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# The Relationship Between Marsh Surface Topography, Hydroperiod, and Growth of *Spartina alterniflora* in a Deteriorating Louisiana Salt Marsh

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**ABSTRACT**

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The relationships between marsh elevation, flooding frequency and duration, and vegetative growth in a *Spartina alterniflora* marsh in coastal Louisiana were evaluated using field surveys, tide gauge records, and plant growth measurements over two growing seasons. Hydroperiod was calculated for different elevations on the marsh surface and relationships determined by regression analysis. Relationships between marsh surface elevation and vegetative parameters changed during the study period. There was a positive relationship between marsh elevation and vegetation vigor. At the beginning of the study, elevation did not appear to influence plant growth, but the effect of elevation on the magnitude of above and below ground standing crop and stem density increased in the second year. Variations in elevation across the study site (12 cm) cause dramatic changes in hydroperiod (> 200%) for vegetation in different areas. Eh measurements indicate reduced soil conditions associated with long-duration flooding events at lower elevations. These data suggest that more flooded areas of the marsh are deteriorating and we anticipate that plant die-back will occur in this area, resulting in wetland loss.

ADDITIONAL INDEX WORDS: Spartina alterniflora, *Louisiana, salt marsh, hydroperiod, plant biomass, marsh loss.*

## INTRODUCTION

In Louisiana, predictions of increased eustatic sea-level rise due to the greenhouse effect (NATIONAL RESEARCH COUNCIL, 1987) threaten approximately 41% of the United States coastal wetlands which provide the foundation for high annual yields of fisheries, waterfowl, and wild furs (CAHOON *et al.*, 1983). Louisiana's wetlands are already disappearing at a rate of over 57 km$^2$/yr (GAGLIANO *et al.*, 1981; BRITSCH and KEMP, 1990). Land loss has occurred throughout the Mississippi deltaic plain (MAY and BRITSCH, 1987), both as marginal erosion (REED, 1989b) and as interior marsh deterioration (SCAIFE *et al.*, 1983; TURNER and CAHOON, 1987). Causes of this wetland loss have been variously attributed to the loss of sediment delivery to marshes caused by navigation and flood controls on the Mississippi River, saltwater intrusion into previously fresh and brackish coastal marshes, dredge and fill activities associated with the exploitation of the area's mineral resources, and natural geological subsidence of Holocene Mississippi deltaic plain sediments (BOESCH, 1982; TURNER and CAHOON, 1987; WALKER *et al.*, 1987; TEMPLET and MEYER-ARENDT, 1988).

Widespread interior marsh deterioration in Louisiana is usually attributed to an aggradation deficit, with relative sea-level rise, increased in Louisiana by subsidence rates in excess of 1.2 cm/yr (PENLAND *et al.*, 1988), being greater than rates of land building in interior marshes, estimated as 0.6–0.9 cm/yr by BAUMANN *et al.* (1984). This deterioration of coastal salt marshes is characterized by plant die-back (MENDELSSOHN and MCKEE, 1988) causing exposure of bare marsh soil which is then readily eroded by tidal flood waters. Small ponds develop that expand and coalesce into larger areas of open water (TURNER and RAO, 1990). The processes of pond initiation and expansion have not been examined in detail in Louisiana, but the mechanical processes of bank slumping (STEVENSON *et al.*, 1985) and channel erosion

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(KEARNEY *et al.*, 1988) are thought to be important in pond development in the Chesapeake Bay area. Bank slumping and channel erosion are unlikely to be of similar significance in Louisiana because of the microtidal nature of the coastal zone, with a mean tidal range of approximately 30 cm. Canals and spoil banks may heavily impact coastal marshes locally (SWENSON and TURNER, 1987) and cause ponding of water on the marsh surface. However, interior marsh deterioration also occurs in areas not impacted by canals and spoil banks (MAY and BRITSCH, 1987; LEIBOWITZ and HILL, 1987), indicating that a more widespread phenomenon, such as insufficient sediment accumulation in the face of rapid subsidence and sea-level rise, could be important across the entire coastal zone.

