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# SOIL CHARACTERISTICS OF *SPARTINA ALTERNIFLORA*, *SPARTINA PATENS*, *JUNCUS ROEMERIANUS*, *SCIRPUS OLNEYI*, AND *DISTICHLIS SPICATA* POPULATIONS AT ONE LOCALITY IN MISSISSIPPI

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*ABSTRACT* Soil characteristics from five adjacent monotypic zones or different populations of tidal marsh plants are determined. Populations of *Spartina alterniflora*, *Spartina patens*, *Juncus roemerianus*, *Scirpus olneyi*, and *Distichlis spicata* located in Graveline Bay marsh, Mississippi, are studied. Slight elevational differences between the plant populations exist. The aerial biomass for each plant population is different based on seasonal determinations. Soil pH, organic matter, N, P, K, S, Zn, Ca, and Mg concentrations are based on analyses of seasonal composite soil samples. Analyses of soil water samples are used to determine water content, salinity, $PO_4$, and $NH_3$. The soil characteristics are highly variable within and among populations. Some soil properties are significantly different, while others are not. These results reflect the complex patterns in the physical and chemical soil characteristics among the salt marsh plant populations studied; however, they may not completely account for the differences in standing crop or the sharp delineation between plant zones.

## INTRODUCTION

The occurrence of plant populations within salt marshes is controlled by varying ecological factors. The dominant ecological factors which control plant zonations are salinity (Bourdeau and Adams 1956) and tidal inundation (Hinde 1954); however, other factors, such as the physical and chemical characteristics of the soil, may also be important. Jackson (1952) reported on edaphic and elevational factors which affect the distribution of tidal marsh plants.

The composition of salt marsh plant communities have been reported on the Atlantic and Gulf Coasts. These plant communities may be composed of two or more plant populations. Adams (1963) described the composition of salt marsh communities of North Carolina, and Penfound and Hathaway (1938) reported on the plant communities of the southeastern Louisiana marshlands. Eleuterius (1972) and Eleuterius and McDaniel (1978) have described the marshes in Mississippi.

Tidal marsh soils are very diverse along the coastline of the northeastern Gulf of Mexico. The tidal marsh soils of the Florida Gulf Coast have been studied extensively by Coultas (1978a, 1978b), and Coultas and Gross (1975, 1977). Chabreck (1972) reported on the diversity of the vegetation and the water and soil characteristics of Louisiana marshlands. Brupbacher et al. (1973) have also reported on the chemical properties of marsh soils in Louisiana. However, no detailed or extensive work has been done on the tidal marsh soils of Mississippi.

Relationships between marsh plant communities and soils in Louisiana have been studied by Palmisano (1970). Palmisano and Chabreck (1972) have also reported on the interrelationships between the chemical variables of marsh soils and the distribution of major plant species in Louisiana marshes.

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This study was initiated to compare the soil characteristics in one general location where monotypic stands or populations of several major tidal marsh plant species occur. Graveline Bay (Figure 1) is a closed marsh system in which the only exchange of water is through the constricted mouth of Graveline Bayou. This marsh system was selected because the salt marsh species, which form extensive monotypic zones, are in close proximity to one another and because the habitats of these various populations are approximately at the same elevation. The five populations are: *Spartina alterniflora* Loisel., *Spartina patens* (Ait.) Muhl., *Juncus roemerianus* Scheele, *Distichlis spicata* (L.) Greene, and *Scirpus olneyi* Gray.

