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TEMPORAL CHANGES IN THE VEGETATION PATTERN IN A TIDAL FRESHWATER MARSH

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Abstract: Temporal changes in vegetation patterns of Chesapeake Bay wetlands have been poorly documented. Data from a 1987 vegetation analysis of a Chesapeake Bay tidal freshwater marsh were compared to those of a vegetation study completed in 1974. Changes in the vegetation pattern were calculated using species importance values and a species diversity index. Comparison of the 1987 and 1974 results shows no significant difference in species diversity index. However, there was a significant difference in species contribution to the index. *Spartina cynosuroides*, an oligohaline species that was not among the dominant species listed in the 1974 study, had the fourth highest importance value in this study. The change in dominant species composition of the marsh may reflect a directional shift from tidal freshwater toward oligohaline conditions.

Key Words: tidal freshwater marsh, vegetation pattern, temporal change, tidal wetlands

INTRODUCTION

Wetlands are valued for many reasons, such as providing wildlife nesting, breeding, and foraging habitat; for water quality and flood control processes; and as shoreline erosion buffers. A mosaic of wetland communities provides a large number of habitats and, therefore, increases the number and types of roles played by wetlands within a watershed (Gosselink and Turner 1978). The functional values of a wetland are most often tied directly to the types, numbers, and distribution of plant species present, i.e., the vegetation community(s)(Brinson 1993).

Chesapeake Bay has a large number of wetland communities that are distributed along both tidal and salinity gradients (Wass and Wright 1969, Odum et al. 1984, Titus 1987). The vegetation community of a wetland depends somewhat on its location along these gradients (Odum et al. 1984, Odum 1988, Perry and Atkinson 1997). In turn, tidal and salinity gradients can vary both spatially and temporally (Odum et al. 1984, Hull and Titus 1987, Odum 1988).

Spatial distribution of wetlands along several primary tributaries of Chesapeake Bay has been well-documented (Anderson et al. 1968, Wass and Wright 1969, Atkinson et al. 1990, Perry and Atkinson 1997). Little information, however, is available concerning temporal vegetation changes in tidal wetland communities of Chesapeake Bay.

In 1987, we conducted a vegetation analysis on Sweet Hall Marsh, a tidal freshwater marsh of the Chesapeake Bay. A previous study of the marsh (Doumlele 1976, 1981) provided historical quantitative vegetation data for comparison. The purpose of our study was to determine and quantify temporal changes that may have occurred within the vegetation pattern of Sweet Hall Marsh between the two studies.

SITE DESCRIPTION

Sweet Hall Marsh has been characterized as a 440 ha tidal freshwater marsh located on the Pamunkey River, King William County, Virginia, USA (Doumlele 1976, 1981), approximately 25 river km upstream from the confluence of the Pamunkey and Mattaponi Rivers (Figure 1). The 60 ha research site is located in the north portion of Sweet Hall Marsh. It is separated from the main portion of the marsh by a 10–15 m wide tidal creek on the south and bordered on the north by scrub/shrub and forested wetlands. The mean tidal range at the site is 0.83 m (Brooks 1983, U.S. Dept. Comm. 1991). The estuary adjacent to the marsh is ebb-dominated, with 6.7 hrs of flood and 5.7 hrs of ebb. Average yearly salinity of the site is approximately 0.45 ppt and ranges from 0 to 7 ppt (calculated from 1970–1980 data (Brooks 1983)). No significant climatic events, such as hurricanes or 100-year floods, have occurred in the Sweet Hall Marsh area during the 14-year period (National Weather Service 1996).

