[Gulf and Caribbean Research](https://aquila.usm.edu/gcr)

Volume 7 | Issue 3

1983

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## Recommended Citation

Reidenbaugh, T. G., W. C. Banta, M. Varricchio, R. P. Strieter and S. Mendoza. 1983. Short-Term Accretional and Erosional Patterns in a Virginia Salt Marsh. Gulf Research Reports 7 (3): 211-215.
Retrieved from https://aquila.usm.edu/gcr/vol7/iss3/17
DOI: https://doi.org/10.18785/grr.0703.17

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*Gulf Research Reports,* Vol. 7, No. 3, 211–215, 1983

# SHORT-TERM ACCRETIONAL AND EROSIONAL PATTERNS IN A VIRGINIA SALT MARSH

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*ABSTRACT* We estimated 3-year average rates of accretion and erosion in different vegetation zones of a juvenile *Spartina alterniflora* salt marsh at Wallops Island, Virginia, by precise releveling of a fixed grid. Seaward of the marsh there was extremely variable accretion and erosion in tidal flat, as a result of winter ice scouring and transport. At the lower limit of the marsh, tall *Spartina* edge marsh accreted at about 6.2 mm $yr^{-1}$, well in excess of relative sea level rise, supplied by mineral sediments. At the upper limit, levee *Spartina* and high marsh accreted at about 1.6 mm $yr^{-1}$, in equilibrium with sea level rise. Accretion there was supplemented by organic sediments from tidal wrack. At mid-elevations, medium *Spartina* middle marsh eroded slightly at about –0.6 mm $yr^{-1}$, and low-density *Spartina* and bare soil eroded rapidly at about –5.3 mm $yr^{-1}$. These zones may be relatively sediment-starved. The most severe erosion resulted from vegetation diebacks beneath tidal wrack. Patterns of accretion and erosion show that this site is maturing topographically from a juvenile foreshore marsh to a creek-drained marsh.

## INTRODUCTION

Zonation in salt marshes is largely a function of substrate elevation relative to tidal flooding (Chapman 1938, Adams 1963). Substrate elevation may change with time as the result of mineral and organic sedimentation, biological production, decomposition, compaction, and scouring by wind, water, and ice. Positive elevational changes indicate net accretion of the substrate; negative changes, net erosion. Marsh succession on subsiding shores or along rising seas depends on the rates of these changes. Where accretion outstrips relative sea level rise, succession progresses from uncolonized tidal flats to low marsh, and then to high marsh, as in Shaler's (1885) description of succession. Where accretion is less than sea level rise, or where there is erosion, high marsh retrogressively succeeds to low marsh, and to tidal flat, as in the Mudge (1858)-Davis (1911) description. Immature salt marshes are mostly intertidal, allowing maximum accretion in excess of sea level rise. Mature salt marshes have substrate elevations near the plane of mean high water, and maximum accretion is usually limited to the rate of sea level rise (Ranwell 1972).

Vegetation of the marshes may influence these elevational changes. Plant shoots, especially leaf blades of the smooth cordgrass *Spartina alterniflora,* in low marsh, interfere with tidal flow, lessening sediment carrying capacities and promoting deposition (Redfield 1972). Root and rhizome mats physically bind the sediments, hindering their erosion (Redfield 1972). *S. alterniflora* is also a major primary producer in low salt marshes, forming a source of organic sediments.

There have been previous studies of long- and short-term elevational changes in salt marshes using historical records (Flessa et al. 1977), marker horizons (Bloom 1967, Richard 1978), vertical stakes (Ranwell 1964), and radioactivity (Armentano and Woodwell 1975, Delaune et al. 1978). Richard (1978) also considered seasonal variations in short-term changes. Most of these measurements, though, have been limited by extremely sparse data.

We estimated short-term elevational changes in a salt marsh by precise releveling of a systematic grid of many data points in different vegetation zones. Releveling allowed us to measure net elevational changes of the entire sediment column, including possible sediment compaction and decomposition, unlike coring to measure changes only above marker horizons. Objectives of the study were to determine rates of accretion or erosion in the different zones, variability in these rates, and patterns of elevational changes among all the zones. Measurements were made in a juvenile foreshore marsh in an area of pronounced recent marsh development leeward of an extending baymouth spit. Elevational changes there may typify juvenile marshes.

