THE GEORGIA RIVERS LAND-MARGIN ECOSYSTEM RESEARCH PROGRAM

Richard G. Wiegert

AUTHOR: Professor, Department of Marine Sciences, University of Georgia, Athens, Georgia 30602.

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Abstract. The Land Margin Ecosystem Research (LMER) Program in the United States is supported by the U.S. National Science Foundation through two of its subsidiary units, Long Term Studies and Biological Oceanography. The LMER program was designed to address gaps in the coverage of certain ecosystems by multi-disciplinary teams, specifically the lack of studies of coastal boundary zones. Our Georgia interdisciplinary team effort is the newest of four such LMER sites around the United States. In the presentation I will describe our rivers and estuaries, discuss the aims and significance of our research questions and, finally, provide an overview of our findings during the first two years. This expanded abstract is used to provide some comparisons and background material against which the research findings can be discussed in the oral presentation. It is a condensed version of a paper produced for a symposium in 1996 in Rostock, Germany (Wiegert et al., in press). A more detailed general comparison of the rivers and our preliminary findings will appear in Alber et al., (in preparation).

THE GEORGIA RIVERS L. M. E. R.

At the coastal boundary, river water meets salt water to produce a physically complex zone collectively called an estuary. This estuarine continuum, from freshwater tidal to the nearshore marine, is the Land-Sea Margin (LSM). Within the LSM, there is a gradient of plant and animal communities arranged in a sequence of tolerance to, or requirement for, salinity and inundation. These communities are connected by the water that flows through or across them as river or tidal current.

In late 1994 we began to study the transport and modification of organic and inorganic matter carried from the land into the sea by the five major coastal rivers of Georgia. From north to south they are: the Savannah, the Ogeechee, the Altamaha, the Satilla, and the St. Marys. We have based our initial approach to this research on two major questions:

Question # 1

What terrestrial materials are transported into/through the LSM and to what extent are they intercepted or modified within this zone? Though some materials (e.g. heavy metals) are clearly trapped within this zone, it is unclear whether terrestrially derived organic matter (e.g. humic acids, lignocellulose) and inorganics, both dissolved and particulate, are sedimented out at the salinity-freshwater interface or simply diluted and carried to the nearshore.

Question # 2

Do the intertidal vegetated zones of the LSM, both riparian wetlands and coastal marshes, significantly filter and trap or modify terrestrially-derived materials and do their characteristics and functions differ significantly with river? Although some salt marshes trap and release material, depending on season, rainfall, and maturity of the marsh, the degree of modification of the materials is an open question, comparative studies are few, and little is known about any of these processes in brackish and freshwater tidal marshes.

Each of the rivers differs from the others in one or more aspects of landscape, geological setting, flow rate, inorganic and organic loading, and pH, but their mouths are all located within a 120 mile segment of coast and thus, in their lower reaches, the river systems share similar temperature, rainfall, and tidal regimes. These rivers provide a rare opportunity for comparative ecological study of the impact of the land, via rivers, on the nearshore ocean and of the impact of the sea, via tidal energy, on the riparian tidal wetlands and coastal marshes.

BACKGROUND MATERIAL

The Land Sea Margin: General Description

As rivers flow to the sea they accumulate, and often exchange, terrestrial materials via runoff, ground water, wind and direct anthropogenic injections. This accumulation and its modifications determine impacts of the terrestrial and lotic systems on the land-sea margin communities. Some processes effecting change are well understood (e.g. the oxidation of organic sewage). In other, perhaps most cases, (e.g. fertilizer runoff and humic acids leached from forest soils) both the processes of change during transport and the ultimate fates are poorly known.

Within the LSM, materials are swept out to sea or deposited, where they may be modified by benthic organisms or buried. Dissolved organic matter (DOM) and dissolved inorganic nutrients may also be removed by the biota or sedimented. Transport and transformation of materials within the vascular plant communities of the LSM are, at best, only partially understood.

The Rivers: A Brief Overview

The five major coastal river systems of Georgia vary with respect to black water input, pollution, channelization, and origin (Piedmont or Coastal Plain). They have small estuaries and large tidal ranges.

The Savannah is a large river with a watershed extending into the Appalachian mountains. Flow, sediment load, and flood plain have been modified by large dams above the Fall Line and dredging and channelization below that point.

