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Saltmarsh Loss in Southeastern North Carolina Lagoons: Importance of Sea Level Rise and Inlet Dredging

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ABSTRACT

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Salt marshes can maintain themselves during perods of relative sea level (RSL) rise through accumulation of autochthonous plant biomass and by capturing sediments. Lagoonal salt marshes in southeastern North Carolina accumulate 358 g m^2yr^{-1} of roots and rhizomes within their sediments. At an average bulk density of 0.3 g cm^{-3} the marsh can vertically accrete 1.2 mm yr^{-1}. The average RSL rise for the past 40 years was 1.9 mm yr^{-1}, thus these salt marshes cannot maintain themselves through autochthonous production alone. Large quantities of sand are available to these marshes through inlets and historical data show that marshes disappeared when this sediment source was eliminated. The predicted increase in the rate of RSL and the removal of large quantities of sand for beach renourishment on developed barrier islands may significantly hasten the drowning and disappearance of large areas of salt marsh in the lagoons of southeastern North Carolina.

ADDITIONAL INDEX WORDS: *Adverse impact, dredging, salt marsh, sea level wetlands.*

INTRODUCTION

Coastal ecologists and managers have long accepted the paradigm recently reiterated by REDFIELD (1972) which holds that tidal marshes can maintain themselves during periods of rapid sea level rise by capturing sediments and adding organic matter through deposition of plant tissues. The paradigm does not seem to apply to broad river deltas underlain with poorly consolidated sediments such as the Mississippi River delta where sediment compaction has accelerated the rate of apparent sea level rise (GAGLIANO *et al.*, 1981). In fact, the paradigm has now been challenged for salt marshes in general (STEVENSON *et al.*, 1985a; 1985b).

On the Mississippi delta in Louisiana 102 km^2 of tidal wetlands are lost each year, with much of the loss attibuted to sediment starvation caused by human control of the Mississippi river and other indirect human alterations (GAGLIANO *et al.*, 1981). Tidal wetlands must accumulate materials to maintain themselves in the intertidal zone and do so with allochthonous inputs of sediments (riverine or marine origin) or autochthonous additions (plant and animal debris). In most drowned river valley type estuaries sediments derived from terrestrial ecosystems dominate. During storm events as as much as 17 cm of sediment can be added during a short time (SCHUBEL and HIRSCHBERG, 1978).

Along the southeastern coast of North Carolina a series of narrow bar-built estuaries are found which lack significant river inputs of sediment and fresh water (Figure 1). These estuaries are clear, contain high salinity water (> 30 ‰) and are important to coastal fish stocks. Because they lack significant input from rivers they are ideal for testing hypotheses regarding the importance of marine sediments and autochthonous marsh production to the maintenance of tidal marshes during sea level rise.

MATERIALS AND METHODS

The accumulation of organic matter was determined with litter bags buried at four different sites between 27 January and 2 February 1984. Three of these sites correspond to the 2 m, 12 m and 18 m sites described in detail by YELVERTON and

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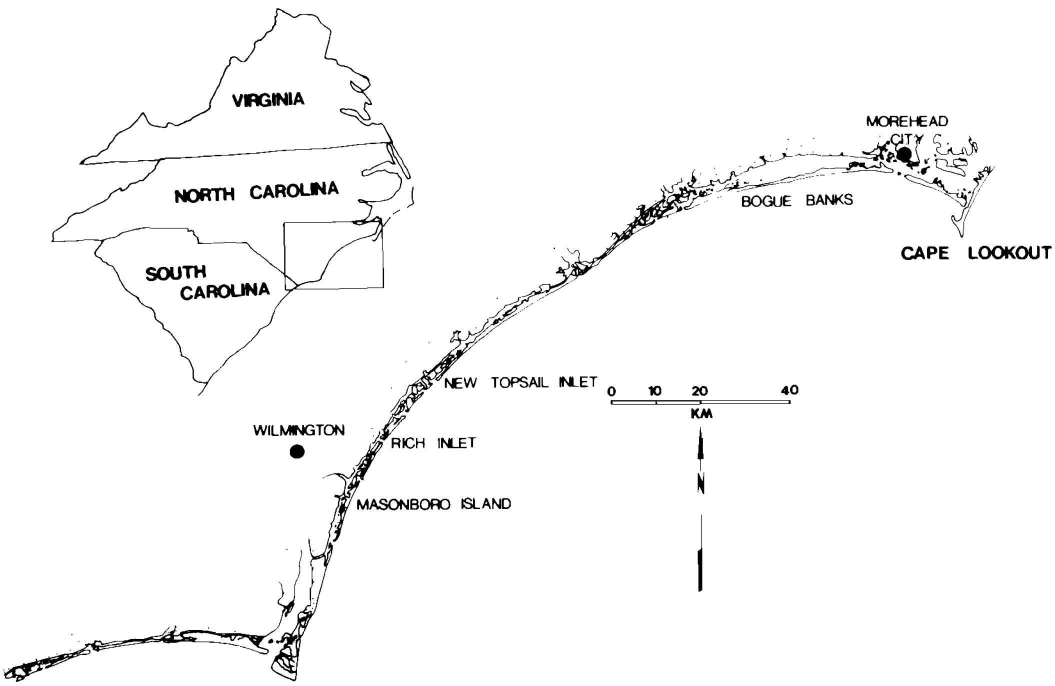

