Sediment Accretion Rates from Four Coastal Wetlands Along the Gulf of Mexico

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ABSTRACT


Our study of sediment accretion rates from four low tidal-range sites along the Gulf of Mexico does not support previous hypotheses concerning the relationship between tidal range and vertical accretion rates. The addition of our data to an earlier data set decreased the correlation between these variables, and all but one of our low-tidal range sites had positive accretion rates, contradicting previous studies which have predicted that low tidal-range sites would have negative net accretion rates. Additionally, in transects across the marsh, accretion rates decreased from low- to high-marsh stations; however, this appeared to be caused by changes in rates of organic matter accumulation, not mineral matter accumulation, as has been proposed in previous studies. Vertical accretion rates were more strongly correlated with organic matter accumulation rates than mineral matter accumulation rates, confirming previous studies which indicated the important role of sediment organic matter in determining sediment structure. These results do not imply that mineral matter is unimportant in maintaining the elevation of the marsh; mineral matter input affects organic matter production and sediment bulk density. There was little correlation between mineral and organic matter accumulation rates, with average organic matter accumulation rates for each site having little variation compared to the variation in mineral matter accumulation rates. This result supports a previous hypothesis that there may be a limit to annual rates of organic matter accumulation. Finally, the study indicates that the negative net accretion rates documented in Louisiana are not typical of other Gulf coast wetlands.

ADDITIONAL INDEX WORDS: Sea-level rise, subsidence, salt marshes, mangroves.

INTRODUCTION

Extensive data have been collected over the last decade concerning sediment accretion rates in coastal wetlands because of the potential impacts of increases in sea-level rise on these habitats. Recent estimates of future eustatic sea-level rise vary from 20 to 115 cm by the year 2100 (Woodroffe, 1993), although more conservative estimates range from 35–50 cm over that time period (Wigley and Raper, 1992). Most coastal wetlands studied to determine sediment accretion rates are keeping pace with current rates of sea-level rise (Griffin and Rabenhorst, 1989; Patrick and DeLaune, 1990; Anderson et al., 1992; Thom, 1992; Craft et al., 1993); however, some are experiencing submergence (DeLaune et al., 1983; Baumann et al., 1984; Stevenson et al., 1985). If future rates of sea-level rise increase, it is unclear how large an increase coastal wetlands will be able to withstand (Orson et al., 1985). Potential impacts to coastal wetlands include the conversion of vegetated wetlands to intertidal mudflats if the inundation tolerances of vegetation are exceeded (Salinas et al., 1986) and the conversion of high marsh to low marsh (Warren and Niering, 1993). Despite the growing number of studies of wetland sedimentation rates, there are still many unknowns concerning the relationship of accretion rate, sea-level rise, subsidence, and other variables.

The maintenance of the relative elevation of an intertidal wetland is a complex process, and many factors, including variables on a variety of scales, may be involved. Some of the key factors that have been proposed to affect accretion rates include: relative elevation (Letzsch and Frey, 1980; Pethick, 1981), tidal range (Harrison and Bloom, 1977), proximity of the sediment source and creek system (Stoddart et al., 1989), plant community and density of vegetation (Richard, 1978; Gleason et al., 1979; Stumpf, 1983), and local rates of subsidence (Redfield, 1972). In a review of accretion processes and sea-level rise, Stevenson et al. (1986) showed a positive linear relationship between tidal range and net accretion rate. However, all of the low-tidal range sites which they studied were experiencing relatively high rates of subsidence and, as a result, had very low rates of net accretion (in fact all were negative). This lead to the question, “Are low net accretion rates really characteristic of low tidal-range sites?”