The Ogeechee arises in the Piedmont, but the coastal plain contributes most to its flow. It is a 'black water' river, but with an atypically high pH in its lower reaches (near 7.0) due to a large input of carbonate-rich water from Magnolia Springs.

The Altamaha is the largest river (second only to the Hudson river) on the east coast of the United States. Its headwaters, like those of the Savannah, arise in the lower Appalachian mountains and flow is dominated by silt-laden water from the Piedmont and Upper Coastal Plain, although it does receive a major input from a 'black water' tributary, the Ohoopee. It is the 'relatively undisturbed' analog of the Savannah River, with no major channelization or dredging and no major reservoirs.

The Satilla lies entirely within the Coastal Plain; it is a typical 'black water' river that flows directly into an estuary. The pH is near 6, midway between that of the Ogeechee and the St. Marys.

The St. Marys is the boundary between Georgia and Florida and drains part of the Okeefenokee Swamp. It too is a 'blackwater' river with a pH around 3.0 in the upper reaches, although, like the Ogeechee, it shows a downstream rise in pH, presumably from leached carbonate.

Estuarine Transport and Transformation

Estuaries trap organic and inorganic materials. Organic sediments, including feces of benthic organisms, provide substrates for bacteria. Inorganics, particularly the fine material abundant in Georgia estuaries, have great adsorptive capacity. Turbidity maxima can provide estimates of trapping efficiency. Gravitational (density-driven) circulation from freshwater discharge and tidal mixing produces a seaward flow overlying a landward flow. This mode weakens landward, and a "null" zone forms where sediments can be trapped, indicated by a turbidity maximum.

During a tidal cycle (usually semidiurnal), large quantities of fine sediments are alternately eroded, deposited and resuspended. A sorting mechanism is provided by flood and ebb dominant asymmetries, a result of tidal wave distortion. Coarser material is deposited in the lower reaches; finer clay-sized particles are carried landward in ebb-dominance. Flood-dominance fills channels with coarse sediment; ebb-dominance tends to flush bed-load.

Ebb-dominance is common south of Cape Romain, SC, because of inefficient exchange, at high water, between the extensive marsh and deep channels; this causes seaward migration of coarse-grained bedforms. The distortion of the tidal wave at the mouth and head of our estuaries is important, for any shift to flood dominance near the "null" point of the gravitational circulation increases sediment trapping. Spring/neap tides (14 day cycle) also affect trapping of sediment, spring tides reducing trapping at the "null" zone.

Estuarine-ocean interactions (tides/river flow) may combine to export material to the continental shelf. The gravitational circulation may extend to the shelf and cause transport of coastal sediments into the estuary. Estuarine material can also be carried seaward and along the coast by low-salinity estuarine discharges that form coastal currents. Moreover, wind-induced upwelling/downwelling cycles dramatically alter the stratification regime; little is known of cyclic effects on estuarine-ocean coupling.

Two of our five estuaries (Savannah and St. Marys) are shipping ports, and the offshore estuarine bar or delta is cut through, allowing the estuarine regime to extend onto the continental shelf. Here the processes discussed above are very important. With intact deltas, the gravitational circulation regime is cut off from a similar regime represented by the coastal frontal zone of Georgia. We need to know how these various interactions of estuarine circulation with the ocean affect the exchange of material within the LSM, considered as a continuum between the land-river and the sea.

Previous studies of tidal ecosystems have concentrated on the communities as separate systems, connected in many ways, but not as parts of a continuum. Fluxes, budgets of energy, and concentrations of organic matter and nutrients have all have been calculated from measurements in situ. Some of these efforts have been lengthy and intensive (North Inlet, SC; Sapelo I., GA), yet major questions remain that can be answered only by regarding the river-LSM-sea as a continuum and setting up comparative investigations. Our two initial questions (above) suggested a third:

Question # 3

Is the impact of a river on the nearshore, mediated through the LSM, only a function of the freshwater flow and the materials brought from the land, or is it the interaction of the river with the communities developed in the particular LSM that is most important to the overall effect?

