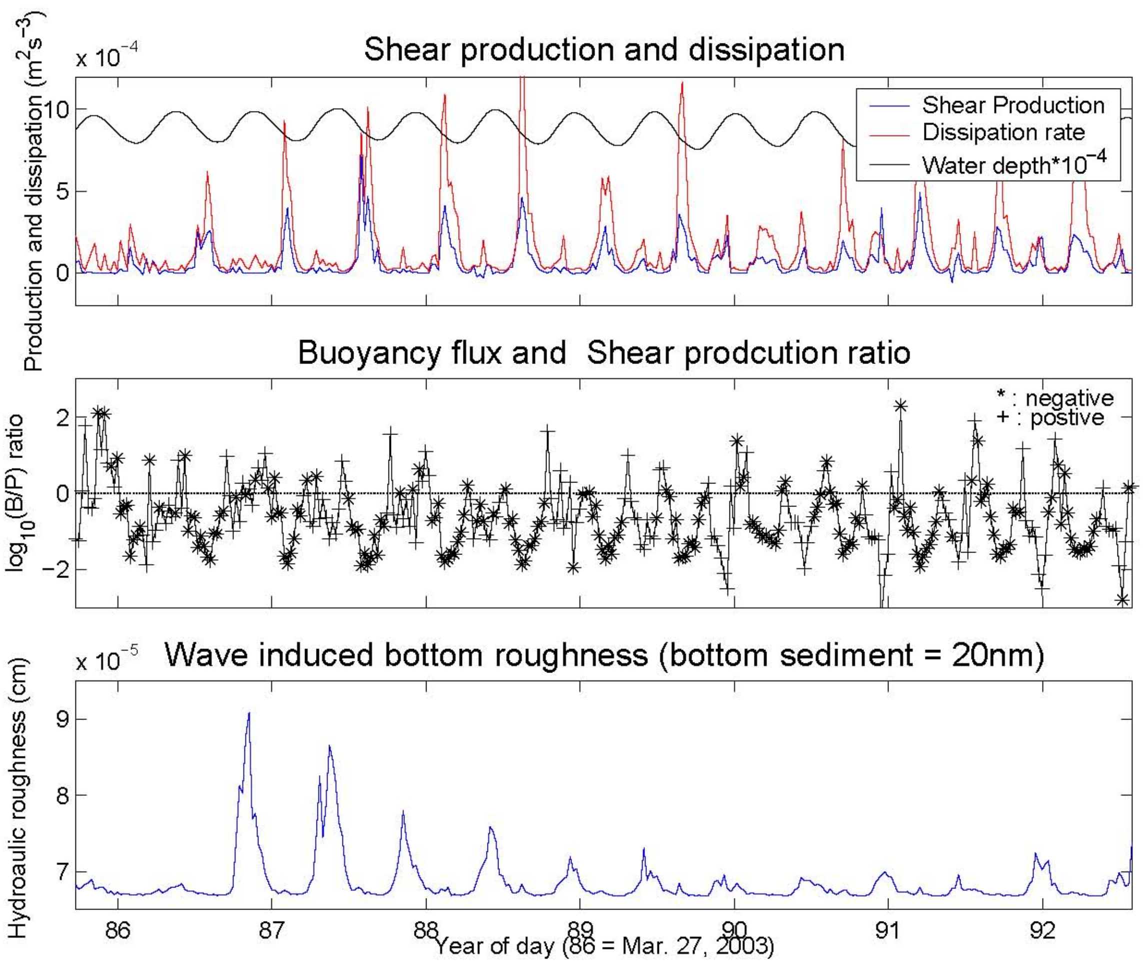


Figure 6: Turbulent kinetic energy sources in the Altamaha River estuary: shear production, buoyancy, and wave enhancement.

Groundwater hydrology

Carolyn Ruppel, Georgia Tech

Research activities: We have focused on the dynamics of saline transition at various sites and between sites. In particular, we have acquired multinode DC resistivity data to constrain *changes* in the saline transition zone over a tidal cycle, instead of using instrumentation to document static conditions. We have also acquired long-term water level monitoring data in wells installed at several GCE sites, with particular focus on the Visitor Center (GCE4) and Moses Hammock (GCE10). We believe these to be the best and most complete time series of this type in existence, and the data should contribute to: (a) testing methods for extracting hydraulic parameters from such data (e.g., Schultz and Ruppel, 2002); (b) refining numerical models for groundwater flow across the interface from upland to marsh (e.g., Fulton et al., in prep.); (c) correlating data with the results obtained from DUPLEX; (d) constraining the characteristics of the fresh to saline transition using data fusion (geophysical and hydrologic data). In the past year, we have refined a numerical model for freshwater outflow at GCE3. At the request of Joye, we instrumented GCE10 before a tracer experiment she had planned.

As noted in last year's report, our focus over the course of the project has shifted from upland-only at the beginning of the work to a more integrative approach to understanding the hydrology of the complete upland-marsh-estuary system through instrumentation of salt marshes, transition zones, and adjacent uplands, and acquisition of geophysical and hydrologic data across these features at various spatial and temporal scales.

Last year, Site GCE3 emerged as the focus of our groundwater-surface water exchange studies and we documented geophysical, hydrologic, geological (sediment logs), and other data acquired at the site. We also reported on the development of a preliminary groundwater model. Early in the 2004-05 funding year, P. Fulton, who has now moved to a PhD program at Penn State, modified the USGS modeling code SUTRA to accommodate the specific hydraulic conductivity constraints and distributions of lithologies from the upland edge across the marsh and to the tidal creek at GCE3. Based on this analysis, we infer a freshwater discharge rate of $\sim 10^{-5}$ m^3/s into the submarsh at GCE3. We caution against extrapolation of this value to other areas since the particular lithologies at GCE3 are not necessarily found elsewhere in the GCE. This research is an example of results from lithologic logging, geophysics, aquifer testing (slug tests), geotechnical tests (laboratory permeability results), and numerical modeling contributing to our understanding of the processes driving salinity distributions at the scale of one GCE site.

In the past year, we have collected several time series of monitoring well water level fluctuations, longer than anything previously obtained. So far, these analyses have clearly demonstrated the utility of such data in identifying the predominant flow pathways at each site. For example, the asymmetric tidally-induced groundwater signal at GCE10 clearly indicates that the hammock's surficial aquifer responds like a confined aquifer to fluctuations in the Duplin River. Thus, we infer relatively low discharge rate or material exchange between the hammock and the tidal creek. At GCE3, we had earlier documented a high degree of hydraulic connectivity between marsh monitoring wells proximal to the upland and the tidal creek, implying the presence of a high permeability pathway between the two and leading us to conclude that submarsh groundwater flow was a reasonable flow pathway along this salinity gradient. At GCE4, on the landward side of the GCE, we see a "normal" signal in which the marsh acts as a low-pass filter for the tidal fluctuations, and there is relatively little evidence of submarsh flow. As we have previously noted, GCE4, unlike other GCE sites we have studied, is heavily dominated by the influence of surface water flow.

Patterns of dissolved and suspended material

James T. Hollibaugh, Samantha Joye, and Merryl Alber University of Georgia

Quarterly water column monitoring

During Year 5, Matthew Erickson from the Joye group served as chief scientist on the LTER quarterly monitoring cruises. We collected a total of ~450 samples from the quarterly monitoring cruises samples to determine concentrations of dissolved nutrients (NO_2^-, NO_3^-, NH_4^+, HPO_4^{2-}, and $H_2SiO_4^{2-}$), dissolved organics (DOC, TDN, DON, TDP, and DOP), chlorophyll a, total suspended sediments, particulate CN, particulate P and Fe. All analyses, less TDP and dissolved gases, have been completed. In June and September, water samples from the core monitoring stations, and a limited number of transect stations, were collected to quantify potential rates of nitrification (NTR) and methane oxidation (MOX) and interactions between MOX and NTR. This work formed the independent study project of Ms. Lori Jarrell, an undergraduate biology major.