## MATERIALS AND METHODS

Composite soil samples were collected seasonally from each of five salt marsh plant populations in Graveline Bay marsh. Three soil samples were collected from 5 to 15 cm below the soil surface, combined, and placed in plastic bags. The samples were frozen until chemical analyses were performed by standard procedures (Black 1965). These seasonal composite soil samples were analyzed for soil pH, organic matter content, total nitrogen (N), acid-extractable phosphorus (P), potassium (K), sulfur (S), zinc (Zn), calcium (Ca), and magnesium (Mg). Salinity, orthophosphate ($PO_4$), and ammonia nitrogen ($NH_3$) analyses were conducted on the soil water from the seasonal composite soil samples. The soil water was removed from the soil samples by vaccuum and analyzed in the water analysis laboratory at the Gulf Coast Research Laboratory. Soil samples were also analyzed for water content seasonally from the five tidal marsh populations. Soil water content is expressed as the ratio of the mass of water present in the sample to the mass of the dry sample, and is presented as a percent (Black 1965). All samples were oven dried in seamless 120-ml cans at 105°C for 48 hours. Preliminary determinations

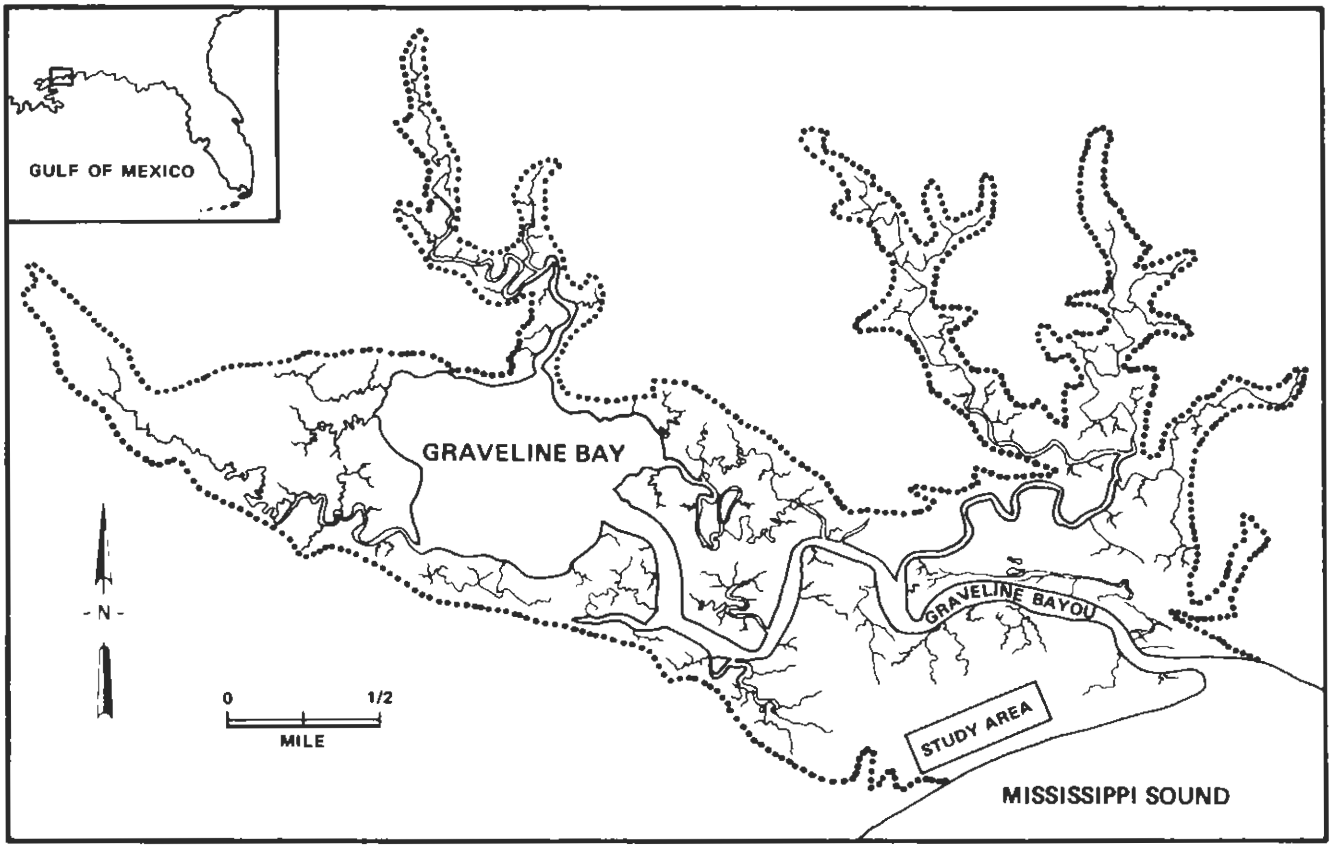


**Figure 1. Map showing general location of plant populations studied in Graveline Bay marsh. Dotted line delineates marsh area.**

indicated that a single seasonal measurement was adequate to approximate these analyses.