## METHODS AND MATERIALS

### *The Study Site*

This study was conducted in the Intensive Biometric Intertidal Survey (IBIS) study site at Wallops Island, Virginia, an Atlantic barrier (Figure 1). Salt marsh colonized Cow Gut Flat on northern Wallops Island, including the study site, since 1949, as Gunboat Point extended northward (Reidenbaugh 1978). Mean tidal range along Cow Gut Flat is 0.8 m.

The marsh includes seven vegetation zones that have been identified *in situ* and in color infrared aerial photographs (Reidenbaugh 1978). They are:

(1) Tidal flat: emergent substrate with no rooted vegetation, below the marsh edge.

(2) Tall *Spartina* edge marsh: monospecific stands of tall form *S. alterniflora* in soft substrate along the marsh edge and bordering juvenile tidal creeks, upward to about mean tide level. The lower limit of *S. alterniflora* varies from near

Manuscript received June 10, 1982; accepted December 8, 1982.

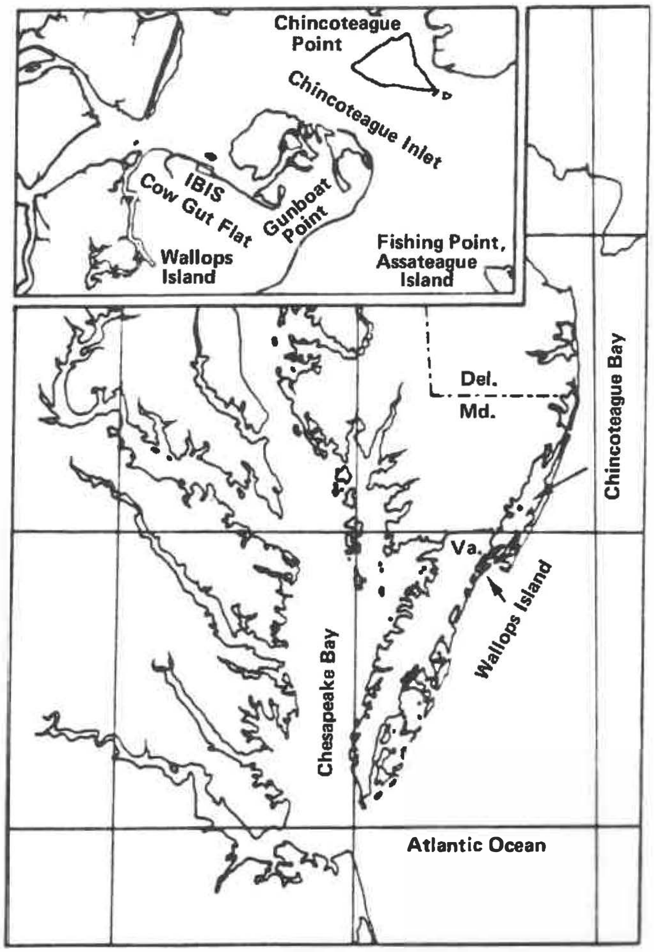


**Figure 1. Location of the study site (IBIS) at Wallops Island, Virginia.**

mean low water to midway between mean low water and mean tide level, depending on distance from spreading centers of colonization and hydrologic energy (Reidenbaugh et al. 1982).

(3) Medium *Spartina* middle marsh: medium form *S. alterniflora* in slowly drained areas of soft substrate above tall *Spartina* edge marsh, mostly between mean tide level and mean high water.

(4) Medium *Spartina* levee marsh: medium form *S. alterniflora* with subdominants *Salicornia* spp. and occasionals *Limonium* sp. and *Distichlis spicata* in quickly drained, sloping areas of firm, sandy substrate near high marsh, mostly between mean high water neaps and mean high water springs.

(5) Low-density medium *Spartina* marsh: sparse medium form *S. alterniflora* in scattered patches amid medium *Spartina* levee marsh and especially medium *Spartina* middle marsh. These have been partially devegetated by diebacks beneath tidal wrack, or have partially revegetated following complete devegetation by wrack (Reidenbaugh and Banta 1980).