River delivery of dissolved and suspended material

During Year 4, we issued a subcontract to Mr Jack Sandow to continue the Altamaha River sampling program with increased sample frequency. As a result, we were able to sample the high flow events resulting from the hurricanes that hit northern Florida and Georgia last summer. We received a total of 36 Altamaha River samples (about 3 samples a month). We have analyzed over 237 river samples since the LTER project began. Samples are analyzed to determine concentrations of DIN, DIP, DSi species, organics (DOC, DON, and DOP) and major ions. A paper describing temporal variations in concentration and estimates of nutrient, dissolved organic matter loading rates to the estuary, and an evaluation of the estuarine response, is being prepared for publication by Nat Weston. Another paper describing increased nutrient loading and decreased Altamaha River flow over a 30 year period and relating these changes to development in the watershed has been submitted for publication (Weston et al.).

Responses of Estuarine Processes to Environmental Forcing

Soil Processes: Sedimentation, Organic Matter Accumulation and Marsh Stability

Chris Craft, Sean Graham and Christina Pruett, Indiana University

We are measuring vertical accretion, sedimentation and C accumulation using SET's (sedimentation-erosion tables), ^{137}Cs 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 LTER study domain sites. ^{137}Cs dating of soil cores is used to quantify long-term rates of sediment C and nutrient (N, P) accumulation in our marshes. Carbon budgets for salt-, brackish- and tidal fresh-water marshes are being developed from these data and other data (emergent NPP, root decomposition, soil respiration) that are collected from the sites.

In addition to our monitoring activities, this year we established three new SET's in the Dean Creek marshes as part of a collaborative effort with the Sapelo. We also set up a fertilization experiment in which nutrients are added to 2x2 m plots in a tidal freshwater marsh. The purpose of this experiment is to determine patterns of N versus P limitation of these understudied wetland ecosystems.

REU student Jillian Bertram also made two trips to Sapelo Island where she assisted with field sampling of SET's, feldspar plots and soil cores, measured soil respiration and collected emergent vegetation from the fertilization plots. She also worked in the lab at Indiana University where she performed soil analyses for ^{137}Cs, C, N and P. She also helped with database management /graphing of LTER-related data. Jillian currently is working on her BSES senior research project investigating the effects of tidal restriction and bridge reconstruction on accretionary processes in the Dean Creek

Groundwater Biogeochemistry

Samantha Joye, Dept. of Marine Sciences, UGA

Groundwater samples from the LTER monitoring wells were obtained four times during 2004, adding to our long-term data set of groundwater biogeochemical signatures at this site. In addition to routine monitoring, we carried out a series of experiments in 2004 to elucidate aquifer processing of nitrogen at the Moses Hammock site. The Moses Hammock Well Experiment began with the DUPLEX project in August of 2003. As part of the DUPLEX project the well field (installed by C. Ruppel of GA Tech) was sampled at low tide on both a Spring (8-14-03) and Neap (8-19-03) tide. The results from these two time points indicated a difference in the biogeochemistry, in particular nitrogen speciation, of the wells that was related to tidal (spring or neap) state. To confirm the initial findings, the wells were sampled again in June 2004 on a Spring (6-16-04) and Neap (6-25-04) tide. Data from nine previous sampling dates were examined for Spring/Neap date correlation and the data was compared. These results were encouraging so we carried out a Push/Pull experiment in the Moses Hammock well field.

For a Push/Pull experiment, water is pumped from the well, spiked with a known concentration of a conservative tracer (Br^- in this case, along with bubbling the water with He) to track the water and a non-conservative tracer (^{15}N-KNO_3) to examine the fate of the added nitrate. In July of 2004, on a Spring tide, a test Push/Pull was run to examine transport between the wells and to determine tracer concentrations. For this test, a map of the well field was generated to determine well locations, distances between wells, and surface elevation. The surface elevation was used along with well depths and water level measurements taken at each time point to determine accurate well volumes. Eight wells along the transect were sampled by purging one well volume and then sampling the second and fourth liter after that. During the test, the wells were sampled for water level, Br^-, He, N_2, NH_4, and SO_4/Cl. The wells were sampled every six hours for 60 hours. Br^- concentrations remained slightly elevated throughout the duration of the experiment; He concentrations were depleted after three time points. The test indicated the need for higher tracer concentrations, and lower sampling volumes.

On August 27, 2004 the Push/Pull experiment was begun. Wells were sampled during the experiment for water level, volume (calculated), dissolved oxygen, temperature, pH, Br^-, SO_4/Cl, salinity (interpolated from SO_4/Cl data), DIC, DOC, Fe, PO_4, H_2S, NO_x, NH_4, He, CH_4, N_2O, $^{28, 29, 30}N_2$, and Ra. The wells were sampled prior to tracer addition to determine background concentrations for the above constituents.

Following the initial sampling, 20 liters of water was pumped from wells MH0214 and MH0201. The water was purged with He for 30 minutes, spiked with Br^- and ^{15}N-KNO_3 to bring the concentration to 10 μM. During the Aug 2004 Spring sampling, water was also collected from the wells for Ra determination by Billy Moore (Univ. of South Carolina).

The Neap sampling dates were scheduled for early September 2004. Hurricane Francis moved up the east coast during the scheduled sampling period preventing the Neap sampling. The wells were sampled two days after the hurricane passed. The results from this sampling show a large lens of fresh water moving beyond its usual upland bounds to include the next two upland wells further down the transect. Rainfall from USGS gauges in nearby areas ranged from 3 to 10 inches of rain during this period. The Neap sampling was rescheduled for Oct. 3rd 2004 to allow the freshwater lens to dissipate. Sampling was carried out in the same manner as above.

There appeared to be little communication between the upland wells, at least not on the order of 60 hours. The wells further down the transect, which are closer together, show some evidence of communication with elevated Br^- levels in wells adjacent to the spiked well during the Spring tide. This communication was not evident during the Neap tide. Elevated ^{15}N levels were observed in the N_2 signal of the spiked wells; however the signal was not apparent in any other wells. Differences between biogeochemistry between the Spring and Neap Push/Pull experiments were not apparent. This could be attributed to several factors. A large amount of water was removed during the experiment; this could influence the biogeochemistry of the wells. The scheduling of the experiment and the delay of the Neap sampling due the hurricane could have adversely affected the results. The addition of a large amount of freshwater (from Francis) into the groundwater would most certainly alter the biogeochemistry, and we have little understanding about how long it would take for this, or any other, system to recover from such a perturbation.

Sediment Biogeochemistry and Modeling

Samantha Joye, Dept. of Marine Sciences, UGA

The effect of salinity intrusion on the biogeochemistry of tidal freshwater sediments in the Altamaha River estuary was examined. Sediment cores from LTER site GCE7 were obtained in July 2004 and returned to the laboratory for flow-through sediment reactor experiments. Experiments were conducted in a Coy anaerobic chamber. Anaerobic artificial freshwater (171 μM NaCl, 100 μM $MgCl_2$, 272 μM $CaCl_2$, 35 μM Na_2SO_4, 67 μM KCl, 670 μM $NaHCO_3$, 1 μM NH_4Cl, 0.1 μM KH_2PO_4 and 20 μM KNO_3) was pumped slowly (approximately 10 ml hr^{-1}) through 2 cm sediment sections. After one week, salinity in six of the twelve reactors was slowly increased (over a period of about 2 weeks) to an artificial brackish water of 10 ‰ salinity (132 mM NaCl, 7 mM $MgCl_2$, 2.9 mM $CaCl_2$, 8 mM Na_2SO_4, 2.8 mM KCl, 670 μM $NaHCO_3$, 1 μM NH_4Cl, 0.1 μM KH_2PO_4 and 0.2 μM KNO_3), and was then held constant for another three weeks. Samples were obtained from the outlets of the reactors throughout the experiment. Concentrations of Cl, Na, Ca, SO4, NO_x, Fe^{2+}, PO_4^{3-}, NH_4^+, CH_4 and DIC were determined and the change in concentration between the inflow and outflow calculated (indicated by δ), and rates (nmol cm^{-3} d^{-1}) determined from δ and flow rates.