This paper examines the relationship between the topography and hydrology of the marsh surface and vegetation parameters which contribute to organic matter accumulation. Marsh sediments consist of both organic and inorganic material, but the processes of marsh accretion are poorly understood. The spatial and temporal variability of salt marsh sediment accretion over short time periods has been demonstrated by many studies (RANWELL, 1972; HARRISON and BLOOM, 1977; LETZSCH and FREY, 1980; SHARMA *et al.*, 1987; REED, 1989a). However, few studies of marsh accretion distinguish between the contributions of organic and inorganic sediments. HARRISON and BLOOM (1977), working on the margins of Long Island Sound, identify their highest organic matter contents in those marsh soils where sedimentation rates are lowest, and find much lower organic contents in areas with higher total sedimentation. Continued vertical peat formation is seen as the main accretionary process operating in the Farm River marshes of Connecticut by MCCAFFREY and THOMPSON (1980). BRICKER-URSO *et al.* (1989) also see organic matter accumulation as more important than inorganic matter in maintaining Rhode Island marshes in the face of sea-level rise, but suggest that there is an asymptotic relationship between organic and inorganic accumulation where inorganic inputs will continue to increase but organic accumulation will level off as sea-level rise increases.

In Louisiana marshes, storm events appear to dominate inputs of inorganic sediment (BAUMANN, 1980; MEEDER, 1987; REED, 1989a; REJMANEK *et al.*, 1988) but processes of organic matter accumulation are less clearly understood. HATTON *et al.* (1983) note that organic carbon represented an approximately constant mass in soils from all marsh types (fresh through to saline) in the Barataria Basin. However, KOSTERS *et al.* (1987) have shown that subsurface accumulation of organic matter is extremely low in saline marshes even though plant production is as great as in fresh marshes. The processes of organic and inorganic matter accumulation are mediated by hydrologic forces which control the input and transport of sediment, as well as inundation or waterlogging stress on the vegetation. The aim of this paper is to elucidate the potential impacts of increased relative sea-level, and hydroperiod, on the contribution of organic matter to land building processes in Louisiana coastal wetlands.

## STUDY AREA

This study was conducted in the marshes of eastern Terrebonne Parish in the Mississippi River deltaic plain, close to the Louisiana Universities Marine Center in Cocodrie (Figure 1). The area was most recently subjected to active delta development between 800 and 1,200 BP (PENLAND *et al.*, 1987). Transgression has been dominant since this period and the marshes may now be classified as coastal submergent (STEVENSON *et al.*, 1986). The deltaic sediments are rapidly subsiding and consequently relative sea-level rise rates for the area (eustatic plus subsidence) are estimated at 1.1–1.29 cm/yr (PENLAND *et al.*, 1988). The area is presently isolated from Mississippi River sediment input and may be termed a sediment-poor environment in comparison to marshes of west Terrebonne Parish, which are influenced by the Atchafalaya River (DELAUNE *et al.*, 1987; MADDEN *et al.*, 1988).

The salinity in the study area varies between 2 and 15 parts per thousand depending upon local rainfall and tidal conditions. The marsh is dominated by *Spartina alterniflora*, with isolated areas of *Distichlis spicata* and *Juncus roemerianus*, and is classified as a salt marsh (CHABRECK and LINSCOMBE, 1978). Experimental plots, 1.5 $m^2$ in area, were established in a backmarsh area to remove streamside effects on topography and vegetation from consideration in the study. Plots were accessed via a permanent boardwalk system. The study site is over 50 m from the closest bayou channel (Figure 1), and the experimental plots are each located at least 2 m from the shallow marsh surface drainage channels.

## METHODS

Two hundred and forty marsh surface elevations were surveyed within a 1 ha area of backmarsh close to the LUMCON Marine Center in Cocodrie. The surveying was associated with a series of 80 experimental 1.5 $m^2$ plots, arranged in 5 rows, each plot being less than 1 m from adjacent plots. Within each plot, one randomly-selected point was surveyed, as well as the highest and lowest points. These three elevations were averaged to give a mean elevation for 80 plot locations across the marsh surface. All elevations were surveyed in relation to a local benchmark, the elevation of which was surveyed in relation to a National Ocean Service tide gauge less than 1 km away, at the Marine Center, for which hourly tide gauge records were available.

Tide gauge records for calendar year 1988 were used in combination with the surveyed mean elevations to calculate the regime of tidal flooding for each plot location. PEAKBASE, a computer program developed at LUMCON, was used to calculate the start and end time, the duration, and the depth of each marsh flooding event for a given marsh elevation from the survey data. These data were summed for given intervals of sampling for the vegetation parameters, in order to establish the flooding regime during the period between seasonal data collection.