An analysis of variance (ANOVA) test was used to determine if a statistical difference existed among the five plant populations for each of the measured soil variables. A Duncan's multiple range test was then used to determine which of the measured soil variables was different among the plant populations.

Elevational data for the plant populations in Graveline Bay marsh were made during an extremely high tide in which the marsh surface was completely covered. Tidal height measurements were taken from the water surface to the soil surface to determine the relative elevation of the plant populations to one another. Statistical analyses were used to determine differences in elevations of the populations.

Three 0.125-$m^2$ quadrat samples of the aerial portion of plants were collected seasonally from each of the five salt marsh plant populations. Plant material was oven dried at 105°C for 24 hours.

## RESULTS

The standing crop values for each of the five different populations at Graveline Bay are shown in Table 1. The winter samples are shown to have the lowest standing crop values in all plant populations. However, the greatest values

**TABLE 1**

**Seasonal comparisons of aerial dry mass values (g) of the dominant species in the five plant populations. Values represent the mean and standard error of the mean for three samples.**

| Plant Populations (species) | Autumn | Winter | Spring | Summer |
|---|---|---|---|---|
| *D. spicata* | 192.3 ± 2.9 | 167.0 ± 6.5 | 180.3 ± 7.0 | 219.3 ± 8.3 |
| *J. roemerianus* | 616.2 ± 25.9 | 490.0 ± 100.3 | 712.0 ± 21.2 | 579.7 ± 40.5 |
| *S. alterniflora* | 300.2 ± 17.0 | 177.0 ± 18.6 | 245.7 ± 24.2 | 225.0 ± 20.1 |
| *S. patens* | 330.4 ± 46.2 | 218.7 ± 21.0 | 543.0 ± 38.7 | 384.3 ± 36.3 |
| *S. olneyi* | 219.3 ± 13.7 | 131.7 ± 11.3 | 268.5 ± 21.8 | 213.7 ± 4.2 |

recorded show that peak aerial plant mass is obtained in the spring for *J. roemerianus* (712.0 g), *S. patens* (543.0 g), and *S. olneyi* (268.5 g). The greatest aerial biomass for *D. spicata* (219.3 g) is recorded in summer, and the greatest value for *S. alterniflora* (300.2 g) occurs in autumn. Comparison of these data clearly shows that *J. roemerianus* has almost twice the standing crop as *S. alterniflora* and *S. patens*, and the standing crop of *D. spicata* is similar to that of *S. olneyi*. Very little seasonal variation occurs in the *D. spicata* population in contrast to fluctuations in the other plant populations.

Elevation varies in the study area from 0.0 to 7.0 cm over the entire area of the five populations and averages 2.8 cm. Comparison of elevational data among the five plant populations in Graveline Bay marsh discloses that the highest elevation is found in the *D. spicata* population. The differences in the elevations among the plant populations show that *J. roemerianus, S. alterniflora, S. olneyi,* and *S. patens* occur at mean elevations below the *D. spicata* population of only 2.1, 2.2, 3.3, and 4.6 cm, respectively. However, statistical analysis on the elevational data indicate that differences exist among some populations. The *D. spicata* population is different from all other populations (Figure 2). The populations of *J. roemerianus, S. alterniflora,* and *S. olneyi* do not differ from each other; however, the results also indicate that the *S. olneyi* population is not different from the population of *S. patens*.