The change in salinity (as shown by chloride concentration, Figure 1) in the salinity intrusion treatment was accompanied by a transient increase in δNH_4^+ and a decreases in δPO_4^{3-} and δCa^{2+} (Fig. 1) when compared to control reactors. Changes in the ion activity associated with the increase in salinity caused several abiotic geochemical shifts in the sediment, such as exchange of NH_4^+ bound to sediment particles, and possibly precipitation of calcium-phosphate minerals (Fig. 1).

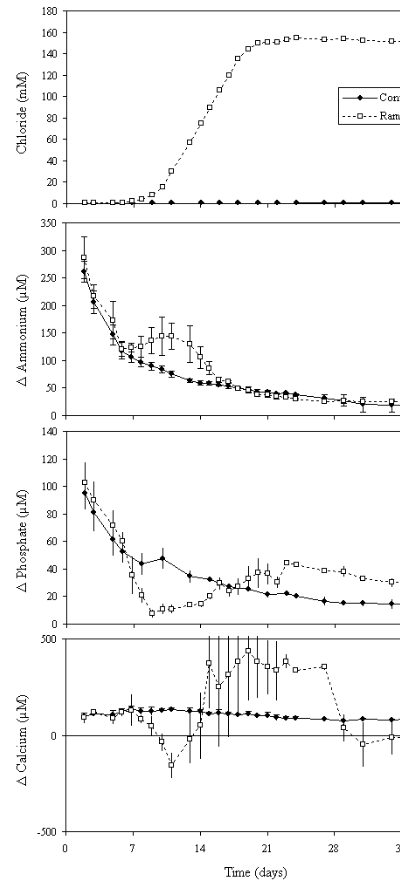


Figure 1. Concentrations of chloride and change in concentration (Δ) between inflow and outflow of ammonium, phosphate and calcium in control and salinity-intrusion reactors.

Changes in salinity were also accompanied by changes in microbial metabolic pathways. Rates of denitrification (δNO_x), methanogenesis (δCH_4) and sulfate reduction (δSO_4^{2-}) clearly indicated shift in terminal metabolic processes during salinity intrusion. In freshwater sediments, methanogenesis and iron reduction (δFe^{2+}) appeared to be the dominant terminal metabolic processes, with denitrification and sulfate reduction accounting for less carbon oxidation (Fig. 2). Denitrification and sulfate reduction rates were substrate-limited in the freshwater sediment, as these terminal electron acceptors were at low concentrations in the inflow water. During salinity-intrusion, sulfate concentrations in the inflow water increased and sulfate reducers were able to quickly take advantage of increased sulfate availability (Fig. 2). Methanogens appear to have been out-competed by sulfate reducers in the salinity treatment, while denitrifiers became substrate limited as NO_3^- concentration in the brackish water was low.

Quantification of iron reduction rates is difficult due to the reaction of reduced iron and hydrogen sulfide in anaerobic sediments. However, it appears that iron reduction was an important pathway of organic matter mineralization, based on the Fe^{2+} exiting both the control and salinity-intrusion reactors (Fig. 2). Increasing salinity may have affected the iron mineralogy in these sediments, as the large peak in ‘apparent’ iron reduction suggests (Fig. 2). This may reflect a change in the bioavailability and/or mineralogy of the iron oxide substrate, and a transient period during salinity intrusion when iron reduction was the dominant terminal electron accepting process.

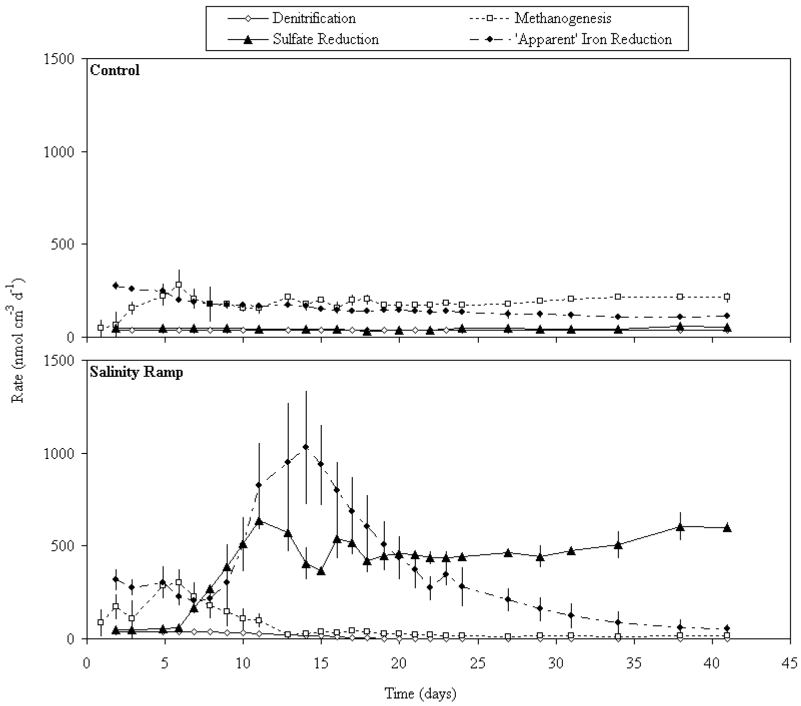


Figure 2. Rates of denitrification, methanogenesis and sulfate reduction and apparent rate of iron reduction in control and salinity-intrusion sediment flow-through reactors.

Plant Production

Steve Pennings, University of Houston

I am monitoring plant biomass to test the hypothesis that end-of-year biomass varies as a function of 1) freshwater discharge from the Altamaha and 2) average sea level. In 2000 we set up permanent plots at all 10 LTER monitoring sites. Plots were established at creek-bank and mid-marsh sites (8 plots/zone/site). Plants were non-destructively monitored (stem counts, heights, flowering status) in October 2000, 2001, 2002, 2003 and 2004. 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. Plant size structure (number of stems, stem heights), flowering status, and biomass have varied among years. Definitively linking these changes to environmental forcing functions will require several more years of data. Plots are also proving useful in documenting spatial and temporal variation in disturbance from physical (wrack) and biotic (grazing) sources.

Fungal Crop

Steve Newell, UGA Marine Institute

This year (2004) of GCE research will be the last one in which I will participate -- I will retire from the University of Georgia in February, 2005. Therefore, I will summarize my key GCE findings below, the monitoring portion of which has shown that within marsh types (saline, brackish, freshwater), fungal crop is a spatially and temporally stable character.

I and a group of GCE scientists (Moran, Hollibaugh, Buchan, Lyons, Biers) conducted a series of experiments (Decomposer Consortium Experiments; DCE) in which we applied DNA technology to take a look from a new viewpoint at the genomes of microbial decomposers involved in decay of smooth-cordgrass (*Spartina alterniflora*) shoots. The basic mycological finding was that there are no major cryptic fungal decomposers (one might have expected the existence of cryptic, unculturable species based on examinations of natural-bacterial-community DNA) -- the species of ascomycetes detectable by direct microscopy were also the culturable species detected by analysis (PCR/TRFLP with ITS) of DNA extracted from naturally decaying leaves. The DNA-technological GCE work revealed that the same small group of ascomycetes was routinely present in all seasons, although there were seasonal shifts in dominance of particular species, and some species were more closely associated with the later stages of decay (see Bot. Mar. 44:277; Limnol. Oceanogr. 46:573; Appl. Environ. Microbiol. 69:6676). We also extended our DNA analyses by amplifying segments of ascomycetous laccase (lignin-modifying enzymes) from naturally decaying cordgrass leaves -- we found that laccases are possessed by all of the major ascomycetes of the cordgrass community and are probably the major enzymes used by the fungi in lysing the marshgrass fiber (see Microb. Ecol. 45:270).