(6) Secondary bare soil: similarly scattered patches that have been completely devegetated by tidal wrack (Reidenbaugh and Banta 1980).

(7) High marsh: saltbushes *Iva frutescens* and *Baccharis halimifolia*, with *Spartina patens*, *D. spicata*, *Salicornia* spp., and some *S. alterniflora*, above mean high water springs.

*Survey Data*

Elevational changes in these vegetation zones were estimated from two level surveys taken three years apart, in June 1975 and June 1978. In both, substrate elevation was surveyed at 201 hardwood stakes driven into the marsh in April–May 1975, in a 17,000-$m^2$ grid of 10 m by 10 m quadrats, extending from tidal flat upward to high marsh. Where stakes were missing in 1978, their positions were located by stretching a cloth tape in line with remaining stakes.

Levels were measured to the nearest 1 mm using simple transits and Frisco metric stadia, with shots of 100 m or less. These were converted to absolute elevations relative to the National Geodetic Vertical Datum (NGVD), by multiple level lines fore- and back-run to a National Oceanic and Atmospheric Administration benchmark, 1.5 km south of the grid on Wallops Island. Standard errors of both 1975 and 1978 level lines were ±2 mm. Tidal datum planes along Cow Gut Flat were previously related to NGVD (Reidenbaugh 1978).

The elevational difference at each stake from 1975 to 1978 was taken to be 3-year net accretion or net erosion. Stakes were grouped into the seven vegetation zones according to an August 1976 aerial infrared photomap (Figure 2), and elevational changes were averaged in each of the zones and reduced to annual rates (one stake that was in tall *Spartina* edge marsh in 1975 was included in tidal flat because it was ice-scoured bare in January 1977, and remained bare and below the marsh edge in 1978). Differences in mean changes were subjected to significance tests for analysis of variance (*t*- and *F*-tests).

## RESULTS AND DISCUSSION

Mean elevational changes ranged from +6.2 mm $yr^{-1}$ accretion in tall *Spartina* edge marsh to –5.3 mm $yr^{-1}$ erosion in low-density *Spartina* and bare soil (Table 1). The difference in erosion between low-density medium *Spartina* marsh and secondary bare soil was insignificant ($t = -0.40$, df = 26), so these two zones were combined, as they have similar origins and occupy similar environments. The two relatively high-elevation zones were also combined, medium *Spartina* levee marsh and high marsh, where difference in accretion was insignificant ($t = 0.30$, df = 76). Elevational change was so variable in tidal flat (standard deviation ±29.1 mm) that it was not significantly different than in any other zone. However, differences in changes among the four remaining vegetated zones (combined from six) were highly significant (Scheffe's $F$ for combined groups = 22.65, df = 3/183, $p < 0.01$).