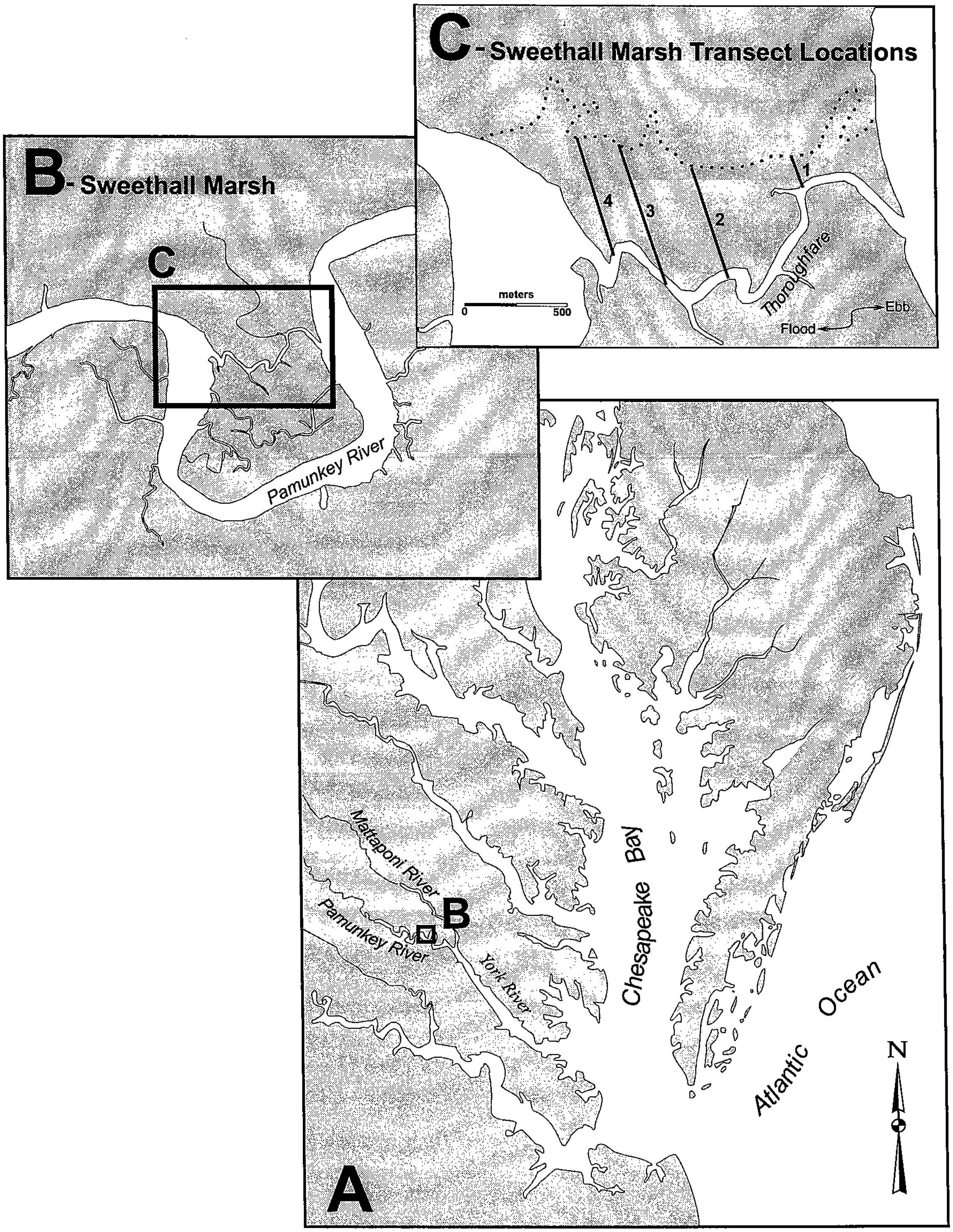

Figure 1A. Location of Sweet Hall Marsh on the Pamunkey River, Virginia. B. Location of the study site. Site consisted of a 60-ha section of Sweet Hall Marsh, Pamunkey River, King William Co., Virginia, USA. C. Position of transects used in this study. Transects were located to allow comparison of data from a previous study of the same site (Doumlele 1976, 1981).

Table 1. Vascular plants for Sweet Hall Marsh that occurred in the collecting plots of this study. Nomenclature follows Gleason and Cronquist (1991).

POLYPODIAPHYTA (ferns)

- Aspleniaceae
  - *Thelypteris palustris* Schott; marsh fern
- Osmundaceae
  - *Osmunda regalis* L.; royal fern

MAGNOLIOPHYTA (flowering plants)