Over the first four years of the GCE project, at the same time as macrophyte biomass was monitored, I monitored the autumnal crop and sexual productivity of the ascomycetes of the standing-dead cordgrass-leaf and other, fresher-water marshgrass-leaf decay systems. I found fungal crop to be a substantial (about 7% living-fungal mass per g autumnal decay system for standing-dead smooth-cordgrass leaves) and stable (CV < 10%) part of the marsh ecosystems, especially for the saline smooth-cordgrass marshes (cf. Limnol. Oceanogr. 46:573). A clear pattern of difference in standing crop of fungi has appeared in all years: the fungal crop is about 2-fold higher in more salty, smooth-cordgrass marshes, than it is in the fresher-water systems. This contrastive pattern was also consistently true for rates of expulsion of ascospores (sexual productivity). I conducted a separate examination of fungal productivity in GCE salty versus fresher macrophytic decay systems, which confirmed that fungal standing crop decreases in the direction of salt-toward-freshwater macrophytes. However, it also revealed that there was higher potential for fungal production rates ([^{14}C]acetate-to-ergosterol) in the fresher-water leaves when the leaves were consistently wet, suggesting that, in the fresher-water systems, fungal production at the sediment surface, in fallen leaves, would be higher than is usually found for the saltier systems, wherein fungal productivity is high in the standing-dead phase (see Newell, 2003, Aquat. Microb. Ecol. 32:95).

Two additional research efforts were associated with the mycological portion of the first years of the GCE project. 1) An attempt was made, with NSF/DEB funding, to develop a non-radioisotopic method for measuring fungal productivity. This would have involved monitoring rates of incorporation of a fluorescently tagged precursor molecule into fungal chitin. Unfortunately, my partners (Molecular Probes Inc. personnel) and I were unsuccessful in our two years of attempts at the synthesis of the fluorescent precursor. 2) A partner from Brown University (Brian Silliman) and I collaborated on a study of the interactions of marsh periwinkles and marsh ascomycetous fungi that impact the ability of the snails to eat green marshgrass containing bitter antifeedants. We found that the snails created conditions conducive to fungal growth in the living leaves by injuring the leaf surfaces with their mouthparts, resulting in a primitive form of fungal-farming -- the snails benefited by eating the “cultivated” fungal tissue (see Silliman and Newell, 2003, PNAS 100:15643).

Plant Community Ecology

Steven Pennings, Univ. of Houston

Responses to eutrophication

In collaboration with Caroline McFarlin (M.S. student) I examined spatial variation in nutrient effects on marsh community structure. The border between two dominant marsh plants, *Spartina alterniflora* and *Juncus roemerianus*, was fertilized at 19 sites within the LTER domain for two years. Across all sites there was a strong increase in biomass of live and dead *S. alterniflora* and a decrease in biomass of live and dead *J. roemerianus* in fertilized plots. Decomposer fungi on dead *S. alterniflora* leaves did not increase per unit of dead leaf, but did increase on a per-plot basis, because of increases in dead leaf biomass. Herbivorous grasshoppers increased in abundance, but detritivorous snails did not. All responses varied among sites. We are exploring correlations between edaphic variables and responses to fertilization to see if we can explain any of the site to site variation.

Plant zonation

In collaboration with Mary-Bestor Grant and Mark Bertness, I examined the factors mediating zonation between *Juncus roemerianus* and *Spartina alterniflora* at Sapelo Island. *Juncus* was precluded from moving to low elevations by a combination of salinity, flooding, and competition. *Spartina* was precluded from moving to higher elevations by competition. These results differ from those of previous zonation studies in New England in that salinity stress played a greater role in Georgia. A manuscript based on this work is in press in the Journal of Ecology.

Annual variation in vegetation borders

I am 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. I have monitored mid-summer plant composition at permanent plots located on 3 types of vegetation borders (*Spartina alterniflora*-*Juncus roemerianus*, *S. alterniflora*-meadow, meadow-*Juncus 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 rigorously test this hypothesis.

Secondary succession of marsh vegetation in GA and AL

I am 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 (*Spartina alterniflora*-meadow border, meadow-*Juncus roemerianus* border, *J. roemerianus* zone) at each of 2 marshes in each state, I cleared replicate 3 x 3 m plots using herbicide and clipping and maintained plots free of vegetation for 2 years. Control plots were marked but unmanipulated. In 2000 individual plots were divided into two or four quadrants, depending on the diversity of the vegetation in each zone, with one quadrant allowed to recover without further manipulation and the other quadrant(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 *Spartina 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.

Benthic invertebrates

Merryl Alber and Dale Bishop, UGA Dept of Marine Sciences

D. Bishop continues to supervise the routine monitoring of marsh fauna, which is conducted twice a year at all permanent sites. He also has an ongoing collaboration with the Sapelo Island National Estuarine Research Reserve. As a part of that, he is monitoring non-indigenous crabs and the green mussel in the Reserve and he has a new project to evaluate the effects of restored tidal flow on the invertebrate community in Dean Creek. He has also initiated a project to document the recruitment of blue crab larvae to the Duplin River.

Grasshopper abundance

Steven Pennings, University of Houston

I am 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 LTER monitoring sites in August 2000, 2001, 2002, 2003 and 2004. 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.

Phytoplankton and bacterioplankton production and biomass

Robert E. Hodson and Edward S. Sheppard, Dept. of Marine Sciences, UGA

Production-irradiance curves and bacterioplankton growth rates (L-leucine incorporation into protein) were measured at all monitoring stations on all of the quarterly monitoring cruises during 2004. Data are being analyzed and readied for incorporation into models of phytoplankton and bacterioplankton productivity. As Sheppard has taken a position in another Department, this activity will be the responsibility of J.T. Hollibaugh's laboratory for the immediate future.

Microbial decomposer consortia directed study

Mary Ann Moran, James T. Hollibaugh, Dept. of Marine Sciences, UGA; Steven Newell, UGA Marine Institute

The directed study of cooperation/competition among bacterial and ascomycetous fungal decomposers of *Spartina alterniflora* was largely concluded with the completion of experiments examining species-specific bacterial-fungal interactions on detritus in Year 3. Previous results indicated that a consistent and predictable community of decomposers develop on *Spartina* detritus, with low spatial variability in composition of both bacterial and fungal decomposers (based on T-RFLP analysis of 16S rRNA genes and ITS regions), but clear seasonal shifts in major players are evident. Two functional genes of importance in decomposition (bacterial ring-cleavage dioxygenase pcaGH and fungal laccase) both have high diversity within salt marsh decomposer communities.

To examine whether this consistent community composition is driven by substrate quality or by biotic processes (e.g., competition or cooperation among decomposer species), we conducted a 'baiting' experiment in which detritus infiltrated with single fungal species was placed in the marsh and colonization by bacterial species was tracked. Results showed that regardless of the fungal bait species, and even in the absence of prior fungal colonization, bacterial community profiles were remarkably similar. Thus, a few species-specific associations, either positive or negative, drive the composition of the bacterial community on *Spartina* detritus, at least during initial colonization.

In Year 4, a new student (Mr Matt First) began studies of the protistan community in GCE sediments (primarily GCE 6 and 10). These studies are aimed at determining the composition of the protistan community and investigating the autecology, for example grazing rates, sulfide tolerance, ability to use DOC, etc., of selected protists.