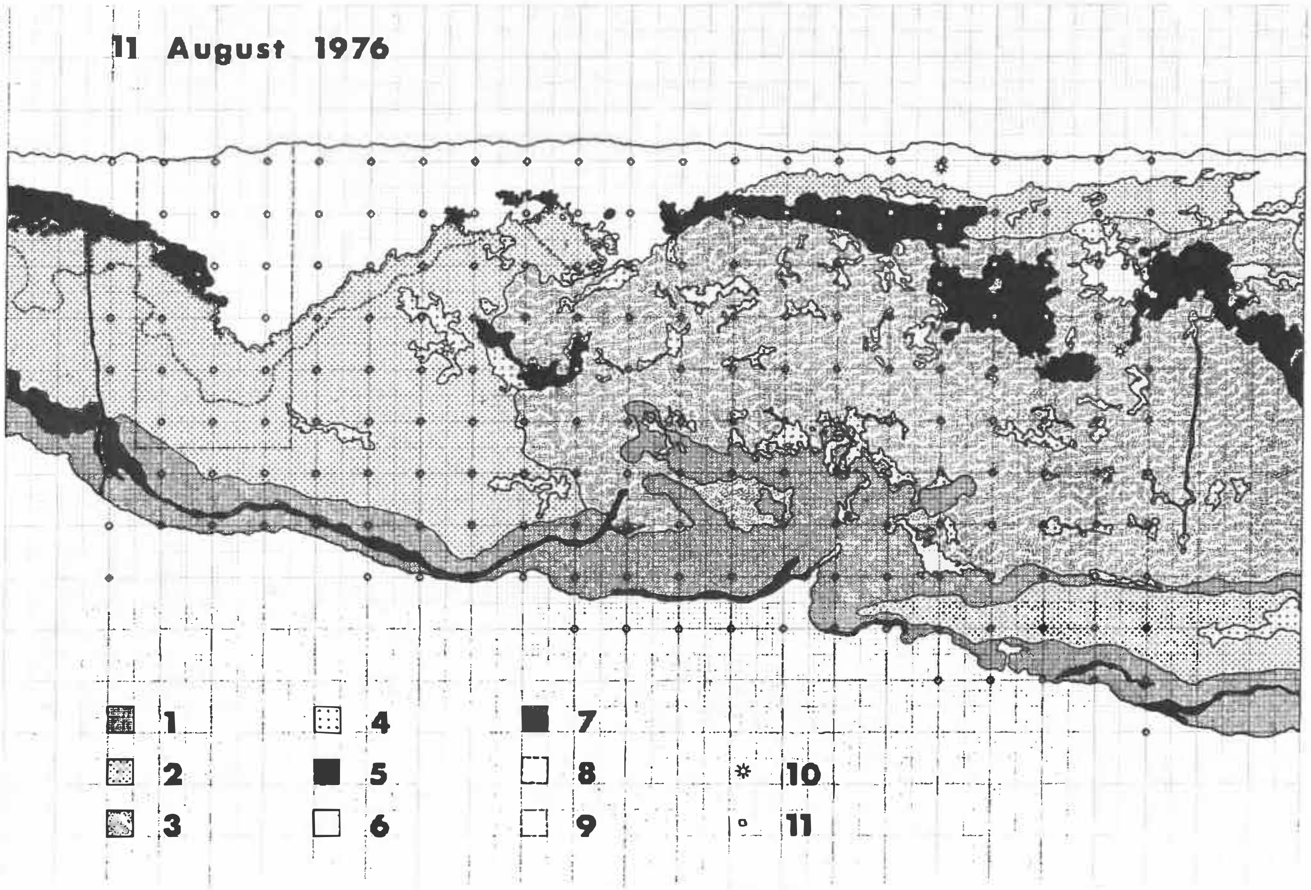


**Figure 2.** Photomap of the study site, showing the different vegetation zones. 1, 7: Tall *Spartina* edge marsh. 2: Medium *Spartina* levee marsh. 3: Medium *Spartina* middle marsh. 4: Low-density medium *Spartina* marsh. 5: Secondary bare soil. 6: High marsh. 8, 9, 10: Not applicable. 11: Wooden stake. Tidal flat is at bottom.

**TABLE 1. Mean rates of short-term accretion (+) and erosion (–), and significance between means (*t*), in different salt marsh vegetation zones at Wallops Island, Virginia.**

| Vegetation Zone | $\overline{X}$ (mm yr$^{-1}$) | n | Std. Dev. (±mm) | Zone 1. | Zone 2. | *t* Zone 3. | Zone 4. | Zone 5. |
|---|---|---|---|---|---|---|---|---|
| 1. Tidal flat | +1.0 | 14 | 29.1 | –– | 0.93 | 0.37 | 1.10 | 0.18 |
| 2. Tall *Spartina* edge marsh | +6.2 | 30 | 7.4 | 0.93 | –– | 4.92* | 6.18* | 3.98* |
| 3. Medium *Spartina* middle marsh | –0.6 | 51 | 5.0 | 0.37 | 4.92* | –– | 3.56* | 2.57* |
| 4. Low-density *Spartina* and bare soil | –5.3 | 28 | 6.7 | 1.10 | 6.18* | 3.56* | –– | 6.11* |
| 5. Levee *Spartina* and high marsh | +1.6 | 78 | 4.4 | 0.18 | 3.98* | 2.57* | 6.11* | –– |

*Significant at p = 0.01.