- Alismataceae
  - *Sagittaria latifolia* var. *latifolia* Willd.; duck potato
- Amaranthaceae
  - *Amaranthus cannabinus* (L.) Sauer; water hemp
- Apiaceae
  - *Cicuta maculata* L.; water hemlock
  - *Sium suave* Walter; water parsnip
- Araceae
  - *Peltandra virginica* (L.) Schott and Endl.; arrow-arum
- Asclepiadaceae
  - *Asclepias incarnata* L.; marsh milkweed
- Asteraceae
  - *Aster racemosus* Elliot; marsh aster
  - *Bidens coronata* (L.) Britton; beggers-tick
  - *B. laevis* (L.) BSP; beggers-tick
  - *Mikania scandens* (L.) Willd.; climbing hempweed
- Balsaminaceae
  - *Impatiens capensis* Meerb.; jewelweed
- Caesalpiniacea
  - *Chamacrista fasciculata* (L.) Moench; partridge pea
- Commelinaceae
  - *Murdania keisak* (Hassk.) Hand.-Mazz; asian day lily
- Convolvulaceae
  - *Calystegia sepium* (L.) R.Br.; hedge-bindweed
- Cyperaceae
  - *Cares hyalinolepis* Steudel; sedge
  - *Carex stricta* Lam.; sedge
  - *Eleocharis quadrangulata* (Michx.) Roemer & Schultes; four-sided spikerush
  - *Eleocharis* sp.; spikerush
  - *Scirpus americanus* Pers.; Olney-threesquare
  - *Scirpus robustus* Pursh; saltmarsh threesquare
  - *Scirpus validus* Vahl; soft-stem bulrush
- Iridaceae
  - *Iris virginica* var. *virginica* L.; blue flag
- Lamiaceae
  - *Teucrium canadensis* var. *canadensis* L.; marsh teucrium
- Malvaceae
  - *Hibiscus moscheutos* L.; marsh mallow

Table 1. Continued.

- Poaceae
  - *Cinna arundinacea* L.; cinna
  - *Echinochloa crusgalli* (L.) P. Beauvois; barnyard grass
  - *Echinochloa walteri* (Pursh) Heller; Walter's millet
  - *Leersia oryzoides* (L.) Swartz; rice cutgrass
  - *Panicum virgatum* L.; panic grass
  - *Phragmites australis* (Cav.) Trin.; tall reed grass
  - *Spartina alterniflora* Loisel.; smooth cord-grass, salt cord-grass
  - *Spartina cynosuroides* (L.) Roth; big cord-grass
  - *Zizania aquatica* L.; wildrice
- Polygonaceae
  - *Polygonum arifolium* L.; narrow leaved tear-thumb
  - *Polygonum punctatum* Elliot; knotweed
  - *Polygonum sagittatum* L.; tear-thumb
  - *Rumex verticillatus* L.; water-dock
- Pontederiaceae
  - *Pontederia cordata* L.; pickerel weed
- Ranunculaceae
  - *Thalictrum pubescens* Pursh; tall marsh-rue
- Rosaceae
  - *Rosa palustris* Marshall; swamp-rose
- Rubiaceae
  - *Galium obtusum* Bigelow; bluntleaved-bedstraw
- Typhaceae
  - *Typha angustifolia* L.; narrow-leaved cat-tail
- Urticaceae
  - *Boehmeria cylindrica* (L.) Swartz; false nettle

METHODS

Flora

All vascular plants encountered in the study plots were identified to species level. Nomenclature follows Gleason and Cronquist (1991). Voucher specimens are deposited at the Virginia Institute of Marine Science teaching herbarium, Gloucester Point, Virginia.

A Sorenson's index of similarity (Kontkanen 1957) was used as a measure of the association between the flora of the two studies and was calculated as follows:

$$QS = \frac{2c}{a + b} \times 100$$

where

QS = Sorenson's index of similarity
a = number of species found in Doumlele's 1976 study
b = number of species found in this study
c = number of species common to both studies.

Table 2. Plants present in Doumlele's study (1976, 1981) but absent from this study. LS = life strategy (A = annual, P = perennial, W = woody). Life strategy of *Hypericum* sp. could not be determined.

Species	LS
Acer rubrum L.	P(w)
Amphicarpa bracteata (L.) Fern.	A
Clematis crispa L.	P
Decodon verticillatus (L.) Ell.	P(w)
Hypericum sp.	?
Juncus effusus L.	P
Parthenocissus quinquefolia (L.) Planch	P(w)
Toxicodendron radicans (L.) Kuntze	P(w)
Vitis sp.	P(w)

Vegetation Parameters

Four vegetation transects were established on site (Figure 1). Three of the transects were resampled from Doumlele's study (Doumlele 1976). A fourth transect used in the original study has been partially lost due to shoreline erosion and could not be resampled. Therefore, a fourth transect (Transect 4) was chosen for this study. Transect 4 is approximately 20 m east of the original transect, with the same orientation and length. Transects started at the creek bank and stretched landward to an adjacent shrub/forested wetland (Figure 1). Lengths were 110, 190, 290, and 240 m for transects 1 to 4, respectively.

