LINKING SHIFTS IN HISTORIC ESTUARINE VEGETATION TO SALINITY CHANGES USING A GIS

Carrie Smith[1], Merryl Alber[2] and Alice Chalmers[3]

AUTHORS: [1]Graduate Student, [2]Assistant Professor, and [3]Research Scientist, Department of Marine Sciences, University of Georgia, Athens, GA 30602.
REFERENCE: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, the University of Georgia, Athens, Georgia.

Abstract. There are anecdotal reports that upstream water withdrawals over the past 50 years have altered the salinity structure of coastal Georgia estuaries. Since few consistent salinity records exist, it may be possible to use shifts in vegetation to document salinity change. The purpose of this study was to use aerial photographs and GIS analysis to determine if the location of the brackish water interface in two Georgia estuaries has changed. Current vegetation maps of the Satilla and Altamaha estuaries were constructed from 1993 USGS DOQQs. Vegetation was outlined and classified as *Juncus roemerianus*, brackish marsh, fresh marsh, salt marsh, or other. Historic vegetation maps were similarly constructed from 1:77000-scale color infrared photographs taken in 1974 and 1:24000-scale black and white photographs taken in 1953. Change maps between all years were constructed for each river. In the Altamaha River, 6,786 hectares of marsh area were mapped, of which 77% did not change between 1953 and 1993. Of the 10,205 hectares of marsh area mapped in the Satilla, 87% did not change between 1953 and 1993. Shifts in *Juncus* constituted the primary vegetation change in both estuaries (95% in the Satilla and 87% in the Altamaha). However, these changes in *Juncus* do not necessarily reflect changes in estuarine salinity, indicating a need for further investigation of *Juncus* interactions in these systems.

INTRODUCTION

Changes in the discharge of a river can result in fundamental changes in the salinity structure of an estuary. Along the coast of Georgia, it is believed that changes in upstream water withdrawals have impacted the amount of freshwater being delivered to the estuaries. Local residents have noted a decrease in crab and shellfish catches, which they attribute to an increase in salinity from increasing surface water withdrawals. However, no salinity records exist that are comprehensive enough to be able to establish long-term salinity trends in these systems.

In estuarine systems, different plant species have specific salinity tolerances, so changes in their distribution can be used as an indicator of salinity change (Earle and Kershaw, 1988). The purpose of this study was to examine possible shifts in salinity in the Altamaha and Satilla estuaries by examining changes in the location of plant communities over time. Our goal was to detect changes in the distribution of the vegetation by generating maps based on historical aerial photographs. We then analyzed differences between these maps using a geographic information system (GIS). Monitoring changes in plant communities using historical aerial photography has been used as an indicator of environmental change in terrestrial systems (Kadmon and Harari-Kremer, 1999), but the techniques have seldom been applied to coastal environments (Cracknell, 1999).

METHODS

Data Sets

In each estuary, three sets of photographs were analyzed to detect vegetation change. The 1993 Digital Orthophoto Quarter Quads (DOQQs) (created by USGS and based on black and white 1:40,000-scale NAPP photography) were used as the most current pictures of the estuaries. Color infrared photographs taken at 1:77000-scale in 1974 and 1:20000-scale black and white photographs taken in 1953 were used as historical data sets. Each of these historical photos was scanned at 400 dpi, registered to UTM coordinates taken from the 1993 DOQQs, and then rectified using ESRI ArcInfo NT software. Root Mean Square errors (RMSE) from the rectification process ranged between +/- 11 and 21 m for the 1974 images and between +/- 2 and 12 m for the 1953 images.