Sea level rise is estimated to be +2 mm yr$^{-1}$ at Assateague Island, Maryland-Virginia (Holdahl and Morrison 1974), near Wallops Island, so marsh substrate at Wallops Island must accrete at about +2 mm yr$^{-1}$ to maintain equilibrium. However, accretion and erosion estimates of the present study cannot be considered absolute, because standard errors of the 1975 and 1978 level lines may shift these estimates all by a few mm in either direction from actual changes (the standard error of all differences based on these level lines is ± 1.3 mm yr$^{-1}$, independent of standard errors of means shown in Figure 3). Relative differences in elevational changes among the vegetation zones, though, are unaffected. These differences suggest several conclusions (Figure 3).

First, the unconsolidated sediments in tidal flat are subject to extreme local accretion and erosion, in no consistent pattern. By far, the greatest individual measurements of accretion (+70 mm yr$^{-1}$) and erosion (–57 mm yr$^{-1}$) occurred in tidal flat. Extreme changes may result largely from winter

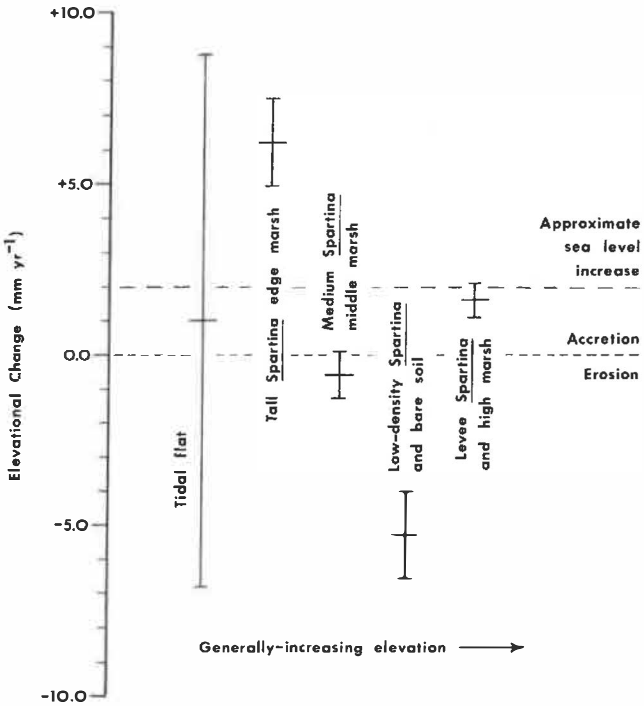


**Figure 3. Mean elevational changes in different vegetation zones at Wallops Island (bar height = ±1 standard error).**

ice scouring that evidently transports substantial sediment loads at low elevations. Thirty-five stakes were sheared off or uprooted from the sampling grid by ice low in the marsh during January–February 1977, including 100% of those in tidal flat and 62% in tall *Spartina* edge marsh. *S. alterniflora* roots and rhizomes bind the sediments sufficiently to resist most ice transport, so variability in elevational change is much less in tall *Spartina* edge marsh than in tidal flat. However, ice scouring is one of the factors that limits or modifies the lowest colonization of *S. alterniflora* in this marsh (Reidenbaugh et al. 1982), with at least one area along the marsh edge scoured of all vegetation in 1977. Richard (1978) found that ice scouring caused seasonal erosion in tidal flat and *S. alterniflora* edge marsh at Long Island, New York. Our measurements suggest that much of the eroded sediment from tidal flat at Wallops Island is redeposited in the same zone. Scouring by winter storm waves may also contribute some of this erosion and transport.

Second, tall *Spartina* edge marsh is accreting rapidly at about +6.2 mm $yr^{-1}$, well in excess of relative sea level rise. Thus, low areas of this juvenile marsh may succeed according to Shaler's (1885) description. Sediments in tall *Spartina* edge marsh consist almost entirely of fine sands with very little organic content (Reidenbaugh 1978). These probably derive from the southward littoral drift across Chincoteague Inlet that has supplied the prolonged accretion of Fishing Point on Assateague Island from the late 1800's to the 1940's, and of Gunboat Point on Wallops Island, from the 1940's to present (Reidenbaugh 1978). Very little deposition of muds indicates that this foreshore marsh occupies a higher energy environment than most interior marshes.