Methods for taking vegetation measures followed Doumlele (1976, 1981), and data were collected on the third week of each month from April through October, 1987. The four transects were divided into 11, 19, 29, and 24 sections 10 m in length for transects 1–4, respectively. However, the last landward section was excluded from the study due to transitional wetland-to-upland properties. During each sampling event, a random point from zero to nine was chosen on each section (zero nearest the water-ward edge of the section, nine the landward edge). A second random number from zero to nine was used to determine distance in meters out from, and perpendicular to, the transect. A coin toss was used to determine perpendicular direction (even=left, odd=right). Therefore, a total of 83 plots were established (11, 19, 29, and 24 on transects 1–4, respectively). Square PVC frames (1.0 m × 1.0 m) were used to establish the plot boundaries. Percent cover and stem densities were recorded for each species within the plot. Frequency, a measure of presence/absence of a species, was indirectly measured when cover data were taken. For each plot on a transect, the list of species that have cover values in the plot represent a count of one (1) for each species measured. To find the overall frequency of an individual species, we divided the total number of times a species occurred on a collecting date (i.e., total number of plots that a species occurred in) by the sum of all species occurrences in all plots for that date. Cover data were estimated directly in the field as a value of 1 to 100% or trace (<1%). Cover data were transposed to mid-class ranges for data analysis using a modified Braun-Blanquet cover scale (Daubenmire 1966, 1968) where: 0<1%=trace, 1 to 5%=2.5%, 6 to 25%=15%, 26 to 50%=37.5%, 51 to 75%=62.5%, 76 to 95%=85.0%, 96 to 100%= 97.5%. For biomass measurements, vegetation within each plot was clipped, returned to the lab, separated by species, and oven dried at 40°C until the weight of samples stabilized. Annual standing crop (ASC) biomass was calculated from monthly peak dry weight (i.e., the month the community biomass peaked) (Doumlele 1976, 1981). Dominant species in each study were based on the species whose sum(s) total ASC biomass is (are) greater than 50% of the total biomass (Muller-Dombois and Ellenberg 1974, Doumlele 1976, 1981).

Relative frequency, relative density, and relative dominance were calculated using the following formulas (Phillips 1959, Mueller-Dombois and Ellenberg 1974, Doumlele 1976, 1981):

Relative frequency

$$= \frac{\text{Species frequency}}{\text{Sum of frequency values for all species}} \times 100$$

Relative density

$$= \frac{\text{Number of stems of individual species}}{\text{Number of stems of all species}} \times 100$$

Relative dominance

$$= \frac{\text{Species coverage}}{\text{Sum of coverage values for all species}} \times 100$$

Species importance values are the sum of the above three parameters (Curtis and McIntosh 1950, Phillips 1959, Mueller-Dombois and Ellenberg 1974) and were used to rank species. Species diversity was calculated using the Shannon index (Shannon and Weaver 1949, Doumlele 1976, 1981). Species richness and evenness were calculated according to Pielou (1969).

Changes in Vegetation Pattern

A Wilcoxon sign-ranked test was used to test for changes in the density (number of stems per square meter), coverage (fraction of 1 m × 1 m plot covered), and importance values of the ten most common species (those with the highest IV) from Doumlele's study and their paired values from this study. Com-

Table 3. Species ranked by mean importance value (IV). Ten most common species from this study marked in bold. All values rounded to nearest one hundredth. Relative density (RD), relative cover (RC), and relative frequency (RF), are seasonal mean (n = 7). * = RF values less than 0.005. LS = life strategy (A = annual, P = perennial). P/A = present (+) or absent (−) from Doumlele's study (1976, 1981). Rank of 10 most common species from Doumlele's study denoted in (). PR = taxa noted by Doumlele as present in the adjacent marsh but not in the study plots.

