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A potential mechanism for disturbance-mediated channel migration in a southeastern United States salt marsh

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Abstract

Coastal salt marsh tidal creeks are thought to show less channel adjustment/movement relative to their terrestrial fluvial counterparts. We propose a mechanism for disturbance-mediated bank failure that may allow/initiate channel migration in these otherwise stable systems. The stability of tidal creeks is promoted by the extensive vegetation root structure along the banks. However, wrack mats (i.e., dead vegetation) deposited on creek banks can cause the death of below-ground vegetation leading to bare, unstable banks that may slump into the channel. We measured the frequency of bank failures associated with wrack-disturbed sites along three creeks on Sapelo Island, Georgia, USA to determine whether these sites were vulnerable to erosion. Approximately 81% of the disturbed sites showed signs of bank failure. Therefore, wrack-induced bank failure may potentially lead to channel migration in creeks previously believed to be static landscape features.

Keywords: Wrack; Disturbance; Salt marsh tidal creek; Channel migration; Erosion

1. Introduction

Coastal marshes differ from their inland counterparts in several aspects. Vegetation along eastern (Atlantic Coast) USA salt marsh tidal creeks is dominated by *Spartina* spp., a cordgrass that thrives in saline conditions (Fischer et al., 2000). Salt marshes are also inundated twice a day from tides, and, as a result, flow within tidal creeks is bi-directional. Additionally, unlike their inland counterparts, salt marsh tidal creeks in eastern United States tend to be very static landscape features (Redfield, 1978; Gabet, 1998). Redfield (1978) noted that a meander bend in a New England salt marsh tidal creek had not migrated in the past 2000 yr. Furthermore, Gabet (1998) observed that the maximum lateral migration of tidal creeks in a California salt marsh was on the order of 23 mm/yr and concluded that the virtual absence of channel migration was due to the persistence of failed bank material. Erosion of banks below the rooted zone can be relatively rapid and result in slump blocks that collapse into the creeks as coherent units of sediment held together by a complex network of fine plant roots. The matrix of fine roots prevents the slump blocks from disintegration during bank failure (Gabet, 1998). Consequently, the failed slump blocks armor the channel banks, resulting in extremely slow erosion and channel migration rates.

Tidal creeks provide corridors for wrack (i.e., mats of dead vegetation) transport into and deposition on salt marshes. Deposited wrack mats often create bare spots by killing not only the surface vegetation, but also the sub-surface root structure indirectly via surface vegetation die-off (Hartman, 1988). Additionally, the extent of

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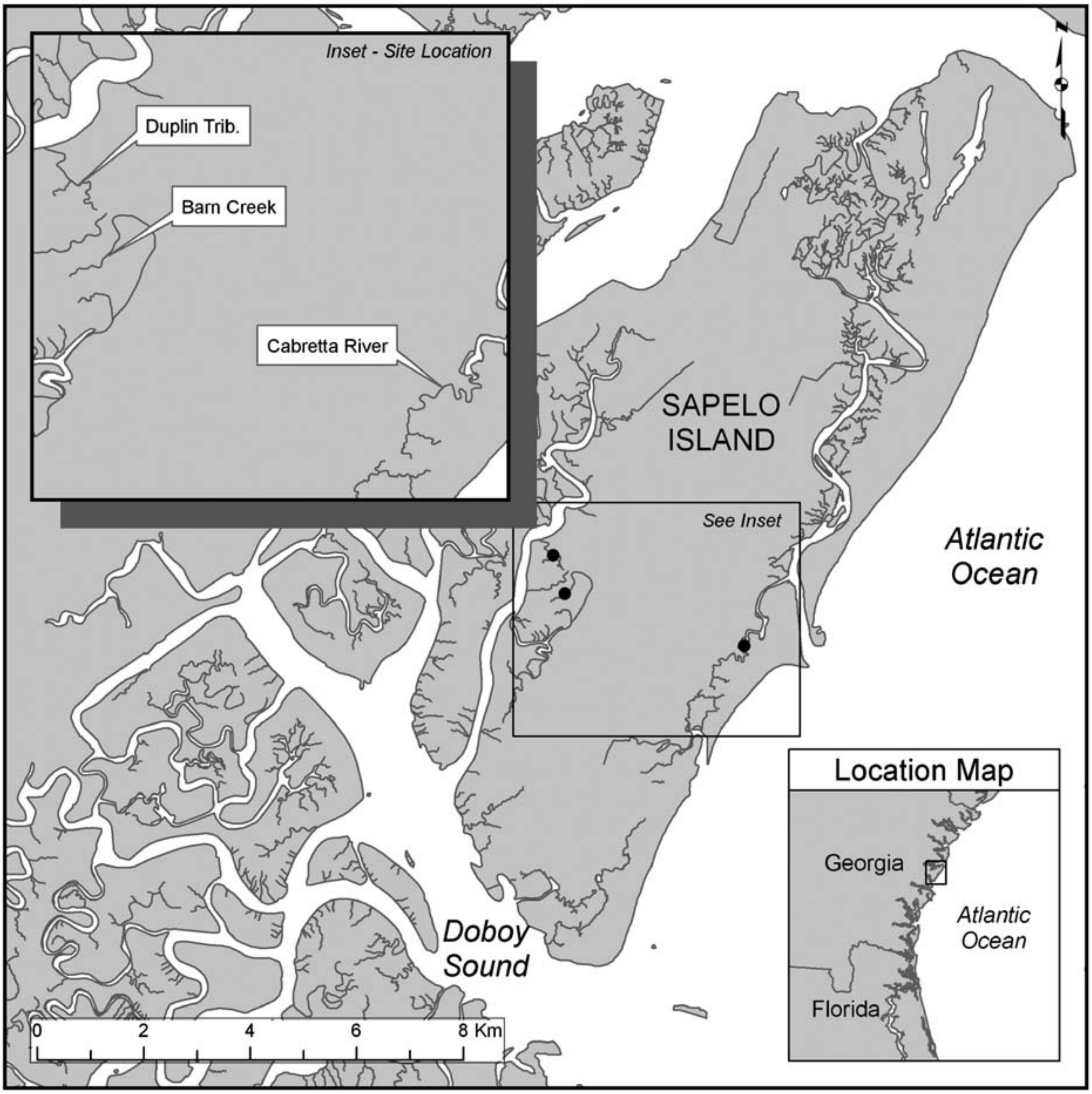