Soil water content varies throughout the year in relation to tidal action and precipitation. The lowest soil water content values ($\bar{x}$ = 43.2%) occurred in the plant population dominated by *D. spicata* (Table 2) and remained relatively low throughout the year. Soil water content values from other plant populations ranged from a low of 63.5% in autumn for the *S. patens* dominated population, to a high of 221.2% for the *S. alterniflora* population in spring. Soil water content values from the populations dominated by *J. roemerianus, S. alterniflora, S. patens,* and *S. olneyi,* show some variation among the populations, as well as from season to season; however, there appears to be no consistent pattern except for generally lower water content values during winter. Statistical analysis on the soil water content shows that differences exist among these populations.

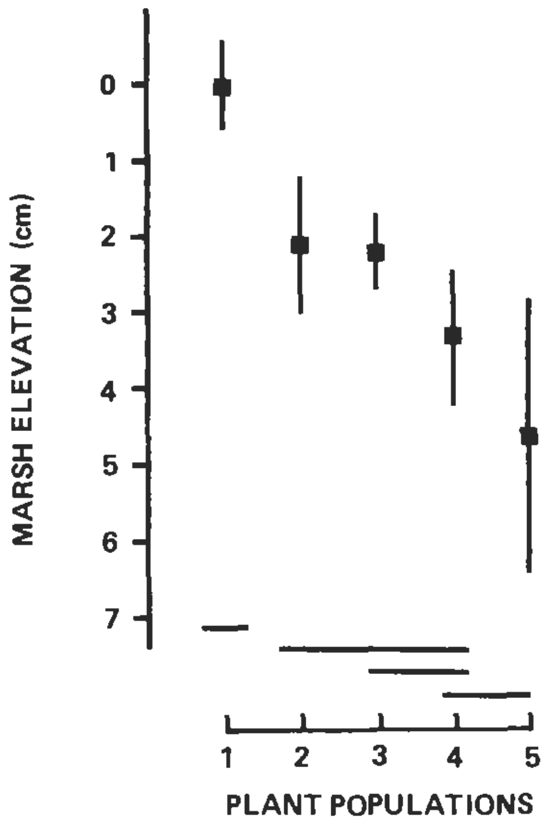


**Figure 2. Elevational mean values for plant populations at Graveline Bay marsh. Plant populations: 1-*Distichlis spicata*, 2-*Juncus roemerianus*, 3-*Spartina alterniflora*, 4-*Scirpus olneyi*, 5-*Spartina patens*. Vertical line indicates 95% confidence interval. Horizontal lines over plant populations indicate significant difference (α = 0.05) from the Duncan's multiple range test.**

TABLE 2

**Soil water content, salinity, orthophosphate and ammonia nitrogen taken from five salt marsh plant populations at Graveline Bay marsh. Four seasonal values recorded for each analysis are combined and presented as the mean and standard error of the mean for the individual plant populations. Soil water content values represent the percentage of water in the soil sample on a dry-mass basis. Means in vertical columns followed by the same capital letters are not significantly different (α = 0.05) according to Duncan's multiple range test.**

| Plant Populations (Species) | Soil Water Content | Salinity (ppt) | Orthophosphate (µg–at P/L) | Ammonia Nitrogen (µg–at N/L) |
|---|---|---|---|---|
| *D. spicata* | 43.2 ± 5.5 A | 12.0 ± 1.5 | 28.32 ± 13.75 | 523.01 ± 306.95 |
| *J. roemerianus* | 151.6 ± 21.0 B | 15.5 ± 1.1 | 25.47 ± 17.21 | 812.34 ± 547.73 |
| *S. alterniflora* | 153.8 ± 25.5 B | 12.8 ± 0.4 | 7.80 ± 2.45 | 371.85 ± 42.35 |
| *S. patens* | 100.4 ± 11.4 A,B | 12.0 ± 0.4 | 9.41 ± 6.39 | 283.75 ± 53.00 |
| *S. olneyi* | 113.4 ± 20.0 B | 12.5 ± 1.1 | 2.52 ± 2.11 | 193.25 ± 64.04 |
| $F_{(4,15)}$* | 4.655† | 1.513 | 0.918 | 0.547 |

*F value from the one-way analysis of variance.
†Significant at the 0.05 level.