Species	RD	RC	RF	IV	LS	P/A
Peltandra virginica	23.58	41.4	21.35	86.34	P	+(1)
Leersia oryzoides	32.75	10.25	15.61	58.61	P	+(2)
Zizania aquatica	11.18	11.73	7.51	30.42	A	+
Spartina cynosuroides	7.17	10.00	8.97	26.15	P	+
Carex hyalinolepis	4.70	9.69	7.08	21.47	P	+
Polygonum punctatum	6.11	3.10	7.42	16.62	A	+(3)
Bidens laevis	2.42	2.35	4.64	9.41	P	+
Carex stricta	3.29	1.51	1.41	6.22	P	+(5)
Echinochloa walteri	1.31	1.08	3.42	5.81	A	+
Amaranthus cannabinus	1.28	0.36	2.98	4.62	A	+
Pontederia cordata	0.82	1.38	2.09	4.28	P	+(4)
Rumex verticillatus	0.38	1.48	1.54	3.41	P	+
Polygonum arifolium	0.21	1.39	1.63	3.23	A	+(8)
Murdania keisak	0.95	0.30	1.59	2.85	A	+(7)
Typha angustifolia	0.31	0.62	1.49	2.42	P	+
Polygonum sagittatum	0.27	0.50	1.50	2.27	A	+
Eleocharis quadrangulata	0.79	0.12	1.31	2.22	P	+
Phragmites australis	0.21	0.47	1.15	1.83	P	+(9)
Scirpus validus	0.32	0.18	1.01	1.51	P	+
Bidens coronata	0.52	0.09	0.65	1.26	A	+
Teucrium canadensis	0.09	0.12	0.87	1.07	P	+
Osmunda regalis v. *spectabilis*	0.13	0.67	0.23	1.02	P	+
Hibiscus moscheutos	0.06	0.31	0.52	0.89	P	+(10)
Cicuta maculata	0.13	0.12	0.52	0.78	P	−
Spartina alterniflora	0.28	0.09	0.38	0.75	P	+
Eleocharis sp.	0.28	0.01	0.33	0.62	P	−
Calystegia sepium	0.07	0.13	0.37	0.57	P	−
Mikania scandens	0.01	0.08	0.37	0.46	P	−
Chamaecrista fasciculata	0.02	0.07	0.25	0.34	A	+
Cinna arundinacea	0.02	0.04	0.23	0.29	P	−
Thelypteris palustris	0.13	0.07	0.06	0.26	P	+
Aster racemosus	0.03	0.46	0.17	0.25	P	−(PR)
Scirpus americanus	0.04	0.03	0.18	0.25	P	+
Thalictrum pubescens	0.04	0.03	0.18	0.25	P	+
Scirpus robustus	0.02	0.02	0.18	0.23	P	−(PR)
Boehmeria cylindrica	0.00	0.02	0.12	0.14	P	+
Panicum virgatum	0.05	0.01	0.06	0.12	P	−
Asclepias incarnata	0.01	0.01	0.07	0.09	P	−(PR)
Galium obtusum	0.02	0.01	0.06	0.09	P	+
Impatiens capensis	0.00	0.01	0.6	0.07	A	+(6)
Iris virginica	0.02	0.0*	0.06	0.07	P	−
Rosa palustris	0.00	0.01	0.06	0.07	P	+
Sagittaria latifolia	0.00	0.01	0.06	0.07	P	+
Echinochloa crusgalli	0.01	0.0*	0.06	0.06	A	−
Sium suave	0.01	0.0*	0.06	0.06	P	−(PR)

parison of seasonal species richness, evenness, and diversity was tested using a Chi-square goodness-of-fit test. Statistics were performed using StatMost for Windows Statistical Analysis and Graphics program (DataMost 1994).

RESULTS

Flora

Forty-five vascular plants, representing 40 genera and 25 families, occurred in the research plots (Table

