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Marsh vertical accretion via vegetative growth

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Abstract

Coastal marshes accrete vertically in response to sea-level rise and subsidence. Inadequate accretion and subsequent conversion of coastal marshes to open water generally is attributed to inadequate mineral sedimentation because mineral sedimentation is widely assumed to control accretion. Using ^{137}Cs dating to determine vertical accretion, mineral sedimentation, and organic matter accumulation, we found that accretion varied with organic accumulation rather than mineral sedimentation across a wide range of conditions in coastal Louisiana, including stable marshes where soil was 80% mineral matter. These results agreed with previous research, but no mechanism had been proposed to explain accretion via vegetative growth. In an exploratory greenhouse experiment, we found that flooding stimulated root growth above the marsh surface. These results indicated the need for additional work to determine if flooding controls accretion in some marshes by stimulating root growth on the marsh surface, rather than by mineral accumulation on the marsh surface. Restoration or management that focus on mineral sedimentation may be ineffective where a relationship between accretion and mineral sedimentation is assumed rather than tested.

Keywords: wetlands; coastal marshes; sea-level change; accretion; sedimentation; peat; United States; Louisiana

1. Introduction

Coastal wetland soils are studied to estimate sea-level rise because wetland surfaces vertically accrete as sea level rises (Redfield and Rubin, 1962; Orson et al., 1998). Coastal wetland soils also are studied because shallow open water replaces wetlands if vertical accretion is slower than submergence. Many studies have predicted the fate of specific coastal wetlands by comparing vertical accretion rates to submergence rates (e.g., DeLaune et al., 1983; Thom, 1992; Roman et al., 1997; Orson et al., 1998).

Often, factors limiting vertical accretion are not explored, and vertical accretion is described as depending on a combination of mineral sedimentation and organic matter accumulation (e.g., Redfield, 1972; Warren and Niering, 1993; Neubauer et al., 2002; Morris et al., 2002; Rooth et al., 2003). When limiting factors are addressed, the fate of coastal wetlands generally is reported to depend primarily on mineral sedimentation (Hatton et al., 1983; Stevenson et al., 1986; Nyman et al., 1990; Reed, 1990; Thom, 1992; Temmerman et al., 2004). Vertical accretion measurements sometimes are used to estimate the amount of mineral sediment contained in marsh soils (Hutchinson and Prandle, 1994), and the mass of mineral sedimentation often is used to compare vertical accretion among sites (Stevenson et al., 1988; Wolaver et al., 1988; Reed, 1989; Childers and Day, 1990; Kuhn et al., 1999; Temmerman et al., 2003). Using the term sediment accumulation to refer to changes in elevation (e.g., Roman et al., 1997) also illustrates the widely held assumption that vertical accretion primarily depends on mineral sedimentation. Tidal, wave, and storm energy delivering sediments are believed to indirectly influence accretion by governing sedimentation (Baumann et al., 1984; Mitsch and Gosselink, 1984; Stoddart et al., 1989), and research

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designed to understand sedimentation in coastal marshes is common.

Despite the widespread assumption that vertical accretion depends on mineral sedimentation or a combination of mineral sedimentation and organic matter accumulation, we are aware of eight reports of vertical accretion depending upon organic matter accumulation (McCaffrey and Thomson, 1980; Hatton et al., 1983; Bricker-Urso et al., 1989; Nyman et al., 1993; Callaway et al., 1997; Anisfeld et al., 1999; Turner et al., 2000; Chmura and Hung, 2004). McCaffrey and Thomson (1980) named this type of accretion "accretion via vegetative growth." Whereas vertical accretion via sedimentation is widely assumed, vertical accretion via vegetative growth seldom is assumed perhaps because quantitative analyses supporting, and explanatory mechanisms describing, vertical accretion via organic matter accumulation are lacking.

We examined coastal marsh soils in coastal Louisiana to determine if vertical accretion was limited by mineral sedimentation or organic matter accumulation; i.e., to determine if accretion varied with mineral sedimentation or with organic matter accumulation. As noted, some reports use the term "sedimentation" to refer to a mass of mineral sediments or to a mass of mineral sediments and organic matter, and others use it to refer to elevation. Hereafter, "accretion" refers to a vertical distance, "sedimentation" refers to a mass of mineral material, and "organic accumulation" refers to a mass of organic material.