According to Valiela et al. (1978), *S. alterniflora* first colonizing tidal flats may develop into tall form because of ample water-borne nutrients. The tall form cordgrass promotes rapid sedimentation, as observed here. Consequently, the substrate accretes to higher elevations where it is flooded less frequently, and as the *S. alterniflora* multiplies, more plants compete for scarcer nutrients, resulting in shorter form cordgrass.

Third, there is some, albeit much less, accretion at about +1.6 mm $yr^{-1}$ at relatively high elevations, in levee *Spartina* and high marsh. This is near the rate of relative sea level rise, as in accretion of mature marsh substrates at similar elevations. However, there is no accretion, or slight erosion at about –0.6 mm $yr^{-1}$, at mid-elevations, in medium *Spartina* middle marsh. This differs from previously reported simple gradients of decreasing sedimentation from low to high elevations (Bloom 1967, Delaune et al. 1978, Richard 1978). We hypothesize that mid-elevations may be sediment-starved in this foreshore marsh, with most mineral sediments deposited lower, in tall *Spartina* edge marsh, and with most organic sediments deposited at higher elevations. Annual influxes of *S. alterniflora* tidal wrack from tall *Spartina* edge marsh supply bulk organics to high elevations in this marsh (Reidenbaugh and Banta 1980). Rafts of this wrack sometimes settle temporarily in medium *Spartina* middle marsh during their upward transport, but they are later refloated to high marsh, where they eventually decompose. Some of the decomposing wrack is incorporated into the substrate. Organic content of high marsh sediments here is only 3%, but this is greater than in low zones of this juvenile marsh (Reidenbaugh 1978). In Massachusetts, Valiela et al. (1978) observed influxes of tidal wrack in high marsh, where the decomposing organics seemed to substitute for water-borne nutrients in promoting tall form *S. alterniflora.* We have made similar observations at Wallops Island.

Redfield (1972) described different developmental stages of accreting *Spartina* marshes. Juvenile marsh follows colonization, and is typified by nearly continuous stands of tall form *S. alterniflora* uninterrupted by significant drainage creeks. That is followed by pan marsh, where water-retaining pans and tidal creeks develop from differential rates of accretion. At Wallops Island, the rapid accretion in low marsh, moderate accretion in high marsh, and no accretion or some erosion in between suggest that this foreshore marsh is beginning to mature topographically from the juvenile stage to the pan stage. Concentration of tidal flow in slight valleys from differential accretion and erosion will promote accelerated accretion and erosion alongside. Permanent creeks and pans will eventually evolve along these pathways.

Fourth, there is marked erosion in areas impacted by strandings of tidal wrack at mid-elevations, during its progression to high marsh. Areas both partially and totally devegetated by wrack eroded at about $-5.3$ mm yr$^{-1}$, possibly from organic decomposition and sediment compaction, as there was little evidence of surface scouring even though sediments were more exposed to wind and waves with reduced *S. alterniflora* cover (ice rarely reaches so high). Thus, wrack provides a mechanism for formation of "rotten spot" pans (Warming 1904, Harshberger 1916) here, but so far all impacted areas have revegetated after a few years, before they eroded sufficiently to form any pans (Reidenbaugh and Banta 1980). Organic content of the soil is probably too low, and sand content too high, in this juvenile marsh to allow pan formation by short-term decomposition and compaction. Still, erosion in the devegetated areas significantly hastens the topographic differentiation of the marsh that will eventually produce tidal creeks, and very likely will form pans as the marsh matures.

## ACKNOWLEDGMENTS

This study originated from course work at the Wallops Island Marine Science Center as part of the Intensive Biometric Intertidal Survey (IBIS). We thank the staff of the National Aeronautics and Space Administration's Wallops Flight Center for aerial photography, access to the study site, and use of the former Wallops Island Coast Guard Station as a laboratory. This study was funded in part by a grant from the Griffis Foundation.

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