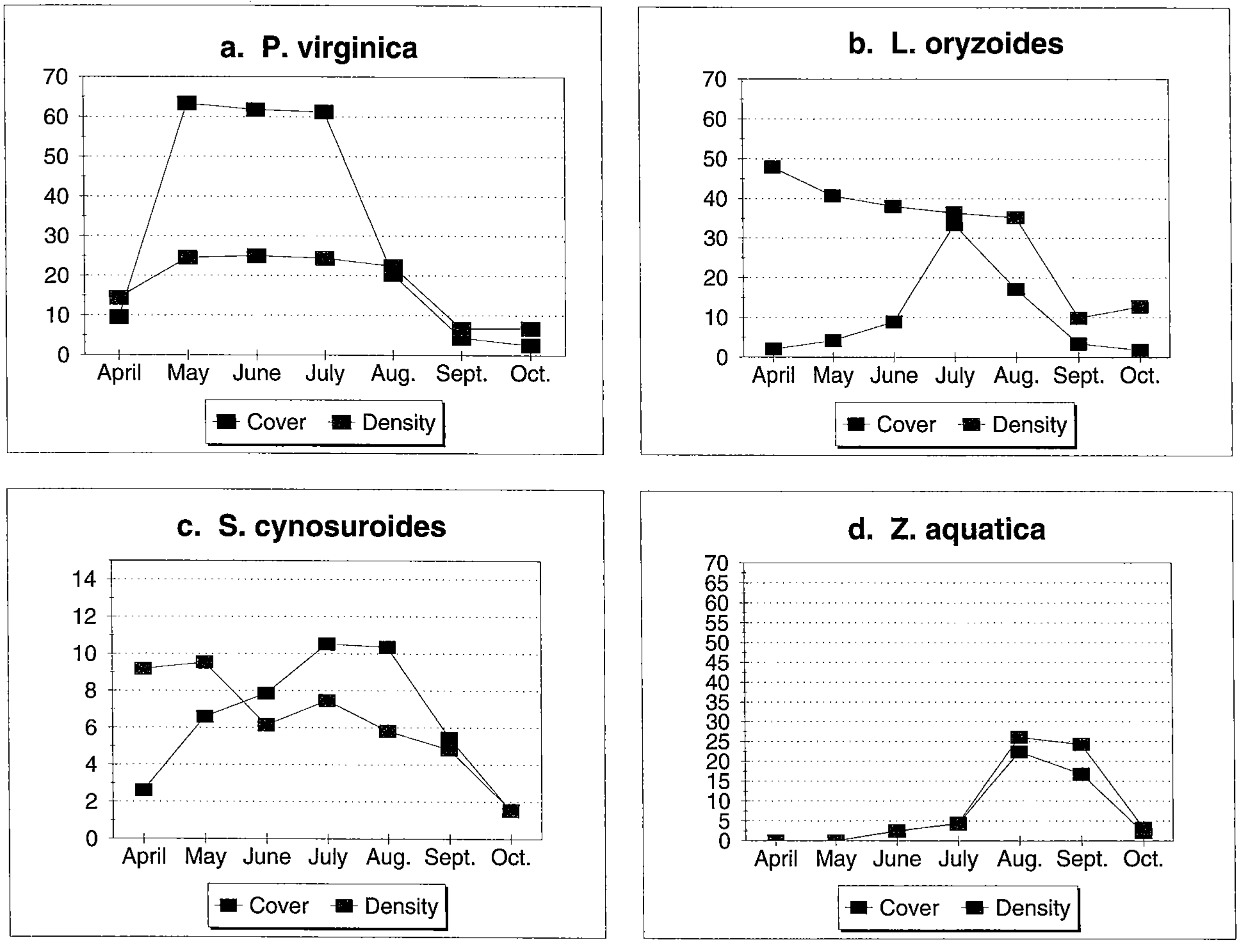

Figure 2. Mean cover and density (n=28) for the four most common species for this study. Cover is presented as mean % areal cover m^{-2}, density is mean number of stems m^{-2}. Note scale difference for *S. cynosuroides.*

1). These included 11 annual, 34 perennial, 11 graminoid (grass, sedge, or rush), and 29 herbaceous species. Doumlele (1976, 1981) observed 43 taxa, including 37 genera, 12 annual, 30 perennial (1 unknown), 11 graminoid, and 29 herbaceous species. QS index of similarity comparing the two flora's was 77.3%, with 34 species in common. Nine species encountered by Doumlele (1976, 1981) were not found in our study plots. Four of these were woody perennial species typical of hardwood swamps (Radford et al. 1964, Silberhorn 1982), and four were vines (Table 2). Of the nine, all but *Vitis* sp. were found in small numbers in the adjacent marsh outside of the study area.

Table 4. Results of Wilcoxon signed-ranked test comparing the ten most common species from Doumlele (1976, 1981) and this study. Tabulated values are two tailed: * = Z > 1.9600 (95% confidence level), ** = Z > 2.5758 (99% confidence level). Minimum = minimum sample size.

Parameter	Minimum	Z
Density	50	2.278174*
Cover	50	2.654969**
IV	50	4.570827**

Vegetation Community

Mean importance values, mean relative density, cover, and frequency (RF), are given for all 45 species in Table 3. *Peltandra virginica,* a broad-leaved perennial species, was the most common species with the highest IV (Table 3). *Sium suave,* a fresh-to-brackish water perennial, had the lowest IV. Seasonal changes were similar to Doumlele (1976, 1981). The monthly relative cover of *P. virginica* peaked early and held through June, then showed a rapid decrease in July (Figure 2a). *Leersia oryzoides* cover peaked in July; however, large numbers of small seedlings were visible through August (Figure 2b). *Spartina cynosuroides* (Figure 2c) peaked in July, but the change in cover was a magnitude lower than that of *P. virginica. Zizania aquatica,* a late season species, started low and

Table 5. Seasonal species richness, evenness, and diversity for Sweet Hall Marsh. The 1974 data are from Doumlele (1976, 1981). April and October data not available.