If it is the latter, then the materials modified and added by these communities are part of the impact of the land, both on the LSM, and through the LSM on the nearshore marine zone. The River Continuum Concept could continue as the "tidal community continuum", to coin a phrase. The predictions from the River Continuum Concept do not always apply to the sinuous, low gradient, coastal plain portions of these southeastern rivers, so the name change may be appropriate. Overarching all of the questions is the uncertainty of what effects will follow from "global change".

RESEARCH RESULTS

During the first two years of our program a number of cruises have been made using the RV Bluefin and supplemented by sampling from a small research boat and from shore. We have concentrated on measurements of inorganic and organic materials in the water and on measurement of physical factors such as tidal movements of sediments and have sampled tidal cycles by moving with the tide and using anchor (fixed) stations.

The five rivers show some predictable differences, but also some remarkable similarities. Some materials show conservative mixing whereas others clearly show dynamic changes as they passs through the land sea margin.

In general, Piedmont-dominated watershed rivers (the Savannah and Altamaha) show a lesser degree of tansformations, sources and sinks for materials as their waters flow through the Land-Sea-Margin. The reasons are: 1) they have higher rates of flow, thus materials pass through the LSM more quickly. 2) marshes comprise a smaller percentage of the watershed, thus lowering the marsh/river discharge ratio. 3) their estuaries, because of the high discharges, have smaller replacement times.

Inorganic transport through the LSM varies widely depending on the compound. Ammonium shows a highly non-conservative mixing pattern with peaks sometimes near zero salinity (Savannah R.) and sometimes in high salinity (St. Marys R.). Nitrite had a consistent pattern of an initial rise with increase in salinity, followed by a decrease at higher salinities. The peak was always near 20 ppt salinity. Nitrate showed no consistent pattern, but differed for both cruises and between all rivers. In a very loose sense, nitrate was slightly non-conservative in Piedmont rivers, with some proportionate losses due to factors other than mixing, i.e. a concave upward decreasing curve with increasing salinity. In the Coastal Plain rivers the pattern faintly resembled that of nitrite, with a peak at about 20 ppt. salinity. Silicate consistently showed completely conservative mixing during both cruises on all the rivers. Phosphate, like nitrate, varied between cruises and rivers. But, except for the Savannah river, phosphate levels were extremely low in both fresh and seawater so that the mixing regression had a slope of approximately zero.

Materials in the freshwater end member of our riverine transects show some differences from river to river. Ammonium was higher in rivers with even a small Piedmont influence (Savannah, Ogeechee and Altamaha). Nitrite was highest in rivers with a major Piedmont influence (Savannah, Altamaha) and lowest in the true blackwater coastal streams (Satilla, St. Marys). Nitrate was also highest in the Piedmont rivers. The Savannah, perhaps because of high population density and/or industry, had the highest nitrate content of all. Silica was lowest in the true blackwater rivers (Satilla, St. Marys). The freshwater value of phosphate was very low in all rivers except the Savannah.

In addition to the inorganic freshwater end member concentrations, we measured suspended sediment, percent organic, Chlorophyll *a* (Chl *a*), particulate organic carbon (POC) and dissolved organic carbon (DOC). The suspended sediment was variable with no clear separation between Piedmont-dominated and Coastal Plain-dominated rivers, but the percent of the suspended sediment that was organic was much higher (by a factor of 2) in the Coastal Plain rivers (Ogeechee, Satilla, St. Marys). Chlorophyll *a* was low at zero salinity in all rivers (an order of magnitude lower compared to the the values upstream at head-of-tide). Within the overall low levels, however, there was more Chl *a* in Piedmont rivers and more active chlorophyll (phaeophytin percent in Piedmont rivers was 67-75 % compared to 83-97 % in Coastal Plain rivers). POC varied for all rivers and both cruises; no trend was apprent. DOC was much higher in the Coastal Plain rivers with their dominant riverine swamps.

During the next 4 years we will be continuing our surveys and performing more experimental-type measurements. By the end of the six year grant period we hope to have a rather complete picture of the transport and transformation capabilities of each river and be able to relate this to the physiognomics characteristics of the river and the pattern of land use in its watershed.

REFERENCES

Wiegert, R.G., M. Alber, C. Alexander, J. Blanton, A. Chalmers, R. Hodson, L. Pomeroy, and W. Wiebe. 1997. The Georgia Rivers LMER Program: A Comparative Study of Five Coastal Rivers. *Limnologica* (in press).