DEVELOPING NATURAL WETLANDS MANAGEMENT STRATEGIES FROM LONG-TERM FIELD MONITORING

Stephen V. Cofer-Shabica[1] and Lindsay D. Nakashima[2]

AUTHORS: [1]Research Oceanographer, National Biological Service, Atlantic Field Station, Submarine Base Kings Bay, 1342 USS Simon Bolivar Road, Kings Bay, Georgia 31547-2529; [2]Geomorphologist, Terra Consulting Corp., 8900 Anselmo Lane, Baton Rouge, Louisiana 79810.
REFERENCE: Proceedings of the 1995 Georgia Water Resources Conference, held April 11 and 12, 1995, at The University of Georgia, Kathryn J. Hatcher, Editor, Carl Vinson Institute of Government, The University of Georgia, Athens, Georgia.

Abstract. Numerous measurement techniques exist to quantify wetland changes, but the causes of coastal land loss remain incompletely understood. Six different methods for measuring sedimentation and erosion rates on marsh and mudflat surfaces were applied at three back barrier study sites on Cumberland Island, Georgia in an effort to determine whether channel dredging is affecting marsh/mudflat habitat sustainability. The measurement techniques were designed to quantify minute changes in wetland elevation and width. The data provided here date from December 1989 through August 1994.

We found that the techniques had differing sensitivities or levels of accuracy for measuring subtle changes in wetlands, which could impact estimates of sedimentation and affect the costs or direction of management strategies in wetlands. The sedimentation-table and sedimentation-pin techniques provided the most accurate and most dynamic results in that they also rendered data for NOAA-based local sea level rise curves. These techniques have been proposed in a practical plan for the National Biological Service to monitor and diagnose critically eroding wetland habitats in the United States.

INTRODUCTION

Coastal wetland loss has become nationally recognized as a significant habitat destruction and degradation process. Wetlands are highly important to coastal estuarine ecosystems. They provide habitat, forage, and shelter areas for numerous vertebrate and invertebrate species including, in the St. Marys' area, the endangered wood stork and manatee.

These areas are also important in nutrient recycling and exchange. Interference with sediment deposition, both quantity and quality, could result in increased shoreline recession and drowning of the marshes as sea level rises. The causes of land loss in wetlands are complex, however, and the linkages to natural processes and cultural factors are poorly understood in most cases. Efforts to establish causal relationships have led a number of researchers to develop an array of techniques for assessing changes in marsh environments.