	May	June	July	Aug.	Sept.	Mean
Richness (1974)	0.768	0.619	0.614	0.768	0.661	0.691
(1987)	0.499	0.590	0.732	0.651	0.352	0.565
Evenness	0.615	0.631	0.693	0.676	0.697	0.662
	0.687	0.722	0.671	0.724	0.781	0.717
Diversity	0.870	0.882	0.980	1.035	1.008	0.955
	1.004	0.805	1.067	1.135	0.745	0.951

increased in all parameters late in the summer, peaking in August and September (Figure 2d).

Changes in Vegetative Pattern

The importance values of the ten most common species from this study are given, with their corresponding ranks from Doumlele (1976, 1981), in descending order in Table 3. The Wilcoxon sign-ranked test on the ten most common species from Doumlele's study and their paired value from this study showed a significant difference in density, cover, and IV (Table 4). There were no significant differences between the seasonal measures of richness, evenness, and diversity for all species of the two studies (Table 5). Therefore, although species diversity was not significantly different between studies, the taxon and quantity of species used to calculate those parameters were significantly different.

Peltandra virginica and *Leersia oryzoides* had the highest IV in both studies. However, only two other species that appeared on Doumlele's list of the ten most common species (*Polygonum punctatum* and *Carex stricta*) were ranked within the ten highest IV in this study (Table 3). Three of the four species common to both studies are perennial (*P. virginica, L. oryzoides,* and *C. stricta*) and one (*Polygonum punctatum*) an annual in our geographic area (Table 3).

Six dominant species from the current study do not appear on Doumlele's list of most common species (denoted by + in Table 3); however, all six were noted by Doumlele as "present" on the site (Doumlele 1976). Two of these six are perennial and four are annuals (Table 3).

Six of the most common species from Doumlele's list were not ranked as one of the ten dominant species in this study. However, the six were present in this study but ranked lower than in 1974 (*P. cordata*: 11th, *P. arifolium*: 13th, *M. keisak*: 14th, *E. quadrangulata*: 17th, *H. moscheutos*: 23rd., and *I. capensis*: 36th, see also Table 3). These included three perennial and three annual species.

Comparison of annual standing crop (ASC) biomass of the dominant five species for each study is given in Table 6. The species with the highest ASC in 1974 was *Peltandra virginica* (70.3% of the total biomass of the five species) but made up less than 45% during the present study (Table 6). To determine dominant species in this study (based on 50% of total ASC biomass), the species with the second highest biomass (*Spartina cynosuroides*) needs to be added. Thus, the biomass indicates that the plant community found in 1987 was co-dominated by *P. virginica* and *S. cynosuroides,* but in 1974, it was dominated solely by *P. virginica.*

DISCUSSION

Flora

The number of vascular plant species occurring in the plots of this study (45) were comparable to other

Table 6. Peak biomass of Sweet Hall Marsh arranged in descending order. Data for only the five most common species were available. Dry weight in g m^{-2} y^{-1}.

1974			1987		
Species	Weight	%	Species	Weight	%
P. virginica	369.72	70.3	*P. virginica*	214.13	42.6
L. oryzoides	57.95	11.1	*S. cynosuroides*	145.42	29.6
P. punctatum	45.29	8.6	*L. oryzoides*	57.92	11.8
P. cordata	30.84	5.9	*Z. aquatica*	55.23	11.2
M. keisak	22.23	4.2	*C. hyalinolepis*	18.65	3.8
Total	526.03	100.0		491.35	100.0

studies of tidal freshwater marsh systems (Doumlele 1981, Odum et al. 1984). Doumlele (1976, 1981) reported sampling 43 vascular plant species during his study of Sweet Hall Marsh. He further noted an additional 37 vascular plants that occurred in the marsh but not in his sample plots. Phillip and Brown (1965) reported 52 vascular plants along the tidal freshwater marsh zone of the South River, Maryland. Odum et al. (1984) listed 168 vascular plants, representing 53 different plant families, that are commonly found in tidal freshwater marshes along the eastern coast of the United States. Odum et al. (1984) suggest that the broad expanses of the areas available for plant establishment and the lack of salinity stress contribute to the high number of vascular plants in tidal freshwater marshes.