Water Column Respiration and CO_2 Chemistry

Wei-Jun Cai, Dept. of Marine Sciences, UGA

We have collected surface water inorganic carbon data (pCO_2, DIC, alkalinity) and are using them as an integrated measure of biological activity in the coastal water of Georgia. We also measured water column respiration rate based on DIC release during dark sample incubation. In 2005, we also began measuring DO changes during incubation. These data clearly show that the marshes are a significant source of CO_2 to coastal waters and the marsh and estuarine waters are highly heterotrophic. One graduate student (Liqing Jiang) is in the process of synthesizing the metabolism study and will report his findings at the GCE annual meeting in February 2005.

We have also extended our Duplin River monitoring program to the fourth year. One M.S. graduate student (Justin Hartman) is in the process of synthesizing the results. Joined by other groups, the GCE-LTER has lunched a Duplin River study (Lead by J. Blanton).

Education and Human Resources

Seven GCE-supported graduate students defended their theses or dissertations this year, including Gayle Albers (M.S., Alber), Caroline McFarlin (M.S., Pennings), Matthew Ogburn (M.S., Alber), Christina Richards (Ph.D., Donnovan), Cristiano Salgado (M.S. Pennings), Merrilee Thoresen (Ph.D., Alber) and Susan White (Ph.D., Alber). Additionally, GCE undergraduate research assistant Steven O'Connell completed his senior thesis at UGA as part of his B.S degree (Alber).

Schoolyard LTER

Patricia Hembree, University of Georgia

In early 2004, I submitted a grant renewal to the Teacher Quality Program for the 2004-2005 Schoolyard (S.A.P.E.L.O. Scientists and Professional Educators Learning Outdoors). I was awarded $44,038 to support 17 teachers. This year' program consisted of: two nine-day workshops in the summer; two three-day conferences of past participants during the academic year; support of the teachers through monitored internet discussions and two visits (by me) to each participant's classroom; and support for data collection, evaluation and dissemination. I also supported the teachers by helping them develop ways to integrate GCE science while meeting the Georgia Performance Standards (formally, the Quality Core Curriculum). It is important to note that 84% of the teachers consider the internet and classroom support instrumental in weaving GCE science into their classroom. In addition, 87% of the past participants have found that the basic academics involved with the field components of the research projects were not out of their reach. During the summer portion of the program, I helped the participants produce two Schoolyard posters and two CDs with over five hundred photographs indexed for use in the teachers' classrooms and schools.

During this past year, I presented current research on the program at two national and two regional organizations for science education and for social science research. In total, I have presented this program design and the research at 10 separate conferences. The teachers presented six papers on the use of the GCE-LTER science in the classroom at district and statewide conferences. To date, there have been nine separate presentations at state and national conferences by participants.

My activities on the network level this past year included hosting two CWT-LTER personnel (Brian Kloeppel and Susan Steiner) to begin developing a cross-site teacher education program. Later, I spent several days at CWT for the same purpose. I also participated in a meeting of network education representatives at Andrews LTER in Oregon. The topics discussed during this meeting included: the strategic plan; the LTER planning grant; future education coordination; and a conference call with Henry Gholz on the state of the network-wide SLTER. Continuing work begun in 2003, I was one of eight education representatives to write the Education Handbook for system-wide SLTER programs.

S.A.P.E.L.O. Project participation

Year	Returning teachers*	New teachers	Teacher Slots	Students Impacted
2000	0	6	6	620
2001	5	5	10	982
2002	9	8	17	1732
2003	8	14	22	2021
2004	13	4	17	1361
Totals	**35**	**37**	**72**	**6716**

*NOTE: There have been 37 different teachers to participate in the S.A.P.E.L.O. project. Only two do not wish to remain involved. However, due to scheduling constraints and attrition, not all who wish to return are able to do so each year. I maintain contact with those who wish to remain active, assisting them in continuing to use GCE-LTER research in their classrooms.

Preservice science teachers—End of program experience on Sapelo (currently not funded through the two grants, but part of the outreach)

Year	Number of student-teachers
2000	10
2001	12
2002	30
2003	12
2004	0*
Total	**64**

*There were no funds available in the department to support class trips last year.

Personnel supported by the GCE-LTER:

Dale Bishop, Post-doctoral associate, UGA
Wade Sheldon, Scientific Computing Professional, UGA

Julie Amft, Research Coordinator, SkIO
Matthew Erickson, Research Coordinator, UGA
Ken Helm, Field technician, UGAMI
Sean Graham, Research Technician, IU
Trent Moore, Research Coordinator, SkIO
Joan Sheldon, Research Coordinator, UGA
Caroline McFarlin, Technician, UGA

Ryan Brown, graduate student, GA Tech
Susan Elston, Ph.D. student, SkIO
Chuan-Kai Ho, Ph.D. student, UH

KiRyong Kang, Ph.D. student, UGA
Liqing Jiang, Ph.D. student, UGA
Rosalynn Lee, Ph.D. student, UGA
Paul McKay, Ph.D. student, UGA
Bill Porubsky, Ph.D. student, UGA
Christina Richards, Ph.D. student, UGA
Merrilee Thoresen, Ph.D. student, UGA
Nathaniel Weston, Ph.D. student, UGA
Susan White, Ph.D. student, UGA
Amanda Wrona, Ph.D. student, UGA
Trisha Hembree, D. Ed. student, UGA

Justin Hartman, M.S. student, UGA
Josh Hall, M.S. student, IU
Amy Kunza, M.S. student, UH
Matthew Ogburn, M.S. student, UGA
Nesrin Omer, M.S. student, IU
Tymeri Schleicher, M.S. student, IU
Liliana Velasquez, M.S. student, UGA

Josh Avitan, undergraduate research assistant, UGA
Rose Asher, undergraduate research assistant, UGA
Ronald Barbieri, undergraduate research assistant, GA Tech
Jillian Bertram, undergraduate research assistant, IU
Ray Dixon, undergraduate research assistant, UGA
Lori Jarrell, undergraduate research assistant, UGA
Jennifer Lindell, undergraduate research assistant, UGA
Wayne Listing, undergraduate research assistant, UGA
Steven O'Connell, undergraduate research assistant, UGA
Lisa Pfau, REU engineering major, UGA
Rochelle Randall, REU mathematics major, Savannah State University
Jacob Shalack, undergraduate research assistant, UGA
Elizabeth Wason, undergraduate research assistant, UH

Broader Impacts

PI Outreach

M. Alber:

- We have exchanged information on marsh dieback with scientists in Louisiana, Massachusetts, Connecticut, and Virginia through the activities of the Georgia Coastal Research Council. M. Alber and S. Joye have recently received funding from EPA along with collaborators in Louisiana (M. Hester and I. Mendelssohn) to use marsh dieback sites in both states as a testing ground to evaluate the ecosystem services provided by tidal marshes.

D. Bishop:

- Open access to the GCE-LTER invertebrate database (maintained by D. Bishop) resulted in numerous direct and indirect contacts and collaborations with both the public and other professionals requesting additional information. Some of the specimens collected in our domain were donated to the collections at the Florida Natural History Museum
- Led a group of teacher-participants in the GCE-LTER Schoolyard Program in a study of the effects of tidal flow restoration on the macroinvertebrate communities of Dean Creek, Sapelo Island, GA. A poster detailing the teachers' summer efforts was used in their classrooms and was displayed at the Fernbank Museum in Atlanta, Georgia for the general public. This work is part of a larger project being conducted by Bishop to monitor the impacts of tidal flow restoration at the Dean Creek bridge construction site.