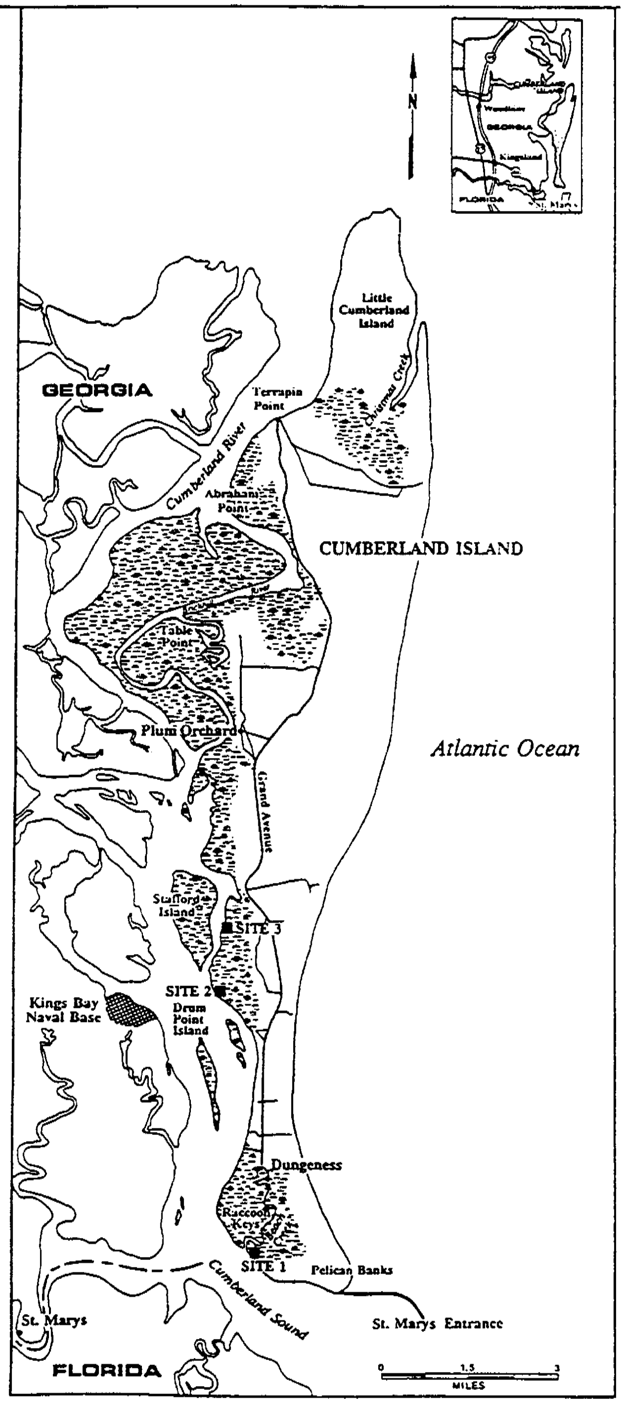

Figure 1: Location of Cumberland Island, Georgia

Purpose

A project was designed to determine if back barrier dredging for the Kings Bay Naval Submarine Base is affecting marsh habitat sustainability on Cumberland Island National Seashore, Georgia. If this operation is indeed exerting an influence on Cumberland Island, it would probably be first perceived in the effect it has on the rates of supply and delivery of sediments to the marshes and mudflats. In a region characterized by a rising sea level, a reduction in the supply of marsh-building sediments would result in drowning because the marsh vegetation would have insufficient substrate for vertical and horizontal growth. To test this hypothesis, six measurement techniques were combined in an innovative field project designed to measure minute changes in elevation at three wetland sites. These techniques included marker layers, profile surveys, and point measurements.

Study Sites

Cumberland Island is the southern most and the largest of Georgia's "Sea Isles" barrier island system. It is backed by Cumberland Sound, which is connected to the Atlantic Ocean via St. Marys Entrance, an artificially-stabilized inlet at the southern end of Cumberland Island. The sound is in a mesotidal setting characterized by semi-diurnal tides with a mean tidal range of 1.9 m and a spring range of 2.6 m.

Three permanent marsh study sites were selected in the southern half of Cumberland Island during early December 1989. The sites consisted of marsh, mudflat, and tidal creek systems that were comparable in morphology, but exhibited a spectrum of different exposures to Cumberland Sound and the St. Marys Entrance (Figure 1).

Site 1 - Beach Creek is the southernmost site, located 3 km northwest of St. Marys Entrance. Wave energy, tidal currents, and exposure to both inlet and tidal creek processes are greater here than at the other two sites. This location was chosen to provide an indication of the upper limits of sediment erosion and deposition dynamics.

Site 2 - This site is located about 6 km north of Site 1 and immediately across the sound from Kings Bay Naval Submarine Base. This location was selected to provide a benchmark for normal rates of back barrier marsh sedimentation away from the influence of the inlet, but near the Kings Bay Naval facility.

Site 3 - This northernmost station is located 1.5 km north of Site 2 in the lee of Stafford Island. This location was chosen as the control site to provide an indication of the lower limits of sediment erosion and deposition dynamics.