We also studied plant growth characteristics because a mechanism for accretion via vegetative growth was not proposed in previous studies. We contend that accretion via vegetative growth must be activated by flooding and be inactivated by draining, as is accretion via sedimentation. Our vegetative studies were designed to rule out the possibility that aquatic root production could control accretion via vegetative growth. This was an exploratory experiment designed to determine if more complex studies are warranted. We use the term "aquatic root" as Koncalova (1990) did to indicate roots that grow into flood water rather than into soil. We studied aquatic roots of *Spartina patens* Ait Muhl., which occurs throughout the Atlantic coast and Gulf of Mexico coast of North America, and is the most common emergent plant in Louisiana's 16,000 km^2 coastal wetlands (Chabreck, 1970).

2. Methods

2.1. Accretion

2.1.1. Core collection sites

We analyzed 68 cores from 31 sites in coastal Louisiana (Fig. 1). We classified these 31 sites as one of three conditions: (1) non-fresh stable, (2) non-fresh deteriorating, or (3) fresh stable. All non-fresh stable sites were *Spartina patens*- or *Spartina alterniflora*-dominated wetlands with relatively slow wetland loss rates, adjacent to Four League Bay (Fig. 1, site 5). All non-fresh deteriorating sites were *Spartina patens*- or *Spartina alterniflora*-dominated wetlands with relatively rapid wetland loss rates north of Lake Barre (Fig. 1, site 7). All fresh stable sites were *Panicum hemitomon* Schultes- or *Sagittaria lancifolia* Willd.-dominated wetlands with relatively slow wetland loss rates.

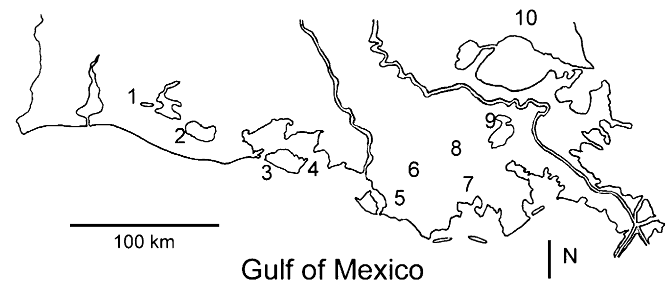

Fig. 1. Map of coastal Louisiana. Cores were collected at Lake Misere (1), a non-fresh stable region (5), a non-fresh deteriorating region (7), Bayou Blue (8), Lake Salvador (9), and Tchefuncte River (10) between 1989 and 1994. Intact plugs of living *Spartina patens* Aiton Muhl were collected from stable marsh at Rockefeller Refuge (2) and Marsh Island (3), and from deteriorating marsh at Marsh Island (4) and Jug Lake (6).

The non-fresh stable and non-fresh deteriorating sites have been described regarding wetland loss rates (May and Britsch, 1987; Britsch and Dunbar, 1993) wetland loss maps (Britsch and Dunbar, 1993; Barras et al., 1994), wetland loss mechanisms (Nyman et al., 1993; DeLaune et al., 1994), flood frequency and duration (Wang et al., 1993,1994,1995), submergence potential (Rybczyk and Cahoon, 2002), plant stress and productivity (Nyman et al., 1995b; Webb et al., 1995), sediment availability (Baumann et al., 1984; Moeller et al., 1993; Wang et al., 1994; Nyman et al., 1995a; Wang, 1995; Adams et al., 1997; Walker and Hammack, 2000), and subsurface geological features (Penland et al., 1988). Floodwaters from the Atchafalaya River supply abundant freshwater and sediment to the non-fresh stable region each spring, but the non-fresh deteriorating region depends on local rainfall and local sediment reworking for freshwater and sediment. The non-fresh stable region contained similar amounts of brackish marsh, dominated by *Spartina patens*, and saline marsh, dominated by *Spartina alterniflora*, whereas the non-fresh deteriorating region contained more saline marsh than brackish marsh. Those plants are common in temperate North America, where they form extensive, almost monospecific stands. Marsh loss averaged 37 ha yr^{-1} between 1974 and 1983 in the non-fresh stable region but 515 ha yr^{-1} in the non-fresh deteriorating region during the same time period (Britsch and Dunbar, 1993). In the non-fresh stable region during 1993, water levels ranged from −15 to 25 cm relative to the marsh surface, and were characterized by long draining periods interspersed by sporadic flooding periods (Wang, 1995). In the non-fresh deteriorating region, water levels during 1993 were lower and ranged from −10 to 50 cm relative to the marsh surface, and were characterized by sporadic draining interspersed by long flooding periods (Wang, 1995). The long periods of flooding in the non-fresh deteriorating region were attributed to a persistent accretion deficit (Rybczyk and Cahoon, 2002) caused by faster shallow subsidence than at the non-fresh stable region (Cahoon et al., 1995). The persistent flooding in the non-fresh deteriorating region stressed emergent vegetation (Nyman et al., 1995b), which