CLIMATE CHANGE, RISING SEA LEVEL AND THE FATE OF COASTAL WETLANDS

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Abstract. Coastal wetlands provide numerous ecological functions and protect urban areas from saltwater intrusion and storm surge. These areas occur at the land-sea interface and are strongly influenced by changing sea-level. Hence, it is of interest to characterize the effects of sea-level rise anticipated to accompany global climate change in the next century. I used a geographic information system (GIS) to define the impacts of sea-level rise on coastal wetlands. This paper presents an analysis of perimeter and interior wetland loss and/or gain of the Sapelo Island complex due to sea-level rise, river deposition and land erosion, during the period from 1920 to 1993. Results indicate significant perimeter and interior changes (loss and/or gain) in the coastal wetlands of the Sapelo Island complex. This study is a prerequisite for the quantification and prediction of responses of coastal wetlands to sea-level rise.

INTRODUCTION

Global climate change is expected to affect temperature and precipitation patterns, oceanic and atmospheric circulation, rate of rising sea level, and the frequency, intensity, timing and distribution of hurricanes and tropical storms. The current sea level rise ranges from 1.2-10.0 mm/yr. Tide gauge records from the Atlantic coast indicate relative sea level rise rates of 1.6 to 4.0 mm/yr over the past century (Stevenson *et al.* 1986). During the next half century, sea level is projected to increase by 80 cm or more due to climate change (Manabe and Wetherald, 1986; Schneider *et al.* 1992; Parkinson *et al.* 1994). Coastal wetlands in the southeastern United States have naturally evolved under a regime of rising sea level and specific patterns of hurricane frequency, intensity, and timing. Hence, it is of interest to quantify the effects of sea-level rise anticipated to accompany global climate change into the next century.

Rising sea level may cause five distinct physical impacts (National Research Council, 1987):
(1) direct inundation (or submergence) of low-lying wetland and dryland areas,
(2) erosion of soft shores by increasing offshore loss of sediment,
(3) increase the salinity of estuaries and aquifers,
(4) raise coastal water tables, and
(5) exacerbate coastal flooding and storm damage.

In addition, barrier islands often are so low-lying that water several meters deep may wash completely over them during unusually high storm tides, especially along the Atlantic and Gulf coasts of North America.

Impacts of Sea-Level Rise on Coastal Wetlands

Sea level along the coast of Georgia has risen 1.66-2.37 mm/yr for the period 1940 through 1972 (Hicks and Crosby, 1974). The trend along the Atlantic Coast during this period ranged from 1.4 to 5.0 mm/yr. The rate of deposition and the relative change in sea level will effect both the total thickness of salt marsh soil and the fate of the marsh (Chapman, 1974). If the rise in sea level is greater than the rate at which sediment is added, the marsh will eventually sink below sea level. If the deposition is greater than sea-level rise or if the sea level drops, then the surface of the marsh will pass eventually into a terrestrial stage. When the rate of deposition and the rise in sea level are the same, the marsh surface will remain in equilibrium.

Letzsch (1983) calculated a deposition rate of 2mm/yr for the salt marsh in the Sapelo Island complex. A later study (Letzsch 1986) showed that this rate of deposition (2 mm/yr) was substantially lower than a previous mean deposition rate of 6.5 mm/yr. Hence, the deposition rate of the Sapelo Island salt marsh currently appears to be less than the sea level rise.

DeLaune *et al.* (1983) postulated that if accretion, currently 6.7 mm/yr, and sea level increase (10.00 mm/yr) continue at present rates, the Louisiana marsh in their study will be converted to an open water body. Conceptually, the dynamics of vertical accretionary adjustments to sea-level rise are widely accepted as the primary factor in determining long-term marsh stability (Kearney *et al.*, 1994).

The Chesapeake Bay is experiencing rapid rates of relative sea-level rise of about 3 mm/yr. At the same time, the coastal wetlands have experienced rapid rates of land loss. These losses can be attributable to an accretion deficit: relative sea-level rise is faster than vertical accretion of the marshes which are ultimately inundated (Stevenson *et al.*, 1986). Geomorphically, the land loss is dominated by interior land loss processes, including the formation of interior ponds.

Unlike many of the coastal wetlands on the mainland, barrier islands are exposed to significant wave activity and have very limited or no protective beaches (Downs *et al.*, 1994; Wray *et al.*, 1995). Wetland loss of marsh-dominated islands (e.g., the Sapelo Island complex, GA) may involve three major group of processes:
(1) perimeter erosion (by wave action),
(2) channel formation and enlargement, and
(3) interior pond formation.

The objective of this study is to define how coastal wetlands respond to rising sea level using the Sapelo Island complex as a model system.

STUDY AREA

The Sapelo Island complex is located eight kilometers off the Georgia coast near Brunswick, GA. The study area, which includes Sapelo Island and Blackbeard Island, encompasses more than 100 square kilometers of marshland and forested uplands (Figure 1). The State of Georgia owns the vast majority of Sapelo Island and leases the southern part to the University of Georgia's Marine Institute. The northern two-thirds of the island is part of the R. J. Reynolds Wildlife Management Area, and is also the location of the Hog Hammock community. The entire area is managed for the State of Georgia by the Game and Fish Division of the Department of Natural Resources.