The Gulf coast is an ideal place to study accretion rates under a low tidal regime. There are an abundance of coastal wetlands and the entire coast has a low tidal regime. Many studies of accretion rates in Louisiana coastal wetlands have
been completed (Delaune et al., 1978; Hatton et al., 1983; Knauts and Van Gent, 1989; Nyman et al., 1990). These areas have low tidal ranges but are also characterized by extremely high rates of subsidence and hence relative sea-level rise. Very few wetland accretion studies have been completed on the Gulf coast outside of Louisiana (Lynch et al., 1989). In order to evaluate sediment accretion processes in low tidal-range wetlands, accretion rates from four different coastal wetlands in the Gulf of Mexico were measured. Sites include three tidal salt marshes from Aransas National Wildlife Refuge (NWR), TX; San Bernard NWR, TX, and Biloxi Bay, MS; and a group of tidal mangrove wetlands in the Florida Keys (Figure 1).

In addition to addressing the correlation of tidal range and accretion rates, this data set allowed evaluation of additional questions concerning wetland accretion processes, including some relationships proposed by other researchers and enumerated above. This study specifically targets the relationships between vertical accretion, organic matter accumulation, and mineral matter accumulation rates. Correlations between these variables are used to help interpret the roles of organic and mineral matter in coastal wetlands (Brucker-Urso et al., 1989; Nyman et al., 1993). This approach was used to determine if similar trends could be found from sites across the Gulf of Mexico. Finally, vertical accretion data from these coastal wetlands identify areas which may be vulnerable to increases in global sea level.

**METHODS**

**Site Locations**

At each of the four sites described below, six cores were collected. Sites were chosen in order to obtain samples from areas ranging broadly across the Gulf coast and with a wide range in rates of relative sea-level rise. At the first three sites, cores were collected along two transects, with sampling stations in the low, mid and high marsh. Throughout the paper, the term “site” is used to refer to the four sampling areas described below and the term “station” to designate a sampling location within a given site. The low-marin station was situated approximately 10 m from the creek bank to avoid abnormally high rates that have been found in “streamside” habitats (Hatton et al., 1983). The mid- and high-marsh stations were each located 20 m farther into the marsh. In the Keys, we were not interested in evaluating changes along transects; however, the remaining samples from these sites were included in the correlation analyses of sediment characteristics and sedimentation rates.

**Collection Methods and Sample Analyses**

Cores were collected in 15 cm diameter aluminum cylinders to a depth of 30–50 cm. Compaction was minimized by using sharpened, thin-walled coring tubes. Sediment compaction was estimated by measuring the elevation of the marsh inside and outside of the core and was less than 1 cm in all cores that we analyzed. Additionally, compaction due to core extraction was estimated by measuring the length of the sediment column before and after extraction. Corrections for compaction were made in estimating sediment depth, and compaction was assumed to be uniform throughout the sediment column.

Cores were sectioned every 2 cm, and individual sections were dried at 80°C, weighed and crushed with a mortar and pestle. ¹³⁷Cs activity of the bulk sediment was counted with a Lithium Drifted Germanium detector and multi-channel analyzer. ¹³⁷Cs is a product of nuclear weapons testing and does not occur naturally. Significant levels of this isotope first appeared in the atmosphere in the early 1950’s with the peak quantities detected in 1963/64 (Ritchie and McHenry, 1990). Sediment profiles are dated based on the 1963 peak in ¹³⁷Cs, giving an average vertical accretion rate for the period from 1963 to the present (Delaune et al., 1978).
Figure 1. Location of sampling sites along the Gulf of Mexico, including Aransas NWR (A), San Bernard NWR (B), Biloxi Bay (C), and the Florida Keys (D).
Table 1. Sediment characteristics for cores from transects from three salt marshes and from mangrove areas in the Florida Keys. Values given are for the top 10 cm of the core. Standard deviations are given in parentheses.

<table>
<thead>
<tr>
<th>Site</th>
<th>Bulk Density (g/cm³)</th>
<th>Organic Content (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aransas NWR</td>
<td>0.70 (0.226)</td>
<td>14.4 (5.20)</td>
</tr>
<tr>
<td>San Bernard NWR</td>
<td>0.90 (0.165)</td>
<td>9.1 (1.84)</td>
</tr>
<tr>
<td>Biloxi Bay</td>
<td>0.28 (0.039)</td>
<td>24.3 (3.98)</td>
</tr>
<tr>
<td>Florida Keys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Mangroves</td>
<td>0.16 (0.013)</td>
<td>55.5 (10.01)</td>
</tr>
<tr>
<td>Black Mangroves</td>
<td>0.15 (0.024)</td>
<td>61.3 (8.86)</td>
</tr>
</tbody>
</table>