Map Generation

For all sets of photographs, areas of different vegetation were outlined using ESRI ArcView v.3.2. Since most individual species could not be identified at

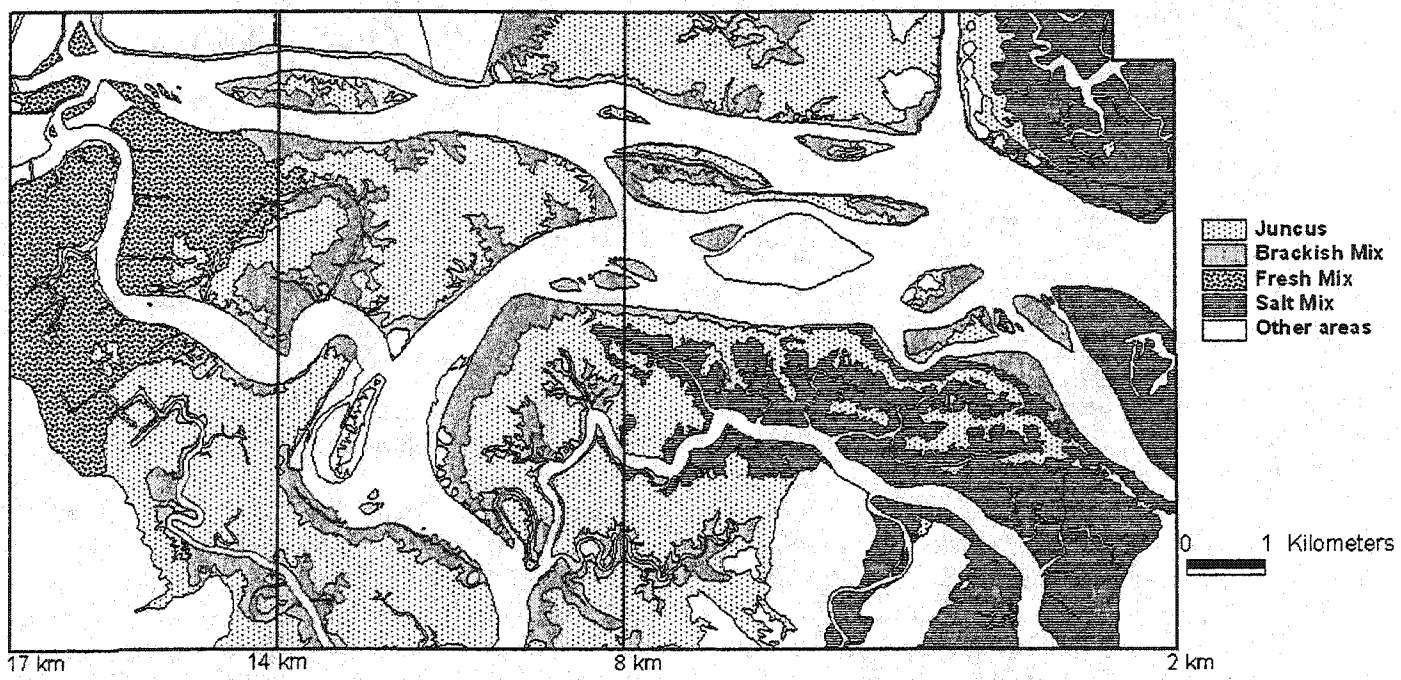

Figure 1. 1993 vegetation classification map for the Altamaha River Estuary. Divisions indicate distance from the river mouth along the main (south) river channel.

the scale of the photographs, different areas were classified as being brackish marsh, fresh marsh, salt marsh, *Juncus*, or other. Brackish marsh contained *Spartina alterniflora* and *S. cynosuroides*; fresh marsh contained *Zizania aquatica, Zizaniopsis miliacae*, and *S cynosuroides*; and salt marsh contained short form *S. alterniflora* and *Distichlis spicata*. Due to its dark color and dense populations, *Juncus roemerianus* was visible as a distinct species and was therefore classified separately. Areas classified as "other" included those covered by water, upland vegetation, or areas that had been heavily impacted by human activities (e.g. dikes, dredge spoils). Classifications of the 1993 maps were groundtruthed in October 1999 and July/August 2000.

Overlay Analysis

Since we were trying to determine what changes had occurred over the entire 40 year time period, only the 1953 and 1993 maps were used in the change analysis. Change maps were constructed by overlaying the 1953 map onto the 1993 map using ArcInfo NT. Using the GIS software we were able to differentiate areas that had changed from those that had not. The estuaries were then divided into sections based on distances from the mouth along the main river channel. These sections were used to determine if changes were occurring in particular regions along the axis of the estuary. The Altamaha was divided into 6 km long sections, while the Satilla was divided into 8 km long sections.