Vegetation parameters were measured at 3-month intervals from May 1988 to August 1989 at fifteen randomly located plots within the study area. Stem density was measured at three randomly selected locations within each plot, using 0.0625 $m^2$ quadrats. Above-ground standing crop of live and dead plant material was estimated by clipping all standing vegetation at ground level within one of the quadrats used for stem density measures. Samples were sorted into live and dead stems, dried for 18 hours at 65 °C, and weighed. Below-ground standing crop of plant matter (live and dead, combined unsorted) was estimated by harvest techniques (after GALLAGHER and PLUMLEY, 1979). Aluminium core tubes (7.5 cm diameter) were gently inserted into the marsh, to a depth of 30 cm. Core compaction was assessed by measuring the distance from the top of the core tube to the sediment surface inside and outside the core tube. The cores were capped tightly to hold the sample in place while the tubes were removed and the bottom sealed on removal. The core holes were refilled with exogenous marsh substrate collected nearby with an identical core tube. Core locations were carefully selected to avoid sampling the same area twice.

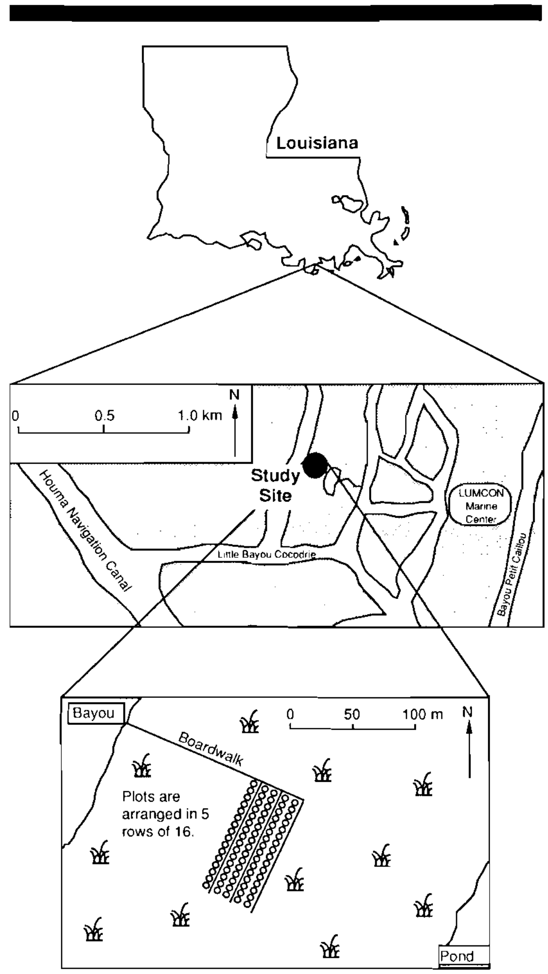


Figure 1. Location of study area.

Samples were extruded from core tubes in the laboratory and cut into 5 cm vertical increments from the sediment surface. Samples were washed thoroughly in a 1 mm mesh sieve to remove soil particles, before being dried and weighed. These vegetation data were combined with the surface topography and hydrology data. Simple linear regression analysis was used to illustrate the strength of the relationships between marsh topography and plant growth. Eh was measured monthly *in situ* on selected plots at 1 cm and 10 cm below the marsh surface using brightened platinum electrodes and the methods of MENDELSSOHN and MCKEE (1988).

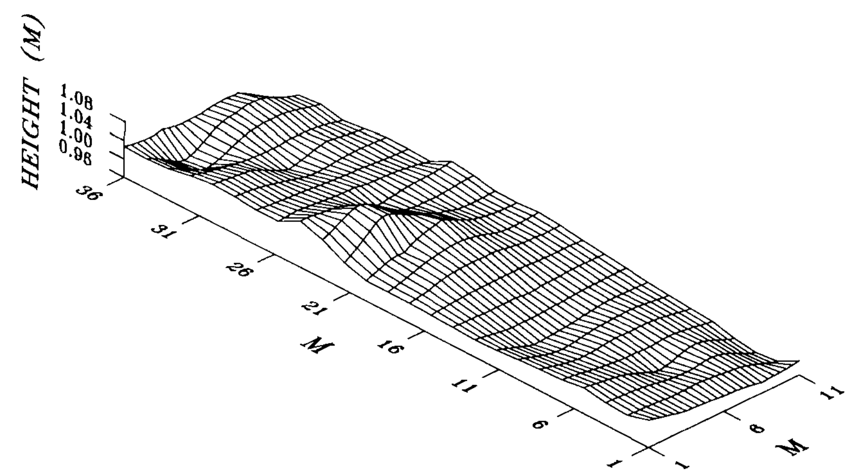


Figure 2. Topography of study area using mean elevations for each experimental plot.