Figure 1. Southeastern coast of North Carolina (USA) between Cape Fear and Cape Lookout showing the narrow bar-built estuaries, inlets and salt marshes. Note the lack of marsh behind Bogue Banks. Insert shows the location relative to North Carolina and neighboring states.

HACKNEY (1986) in a medium height form *Spartina alterniflora* marsh. The final site was in a short-form *S. alterniflora* marsh in Bradley Creek described by PADGETT *et al.* (1986). These sites represent the range of conditions found in marshes along southeastern North Carolina, from highly reduced (Eh= −200 mV), poorly drained sediments to well drained, oxygenated sites. Forty-eight bags (10 x 20 cm, 1.6 mm mesh, fiberglass screen) were inserted into the sediment through a vertical slit made with a flat spade. Each bag was positioned such that the top edge of the bag was 5 cm from the surface and the bottom 15 cm. Each bag was sealed in the sediment by pressing lightly on both sides of the slit. This procedure minimized damage to plant roots and insured that each litter bag was in contact with living roots at the start of the experiment. No delay in decomposition was noted as in previous studies (HACKNEY and DE LA CRUZ, 1980). Litter bags were filled with mixed age, roots and rhizomes which were air dried to a constant weight. A conversion factor which related air dried mass to mass dried at 103° C allowed the estimation of initial mass. Eight bags were removed from each site every two months for a year, the contents washed and dried at 103° C and related to the initial weight. Decay rates were calculated based on linear regressions of bags at each site.

Data on dredging and sediment removal were obtained from the U.S. Army Corps of Engineers, Wilmington District, Wilmington, North Carolina. Surface areas of lagoons were determined by Polar Planimetry and included marshes, shallow water as well as dredged and natural deep-water channels. The location of New Topsail Inlet (Figure 2) was determined by two means. Analysis of sequential aerial photographs (1938-1986) provided information on contemporary history. These photographs also identified narrow, elongate islands within the lagoon which are indicative of former inlet locations. Such islands develop where sands of the flood tidal delta cover adjacent marsh and indicate the location of a former inlet.

Secondly, the inlet location was derived from inspection of historic coastal maps and charts.

WOMBLE's 1738 map is the first and most accurate in terms of delineating this part of the North Carolina coast. All charts and maps were enlarged to a common scale. Verification of inlet migration through coring confirms that the southern part of Topsail Island is underlain by an inlet fill sequence (CLEARY and HOSIER, 1979).

RESULTS AND DISCUSSION

Decomposition of below-ground materials in-situ was slow (25.5% per year). No difference was found in decay rates among the four sites despite inherent differences among sites and this value represents the results of a regression equation based on combined data. Approximately, 75% (358 g $m^{-2}yr^{-1}$) of the average annual NPP (Net Primary Production) of 480 g $m^{-2}yr^{-1}$ (STROUD, 1976; YELVERTON and HACKNEY, 1986) remains in the sediment each year. The average bulk density of below-ground materials in tidal marshes is 0.3 g cm^{-3} (STEVENSON *et al.*, 1986). At this bulk density the marsh is accreting 1.2 mm yr^{-1} or 1 cm of vertical accretion occurs for each 3 kg m^{-2} of organic material accumulated in marsh sediments. Sea level is rising 1.9 mm yr^{-1} (STEVENSON *et al.*, 1986) or 1.0 cm every 5.2 years. The marshes are adding only 1.86 kg m^{-2} of organic matter every 5.2 years which means that the tidal marsh is inundated by an additional 3.7 mm every 5.2 years at the present rate of SL rise. The almost constant seawater salinity and low clay content of marsh sediments (YELVERTON and HACKNEY, 1986) confirm the assumption that terrestrial riverborne sediments are relatively insignificant to these marshes. Marine sands are abundant nearshore and the low mesotidal regime along this part of the North Carolina coast produces moderate size flood tidal deltas. These sandy deltas typically provide substrate for salt marsh establishment (GODFREY, 1976; CLEARY and HOSIER, 1979; HAYDEN and DOLAN, 1979). Coarse sands constituted 56% of the inorganic sediments in one typical marsh 1-2 km from Rich's inlet (YELVERTON and HACKNEY,