RESULTS

Vegetation Classification

Of the 6,768 ha of marsh vegetation that were mapped in the Altamaha estuary in 1993 (Fig. 1), 24% was classified as salt marsh, 45% as *Juncus*, 20% as brackish marsh, and 11% as fresh marsh. Of the 11,420 ha of marsh that were mapped in the Satilla in 1993 (Fig. 2), 42% was classified as salt marsh, 48% as *Juncus*, 9% as brackish marsh, and 1% as fresh marsh. In both estuaries, salt marsh was found closest to the mouth, brackish marsh was in the middle, and fresh marsh was furthest upstream. *Juncus* was distributed throughout the Altamaha. In the Satilla, *Juncus* was only observed upstream of 12 km. The Satilla is a smaller river than the Altamaha, with characteristic higher salinities towards the mouth. This may explain the higher proportion of salt marsh and lower abundance of *Juncus* seen downstream in the Satilla.

Similar maps were constructed from the 1974 and the 1953 photographs. Table 1 shows a summary of the vegetation classifications for all 3 data sets. In the Altamaha, there was a net gain in *Juncus* of 246 ha between 1953 and 1993. Brackish marsh showed an increase of 88 ha by 1974, which was followed by a large decrease by 1993. In the Satilla, there was a large gain of 328 ha in *Juncus* that occurred between 1974 and 1993. Brackish marsh increased 350 ha from 1953 to 1974, but then decreased by 406 ha in 1993.