C. Craft:

- Understanding role of freshwater pulsing in marsh accretion is important for predicting how climate change and human activities will affect the long-term stability of these important ecosystems. Our research is important not only to the scientific community but also to natural resource managers and regulatory agencies as evidenced by supplemental funding from US EPA STAR to investigate effects of sea level rise and climate variability on ecosystem services of tidal (salt-, brackish-, tidal fresh-water) marshes that vary in freshwater inundation. Tidal marshes are among the most important ecosystems in the world with respect to the ecosystem services (e.g. disturbance & gas regulation, soil formation, nutrient regulation, waste treatment, refugium, food) they provide. Our research at Indiana University provides research opportunities for undergraduate and graduate students including three women, one (Nesrin Omer) from Sudan.
- We submitted a proposal to the NOAA National Estuarine Research Reserve (NERR) system to investigate the effects of reconstruction of the 50 yr-old bridge across Dean Creek. The $33,000 project, a collaborative effort with the Sapelo Island NERR, will investigate the effects of 50 years of tidal restriction on sediment deposition and vertical accretion and, the benefits of restoring tidal flow on these processes and on and emergent plant communities of marshes of upper Dean Creek. If funded, some of these monies will be used to support the senior research project of Jillian Bertram, described above.

S. Newell:

- Served as a member of the Georgia Coastal Advisory Council (CAC), which meets quarterly and provides advice to the Georgia Department of Natural Resources (DNR) and its Coastal Zone Management Program. The CAC is a potential conduit from GCE/LTER for information useful to environmental managers.

S. Pennings:

- Member of 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.

C. Ruppel:

- Using Year 3 supplementary funds, we acquired a transducer with telemetry capabilities for installation in a marsh-based monitoring well at GCE3, the Visitors' Center site, as part of a public outreach effort highlighting dynamic processes in the environment and the integration of physical, chemical, and ecological processes within the GCE-LTER framework. Installation will proceed once equipment problems have been resolved.

W. Sheldon:

- Continues to serve on the LTER Information Management Executive committee
- Served on an NSF proposal panel as an informatics reviewer
- Participated at the LTER Planning Grant "Meeting of 100" at Cape Canaveral, FL
- Led a working group at LNO to develop best practices for EML metadata at LTER Sites (report and example schemas under review, to be released 3/2005)
- Co-developed a metadata catalog exchange standard with LNO and NCEAS developers to support automated harvesting of EML metadata for inclusion in metadata repositories
- Assisted information managers from four other LTER sites in developing EML implementations for their sites (CWT, NWT, PAL, VCR)

Synthetic Activities

C. Craft:

- We submitted a proposal to the NOAA National Estuarine Research Reserve (NERR) system to investigate the effects of reconstruction of the 50 yr-old bridge across Dean Creek. The $33,000 project, a collaborative effort with the Sapelo Island NERR, will investigate the effects of 50 years of tidal restriction on sediment deposition and vertical accretion and, the benefits of restoring tidal flow on these processes and on and emergent plant communities of marshes of upper Dean Creek. If funded, some of these monies will be used to support the senior research project of Jillian Bertram, described above.

S. Pennings:

- I am 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. We have two manuscripts in press.
- My externally-funded research is examining latitudinal variation in plant-herbivore interactions along the Atlantic Coast of the United States. Study sites include 3 LTER sites and a number of NERR sites. Two manuscripts based on this work were accepted for publication in Ecology this year.

C. Ruppel:

- Our studies are al motivated by understanding the physics and chemistry related to biological/ecological processes. The reviews on the redox zonation paper we published in Journal of Hydrology highlighted the uniqueness of our

interpretation and data set, particularly in terms of its implications for microbial processes. The coincident acquisition of physical, chemical, and ecological data has been tried at the scale we have undertaken at very few other marsh-based research sites.
- We have fielded numerous inquiries about our hammock-based hydrology program. We have the most complete hydrologic data set ever assembled for a Georgia marsh hammock, and such data may inform coastal stakeholders during decision making on development and conservation projects.

W. Sheldon:

- The comprehensive EML implementation and support for EML-based automated data streaming developed by W. Sheldon at GCE has enabled NCEAS and the KNB and SEEK projects to prototype, test and demonstrate EML-based data analysis and workflow tools (e.g. Kepler, http://seek.ecoinformatics.org) using realistic ecological data sets, significantly aiding these projects.
- This effort has also facilitated the LTER cross-site synthesis project on plant fertilization by allowing SEEK developers collaborating on the project to access relevant GCE data sets using EML-based data integration tools being developed in support of this project.

Schoolyard LTER

The S.A.P.E.L.O. Schoolyard LTER workshops capitalize on the way field science activities differ from the traditional school-based or laboratory-based science—a view that teachers rarely get to see, much less come to understand as something to be included in a typical curriculum. Because the program establishes a long-term partnership, the teachers develop a confidence not seen in a typical science class. This support may very well be the reason why 95% of the teachers have remained invested, purposefully working to put GCE science concepts into the routine of the class and their schools. Additionally, this long-term relationship has provided for extensive evaluation and feedback. Indeed, the results of my research on the Schoolyard program showed that the teachers' epistemology of science—the way they think science knowledge is constructed—was challenged and revised to include a more sophisticated, constructivist view of science as active, temporary, and local. This revision caused teachers to change their self-view to include personal and professional empowerment and a new sense of comfort in their practice. These results form a solid basis for future professional development designs and opportunities for teachers.

The Georgia Coastal Research Council

We continue to provide outreach to managers, scientists, and the general public through the Georgia Coastal Research Council (the GCRC, headed by M. Alber, is partially supported by the GCE-LTER). Working in collaboration with investigators from Louisiana, the GCRC organized a workshop on February 3-4, 2004 in Savannah, GA as a way for investigators in both areas to exchange technical information on the issue of marsh dieback. A total of 65 scientists and managers from Georgia, Louisiana, and South Carolina attended the meeting, including representatives from academic institutions, research institutes, DNR (and other state agencies), Sea Grant (GA, SC, LA), and the US Geological Survey. The scientific workshop was followed by a 2-hour public information meeting as an opportunity provide an overview of the technical workshop and answer questions from the audience. Approximately 80 people attended the meeting. Evaluation of both events were quite positive: 89% of the workshop participants "will be able to apply new knowledge and skills" in his/her work and 100% at the public meeting responded "yes" to the question, "Do you feel you have increased (scientific) understanding of this coastal issue?" The issue has also garnered continuing media coverage, and an article describing the workshop was picked up by the Associated Press.

In addition to our work on the marsh dieback issue, GCRC accomplishments this year include assisting NOAA in the preparation of a federally-mandated inventory of Georgia Marine Protected Areas, and conducting initial water resource assessments of Cumberland Island National Seashore and Fort Pulaski National Monument for the National Park Service. The GCRC has 100 coastal managers and scientists as affiliated members. During the past year the GCRC listserv was used to distribute information on marsh dieback activities, a request from the Georgia DNR for input on new marsh and shore regulations, and information on a U.S. Geological Survey initiative to collaborate on site-selection and operation of additional coastal water monitoring stations. The GCRC web site (http://www.marsci.uga.edu/coastalcouncil), which is linked to the GCE-LTER web site, is used as a clearinghouse for coastal scientific information. In 2004 the GCRC site logged 3217 page views by 1465 visitors from 40 nations.)

Additional Funding

Merryl Alber:

- Environmental Protection Agency - Climate-linked alteration of ecosystem services in tidal salt marshes of Georgia and Louisiana (with M. Hester, I. Mendelssohn, and S. Joye), $94,364 (October 2004 – September 2007)
- Georgia Coastal Resources Division - Georgia Coastal Research Council: Development of a Watershed-compatible nitrogen model for the Altamaha River Estuary, $245,794 (October 2004 – September 2007)
- Georgia Coastal Resources Division - Salt Marsh Dieback in the South Atlantic Bight, $9,020 (August 2003 – July 2004).
- Georgia College Sea Grant Program: Research Experience for Undergraduates: Characterization of Salt Marsh Die-back Areas in Coastal Georgia (Co-investigator with M. C. Curran), $5,160 (May 2003 – April 2004)
- Georgia Sea Grant - Georgia Coastal Research Council, $106,900 (March 2004 - February 2006)

T. Dale Bishop:

- Sapelo Island NERR - Sapelo Island National Estuarine Research Reserve non-indigenous species monitoring, $5,000 (June 2004 – December 2005)

- Sapelo Island NERR - Monitoring the invasion of the green mussel, Perna viridis, into the Sapelo Island National Estaurine Research Reserve (with R. Walker, A. Power), $15,000 (March 2004 – March 2005)

Jackson Blanton, Daniela Di Iorio:
- NOAA – Coastal Zone Management Grant, $240,000 (Oct 2001-March 2005)
- NOAA – Land User Coastal Ecosystem Study, $502,000 (July 1999-June 2005)
- NMS/NOAA – National Marine Sanctuaries, $20,000 (May 2004-April 2005)

Christopher Craft, Indiana University:
- Sapelo Island NERR - construct and monitor SET's in the Dean Creek marshes, $3000
- U.S. EPA STAR grant program - Effects of sea level rise and climate variability on ecosystem services of tidal marshes, South Atlantic coast, $749,974 (begins January 1 2005).