Fig. 1. Site location map for the three tidal creeks (Cabrettra R., Barn Cr., and Duplin Trib.) surveyed in this study on Sapelo Island, Georgia, USA.

vegetation destruction is limited by the size of deposited wrack. These bare spots may also persist for long periods of time (e.g., 1–5 yr). Because sediment lacking a complex fine root structure erodes more than twice as fast as the corresponding sediment with a dense fine root structure (Gabet, 1998), we hypothesize that deposition of wrack mats and subsequent destruction of above- and below-ground vegetation may influence erosion of tidal creek banks and, therefore, lateral channel migration. To test the first part of this hypothesis (i.e., that disturbed sites are prone to bank failure and erosion), we measured the frequency of bank failure in association with wrack-disturbance sites along three salt marsh tidal creeks on Sapelo Island, Georgia, USA. We hypothesized that disturbed sites should show signs of bank failure and erosion, which would be expected following the loss of roots, and is consistent with our suggestion that these sites may be preferential areas of erosion along tidal creeks.

2. Methods

Data were collected on Sapelo Island, a barrier island on the Georgia coast (Fig. 1). We quantified the number

Fig. 2. Wrack-disturbance site located on a sharp bend of a tidal creek on Sapelo Island, Georgia, USA. Both photos were taken at mid-tide. Panel A shows the extent of vegetation destruction as a result of wrack deposition on both the right and left hand banks, which is typical of Sapelo Island creeks. Panel B shows the erosion that often occurs in association with these disturbance sites. Panel B corresponds with the bottom left disturbance site noted in Panel A.

of disturbed sites along three tidal creeks (Barn Creek, Duplin Tributary, and Cabretta River) ranging from 1 to 2 km in length, and noted whether signs of bank failure (i.e., slumping) existed. Channel widths ranged from 1 m to >20 m and thawleg depth ranged from <1 m to >2 m at high tide. Cabretta River was the largest (>20 m wide at some points) of all three study sites, while Duplin Tributary and Barn Creek were more comparable (generally <7 m wide). The dominant vegetation along all three tidal creeks was *Spartina alterniflora*, which ranged in height from 1 to 2 m.

Wrack-disturbed sites were defined as bare patches without any vegetation within approximately 1 m of the active channel. The number of wrack sites exhibiting signs of bank failure (Fig. 2) along with those having a stable bank structure were recorded along both the right and the left bank of each tidal creek. The percentage of disturbed sites with evident signs of bank failure was calculated along with 95% binomial confidence intervals (Agresti and Coull, 1998).

3. Results and discussion

Salt marsh tidal creeks are often static landscape features that have minimal, if any, lateral channel migration (Redfield, 1978; Gabet, 1998). However, based on our observations along several tidal creeks, we hypothesized that wrack disturbances may influence the rates of erosion and, therefore, channel migration by removing the root structure responsible for maintaining stable bank forms. One of the first steps in addressing this hypothesis is to determine whether these wrack-disturbance sites demonstrate signs of active erosion.