Results of the Duncan's multiple range test indicate that the *S. patens* population did not differ from the other populations. However, the *D. spicata* population is different from the populations of *J. roemerianus, S. alterniflora,* and *S. olneyi.*

Soil water salinity fluctuates in the salt marsh with the amount of tidal flooding, evaporation, and precipitation. Seasonal soil water salinity samples show minor variations among the plant populations during each season, however, there is no statistical difference (Table 2). The greatest soil water salinity values are generally obtained in the summer and the lowest values occur in the winter. Soil water salinity values range from 7 to 15 ppt in the *D. spicata* population and from 12 to 18 ppt in the *J. roemerianus* population. The salinities in the populations dominated by *S. alterniflora, S. patens,* and *S. olneyi* range from 12 to 14 ppt, 11 to 13 ppt, and 9 to 15 ppt, respectively.

Orthophosphate and ammonia nitrogen concentrations vary greatly not only among the plant populations sampled during the same season, but also among the seasons for the individual plant populations. Orthophosphate concentrations vary from 3.67 μg in autumn to 74.90 μg in summer for the *D. spicata* population and from 2.47 μg in winter to 84.93 μg in spring for the population dominated by *J. roemerianus.* Concentrations in the *S. alterniflora* population range from 2.51 μg in winter to 15.82 μg in summer. The *S. patens* and *S. olneyi* populations range from 0.00 μg in summer to 31.12 μg and 9.83 μg, respectively, in spring. Ammonia nitrogen concentrations for the *D. spicata* and *S. patens* populations range from 53.73 μg and 161.54 μg, respectively, in summer to 1554.00 μg and 411.60 μg, respectively, in winter. The ammonia nitrogen in the populations of *S. alterniflora* and *S. olneyi* ranges from 261.96 μg and 34.58 μg, respectively, in spring to 478.00 μg in winter for *S. alterniflora* and 392.08 μg in autumn for *S. olneyi.* The ammonia nitrogen in the *J. roemerianus* population ranges from 122.64 μg in summer to 2706.25 μg in autumn. Although the variations in $PO_4$ and $NH_3$ are large, there are no statistical differences (Table 2).

No statistical differences are indicated by the ANOVA test among the plant populations for the soil elements K, S, Zn, Ca, and Mg (Table 3). However, there is a difference among the plant populations for the variables pH, N, P, and organic matter content.

Soil pH values are greater in the *D. spicata* plant population than in all other populations. Statistical comparison of the *D. spicata* population to all others shows it to be different. The populations of *J. roemerianus, S. patens,* and *S. alterniflora* are similar in soil pH and do not differ statistically. However, the soil pH values of the *S. alterniflora* population are also similar to those in the population of *S. olneyi.* And the values of these two populations are not statistically different. The range and mean pH values are shown in Table 3, along with the statistical relationships between the five plant populations.

Total nitrogen concentrations and the amount of organic matter in the soils are considerably lower in the *D. spicata* population than in all other plant populations. Phosphorus concentrations in the *D. spicata* population are greater than concentrations in the *J. roemerianus* population and the

TABLE 3

**Chemical characteristics of composite soil samples taken from five salt marsh plant populations at Graveline Bay marsh. The four seasonal values recorded for each soil analysis were combined and presented as a mean and standard error of the mean for the individual plant population. Means in vertical columns followed by the same capital letters are not significantly different ($\alpha = 0.05$) according to Duncan's multiple range test. Range values are in parenthesis.**