Patricia Hembree, University of Georgia (SLTER Coordinator)
- Eisenhower Teacher Quality Program grant to support 17 teachers, $44,038

Samantha Joye, University of Georgia:
- U.S. EPA STAR grant program - Effects of sea level rise and climate variability on ecosystem services of tidal marshes, South Atlantic coast, (with C. Craft, S. Pennings, D. Park, J. Ehman) $217,556 (begins January 1 2005).
- U.S. EPA STAR grant program - Climate-linked alteration of ecosystem services in tidal salt marshes of Georgia and Louisiana (with M. Hester, I. Mendelssohn, and M. Alber), $227,855 (October 2004 – September 2007).

Steven Newell, UGA Marine Institute:
- NSF/DEB - Improving Accuracy and Availability of Productivity Methods for a Keystone Functional Group of Microbes, $56,894 (2003-2004)

Steve Pennings, University of Houston:
- NSF - Latitudinal gradients in plant palatability in Atlantic coast salt marshes, S. Pennings, $314,125 (January, 2002-December, 2004). This project is comparing plant-herbivore interactions in northeastern versus southeastern salt marshes. Several of the study sites overlap with LTER sites (GCE and PIE), and the results of this study will provide information on insect distributions and plant-herbivore interactions that will be of relevance to the three Atlantic Coast LTER salt marsh sites.
- Environmental Institute of Houston - Diversity patterns in Texas salt marsh plant communities, S. Pennings (PI), $14,880 (January 2005-Auguest 2005). This project is comparing plant diversity patterns in Texas salt marshes with those in GA salt marshes, with the goal of understanding controls on diversity. GA study sites are within the GCE-LTER domain, and the result will provide information on

how plant diversity patterns within GA marshes compare to those in other geographic regions.

- USEPA - Effects of sea level rise and climate variability on ecosystem services of tidal marshes, south Atlantic Coast, Craft, C. (PI), Joy, S. (Co-PI), Pennings, S. C. (Co-PI), Park, D. (Co-PI) and Ehman, J. (Co-PI), $749,974 total. This project is comparing the ecosystem services of tidal fresh, brackish and salt marshes. A number of the study sites are within the GCE domain, and the results will greatly enhance our understanding of the ecology of marshes across the estuarine gradient.

Wei-Jun Cai, UGA:

- NSF - Marsh-Dominated Ocean Margins as a Source of CO_2 to the Atmosphere and Open Oceans: A Field Study in the U.S. Southeastern Continental Shelf. Wei-Jun Cai (sole PI), $453,573 (NSF-OCE-0425153, 8/04 to 8/08).

Publications

Peer-reviewed Journal Articles

Published and Accepted

Cai, W.-J. and Dai, M., 2004. A Comment on "Enhanced open ocean storage of CO2 from shelf sea pumping". Science, 306: 1477c.

Cai, W.-J. et al., 2004. The biogeochemistry of inorganic carbon and nutrients in the Pearl River estuary and the adjacent Northern South China Sea. Continental Shelf Research, 24: 1301-1319.

Goranson, C.E., Ho, C.-K. and Pennings, S.C., 2004. Environmental gradients and herbivore feeding preferences in coastal salt marshes. 140: 591-600.

Magalhães, C.M., Joye, S.B., Moreira, R.M., Wiebe, W.J. and Bordalo, A.A., 2005. Salinity and inorganic nitrogen effects on nitrification and denitrification rates in intertidal sediments and rocky biofilms: Douro River estuary, Portuga. Water Research.

Pennings, S.C. and Silliman, B.R., 2005. Linking biogeography and community ecology: latitudinal variation in plant-herbivore interaction strength. Ecology.

Richards, C.L., Hamrick, J.L., Donovan, L.L. and Mauricio, R., 2004. Unexpectedly high clonal diversity of two salt marsh perennials across a severe environmental gradient. Ecology Letters, 2004(7): 1155-1162.

Richards, C.L., Pennings, S.C. and Donovan, L.A., 2004. Community-wide patterns of phenotypic variation in salt marsh plants. Plant Ecology.

Salgado, C.S. and Pennings, S.C., 2005. Latitudinal variation in palatability of salt-marsh plants: are differences constitutive? Ecology.

Schultz, G. and C. Ruppel, Inversion of inductive electromagnetic data in high induction number terrains, Geophysics, 70, G16-G28, 2005. (doi:10.1190/1.1852775)

Snyder, M., M. Taillefert, and C. Ruppel, Redox zonation at the saline-influenced boundaries of a permeable surficial aquifer: effects of physical forcing on the biogeochemical cycling of iron and manganese, J. Hydrology, 296, 164-178, 2004 (doi: 10.1016/j.jhydrol.2004.03.019.)

Wang, Z. and Cai, W.-J., 2004. Carbon dioxide degassing and inorganic carbon export from a marsh dominated estuary (the Duplin River): A marsh CO2 pump. Limnology & Oceanography, 49(2): 341-352.

Zimmer, M., Pennings, S.C., Buck, T.L. and Carefoot, T.H., 2004. Salt Marsh Litter and Detritivores: A Closer Look at Redundancy. Estuaries, 27(5): 753–769.

Submitted

Kang, K. and Di Iorio, D., Depth and current induced effects on wave propagation into the Altamaha River Estuary, Georgia. Estuarine, Coastal and Shelf Science.

Lyons, J.I., Newell, S.Y., Brown, R.P. and Moran, M.A., Screening for bacterial-fungal associations in a southeastern U.S. salt marsh using pre-established fungal monocultures. FEMS Microbiology Ecology.

Richards, C.L. et al., Evidence for adaptive plasticity along a salinity gradient in a salt marsh perennial. New Phytologist.

Sheldon, J.E. and Alber, M., The calculation of estuarine turnover times using freshwater fraction and tidal prism models: a critical evaluation. Limnology and Oceanography.

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. Ecological Applications.

Weston, N.B. et al., Pore water stoichiometry of dissolved organic matter and inorganic redox metobolites in intertidal systems. Biogeochemistry.

Books and Book Sections

Blanton, J.O., Andrade, F. and Adelaide Ferreira, M., 2005. The Relationship of Hydrodynamics and Morphology in Tidal-Creek and Salt-Marsh Systems in South Carolina and Georgia. In: Implications of changing land use patterns to coastal ecosystems. Springer-Verlag, New York, NY.

Craft, C.B., 2005. Natural and constructed wetlands. In: Encyclopedia of Hydrological Sciences. John Wiley and Sons, New York.

Kohlmeyer, J., Volkmann-Kohlmeyer, B. and Newell, S.Y., 2004. Marine and estuarine mycelial Eumycota and Oomycota. In: G.M. Mueller, G.F. Bills and M.S. Foster (Editors), Biodiversity of Fungi. Inventory and Monitoring Methods. Elsevier Academic Press, Amsterdam, pp. 533-545.

Newell, S.Y., Lyons, J.I. and Moran, M.A., 2005. A saltmarsh decomposition system and its ascomycetous laccase genes. In: Fungi in the Environment. Cambridge University Press, Cambridge, UK.