In addition to the $^{137}$Cs analysis, 5 g subsamples were taken from each section for combustion at 400 °C in order to determine organic matter content by loss-on-ignition (BALL, 1964; CRAFT et al., 1991). Using the organic/mineral content of the sediment and the bulk density, vertical accretion rates were converted to mass-based rates and divided into organic and mineral components in order to evaluate the importance of these components to the accretion process. Profiles of organic content and sediment bulk density were constructed in order to evaluate changes in these parameters with depth. These profiles were also converted to volume distribution profiles, using specific gravity conversions for organic matter and mineral matter of 1.14 and 2.61 g/cm³ respectively (SMITH, 1943; DELAUNÉ et al., 1983).

Many different terms have been used in studies of sedimentation rates and clear definitions of these terms are necessary in order to ensure understanding. Vertical accretion rates are gross linear rates of sediment accumulation averaged over a particular time period. Dating with $^{137}$Cs gives average rates from 1963 until the present, while other methods may give averages for shorter or longer periods. The term “accumulation rate” is used to refer to mass-based sedimentation, either organic or mineral. Net accretion rates or accretion balance equals the gross vertical accretion rate minus relative sea-level rise for a given site. This is equal to the change in the relative elevation of the wetland sediment surface over a given period and indicates whether or not the wetland is keeping pace with sea-level rise or is undergoing submergence.

Statistical analyses were performed using PC SAS (SAS, 1988). We used a two-way ANOVA without replication in testing for differences between different stations along the transects. The Tukey Test for non-additivity was used to determine the significance of the interaction term. Since it was not significant, the interaction term was used as the error term for the two-way ANOVA without replication (SOIK and ROHLF, 1981). Treatment comparisons were made using Duncan’s Multiple Range Test which is a procedure for obtaining all pairwise comparisons among sample means.

RESULTS

Sediment Characteristics and Profiles

Large differences were found in sediment characteristics between the different sites (Table 1). Cores from mangroves in Florida had the lowest bulk densities and the highest organic content. The sediments from the coastal salt marshes in Aransas and San Bernard both had very high bulk densities; whereas Biloxi Bay sediments were mid range. Organic content was negatively correlated with bulk density (Figure 2); although the relationship between these two variables was very different for mangrove sediments than for the salt marsh sediments from Aransas, San Bernard and Biloxi Bay. Previous studies of soil bulk density and organic content have shown similar relationships for sediments from Louisiana coastal marshes (GOSELINK and HATTON, 1984). There were no consistent trends in organic content or bulk density across the marsh transects.

Most cores exhibited decreases in organic content and increases in bulk density with depth (Figures 3a and 3b). These changes were paralleled in the volume distribution profiles, with relatively less space occupied by organic matter and pore space and more space being occupied by mineral matter as the depth increases. These changes in sediment characteristics with depth are due to below-ground organic matter production, decomposition and compaction throughout the sediment profile. RAE and ALLEN (1993) have documented similar trends, although it is difficult to separate the relative importance of the three factors above because all are occurring simultaneously. In order to evaluate these processes, a computer model was developed. The model simulated sediment processes over both depth and time using data taken from one of the cores from the high-marsh station at Biloxi Bay (CALLAWAY et al., in press). The model was calibrated with profiles of organic matter and bulk density, as well as $^{137}$Cs-based accretion rates and simulated processes such as
compaction, decomposition and organic matter production, and changes in the relative elevation of the marsh over time.

Vertical Accretion Rates

Based on $^{137}$Cs peaks (Figure 4), rates of vertical accretion from the individual cores ranged from 0.18 to 0.89 cm/yr. At all of the three sites where samples were collected on a transect through the marsh (Aransas NWR, San Bernard NWR, and Biloxi Bay), accretion rates decreased from the low to high station (Figure 5). There were significant differences between high, mid, and low marshes ($p = 0.001$; Duncan’s Multiple Range Test for differences between stations, $p = 0.05$). Using average rates from the transects only, rates of vertical accretion were highest at Biloxi Bay and lowest at Aransas NWR (Table 2).