METHODS

This study uses a Geographic Information System (GIS) approach in defining the impacts of sea-level rise on coastal wetlands. This approach has proved to be excellent in handling the complex topology of the wetland/water interface (Kearney *et al.*, 1988; Downs *et al.*, 1994). In its most basic form a GIS is a computer-based system for integrating the collection, processing, storage, retrieval, analysis and display of geographic data. The historical comparison of island change from 1920 to 1993 is conducted by delineating wetland/water and upland/wetland boundaries in ARC/INFO GIS. Wetland loss and/or gain due to sea-level rise, river deposition and land erosion are detected by conducting an overlay of the coverages in the database followed by statistical analysis.

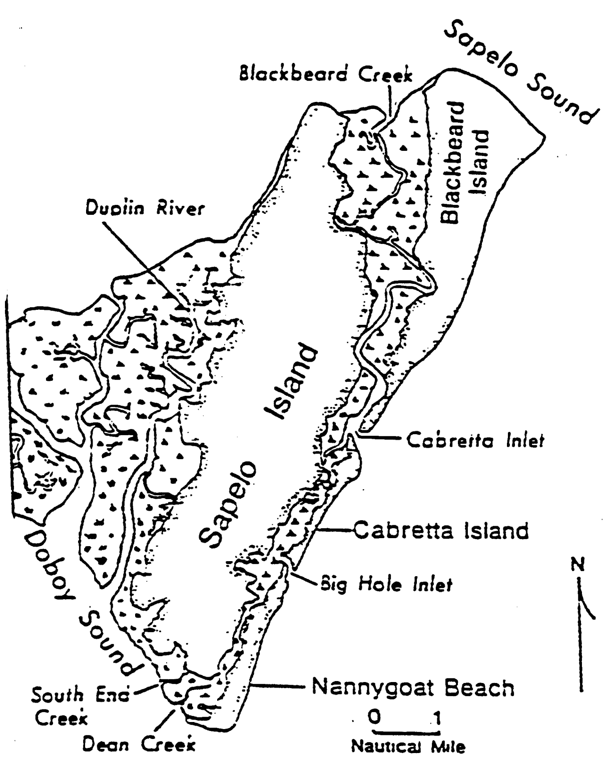

Figure 1. The Sapelo Island complex.

FINDINGS

The observed wetland loss is divided into four geomorphic types: (1) perimeter land loss, (2) channel widening and extension, (3) channel ponding, and (4) non-channel ponding. Collectively, (2), (3) and (4) produce all the interior wetland loss. A channel is a long narrow body of water, and it may widen or increase in length with time. Ponds can form or enlarge in two situations: channel ponds which are on the drainage network, usually at the head of a channel; or non-channel ponds which are not connected to an obvious surface channel. These interior wetland loss types are important as, in general terms, they can be interpreted as indicating inundation due to relative sea-level rise (Kearney *et al.*, 1988; Downs *et al.*, 1994). Channel widening and extension can be primarily attributed to tidal action with the increased flows brought on to the marsh surface by rising sea level. Ponds primarily form due to a deficit of sediment or organic input. The increased waterlogging kills the marsh plants (DeLaune *et al.*, 1994), and the exposed substrate is removed by other processes such as wave action. Perimeter island loss is primarily due to erosion from wave action and in-place drowning with sea-level rise as an underlying cause. Perimeter island gain was also detected in some areas.

CONCLUSIONS

The presently projected global warming may cause a substantial rise in the sea level. Current evidence indicates that a 0.3 m rise could occur in the next 50 years, a 0.5 to 2.0 m rise by 2100, and a 5 m rise in the next 200 to 500 years. Such a rise will inundate wetlands and lowlands; accelerate coastal erosion; increase the risk of flood disasters; create problems with respect to drainage and irrigation systems; and increase salt water intrusion into groundwater, rivers, bays and farmland. These effects could damage port facilities and coastal structures; destroy quality farmland; disrupt fisheries and bird habitats; diminish storm buffer protection; and result in the loss of recreational beaches. Because the increase in the rate of sea-level rise will be very gradual, it may be difficult to reach a consensus about the need for taking actions. Unfortunately, present data on sea-level are limited.

Communities can respond to sea-level rise by
a) defending the shore,
b) raising the land surface either naturally or artificially,
c) moving present activities and developments landward, or
d) adapting to increased flooding and inundation.

The rising sea level is not unprecedented. Many areas of the world have experienced substantial local rises. This constitutes a valuable body of experience that could be useful when responding to future sea-level increases.

RECOMMENDATIONS

Research

Governments and the world scientific community needs to develop a coordinated international research program on the impact and policy implications of sea-level rise. This would entail:

a) improving the accuracy of estimates of future rise in sea level;
b) defining the ecological, economic, and social costs and benefits of coastal defense systems, planned resettlement, and other strategies;
c) developing methods and models for integrating the diverse interdisciplinary information about the impact and policy implications of sea-level rise, and
d) investigating the experiences of areas that have undergone local rises in sea level.

Monitoring

Coordinated local, regional, and international programs that monitor sea-level rise, related processes, and their impacts need to be initiated. These programs should examine:

a) sea levels, tides, waves, surges, and related climatic parameters;
b) hydrology and geomorphology including runoff, salinity, sediment transport, and changes in sea bottoms and shorelines;
c) ecology, especially the responses of individual species and entire ecosystems to sea-level rise;
d) social aspects, particularly the reactions of human populations to the threats involved with sea-level rise, and
e) demographic and economic activities in areas potentially affected by sea-level rise.

Awareness

It is important to increase the awareness of the implications of sea-level rise for present and future developments and planning activities. It will be necessary to:

a) bring together scientists, engineers and policy makers local, regional and international workshops;
b) brief Ministers of national governments on the potential impact of sea-level rise; and
c) incorporate sea-level rise and other effects of climate change into the curricula of secondary schools and universities.

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