METHODS

Six field techniques were employed to monitor the areal and vertical extent of erosion and accretion at the three back barrier marsh sites of Cumberland Island. These techniques were classified as:

Repeated-Point Measures (Relative Measures)
- * sedimentation pins
- * sedimentation table
- * field surveys

Marker-Layer Measures (Absolute Measures)
- * clay-marker horizons
- * stable rare-earth tracers

Dating (Absolute Measure)
- * Cesium (^{137}Cs)

Sedimentation Pins: Sedimentation pins are used to obtain detailed local information on erosion and accretion in wetland environments (Pethick and Reed, 1987). Fifty cm-long stainless steel pins were pushed into the marsh surface to a 27.1 cm depth. Net erosion, accretion or stability of the marsh was determined by measuring the distance from the top of the sedimentation pin to the sediment surface (outside of any local scour hole) using a steel rule incremented in millimeters.

Sedimentation Table: The sedimentation table (Schoot and de Jong, 1982) complements the data obtained with sedimentation pins and clay marker plots. With the table, many detailed measurements of net change in sedimentation may be obtained without the need to leave any marker or pins in place. The table is designed to repeatedly measure elevation of the sediment surface of vegetated areas to an accuracy of a few millimeters. The procedure causes no disturbance of the surface being measured and the many measurements provided over small areas give a measure of spatial variability associated with microtopography. The sedimentation table required the installation of a stable mounting post, which also served as the field survey subdatum at each site. The mounting post, an aluminum irrigation pipe, was vibracored into the marsh substrate until refusal. The pipe was filled with cement and fitted with a machined aluminum mounting pin that accommodates the sedimentation table. When leveled, the table on the end of the horizontal arm provides a constant plane in space from which the distance to the sediment surface is measured with nine pins that pass through holes in the table. When the table was level, the nine pins could be manually and individually lowered to the sediment surface. After the pins were lowered, they were locked in place and the length of each pin above the table measured to the nearest millimeter. The distance to the sediment surface was then calculated by difference. The procedure was repeated at each of the four directions to yield 27 elevation measurements.

Field Surveys: Field surveys are the standard ground truth method for determining rates of shoreline change

(Tanner, 1978). The method developed by Nakashima and others (1983) is utilized here. A permanent working subdatum was established at each site from which repeated surveys could be made. Then, 2.5 m-long metal stakes were placed at 5 m intervals following a line-of-sight established using an engineers level. Distances above the survey line were determined using standard field survey methods out to the maximum limit of wading. The subdatums were tied into permanent US Army Corps of Engineers benchmarks. Two survey transects were established at each of the three field sites. The even spacing of readings every 5 m along the transect was selected to simplify further statistical analyses.

Clay-Marker Horizons: Visual monitoring of sediment accumulation above artificial soil horizons of white feldspar-clay has been found to be an effective and inexpensive technique for monitoring accretion in Louisiana marshes (Cahoon and Turner, 1987). For the purposes of this project, a layer of feldspar-clay was emplaced in two 30 cm^2 plots at each site. A total of nine shallow cores were taken from these marker plots after a six month interval, providing a six-month estimate of net accretion.

Stable Rare-Earth Element Tracer: The method of using stable, rare-earth tracers as non-obtrusive soil horizon markers has recently been tested on a large scale in Louisiana marshes and was found t offer some advantages to techniques depending on a visual marker, such as feldspar (Knaus and Van Gent, 1987). The two rare-earth elements used in the present work were dysprosium (Dy) and samarium (Sm), which were determined to be biologically non-essential and chemically inert. When samples containing these non-radioactive elements are bombarded with neutrons in a reactor using Instrumental Neutron Activation Analysis (INAA), a relatively low-cost detection method, radionuclides are produced that have a gamma ray emission that is sufficiently intense and energetic that the presence of these elements can be quantified at concentrations as low as 0.1 microgram per sample. For marker layer preparation, measured amounts of a slightly acidified Dy-Sm nitrate mixture diluted with marsh water are applied to exposed sediment surfaces using a sprayer. The tracer rapidly precipitates onto all surfaces contacted, forming a permanent, insoluble tracer which moves only when the sediment particle itself moves. In Louisiana marshes, use of the INAA technique resulted in meaningful measurements made on sediment slices as thin as 3 mm.