| Plant Populations (species) | pH | Organic Matter (%) | N (ppm) | P (ppm) | K (ppm) | S (ppm) | Zn (ppm) | Ca (ppm) | Mg (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| *D. spicata* | (7.4–7.7)<br>7.5 A<br>±0.1 | 3.9 A<br>±0.4 | 1446 A<br>±133 | 189 A<br>±24 | 285+<br>±0 | 300+<br>±0 | 5.19<br>±0.74 | 1616<br>±230 | 1420<br>±113 |
| *J. roemerianus* | (5.7–6.2)<br>6.0 B<br>±0.1 | 9.7 B<br>±0.9 | 4574 B<br>±858 | 133 B<br>±11 | 285+<br>±0 | 300+<br>±0 | 5.69<br>±0.89 | 1372<br>±225 | 2694<br>±465 |
| *S. alterniflora* | (4.6–6.4)<br>5.6 B,C<br>±0.4 | 10.1 B<br>±0.5 | 4494 B<br>±529 | 74 C<br>±5 | 285+<br>±0 | 300+<br>±0 | 6.81<br>±0.48 | 1044<br>±143 | 2167<br>±305 |
| *S. patens* | (5.5–6.9)<br>6.0 B<br>±0.3 | 10.4 B<br>±0.2 | 4204 B<br>±522 | 76 C<br>±2 | 285+<br>±0 | 300+<br>±0 | 7.73<br>±0.67 | 1084<br>±66 | 2106<br>±92 |
| *S. olneyi* | (3.7–6.3)<br>4.8 C<br>±0.5 | 8.7 B<br>±1.3 | 4089 B<br>±986 | 67 C<br>±3 | 285+<br>±0 | 300+<br>±0 | 7.48<br>±0.54 | 1080<br>±208 | 1948<br>±371 |
| $F_{(4,15)}$ | 8.767† | 12.376† | 3.761† | 17.835† | 0.000 | 0.000 | 2.650 | 1.794 | 2.230 |

†Significant at the 0.05 level.

concentrations of phosphorus in the soils of these two populations are greater than those of the areas supporting the other plant populations. The populations of *S. patens, S. alterniflora,* and *S. olneyi* do not differ from each other in the concentration of soil phosphorus. No differences in soil sulfur and potassium concentrations are found among the five plant populations. The concentrations for the soil elements Mg, Ca, and Zn show variation among the plant populations, although no statistical differences are noted.

## DISCUSSION

Variations in the soil properties of salt marshes have been studied along the Gulf Coast in Florida (Coultas and Gross 1977) and Louisiana (Chabreck 1972); however, the soils of the marshlands of Mississippi have not been adequately surveyed. Plant zonation in salt marshes has been studied along the Atlantic and Gulf coasts; however, the relative importanee of different environmental factors, sueh as salinity, tides, elevation, and soil characteristics affecting the zonation in salt marshes is unclear. For example, some studies indicate that elevation may be the cause for plant zonation (Harshberger 1911, Johnson and York 1915, Reed 1947, Hinde 1954). However, Eleuterius and Eleuterius (1979) indicated that other factors, such as soil water salinity, may be involved, which are superimposed on the elevation-tide level relationship. Jackson (1952), Kurz and Wagner (1957), Adams (1963), and Shiflet (1963) indicated that soil water salinity was the primary factor affecting plant zonation in tidal marshes. Furthermore, Gillham (1957), Beeftink (1966), and Ranwell (1972), have observed inversions of zonation to tidal submergence. These reports and the present study, where no differences in soil water salinity are found among populations, indicate that perplexing relationships exist among plant zonation, elevation, and tidal submergence. Palmisano (1970) and Palmisano and Chabreck (1972) have reported on the relationship between the soils and plant communities in Louisiana marshlands and no consistent relationships between soil nutrients and vegetational type were found. Considerable overlaps were observed in nutrient concentrations among vegetational types. Lanning and Eleuterius (1978) showed that the silica content of soils from four populations of *J. roemerianus* was different.

The Graveline Bay marsh plant populations studied are predominantly pure stands of the salt marsh species. The *S. olneyi* stand is a pure stand; however, occasional plants of *D. spicata* are found intermixed with *J. roemerianus.* A few plants of *Borrichia frutescens* are found around the edge of the *D. spicata* stand. The *S. alterniflora* stand contains an occasional plant of *Spartina cynosuroides.* The *S. patens* stand is pure. The fluctuations in the aerial plant mass during the seasons are considered to be typical of the respective salt marsh plant species. In late summer, *D. spicata* reaches maximum aerial mass; *J. roemerianus, S. patens,* and *S. olneyi* each reach maximum aerial mass in spring; and *S. alterniflora* has the greatest aerial mass in autumn.