## RESULTS AND DISCUSSION

### Marsh Surface Topography and Hydrology

Elevation data from all plots show a 12 cm variation in mean surface topography across the study plots (Figure 2). The maximum range of all the surveyed points was 26 cm. These variations were not caused by streamside effects, frequently seen as a major contributor to marsh topography (BAUMANN, 1980; HATTON *et al.*, 1983; SHARMA *et al.*, 1987). Although the topography of the area shows no clear pattern, field observations suggest that some of the narrow elongated depressions may be associated with animal tracks (raccoons and nutria are common in the area), and some of the localized high spots are areas where ribbed mussels (*Geukensia demissa*) occur within the surface soil horizons (BERTNESS, 1984).

Whatever the cause of these variations in marsh surface topography, they have a clear impact on marsh flooding frequency and duration. FREY and BASAN (1985) discuss instances in marshes on the east coast of the United States where hydrography, or tidal flooding of the marsh surface, appears to influence the microtopography of the marsh surface through deposition. However, this is unlikely to be the case in the micro-tidal, low-energy environment of our study. If sediment was readily available for deposition on the marsh surface during all tidal cycles, lower areas of marsh would experience greater sedimentation rates with some feedback between topography and hydrology. However, sediment deposition in these marshes has been shown to be closely related to storm events (BAUMANN *et al.*, 1984; REED, 1989a) with far less sedimentation occurring during inundation by astronomical tides.

The results of this study show that total flooding duration for 1988 varied from 1,872 hr (21.3% of the time) at the highest topographic points to 4,678 hr (53.2% of the time) at the lowest. These flooding durations may be higher than average due to the influence of two hurricanes on the Louisiana coast in September and a tropical storm in June (REED, 1989b). A frequency distribution of the duration of marsh flooding events (Figure 3a), calculated for an elevation representing the mean of all plot elevations, shows that the modal flooding event lasted between 10 and 20 hr. One event, however, lasted 206 hr and was associated with the passage of Hurricane Gilbert across the Gulf of Mexico in September. This is also reflected in Figure 3b, a frequency distribution of the maximum depth of marsh flooding during each inundation event. The modal depth of marsh flooding is between 5 and 10 cm, although this varies according to individual plot elevation. Only one event in 1988 flooded the marsh to a depth of over 0.5 m. Again this was in September and was associated with the passage of Hurricane Gilbert.

Clearly, variations in topography across the marsh surface measured in this study cause some areas of the marsh to be flooded more frequently and for longer periods than others. Hydrology data were based on the use of tide gauge data from a remote location together with surveyed eleva-

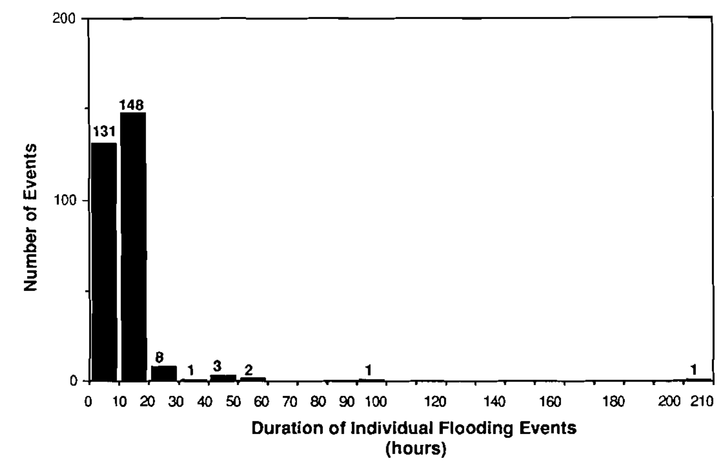


Figure 3a. Frequency distribution of the duration of marsh flooding events, January–December 1988.

tions. Hence, these calculations are estimates of how much water should be on the marsh surface. Drainage across the marsh surface is an important component in determining the duration and frequency of flooding (SWENSON and TURNER, 1987). The data presented here do not account for local ponding effects, which would increase durations and lower frequencies, but assume that drainage to and from the marsh is efficient. This will not always be the case, but our data can be used to represent the minimum flooding regime for various parts of the marsh surface.

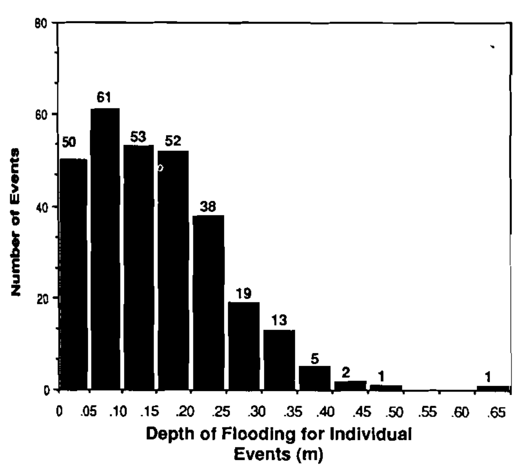


Figure 3b. Frequency distribution of the depth of individual marsh flooding events, January–December 1988.