Cesium (^{137}Cs): ^{137}Cs is a product of atmospheric nuclear weapons testing which does not occur naturally. Significant levels first appeared in the atmosphere in the early 1950s, with peak quantities detected in 1963-64 (Pennington and others, 1973). This radionuclide was introduced to surface soils from atmospheric deposition and accumulated. In the sediments it decays exponentially to ^{137}Ba, with a 30-year half-life. The distribution of ^{137} Cs in Wetland soils has been used throughout the world to measure relatively recent accretion (DeLaune and others, 1983). Typically, the profile of ^{137}Cs with depth shows a maximum corresponding to the 1963 peak in atmospheric testing. The evaluation work for this project involved the collection and analysis of ^{137}Cs profiles on a total of five cores.

The areas sampled for each method were nested in close proximity to one another in order to provide a good basis for comparison. Wooden walkways were constructed to provide undisturbed access to the survey sites.

RESULTS

The six different methods for measuring sedimentation and erosion rates on marsh and mudflat surfaces were applied at three back barrier study sites on Cumberland Island in an effort to determine whether channel dredging is affecting marsh/mudflat habitat sustainability. The data included in the current database date from December 1989 through August 1994.

Evaluation of Six Methods

In the first year, the study team compared the six different methods (field surveys, sedimentation pins, sedimentation table, Cesium activity, stable rare-earth tracers, and clay-marker layers) for monitoring sedimentation. An initial evaluation was made of the relative strengths and weaknesses of these various methods. The two marker-layer (absolute) methods were seriously deficient in that they did not have the capability to record erosion. The standard survey (relative) approach was too imprecise for recording vertical changes in the soft marsh surface. The sedimentation pins (relative) provided useful results, although they were subject to disturbance from flotsam/jetsam and accidental contact. The sedimentation table (relative) was found to have the most advantages (Cofer-Shabica and Nakashima, 1992, 1993).

The database allows an evaluation of the following:
(A) The differences in marsh surface elevations between sites.
(B) The magnitude of short-term vertical changes.

A. Differences In Marsh Surface Elevations Between Sites

The interior marsh surface exhibits an apparently regional trend of increasing elevation from south to north, with a range of 40 cm between Sites 1 and 3. The marsh surface also varies considerably within individual sites. Topographic surveys established that the surface typically slopes at a slight angle towards the sound and creeks. The other methods show that elevation is also affected by elements of microtopography, which range from high-tide debris deposits to footprints and fiddler crab burrows.

The survey results show that over a distance of tens of meters, the average vegetated marsh and mudflat surface elevation at any one site at any single time varies within a range of 4 to 17 cm. Over smaller distances of a single meter or less (based on results obtained from the other methods), the marsh and mud surfaces exhibit a range in elevation or roughness of 2 to 6 mm.

B. Magnitude of Vertical Changes

Accretion and erosion of the marsh surface are assumed to be manifested in apparent changes in the elevation of this surface relative to a benchmark or subdatum. Vertical accretion of the Cumberland Island marshes is approximately 0.50 cm yr^{-1}, based on the long-term ^{137}Cs results. Summaries of the short-term records of accretion and erosion for the sedimentation table at the three sites are shown in Figures 2 and 3 for the marsh and mudflats, respectively. Accretion or erosion is signified by a plus (+) or minus (-) value, in millimeters. The overall trend was one of net accretion, ranging from 2 to 4 mm.