Vertical accretion rates from the incomplete transects that are not included in Figure 5 and individual rates for cores from the mangrove sites are given in Table 3. The three samples from the incomplete transects were similar to those found along the complete transects, with the exception of the high rates found at the high station on Biloxi Bay transect #1. This was probably due to the fact that this sample, although being at the upper end of the marsh, was also very near to an adjacent tidal creek that may have delivered material and drained this area, causing it to function similarly to a low-marsh station. This exception indicates some of the variability that is typical across any wetland and makes assessing rates for a given area very difficult.

A similar evaluation of rates across the wetland was not possible for the mangrove samples, since samples were not collected along transects; however, average rates were higher for the red mangrove stations (0.40 cm/yr vs. 0.27 cm/yr for black mangrove stations). This agrees with the trend found along the salt marsh transects, because red mangroves grow along the lowest edge of the wetland, with black mangroves in the interior of the mangrove swamp (ODUM et al., 1982). These rates of vertical accretion are higher than have been shown previously for other mangrove swamps in Florida (LYNCH et al., 1989).

Gross vertical accretion rates were compared to rates of relative sea-level rise for each site. Data for relative sea-level
rise are from tide-gauge analysis by Penland and Ramsey (1990). Three of the four sites had vertical accretion rates greater than recent rates of relative sea-level rise (Table 2). San Bernard NWR was the only site with a negative accretion balance. In fact, the rate of relative sea-level rise that was used for this site may be too large, because the only nearby tide-gauge station that was available was from Galveston, where rates of subsidence are relatively high and are probably higher than at San Bernard NWR.

Mass-Based Accumulation Rates

Organic matter accumulation declined consistently across the marsh (p = 0.0027), with significant differences between all stations based on Duncan’s Multiple Range Test with p = 0.05 (Figure 5). Mineral matter accumulation rates also declined across the marsh (p = 0.032); however, significant differences were found only between the low-marsh station and the other stations using the same Duncan’s Test (Figure 5).

Average organic accumulation rates at the four sites ranged from 210 to 380 g/m²/yr, with a much larger variation in average rates of mineral matter accumulation (Table 4). San Bernard NWR and Aransas NWR had the highest rates of mineral matter accumulation; whereas rates from the mangroves in the Florida Keys were extremely low (Table 4). The rates of mineral matter accumulation from San Bernard NWR and Aransas NWR are much greater than other published values for most coastal salt marshes (Bricker-Urso et al., 1989).

Table 2. Average vertical rates of accretion. Standard deviations are given in parentheses. Rates of relative sea-level rise are from tide-gauge data from Penland and Ramsey (1990).
DISCUSSION

Differences along the Transects

Previous authors have reported decreases in accretion rates with increasing elevation within the marsh or with increasing distance from a tidal channel (Richard, 1978; Pethick, 1981; Oenema and Delaune, 1988). Pethick (1981) stated that the frequency and duration of inundation were most important in affecting rates of accretion across the marsh. Letzsch (1983) used marker horizons in a seven-year study of six different stations in a Georgia marsh and found consistently lower accretion rates in the upper part of the marsh. Stoddart et al. (1989) evaluated changes with distance from tidal channels at a macrotidal site along the Norfolk coast in Britain. It was assumed that the channels were the main source of mineral matter for the marsh, and they found lower accretion rates with increasing distance from the channel.

Our data with $^{137}$Cs dating confirm these trends over a 30-year time scale. However, the results of the mineral matter accumulation estimates indicate that the cause may not be simply a decrease in the delivery of mineral sediments to the upper marsh, due to the shorter duration of flooding at higher elevation as had been proposed previously. If this were the case, we would expect a sharp decrease in mineral matter accumulation rates across the marsh. However, our results showed that vertical accretion rates across the marsh decreased significantly, but mineral matter accumulation rates were only significantly greater at the low station (Figure 5). It appears that the decrease in vertical accretion rates was due to decreases in organic accumulation rates, which also were significantly different across all three stations, not the delivery of mineral matter to the marsh surface (Figure 5).