Changes in Vegetation Pattern

Although species richness, evenness, and diversity were not significantly different between studies, the taxa and quantity of species used to calculate those parameters were significantly different. This implies that a change has occurred in the most common species of the marsh community. The importance values and annual standing crop biomass measured in the two studies suggest that there is a shift toward the more salt-tolerant species (*e.g., Spartina cynosuroides, Carex hyalinolepis*), which are contributing increasingly to the marsh community (Tables 3 and 6). Although *Peltandra virginica* dominated the total peak standing crop in both 1974 and 1987, there was a noticeable decrease in the relative biomass of *P. virginica* between studies (70.3% vs. 45%, respectively).

The distance upstream that salinity influences growth of wetland vegetation is a function of the dilution of the tidal saltwater with freshwater runoff. When freshwater enters an estuarine system as surface flow or freshets, the salt gradient of the estuary moves seaward (Knauss 1978, Bradshaw and Kuo 1987). If the amount of sea water available to an estuary were to increase (e.g., an increase in relative sea level through thermal warming) and/or the amount of available freshwater were to decrease (e.g., drought), there would be an increase in upstream salinity (Knauss 1978). If the amount of sea water were to decrease (e.g., thermal cooling) and/or the run off volume were to increase (e.g., heavy rains from tropical and northeasterly storms) there would be a decrease in upstream salinity effects on the upstream reaches.

Increases in the relative sea level at Sweet Hall Marsh may be brought about by eustatic sea level rise, isostatic effects (crustal plate elevation or subsidence), and/or local events (e.g., subsidence due to groundwater withdrawal). The effect would be an increase in the salinity upstream. Data from Chesapeake Bay indicates that relative sea level is rising at a rate of approximately 3 to 5 mm per year (Hicks 1972, Froomer 1980). Hodahl and Morrison (1974) measured the relative sea level rise in the Sweet Hall Marsh area of 3 to 5 mm yr^{-1}. Hull and Tortoriello (in Hull and Titus 1986) estimated, using a model simulation for the Delaware River, that with a 13 cm sea level rise over 35 years, chlorinity increases would be most pronounced at river kilometer 96.6 (river mile 60), and increases were felt as far upstream as river kilometer 185.1 (river mile 115). Sweet Hall Marsh, located at river kilometer 122 (river mile 75) upstream from the mouth of Chesapeake Bay, is within the geographic range where an increase in chlorinity would be expected with a rise in sea level. Therefore, with over 14 years between the vegetation surveys, an increase in salt water influence would not be surprising. However, the effects of the increased salinity on tidal freshwater wetlands are still poorly understood (Odum et al. 1984, Odum 1988).

Predicting Future Vegetation Patterns

No cause and effect relationship was investigated in this study, however, we hypothesize that the observed change in the vegetation pattern may be a response to documented changes in environmental parameters. Holdahl and Morrison (1974) calculated a relative sea level rise in the Sweet Hall Marsh area of approximately 4 mm yr^{-1}. Rising sea level, therefore at least in part, may be responsible for an increased salinity stress on Sweet Hall Marsh vascular plant communities.

If the changes described above are indeed directional, we would anticipate that the vegetation pattern of Sweet Hall Marsh would change from the present freshwater-species-dominated system to one dominated by salt-tolerant graminoids (e.g., *S. cynosuroides, C. hyalinolepis*). Autecological studies on the response of individual species to inundation and salinity stress would provide valuable information concerning the rate at which the vegetation responds to each parameter.

Role of Annual vs. Perennial Species

Life-history of a vascular plant is an important factor in determining wetland succession (Kadlec 1962, van der Valk and Davis 1978, van der Valk 1981). Annual plants are more opportunistic in distribution, often requiring "mudflat" conditions to germinate (van der Valk and Davis 1976). Variation in the distribution of annuals, therefore, may be common and would make suspect the value of using temporal changes in annuals as indicators of directional community changes. Conversely, perennial plants are persistent once established and integrate environmental conditions over greater time spans (Warren and Niering 1993, Hackney et al. 1996). Therefore, perennials may be more useful as indicators of directional community changes. Such may be the case in Sweet Hall Marsh, where perennial facultative halophyte species have shown an increase in IV and biomass and the influence of perennial glycophytes (e.g., *Peltandra virginica*) has decreased.

CONCLUSIONS

Although there was no significant difference in community species diversity indices between the two studies, changes in the species that comprised the indices were significant. The increased importance value of *Spartina cynosuroides* and *Carex hyalinolepis* suggests that the vegetation of Sweet Hall Marsh is shifting to include the more oligohaline (i.e., salt-tolerant) species. It is possible that these changes represent trends towards a more oligohaline system in response to salinity increases.

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