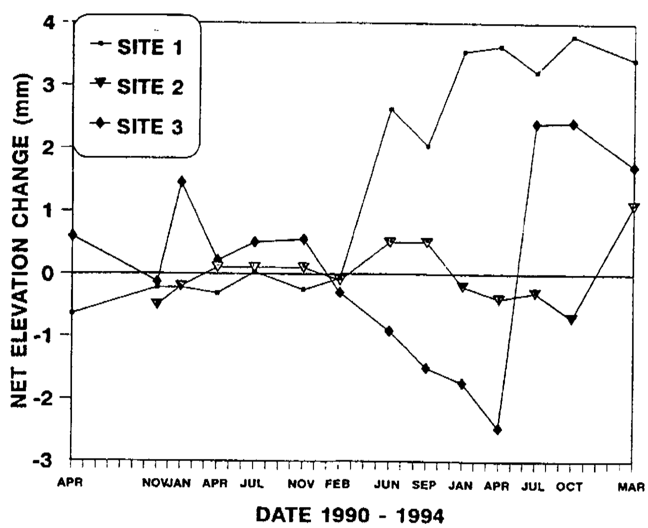

Figure 2. Marsh Sedimentation Table Changes

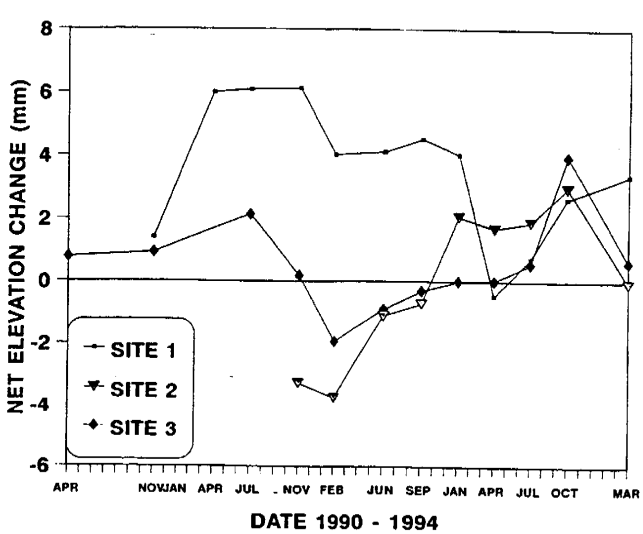

Figure 3. Mudflat Sedimentation Changes

MANAGEMENT STRATEGY

The foregoing methodology, consisting of both sedimentation table and pins, has been proposed to the newly formed National Biological Service as a means of observing and quantifying the status and trends of the Nation's coastal marsh lands. We believe that the simplicity of the techniques coupled with their low implementation costs (less than $1700 per station to establish, materials and labor; $300 per station per year for monitoring and data management) would allow the establishment of a long-term monitoring network for maritime wetlands along the coastal zone of the United States. Conducted annually, survey results for each station would be layered in a centrally located geographical information system (GIS) of the coastal zone. By establishing "critical change" criteria for each survey technique within each coastal wetlands area, "red flags" would automatically be raised as survey results were entered into the GIS. The criteria for the "critical change" designations would be based on a review of pertinent ecological data, the physical processes of each area, and the time series of survey results. As the data base increased over time, more refined "critical change" criteria would be available to the decision-maker.

The ecological and physical processes data would form data layers in the GIS during the characterization of each monitoring site. The addition of the annual site survey data into the GIS permit the rapid identification of areas undergoing critical change and signal the necessity for an evaluation of the site by a team of coastal experts. Such a team would conceivably consist of a coastal ecologist, a coastal geomorphologist, a botanist, an estuarine hydrologist, a sociologist, and a resource management specialist. Recommendations as to the status of the wetland in terms of natural and/or anthropogenic influences would be made to those responsible for the management of the area.

SUMMARY

Results are presented from one part of a four-year program designed to determine the effects of the deepening of the Kings Bay Naval Submarine Base dredged channel on the marshes, tidal creeks, and mudflats of Cumberland Island National Seashore.

For measuring minute changes (to the nearest mm) in marsh surfaces, repeated-point (relative) measures (sedimentation table and sedimentation pins) are favored over marker-layer (absolute) methods (clay-markers and stable rare-earth tracers).