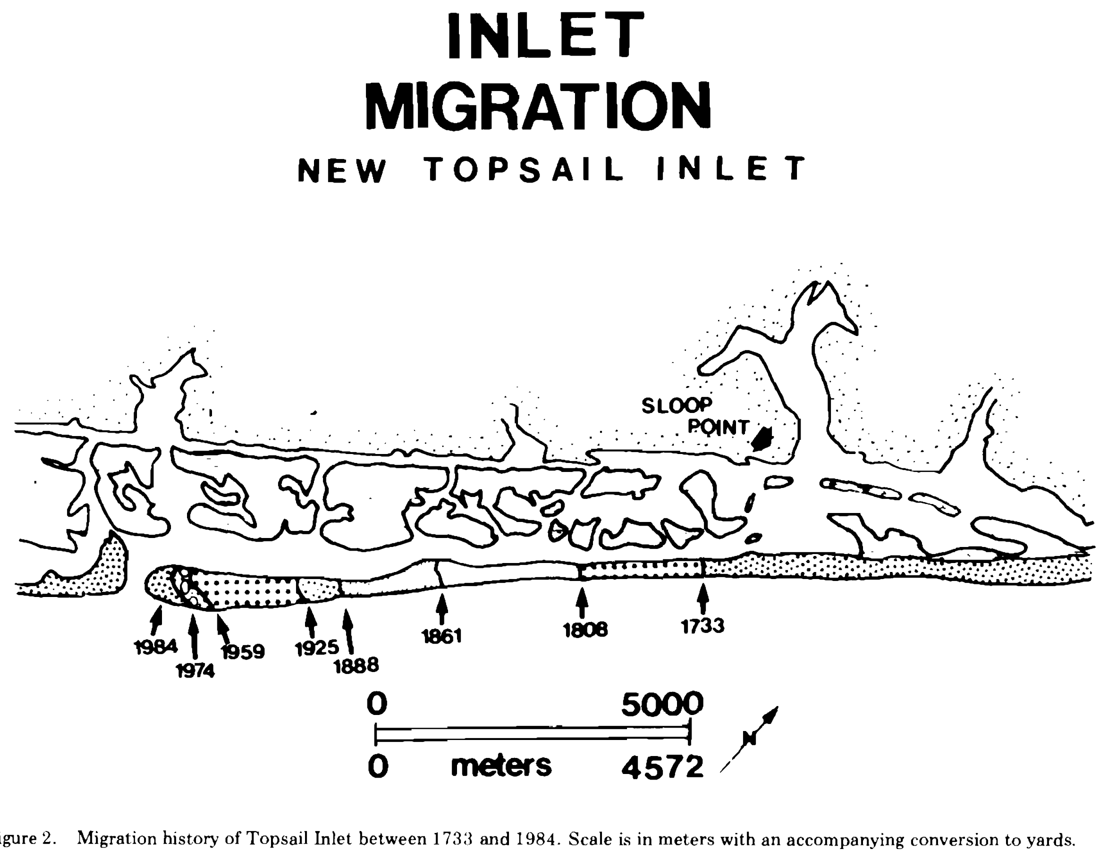

Figure 2. Migration history of Topsail Inlet between 1733 and 1984. Scale is in meters with an accompanying conversion to yards.

1986). Shallow cores from marshes located away from contemporaneous inlet influences show that 80% of the upper 1 m of sediment is composed of materials greater than 63 μm in size also suggesting that fine, muddy sediments are volumetrically unimportant (CLEARY and HOSIER, 1979). A marsh near Rich's Inlet contained only 10% organic matter in the top 20 cm of sediment (YELVERTON and HACKNEY, 1986) indicating that marine sands are much more important than autochthonous organic production to the natural maintenance of the marsh relative to sea level rise.

The implication of these data is that if marine sands are denied to these lagoonal marshes, rising sea level would eventually drown the marshes and they would disappear. The migration history of New Topsail Inlet since 1738 provides an example of this natural process (Figure 2). Since its opening in pre-colonial times, the inlet has migrated 10 km to the southwest (Figure 2). Marshes formed on flood tidal deltas associated with 18th and 19th century inlets have visibly disintegrated. Where marshes once flourished an open, shallow bay now is present. Other examples of locally disintegrating marshes also exist, notably Masonboro Island (Figure 1). Along this 14 km long, narrow island the best developed marshes occur in the vicinity of historic or active inlets and along the backbarrier fringe where overwash fans extend into the lagoon (CLEARY and HOSIER, 1979).

Perhaps the best example of the role of inlets and marine sands to marsh development and maintenance on a regional scale is Bogue Banks, a 40 km long, 1.1 km wide barrier island (Figure 1). It is composed of a Holocene regressional recurved beach ridge sequence that fronts a lagoon almost free of marshes. Since its initial development 4000 years B.P. the wide, high barrier island has effectively prohibited coarse grained sediments from entering the lagoon. Subsequent sea level rise has drowned the former marsh producing a lagoon (CLEARY and HOSIER, 1979; STEELE, 1980; HINE and SNYDER, 1985).