A tidal subsidy is still possible at these sites, even if it is not in the form of mineral matter delivery. Increased drainage combined with above- and below-ground plant production at the low end of the marsh may have been the cause for increased rates of organic matter accumulation in these lower stations. Wiegert et al. (1983) have shown a significant increase in above-ground production with increased drainage and soil water movement. Other studies have also documented trends in production across the marsh (DeLaune et al., 1979). The differences in organic matter accumulation could also be due to differences in below-ground decomposition rates across the marsh, although most evidence indicates that decomposition rates would be higher where drainage is better because of increased aerobic decomposition rates (Heminga et al., 1988). Further study of production and decomposition rates across the marsh are needed to confirm these hypotheses.

Tidal Range Versus Net Accretion Rates

On a scale larger than a single marsh, tidal range has been correlated with accretion rates (Harrison and Bloom, 1977; Stevenson et al., 1986). Previous studies have indicated a positive relationship between tidal range and accretion rates. In a study of five high marsh sites along the Connecticut coast in Long Island Sound, Harrison and Bloom (1977) found that gross accretion rates along the sound increased with increases in mean tidal range. Harrison and Bloom (1977) provided several explanations for this and indicated that the most probable was the increased input of mineral material with increases in tidal range and not organic matter or the availability of mineral matter at different sites. Stevenson et al. (1986) also proposed a positive relationship between tidal range and accretion rates in their review of accretion processes; however, this was for net accretion rates rather than gross vertical accretion rates. They found a significant positive correlation between net accretion rate and tidal range for 13 wetland sites. However, the only low tidal-range sites that had been measured at that time were sites with high rates of local subsidence (Louisiana and Chesapeake Bay). Furthermore, Stevenson et al. (1986) pointed out that additional data from low tidal-range sites were necessary in order to confirm their findings. Data from this study indicate that this trend is probably not as simple as has been shown in the past (Figure 6). The four data points that we added to Stevenson et al.’s study decreased the $r^2$ of the regression from 0.73 to 0.42, although the regression remained significant ($p = 0.0037$). In addition, our samples indicate that low-tidal range sites do not necessarily have negative accretion balances, as had been proposed (Stevenson et al., 1986).

Recent studies from two areas on the Atlantic coast also does not support the relationship between tidal range and

Table 4. Average rates of organic and mineral accumulation. Standard deviations are given in parentheses.

<table>
<thead>
<tr>
<th>Site</th>
<th>Organic Accumulation Rate (g/m²/yr)</th>
<th>Mineral Accumulation Rate (g/m²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aransas NWR</td>
<td>333.4 (125.67)</td>
<td>2,248.4 (686.97)</td>
</tr>
<tr>
<td>San Bernard NWR</td>
<td>415.0 (91.71)</td>
<td>4,895.2 (937.84)</td>
</tr>
<tr>
<td>Biloxi Bay</td>
<td>359.6 (56.17)</td>
<td>1,288.1 (318.86)</td>
</tr>
<tr>
<td>Florida Keys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Mangrove</td>
<td>318.0 (13.62)</td>
<td>157.5 (13.97)</td>
</tr>
<tr>
<td>Black Mangrove</td>
<td>210.9 (107.46)</td>
<td>164.0 (101.64)</td>
</tr>
</tbody>
</table>

Table 3. Vertical accretion, organic accumulation and mineral accumulation rates for cores from incomplete transects and for mangrove cores from the Florida Keys.