Our data illustrate the importance of microtopography in controlling flooding regimes. Even small variations in elevations of 0.04 m across the marsh surface (see SWENSON and TURNER, 1987) can produce significant changes in hydroperiod. Using PEAKBASE, hourly water level data for 1987 (a year with no major tropical storm activity in the vicinity of the Louisiana coast) was used to calculate the difference in tidal flooding regime for two plot elevations with a difference of 0.04 m. The mean monthly flooding duration for the higher elevation is 19.59 hr and 27.30 hr for the lower plot. A t-test shows these values to be significantly different at the $p = 0.0005$ level. Single point measurements of water level variations, therefore, fail to incorporate spatial variations in tidal flooding caused by the microtopography of the marsh surface.

### Marsh Surface Topography and Vegetation Parameters

Results of seasonal surveys of vegetation in 15 randomly located plots were used in regression analysis to investigate the influence of marsh elevation on stem density, above-ground standing crop, and below-ground standing crop. The stem density data show an increase in influence of elevation throughout the sampling period, with more significant relationships in February, May and August 1989 than in previous periods (Table 1). There is no such trend in data for above-ground live or below-ground standing crop. Above-ground live standing crop (AGL) only shows a significant

Table 1. *R-squared values for regression analyses of control plot elevation vs. variables shown.*

| Date | Stem Density | AGL | BGT 0–5 cm | BGT 5–10 cm | BGT 10–15 cm | BGT 15–20 cm | BGT Total 0–20 cm |
|---|---|---|---|---|---|---|---|
| May 1988 | 0.146 | 0.08 | 0.233 | 0.155 | 0.39[a] | 0.072 | 0.331[a] |
| Aug 1988 | 0.007 | 0.072 | 0.011 | 0.049 | 0.34[a]* | 0.379[a]** | 0.368[a]** |
| Nov 1988 | 0.247 | 0.166 | 0.004 | 0.203 | 0.059 | 0.291[a]* | 0.124* |
| Feb 1989 | 0.678[a] | 0.418[a] | 0.341[a] | 0.336[a] | 0.286[a]* | 0.542[a]* | 0.452[a]* |
| May 1989 | 0.626[a] | 0.058 | 0.091 | 0.073* | 0.297[a]* | 0.266* | 0.239* |
| Aug 1989 | 0.369[a] | 0.174 | 0.42[a] | 0.447[a] | 0.313[a] | 0.343[a] | 0.543[a] |

[a]Significant at $p = 0.05$
*N = 14
**N = 13
AGL—Live above-ground standing crop. BGT—Below-ground total standing crop (combined live and dead). N = 15 for all variables except where indicated

relationship with plot elevation in February 1989. Total (live and dead) below-ground standing crop (BGT) shows a pattern that varies through time and with depth. Surface values (0–5 cm below the surface) and values at 5–10 cm below the surface show significant relationships with plot elevation in February and August 1989 only. At lower depths, BGT is more frequently influenced by plot elevation. Overall, November 1988 and May 1989 are the periods when plot elevation appears to have least influence on BGT.

The complexity of the relationship between vegetation parameters and plot elevation (Table 1) indicates that factors other than elevation influence vegetation growth. Seasonal variations in below-ground standing crop and productivity in *Spartina alterniflora* marshes have been examined by a number of workers (SCHUBAUER and HOPKINSON, 1984; GOOD *et al.*, 1982). WHITE *et al.* (1978) examined new root production in a Louisiana salt marsh and noted that production varies with the time of year. The greatest quantity of new growth occurs in mid-summer with a second peak in early winter. SCHUBAUER and HOPKINSON (1984) working in Georgia marshes note that *Spartina alterniflora* biomass reached major peaks in February followed by a second peak in the fall. They also describe a temporal asynchrony between above- and below-ground biomass. Below-ground biomass (BG) peaked when above-ground biomass (AG) was lowest. Their smaller secondary fall peak in BG coincided with high mortality in sub-aerial plants. However, DAME and KENNY (1986) showed in their study of *Spartina alterniflora* marshes in South Carolina that the greatest maximum in live biomass occurred at similar times above and below ground. At their study site in an area of short-form *Spartina alterniflora* the minimum period for below-ground biomass (live and dead combined) was January-February. GALLAGHER (1983) demonstrated in a Georgia *Spartina alterniflora* marsh that below-ground reserves were high in the fall and were used throughout the winter and spring to produce the spring leaf canopy.