Disturbed sites were prevalent along each tidal creek and often exhibited extensive signs of bank failure (Fig. 3). A total of eighty disturbed sites were observed adjacent to the creeks and approximately 81% of these sites exhibited signs of bank failure. Based on our literature review, we were unable to determine what percentage of a tidal creek bank should naturally be slumping into the channel. However, our results suggest that large percentages (68–90%) of disturbed sites are undergoing active slumping and erosion (Fig. 3). If the assumption is made that the distributions of disturbed sites with bank failure and disturbed sites without bank failure are equal, the binomial probability (Zar, 1999) of those two distributions being equal is extremely small ($p<0.0001$) in this study. However, it is important to note that we do not know what the true distribution of bank failure is along tidal creeks on Sapelo Island.

One of the primary tenets of Gabet's (1998) study was that, under non-disturbed conditions, the root

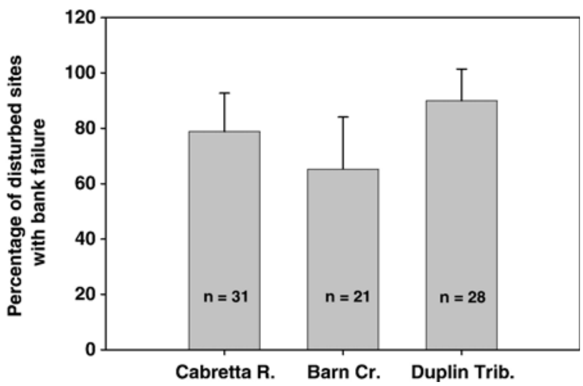

Fig. 3. Comparison of tidal creek bank stability associated with wrack-disturbance sites on Sapelo Island, Georgia, USA. Error bars represent mean ± 95% C.I.

structure is intact when the bank collapses into the creek channel and therefore decreases the rate of erosion relative to sediment lacking any root structure. Gabet (1998) concluded that unrooted bank sediment eroded twice as fast as its rooted counterpart. Because wrack disturbances have the capacity to destroy both above- and below-ground vegetation along tidal creeks (Hartman, 1988), it should also reduce or perhaps even remove the primary facet of tidal creek banks that make them resistant to erosion.

Therefore, drawing from Gabet's (1998) work, it is probable that these disturbed sites have the potential to erode significantly faster than their vegetated counterparts. Rough calculations using Gabet's (1998) erosion coefficients for unrooted banks (57 mm/yr) and rooted banks (11 mm/yr) suggest that disturbed sites may erode anywhere from 0.6 m to 2.9 m over the a 1–5 yr period (i.e., the typical time before re-colonization of a disturbed site). On the other hand, vegetated sites may erode anywhere from 0.1 m to 0.6 m over the same period.

Additionally, wrack-disturbance sites often occur adjacent to sharp bends along tidal creeks (Fischer et al., 2000; personal observation) and, as a result, could potentially enhance the formation of meander bends. Wrack-disturbance frequency may also be greater in areas where seasonal senescence provides large amounts of dead litter (Valiela and Rietsma, 1995; Pennings and Richards, 1998). Taken together, these studies suggest that erosion of tidal stream banks as a result of wrack deposition and the subsequent destruction of below-ground vegetation may be more frequent in climates where seasonal dieback occurs, and be both spatially explicit and a function of tidal creek geomorphology.

Our proposed mechanism should result in small but perhaps steady changes in channel form, consistent with the relatively slow rate of change in channel form of North American salt marsh creeks. Additionally, the extent of bank erosion will most likely be limited by the rates of vegetation re-colonization which will eventually result in the re-establishment of the bank-stabilizing root matrix. Therefore, the time periods during which disturbance-mediated bank erosion may occur are most likely limited, but nevertheless, important in terms of providing a window of opportunity. However, this mechanism of change may not be applicable to all coastal marshes, as salt marshes along the United Kingdom are undergoing rapid erosion (Wolters et al., 2005) due to physical (van de Wal and Pye, 2004) and biological (Hughes and Paramo, 2004) processes.

As a result of this initial study, we suggest that some future areas of research may be to compare bank erosion rates in wrack-disturbed and undisturbed areas, and try to relate channel meandering with wrack-disturbance sites. Additionally, interesting insights into this proposed mechanism may be gained by comparing meandering rates in seasonal versus non-seasonal tidal marsh creeks. The work presented here is by no means meant to validate our proposed mechanism, but rather to build a foundation from which further research may expand upon in order to begin to understand how disturbance and geomorphic processes may interact in salt marsh tidal creeks.

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