<table>
<thead>
<tr>
<th>Site and Core Location</th>
<th>Vertical Accretion Rate (cm/yr)</th>
<th>Organic Accumulation Rate (g/m²/yr)</th>
<th>Mineral Accumulation Rate (g/m²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aransas NWR #2 high</td>
<td>0.48</td>
<td>368.4</td>
<td>2,626.3</td>
</tr>
<tr>
<td>Biloxi Bay #1 mid</td>
<td>0.32</td>
<td>205.4</td>
<td>669.5</td>
</tr>
<tr>
<td>Biloxi Bay #1 high</td>
<td>0.61</td>
<td>350.3</td>
<td>1,304.3</td>
</tr>
<tr>
<td>Florida Keys—red mangroves Core #3</td>
<td>0.42</td>
<td>331.6</td>
<td>143.5</td>
</tr>
<tr>
<td></td>
<td>Core #6</td>
<td>0.39</td>
<td>304.4</td>
</tr>
<tr>
<td>Florida Keys—black mangroves Core #2</td>
<td>0.42</td>
<td>361.0</td>
<td>303.7</td>
</tr>
<tr>
<td></td>
<td>Core #4</td>
<td>0.19</td>
<td>115.4</td>
</tr>
<tr>
<td></td>
<td>Core #5</td>
<td>0.19</td>
<td>156.3</td>
</tr>
</tbody>
</table>
accretion rates, nor the fact that wetlands with low tidal ranges are likely to have negative accretion balances. WOOD et al. (1989) studied short term accretion rates at 26 sites in Maine, with tidal ranges varying from 2.5 to 5.5 m, and found no relationship between mean tidal range and accretion balance for these sites (see Figure 8 from WOOD et al., 1989). Additionally, CRAFT et al. (1993) found positive accretion balances for three of the four microtidal sites that they studied on the North Carolina coast. They measured rates in regularly and irregularly flooded marshes and found a deficit of 0.1 cm/yr in the regularly flooded backmarsh site, while all other areas had positive accretion balances, ranging from 0.05 to 0.17 cm/yr (CRAFT et al., 1993). Our data together with these additional studies do not imply that there is no relationship between tidal range and accretion rates; however, they do indicate that tidal range alone cannot predict the accretion balance of a particular site. Many more local variables affect the average accretion rate and accretion balance for a given wetland, such as organic matter production, below-ground decomposition, mineral inputs, and other factors.

Correlations of Vertical Accretion, Organic and Mineral Accumulation Rates

Given the fact that there appears to be more involved in the vertical accretion rates at these sites than just the delivery of mineral matter, the question arises, "What is controlling the accumulation of sediment in coastal wetlands along the Gulf of Mexico?" Using data from all of our 20 cores, rather than just the transect data, we evaluated the correlation between vertical accretion, mineral accumulation and organic accumulation rates. As other authors (NYMAN et al., 1993) have pointed out, vertical accretion rates are used in the calculation of the mass-based accumulation rates, so it is to be expected that these rates are correlated. However, the evaluation of these trends can still assist in the understanding of accretion processes in coastal wetlands.

For the wetlands that we evaluated, vertical accretion was more highly correlated with organic accumulation rates than mineral accumulation rates (Figure 7). The $r^2$ value for vertical accretion and organic accumulation rates was 0.895; whereas, it was 0.458 for vertical accretion and mineral accumulation rates. This reinforces the trends that we found along the transects and is to be expected since we used some of the same data in this analysis. The correlation that we found for vertical accretion and organic accumulation rates is very similar to the relationship that NYMAN et al. (1993), found from coastal wetlands in Louisiana, and indicates that there may be a similar relationship for organic matter accumulation and vertical accretion across the Gulf coast region. Other researchers have also looked at the relationship of organic matter and mineral matter accumulation rates in hopes of interpreting sedimentation processes in some areas (McCaffrey and THOMSON, 1980; BRICKER-URSO et al., 1989). Our data adds further support to the hypothesis that organic matter is

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Figure 6. Relationship of mean tidal range and net accretion rate for data from the sites sampled and from other coastal wetlands (additional data from STEVENSON et al., 1986). Tidal-range values for Gulf coast sites are from NOAA (1993).

Figure 7. Correlation of vertical accretion rates with mineral accumulation rates (top) and organic accumulation rates (bottom) for all cores.
the key to the development of marsh sediment (McCaffrey and Thomson, 1980; Nyman et al., 1993).