BGT, AGL and stem density data for the plots used in this study varied seasonally (Figure 4a, b and c). During the first year of study (spring 1988–winter 1989) AGL and stem density peaked in August and were at a minimum in February (Figure 4a and 4b). BGT also reached a maximum in August 1988 (Figure 4c), indicating that the temporal asynchrony shown by SCHUBAUER and HOPKINSON (1984) in Georgia is not present here and our data conform with the findings of DAME and KENNY (1986) in South Carolina and GALLAGHER (1983) in Georgia. However, during the remaining monitored time the pattern seems to change and BGT levels in August 1989 are similar to those in May 1989. AGL and stem density do increase in August 1989, but not to the same levels achieved in summer 1988 (Figure 4a and b).

Examining Table 1 in relation to the above observations shows that the only time when there is a significant relationship between AGL and plot elevation is in February 1989 when AGL values are at their lowest. This indicates that when live aerial plant growth across the marsh is lowest, there is more live aerial plant material in higher parts of the marsh. Lower areas show lower live plant standing crop. Some seasonal factors also appear to influence BGT across the marsh surface. Plot elevation is not a significant influence on BGT 0–20 cm below the surface in May 1989, and, although the relationship is significant in May 1988, the r-squared value is the lowest of all those shown as significant for BGT 0–20 cm. During the first year of seasonal monitoring, plot elevation

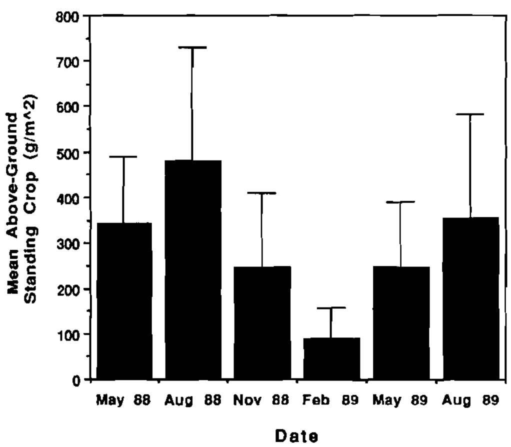


Figure 4a. Seasonal measurements of above-ground standing crop for control plots.

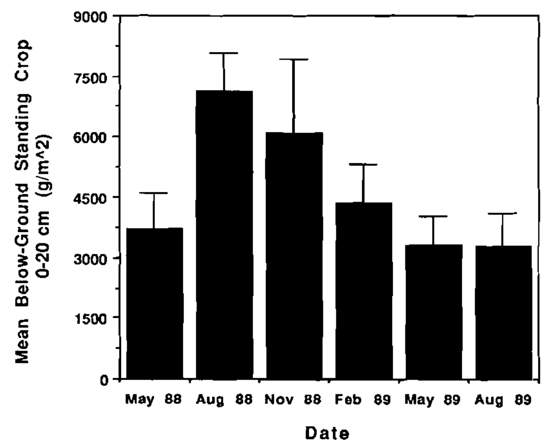


Figure 4c. Seasonal measurements of below-ground standing crops for control plots.

influences BGT in May 1988, the time when BGT values are lowest. This means that BGT is low across the marsh in May but differs between high areas and low areas. A different type of relationship is shown in November 1988. BGT declines after the summer peak in August, when high areas of marsh show higher BGT values than lower areas. Apparently the decline in BGT in November is greater in areas with higher August values, resulting in a more even distribution of BGT across the marsh and an insignificant relationship with plot elevation.

In August 1989 mean BGT values do not show a peak, as in 1988 (Figure 4c). Rather there is some decline in BGT, although mean AGL does

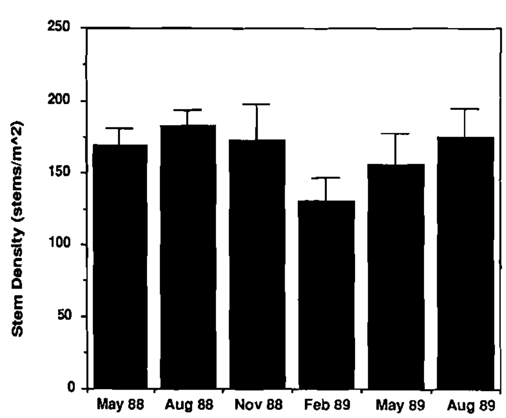


Figure 4b. Seasonal measurements of stem density for control plots.