Marsh elevations increase from south to north, with a range of 40 cm between Sites 1 and 3. The marsh surface also varies considerably within individual sites, with the elevation affected by small-scale perturbations, which range from high-tide debris deposits to fiddler crab burrows.

Sedimentation at the marsh/sound/creek interface at Site 1 was the most dynamic. Sediments are being redistributed on the marsh profile, and areas of erosion and accretion have changed with migration of the marsh vegetation line.

RECOMMENDATIONS

This evaluation of marsh sedimentation techniques provides the following considerations for developing scientifically-based wetlands management strategies and for shaping public wetlands policy:

Technical: Sedimentation pins and the sedimentation table are the most accurate indicators of marsh response in micro- and mesotidal settings.

Management: The sustainability of marshes is understood both locally and regionally with the application of a single, simple, and inexpensive monitoring approach.

Future Applications: Candidate monitoring sites throughout the United States were proposed to the National Biological Service for a national marsh-management program.

ACKNOWLEDGMENTS

Funding for this project was provided by the Department of the Navy under Interagency Agreement No. IA 5000-8-8002 with the Department of the Interior.

LITERATURE CITED

Cahoon, D.R. and R.E. Turner, 1987. Marsh accretion, mineral sediment deposition, and organic matter accumulation: clay marker horizon technique. In R.E. Turner and D.R. Cahoon, eds. Causes of Wetland loss in the Coastal Central Gulf of Mexico. Vol. II: Technical Narrative. Final Report to Minerals Management Service, New Orleans, LA. Contract No. 14-12-0001-30252, OCS Study/MMS 87-0120, p. 259-275.

Cofer-Shabica, S.V. and L.D. Nakashima, 1993. Secular and recent rates of local sea level rise and their impacts on wetland sedimentation. International Symposium Coastal Geomorphology, Hilton Head Island, SC.

Cofer-Shabica, S.V. and L.D. Nakashima, 1992. Sedimentological equilibrium of marshes and mudflats at Cumberland Island National Seashore, Georgia, Seventh Conference Research and Resource Management in National Parks, George Wright Society, Jacksonville, FL, 11 pp.

DeLaune, R.D., R.H. 1Baumann, and J.G. Gosselink, 1983. Relationships among vertical accretion, coastal submergence, and erosion in a Louisiana Gulf Coast marsh. *J. Sed. Petrol.* 53:147-157.

Knaus, R.M. and D.L. Van Gent. 1987. Marsh accretion, mineral sediment deposition and organic matter accumulation: rare earth stable tracer technique. In R.E. Turner and D.R. Cahoon, eds. Causes of Wetland Loss in the Coastal Central Gulf of Mexico. Vol. II: Technical Narrative. Final Report to Minerals Management Service, New Orleans, LA. Contract No. 14-12-0001-30252, OCS Study/MMS 87-0120, p. 145-180.

Nakashima, L.D., J.M. McCluskey, N.P. Psuty, and P.A. Gares. 1983. Short Term Protection of a Rapidly Eroding Beach, Coastal Zone '83, ASCE, San Diego, CA, p.682-697.

Pennington, W., R.S. Canbray, and E.H. Fisher. 1973. Observations on lake sediments using fallout ^{137}Cs as a tracer. *Nature* 242:326-326.

Pethick, J. And D. Reed. 1987. Coastal protection in an area of salt marsh erosion. Proc. Coastal Seds. 1987, ASCE, New Orleans, LA, p.1094-1104.

Schoot, P. And J. De Jong. 1982. Sedimentation and erosion measurements using the sedi-eros table (SET). Rijkswaterstaat Notikie DPMI-82.401, Deltadienst, the Netherlands.

Tanner, W.F. 1978. Standards for measuring shoreline changes: Coastal Research and Geology Department, Florida State University, Tallahassee, FL, 88 pp.