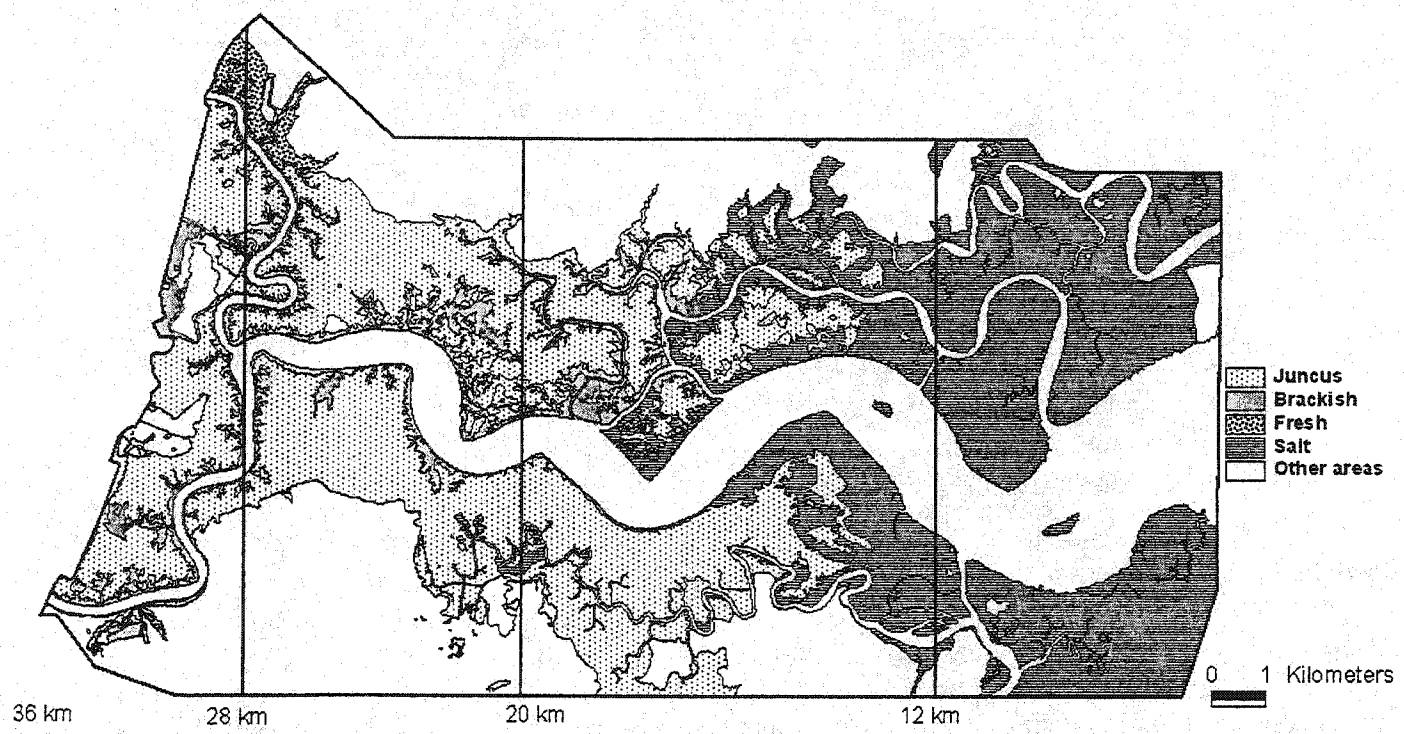

Figure 2. 1993 vegetation classification map for the Satilla River Estuary. Divisions indicate distance from the river mouth along the main river channel.

Change Analysis

Most of the marsh vegetation classifications remained the same in both estuaries between 1953 and 1993. Of the mapped marsh areas, 77% (5,562 ha) of the Altamaha and 87% (8,871 ha) of the Satilla did not change. In both systems, the majority of the changes (87% Altamaha and 95% Satilla) involved either an increase or a decrease in *Juncus*, although the locations and types of interactions were specific to each estuary (Fig. 3). In the Altamaha, most of these changes involved brackish marsh. In the Satilla, however, they involved both brackish and salt marsh. This is probably due to the increased amount of salt marsh in contact with *Juncus* in the Satilla. There was a net increase in *Juncus* in both estuaries.

Table 1. Total Area (ha) in Each Vegetation Class.

	Juncus	Brackish	Fresh	Salt	Other
Altamaha					
1953	2740	1618	808	1661	4635
1974	2930	1706	626	1559	4641
1993	2986	1352	793	1578	4753
Satilla					
1953	4438	964	232	4531	9830
1974	4339	1304	114	4529	9707
1993	4667	898	147	4497	9786

DISCUSSION

Our analyses demonstrate that aerial photographs and GIS can be used to map current and historic estuarine vegetation. We were able to generate maps that showed different vegetation patterns. The comparison of maps from different years suggests that the Altamaha and Satilla estuaries are very dynamic systems, with patches of vegetation that frequently change in both size and location. As shown in Table 1, the amount of each vegetation class did not remain constant over time, nor did increases in one class directly reflect decreases in another. We are currently involved in further GIS analyses of these data sets to better understand these changes.

Our analysis indicates that *Juncus* is one of the dominant vegetation types in each estuary. Moreover, it was involved in almost all of the changes seen in each system. *Juncus roemerianus* is an exclusively estuarine species that grows in monotypic stands in a variety of habitats (Eleuterius, 1984). Its ability to flourish in a wide variety of salinity regimes helps to explain why it is so abundant in these systems. Unfortunately, this adaptability makes it nearly impossible to use as an indicator of salinity variation (Woerner and Hackney, 1997). Therefore, our observed increase in *Juncus* cannot be directly linked to changes