increase above the value for May (Figure 4a). Higher elevations show higher levels of BGT than do lower elevations in 1989. In addition, the relationship is significant for BGT measured at all depths in the soil profile. This is not the case in August 1988 when plot elevation does not influence BGT at 0–5 or 5–10 cm below the marsh surface (Table 1). SMITH *et al.* (1979) examined vertical changes in below-ground production for a *Spartina alterniflora* marsh in New Jersey. They observed increasing decomposition with depth and that all layers showed the same general seasonal pattern with maxima in July and minima in February. In addition to these seasonal variations, a biomass decline was noted during August which corresponded with a period of very hot weather, low precipitation and high salinity at their study site.

The fact that elevation did not influence BGT in August 1988 but did influence BGT in August 1989 (Table 1) suggests that changes are occurring within the marsh that are suppressing below-ground production in lower areas of the marsh. These changes result in a more significant relationship with elevation. This change from one year to the next, from maximum to minimum below-ground standing crop, combined with the change in relationship with plot elevation, may indicate environmental stress on the vegetation, similar to that observed in the short-term by SMITH *et al.* (1979), and that below-ground reserves of nutrients to support above-ground production are being depleted. The stem density data in Table 1 also reflect deterioration of the vegetation in lower parts of the marsh. At the beginning of the study there was no relationship between stem density and plot elevation. During 1989 monitoring periods, however, lower elevations on the marsh surface have consistently shown lower stem densities.

We attribute the increased significance in the relationship between elevation and vegetation parameters to differential response across the marsh surface to seasonal environmental changes (*e.g.*, water level, water salinity, temperature, photoperiod, *etc.*). Although this relationship is complicated by seasonal influences, our data indicate that the marsh in the study area is undergoing some deterioration of vegetation and biomass reserves, and elevation is therefore becoming an increasingly important factor influencing vegetation health and vigor.

### Marsh Surface Hydrology and Mechanisms of Deterioration

The relationships between vegetation parameters and marsh elevation, outlined above, indicate the importance of marsh surface topography and illustrate the stress which may be placed upon vegetation by waterlogging effects. The effect of waterlogging has been documented for *Spartina alterniflora* in various studies using both field and greenhouse manipulations of the elevation of blocks of marsh (MENDELSSOHN and MCKEE, 1987; 1988). In their field experiments MENDELSSOHN and MCKEE moved blocks of marsh to either 10 cm above or 10 cm below the marsh surface and monitored aspects of their subsequent growth. They noted that a 10 cm lower elevation caused reductions in height, density and biomass, and a significant effect on soil Eh and sulfide accumulation (MENDELSSOHN and MCKEE, 1987). To examine the hydrological implications of such a change in elevation, PEAKBASE was used to calculate the change in tidal flooding regime during 1988 for two plot elevations with a 10 cm difference in height. The hydroperiod for calendar year 1988 varied between 2,639 hr for the higher elevation and 4,565 hr for the lower. There was no examination of marsh surface topography in relation to MENDELSSOHN and MCKEE'S field experiments, so these calculated differences could not show the changes to which their marsh blocks were subjected. However, these data illustrate the magnitude of change in inundation caused by a 10 cm change in marsh elevation.

Waterlogging is thought to impose stress on marsh vegetation by producing reduced soil conditions leading to the accumulation of toxic sulfides (MENDELSSOHN *et al.*, 1981; KING *et al.*, 1982; DELAUNE *et al.*, 1983; KOCH *et al.*, 1990). In this study soil Eh was measured monthly at a number of plot locations, at both 1 cm and 10 cm below the soil surface. Between 29 August and 1 October 1988, mean Eh for 15 measured plots decreased from −66 mV to −95 mV at 1 cm, and from −80 mV to −112 mV at 10 cm. These differences are significant at the $p = 0.02$ and $p = 0.05$ levels respectively. In the interval between these measurements the marsh was flooded for a total of 616 hr (calculated using PEAKBASE and the mean plot elevation). This period includes one flooding event lasting 206 hr, from 1 AM on 10 September to 3 PM on 18 September, associated with Hurricanes Florence and Gilbert. Although these Eh values are not as low as those described by SWENSON and TURNER (1987), who suggest that Eh can drop by 380 mV when marsh sediment is flooded for one week, they show the impact of a major flooding event on soil redox conditions 10 d after the marsh has returned to a normal tidal flooding regime.