Results presented here show little variation in the elevation among plant populations in Graveline Bay marsh; however, *D. spicata* occurs at the highest elevation and *S. patens* occurs at the lowest elevation, with *J. roemerianus, S. alterniflora,* and *S. olneyi* occurring at approximately the same elevation. These data indicate that there are elevational differences among the five plant populations, but all of the populations only span an average range of 4.6 cm.

Soil water content values are consistently lower in the *D. spicata* population, when compared seasonally to the other plant populations. Soil water content values for the other plant populations seem to be similar to one another, although variations occur among seasons and populations. Soil water content and organic matter appear to be related to marsh elevation. The lowest water content and lowest amount of organic matter are found in the *D. spicata* population, which occurs at the highest elevation.

The seasonal soil water salinity values show only slight variations of less than 6 ppt among the plant populations. However, the soil water salinities are generally lower in winter and higher in summer. Although the soil water salinity values vary, there are no appreciable differences among the five plant populations. Orthophosphate and ammonia nitrogen concentrations from the soil water show seasonal variations for each plant population and also show a wide range of differences among plant populations for individual seasons.

Although the soil pH values found in the plant populations range from 3.7 to 7.7, they are typical for tidal marsh soils and correspond closely to those reported by Chabreck (1972). The percent of soil organic matter varied widely among the plant populations studied. Boyd (1970) showed that there was a correlation between soil organic matter content and soil nitrogen for aquatic plant habitats. This relationship was also found in the present study, where lower organic matter content in the soil corresponds to lower soil nitrogen concentration. The *D. spicata* population has the lowest mean amount of organic matter in the soil and the populations of *S. patens* and *S. alterniflora* have the greatest mean organic matter values. The mean total nitrogen concentration in the soil is considerably less in the *D. spicata* population than in other plant populations studied. Although the soil organic matter varied among the populations of *J. roemerianus, S. alterniflora, S. patens,* and *S. olneyi,* they all have similar soil total nitrogen concentrations.

Brupbacher et al. (1973) reported large variations in phosphorus from the marsh soils of Louisiana. In the present study, soil phosphorus concentrations represent a wide range of values among the plant populations, but these concentrations are within the ranges of those reported by Brupbacher et al. (1973). The *D. spicata* population has the greatest soil phosphorus concentration and *S. alterniflora,* *S. patens*, and *S. olneyi* populations are considerably less. DeLaune and Patrick (1980) stated that nitrogen was more important than phosphorus to plant growth in Louisiana marshes.

Brupbacher et al. (1973) reported large variations in Ca and Mg for the marsh soils in Louisiana, however, our results show only slight variations. Dunstan and Windom (1975) have reported zinc concentrations in marsh sediments on the Atlantic Coast ranging from 14.9 to 69.6 ppm. We found the greatest mean concentrations of Mg in the *J. roemerianus* population and the lowest mean concentrations in the population of *D. spicata*. For the element Ca, the *D. spicata* population has the greatest mean concentrations and the *S. alterniflora* population the lowest. In the present study, soil concentrations of the element Zn show only a small range from a mean high of 7.73 ppm in the *S. patens* population to a low of 5.19 ppm in the *D. spicata* population.

Boyd and Hess (1969) showed that an increase in soil nutrients increased shoot production of *Typha latifolia*. The five plant species reported upon in the present paper are represented by different standing crops. Biomass depends largely on the peculiar vegetative morphology of each species. Although our results reflect some differences in physical and chemical soil characteristics among the five salt marsh plant populations, their role in the sharp delineation between plant zones remains unknown. It should also be pointed out that the vegetational composition of the area studied here is not characteristic of all marshes in Mississippi. The Graveline Bay marsh is unusual in having five different kinds of plant populations present adjacent to one another. However, the study clearly shows that the five plant species can and do form populations on intertidal areas with similar soil characteristics and that they are capable of occupying the same terrain in some locations.

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