Pennings, S.C. and Borneman, E.H., 2005. Indirect effects of interactions among species on coral reefs. In: Life and death of coral reefs. Chapman & Hall, London.

Pomeroy, L.R. and Cai, W.-J., 2005. Oxygen, carbon dioxide, and estuarine condition. In: Implications of changing land use patterns to coastal ecosystems. Springer-Verlag, New York.

Schultz, G. and C. Ruppel, Spectral response of coastal aquifers to tidal forcing: Theory and observations, submitted to Advances in Water Resources.

Theses and Dissertations

Albers, G., 2004. Applications of Island Biogeography: Plant Diversity and Soil Characteristics Among Back-Barrier Islands Near Sapelo Island, Georgia. Masters Thesis, University of Georgia, Athens, Georgia.

McFarlin, C.R., 2004. Impact of Fertilization on a Salt Marsh Food Web in Georgia. Masters Thesis, University of Georgia, Athens, Georgia, 127pp. pp.

Ogburn, M., 2004. Investigations of salt marsh die-back in coastal Georgia. Masters Thesis, University of Georgia, Athens, Georgia.

Richards, C.L., 2004. Evolution in closely adjacent salt marsh environments. PhD Thesis, University of Georgia, Athens, GA, 141pp.

Salgado, C., 2004. Latitudinal variation in palatability of salt marsh plants: Constitutive or induced? Masters Thesis, University of Houston, Houston, TX.

Thoresen, M., 2004. Temporal and spatial variation in seston available to oysters and the contribution of benthic diatoms to their diet in the Duplin River, Georgia. PhD Thesis, University of Georgia, Athens, Georgia.

White, S.N., 2004. Spartina species zonation along an estuarine gradient in Georgia: Exploring mechanisms controlling distribution. PhD Thesis, University of Georgia, Athens, Georgia.

Posters and Presentations

Alber, M., 2004. Effects of surface water management on coastal resources, Georgia River Network Annual Meeting, Milledgeville, Georgia.

Alber, M., 2004. The Georgia Coastal Research Council: Where science meets policy, Institute for Georgia Environmental Leadership, Jekyll Island, Georgia.

Alber, M., 2004. Marsh dieback efforts and workshop report, Georgia Coastal Research Council Conference, Savannah, Georgia.

Alber, M., 2004. Marsh dieback studies in Georgia, Georgia Coastal Research Council Marsh Dieback Workshop, Savannah, Georgia.

Aretxabaleta, A. et al., 2004. Cold Event in the South Atlantic Bight During Summer of 2003: Anomalous Hydrographic and Atmospheric Conditions, Fall Meeting Supplement. Ocean Sciences. EOS Transactions of the American Geophysical Union, San Francisco, CA, pp. Abstract OS32B-03.

Brown, R., C. Ruppel, and G. Schultz, Nonlinear analysis of tidal forcing of water level fluctuations in an unconfined permeable coastal aquifer, Georgia Coastal Ecosystems LTER, AGU Fall Meeting, 2004.

Craft, C.B., 2004. Vegetation ecology in wetlands, ASLO 2004 Summer Meeting. American Society of Limnology and Oceanography, Savannah, Georgia.

Edmonds, J.W., Weston, N.B., Joye, S.B. and Moran, M.A., 2004. Changes in Microbial Community Structure and Activity in Response to Fluctuations in Organic Carbon Pools in Salt Marsh Sediments, Annual Meeting of the American Society of Microbiology. American Society of Microbiology, Atlanta, Georgia.

P. Fulton, C. Ruppel, and G. Schultz, Permeable submarsh pathways for freshwater flow to estuaries: hydrologic, geophysical, and geochemical controls, ASLO spring meeting, Savannah GA June 2004.

Hembree, P.A., 2004. Collaboration, Dialogue, and Empowerment (CDE): Signposts Toward a Culture of Effective Science Teacher Education, Southeastern Association for the Education of Teachers in Science. Sustainment: Teachers' experiences in long-term, collaborative, field-based research, Gainesville, Florida.

Joye, S.B., Lee, R.Y., Porubsky, W.P. and Weston, N.B., 2004. Environmental Controls On Denitrification In Temperate And Tropical Shallow Sediments, ASLO Aquatic Sciences Meeting. American Society of Limnology and Oceanography, Salt Lake City, Utah.

Li, C.Y. and Blanton, J.O., 2004. Tidal flushing of three inlets along the central Georgia coast, ASLO 2004 Summer Meeting: The Changing Landscapes of Oceans and Freshwater. Physical processes. American Society of Limnology and Oceanography, Savannah, GA.

Newell, S.Y., Lyons, J.I. and Moran, M.A., 2004. A Saltmarsh Decomposition System and its Ascomycetous Laccase Genes, Abstracts of the Annual Scientific Meeting of the British Mycological Society. Molecular Ecology of Fungi in the Environment. British Mycological Society, Nottingham, UK.

O'Connell, S.G., Ogburn, M. and Alber, M., 2004. Soil characteristics at marsh dieback areas along the Georgia coast, Semiannual Meeting of the Southeastern Estuarine Research Society. Marsh Grass - Poster Session. Southeastern Estuarine Research Society, Ft. Pierce, FL.

Ogburn, M. and Alber, M., 2004. An Investigation of Salt Marsh Dieback using Transplant Experiments, Georgia Coastal Research Council Conference, Savannah, Georgia.

Ogburn, M. and Alber, M., 2004. Salt Marsh Dieback in Georgia: Field Survey and Transplant Experiments, Semiannual Meeting of the Southeastern Estuarine Research Society. Southeastern Estuarine Research Society, Ft. Pierce, FL.

Pennings, S.C., 2004. Local and geographic variation in Spartina-herbivore interactions, Third International Conference on Invasive Spartina, San Francisco, CA.

Seim, H.S., Blanton, J.O. and Elston-Graham, S.A., 2004. Tidal circulation and energy dissipation in a sinuous coastal plain estuary, 2004 Biannual Meeting: Hydrodynamics and morphodynamics in estuaries and coastal seas. Physics of Estuaries and Coastal Seas, Merida, Yucatán, Mexico.

Shalack, J. and Bishop, T.D., 2004. Spatial and temporal variability in recruitment of decapod megalopae in the Duplin River, Georgia, Semiannual Meeting of the Southeastern Estuarine Research Society. Invertebrates - Poster Session. Southeastern Estuarine Research Society, Ft. Pierce, FL.

Sheldon, J.E. and Alber, M., 2004. SqueezeBox: Flow-scaled 1-D box models for estuary residence time estimates, NOS Workshop on Residence/Flushing Times in Bays and Estuaries. National Oceanic and Atmospheric Administration, Silver Spring, Maryland.

Sheldon, J.E. and Alber, M., 2004. SqueezeBox: Flow-scaled 1-D box models for estuary residence time estimates, Spring 2004 meeting. Southeastern Estuarine Research Society (SEERS), Wilmington, North Carolina.

Sheldon, W.M., 2004. EML Best Practices for LTER Site Metadata, 2004 LTER Information Managers Meeting, Portland, Oregon.

Sheldon, W.M., 2004. LTER Metadata Query Interface – Current Status and Future Challenges, 2004 LTER Information Managers Meeting, Portland, Oregon.

Thoreson, M. and Alber, M., 2004. Utilization of Benthic Diatoms by Oysters (Crassostrea virginica), Semiannual Meeting of the Southeastern Estuarine Research Society. Southeastern Estuarine Research Society, Ft. Pierce, FL.

Weston, N.B. and Joye, S.B., 2004. Seasonal patterns of coupling between hydrolytic/fermentative and terminal metabolic microbial communities in an estuarine sediment, ASLO Aquatic Sciences Meeting. American Society of Limnology and Oceanography, Salt Lake City, Utah.