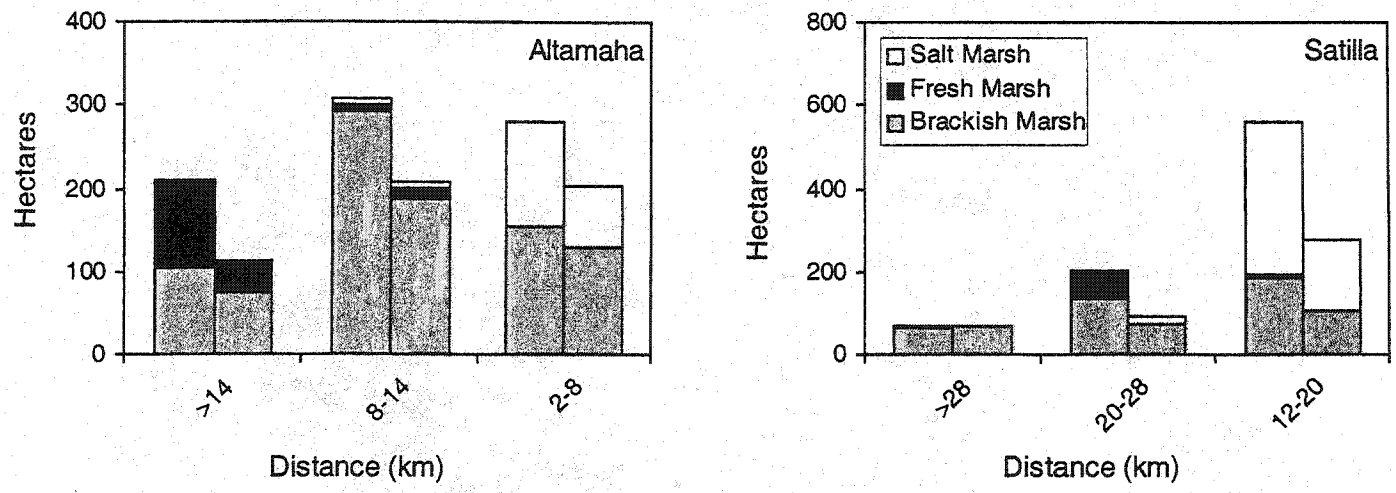

Figure 3. *Juncus* changes between 1953 and 1993. Areas of *Juncus* increase (left hand bars) and *Juncus* decrease (right hand bars) are from or to the noted vegetation class. Note scale change.

in estuarine salinity, and subsequently cannot be linked to changes in upstream water withdrawals.

In addition to salinity, there are other factors that influence the distribution of *Juncus*. *Juncus* prefers to grow in areas that have a slightly higher elevation relative to nearby vegetation zones, and therefore have less tidal flooding and disturbance by wrack (Brinson and Christian, 1999). Our observed *Juncus* changes may be related to interactions between surface elevation, local salinity, and plant competition within specific sections of the estuary. We recommend further investigation of the interactions between *Juncus* and other marsh plants, as well as on the environmental controls of suitable *Juncus* habitat, so that the implications of the changes observed in these complicated estuarine systems can be better understood.

ACKNOWLEDGEMENTS

We would like to thank D. Bishop and the Captain and crew of the R/V Bluefin for their assistance with field observations, and D. Elkins and J. Sheldon for their technical assistance. Financial support was provided by the Georgia Coastal Management Program and the Office of Ocean and Coastal Resource Management through the Coastal Zone Management Act of 1972, NOAA Awards NA87OZ0115, NA87OZ0231, and NA97OZ0159, and by NSF Grant Nos. DEB 9412089 and OCE 99-82133.

REFERENCES

Brinson, M.M., and R.R. Christian. 1999. Stability of *Juncus roemerianus* patches in a salt marsh. *Wetlands*. 19.1:65-70.

Cracknell, A.P. 1999. Remote sensing techniques in estuaries and coastal zones - an update. *International Journal of Remote Sensing*. 19.3:485-496.

Earle, J.C. and K.A. Kershaw. 1988. Vegetation patterns in James Bay coastal marshes. III. Salinity and elevation as factors influencing plant zonations. *Canadian Journal of Botany* 67:2967-2974.

Eleuterius, L.N. 1984. Autoecology of the black needlerush, *Juncus roemerianus*. *Gulf Research Reports*. 7:339-350.

Kadmon, R. and R. Harari-Kremer. 1999. Studying long term vegetation dynamics using digital processing of historical aerial photographs. *Remote Sensing of the Environment*. 68:164-176.

Woerner, L.S. and C.T. Hackney. 1997. Distribution of *Juncus roemerianus* in North Carolina tidal marshes: The importance of physical and biotic variables. *Wetlands*. 17.2:284-291.