### Marsh Surface Hydrology and Land Building Processes

The relationships shown in Table 1 between vegetation parameters and marsh elevation indicate that waterlogging stress on plants in the study area may be an important factor in decreasing the organic contribution to land building processes. Increased hydroperiod and flooding of lower parts of the marsh surface may allow greater opportunities for allocthonous sediment to be deposited, especially the inorganic fraction. Sedimentation in Louisiana marshes, however, is dominated by storm events (BAUMANN *et al.*, 1984), which affect all elevations of the marsh. REED (1989a) suggests that optimum sediment accumulation occurs when newly deposited sediment dries and consolidates on the marsh surface. In low-lying, waterlogged areas, surface sediments will be more frequently saturated and more susceptible to resuspension than those in higher, drier parts of the marsh. Decreased organic accumulation is, therefore, not compensated for by increased inorganic sediment deposition, and the balance between sea-level rise and land building becomes even more asymmetric. These processes eventually lead to plant death and the removal of the vegetation baffle to tidal action on the marsh surface. Removal of marsh soil and a further decrease in surface elevation results in standing open water and the initiation of marsh ponds.

## CONCLUSIONS

There is a positive relationship between marsh elevation and vegetation vigor for this study site. The topography and hydrology data presented here show how variations in marsh topography can cause dramatic changes in marsh hydroperiod. The lower areas of the marsh surface in the study area are readily subjected to waterlogging, and there is some indication in the vegetation data that plant deterioration is progressing. The implications of this are serious for the balance between land building and seal-level rise in salt marshes in Louisiana. As the rate of relative sea-level rise increases, marshes must increase their rate of land building. If the relationship is out of balance, with sea level dominant, then plant deterioration will begin to occur in the lower parts of marshes. This study shows that this occurs naturally without any requirement for topographic or hydrologic alteration or interference by man, although such alterations could enhance this deterioration.

## ACKNOWLEDGEMENTS

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□ RÉSUMÉ □

On a évalué sur un marais maritime à *Spartina alterniflora*, situé en Louisiane, les liaisons entre la croissance végétale et l'altitude du marais, la fréquence ainsi que la durée de sa submersion. On a utilisé des campagnes de terrain, des enregistrements de marégraphe, et des mesures de la croissance des plantes. L'hydropériode a été calculée à différentes altitudes de la surface du marais, et on a calculée les relations par analyse de régression. Les relations entre l'altitude du marais et les paramètres végétaux on changé au cours de la durée de l'étude. Il y avait une relation positive entre l'altitude et la vigueur de la végétation. Au début de l'étude, l'altitude ne semblait pas influencer la croissance de la plante, mais son effet sur l'ordre de gandeur au dessus et en dessous du sol des plantes sur pied et sur la densité des tiges s'est accru durant la seconde année. Les variations d'altitude sur le site (12 cm) provoquent des changements dramatiques de l'hydropériode (>200%) pour la végétation en différentes zones. Des mesures de Eh indiquent qu'on a, à de faibles hauteurs, des conditions de sol réduites associées à des évènements d'immersion de longue durée. Ces données suggèrent que ce ne sont pas seulement les zones ennoyées du marais qui sont en train de se détériorer. On pense qu'il y aura une récession des plantes, et une dégradation du marais.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ RESUMEN □

La relación entre la altura de la marisma, la frecuencia y duración de las inundaciones, y el crecimiento de los vegetales de la marisma de *Spartina alterniflora*, de la costa de Louisiana, fueron evaluadas por medio de mediciones de campo, registros de marea y mediciones del crecimiento de las plantas durante dos estaciones de desarrollo. Las diferentes alturas sobre la superficie de la marisma eran calculadas para los períodos húmedos y las relaciones eran determinadas por análisis de regresión. Las relaciones entre la elevación de la marisma y los parámetros vegetativos cambió durante el período de estudio. Había una relación positiva entre la altura de la marisma y la fuerza de la vegetación. Al comienzo del estudio la altura parecía no tener influencia en el crecimiento de la planta, pero sí en la densidad de los tallos que aumentó en el segundo año. Cruzando el sitio estudiado se vieron variaciones en la altura (12 cm) que dieron lugar a cambios importantes en el período húmedo (>200%), para la vegetación en áreas diferentes. Las mediciones indicaron que las condiciones del suelo estaban asociadas con las inundaciones de larga duración. Estos datos sugieren que cuanto más se inundan las áreas de marismas más se deterioran y nos anticipa que la planta se marchita cuando esto ocurre en el área, resultando en pérdidas de las tierras húmendas.—*Néstor W. Lanfredi, CIC-UNLP, La Plata, Argentina.*