In order to interpret processes on a regional scale, it is instructive to evaluate the relationship between organic and mineral matter accumulation rates, using data from individual cores as well as average values for each site (Figure 8). The difficulties in assigning an average value for a given site have been discussed above; however, the researchers in this study feel that the transect approach is the best method for obtaining an average value. Most of the variability in the rates of organic matter accumulation was due to changes across the transects or within a given mangrove area, and when data were averaged for individual sites, average organic accumulation rates from all of the sites were very similar (Table 4). Brickor-Urso et al. (1989) have suggested that there may be a limit to the organic matter accumulation in marshes along the Atlantic and Gulf coasts (see their Figure 12). The average data from our sites showed little increase in organic matter accumulation despite large increases in mineral matter accumulation rates. Average mineral matter accumulation rates at our sites varied from approximately 160 to 5,000 g/m²/yr, while organic matter accumulation rates varied from approximately 200 to 400 g/m²/yr. The small range of organic matter accumulation rates indicates that there may be a limit to organic matter accumulation as Brickor-Urso et al. (1989) have suggested. If in fact there were a limit to the maximum rates of organic matter accumulation, this could have important consequences for the ability of marshes to compensate for future increases in sea-level rise.

POSSIBLE EFFECTS OF SEA-LEVEL RISE AND CONCLUSIONS

There was not a significant relationship between subsidence rates (relative sea-level rise rates) and accretion rates based on data from our 4 sites. The r² value for these 2 variables including data from all 20 cores was 0.19 (p = 0.055). Although it has been suggested that there is a positive relationship between relative sea-level rise and accretion (Redfield, 1972), the lack of a statistical relationship has been shown by other researchers (Stevenson et al., 1986; Wood et al., 1989).

Vertical accretion rates at the coastal wetlands that we studied were large enough to compensate for rates of local sea-level rise, and these wetlands are not likely to be flooded in the near future (Figure 9). The one site that may experi-
ence flooding is San Bernard NWR. Interestingly this site had the highest rates of mineral matter accumulation. Also, the estimate of the subsidence rate for this site may be too high, as discussed earlier. These Gulf sites are functioning very differently than sites that have been studied in Louisiana (Figure 9). Several studies (DeLaune et al., 1983; Baumann et al., 1984; Salinas et al., 1986) have documented the relationship between negative accretion balances and the loss of coastal marsh acreage in coastal Louisiana. However, the four sites from the Gulf of Mexico that we studied do not have negative accretion balances and are not experiencing major losses of coastal wetlands. There is a Gulf wide trend in subsidence rates with higher rates near the influence of the Mississippi River Delta (Penland and Ramsey, 1990), but sites away from this delta are currently not likely to experience submergence.

There are potential problems with using tide-gauge data sets for estimating rates of relative sea-level rise for marsh accretion studies. Turner (1991) concluded that in order to minimize the effect of short-term trends in the tide-gauge signal on estimates of relative sea-level rise, the longest available data set should be used. In addition, rates of subsidence are probably not the same in tidal channels, where tide gauges are usually installed as they are in coastal wetlands (Turner, 1991). Because of the processes, such as organic matter production, decomposition, and compaction which occur within the sediment column in coastal wetlands, it is likely that rates of sea-level rise would be different in the wetland. If this is the case, positive values for accretion balance may not necessarily mean that the relative elevation of the marsh is increasing. Rather, if the differences between processes at the tide gauge and within the wetland (decomposition and compaction) are also considered, slightly positive values of accretion balance may indicate that the wetland is simply keeping pace with measured increases in relative sea-level rise.

Besides actual land loss, one potential impact of an increase in sea-level rise that could be very important is the conversion of high marsh to low marsh. High marsh areas are likely to be converted to low-marsh habitats because of the lower vertical accretion rates in the high marsh (Figure 5). This type of a change in vegetation communities has been documented in New England tidal marshes over the past 50 years and through peat core analysis (Warren and Niering, 1993). There could be a similar change in coastal wetland plant communities along the Gulf coast, and this conversion of upper marsh habitat could have important consequences for wildlife and other marsh functions, even though there would not be a net loss of wetland habitat.

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LITERATURE CITED


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