ORSON *et al.* (1985) speculated that tidal marshes will disappear even more rapidly if the rate of sea level rise increases. HOFFMAN (1984) predicts that sea level will rise between 4.8 and 17.1 cm by the year 2000. Even assuming his lower estimate, the low NPP of the lagoonal marshes in southeastern North Carolina will not match such an increase. Other marshes with higher autochthonous production (GOOD *et al.*, 1982) may survive this more rapid sea level rise. REDFIELD and RUBIN (1962) note accretion rates of 1.5 to 6.3 mm yr^{-1} for east coast marshes. Lagoons which have no riverine sediments must depend exclusively on transport of marine sands into the lagoons.

Human activities along the southeastern North Carolina coast are disrupting the transport of sand into these lagoons. Many inlets are maintained for recreational and commercial boat traffic by dredging. Jetties have been constructed to prevent sand from moving into inlets and sand stored in inlet systems is regarded as a resource for beach renourishment on developed barrier islands. Between 1967 and 1985 a minimum of 776,899 m^3 of sand was removed from New Topsail inlet (Figure 1) and the channels inside the inlet (Unpublished Reports, U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC). Similarly, over 5.8 million m^3 was removed from Masonboro inlet (Figure 1) between 1957 and 1985. The total areas of the lagoons near these two inlets is 867 and 1187 ha, respectively. If all of this dredged sand were instead added to the estuarine area it would add 5 mm yr^{-1} of vertical accretion to the sound area near Topsail inlet and 18.8 mm yr^{-1} near Masonboro inlet; more than enough to match sea level rise.

Sediment transport through inlets is complex and occurs even with the current dredging program. In fact, much of the sand removed by dredging probably finds its way back into the inlets. Based on the migration of New Topsail inlet it has taken about 250 years for the marsh to drown. With an increased rate of sea level rise and the potential change of sediment transport rates into the sounds by dredging, these marshes will probably be even more ephemeral. It is impossible to know if current dredging frequency is having a significant impact on sand transport to marshes. As the rate of SL rise increases, however, so does the probability that sand removal will hasten marsh submergence.

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□ RESUMEN □

Las marismas salinas pueden mantenerse durante periodos de subida del nivel relativo del mar (RSL) a través de la acumulación de biomasa vegetal autóctona y mediante captura de sedimentos. Las marismas salinas lagunares del sureste de Carolina del Norte acumulan 358 g m^2 año^{-1} de raices y rizomas en sus sedimentos. A una densidad masiva media de 0.3 g cm^{-3} la marisma puede crecer verticalmente 1.2 mm año^{-1}. El aumento medio del RSL en los últimos 40 años fue de 1.9 mm año^{-1}, de modo que estas marismas salinas no pueden mantenerse por si mismas solamente mediante la producción autóctona. Son accesibles grandes cantidades de arena a estas marismas a través de comunicaciones con el mar, y los datos históricos indican que las marismas desaparecieron cuando esta fuente de sedimentos fue eliminada. El incremento previsto en la tasa de RSL y la remoción de grandes cantidades de arena para realimentación de playas en las islas barreras desarrolladas pueden acelerar significativamente el anegamiento y desaparición de grandes áreas de marisma salina en las lagunas del sureste de Carolina del Norte.

□ ZUSAMMENFASSUNG □

Während Perioden der steigenden Relativmeereshöhe (RSL) können sich Salzwassersumpfen durch die Anlagern der bodenständigen Biomasse und die Erbeuten der Sedimente unterhalten. In der Südost der Nordkarolina anlagern Lagunensumpfen unter ihren Sedimente 358 g m^2pro Jahr^{-1} Würzeln und Rhizome. Bei einer durchschnittlichen Massendichtigkeit von 0.3 g cm^{-3} können die Sumpfen 1.2 mm pro Jahr^{-1} vertikal zuwachsen. Im Lauf der vergangenen 40 Jahre war der durchschnittlich Ansteig der RSL 1.9 mm pro Jahr^{-1}, so können sich diese Sumpfen allein durch bodenständige Herstellung nicht unterhalten. Grosse Menge Sands stehen zur Verfügung der Sumpfen durch Eingänge; die Geschichtsdata zeigt es, wenn diese Sedimentquellen ausgeschlossen sind, haben die Sumpfen verschwunden. Die voraussagene Ansteigsgeschwindigkeit der RSL und das Wegschaffen grossen Mengen Sands zur Strandnahrung der entwickelten Sperrinseln vermöglichen wesentlich die Ertrinken und die Verschwinden vieler Sumpfen südostlichen Nordkarolinas.