1989

Recent Vegetation and Area Changes in a Tidal Marsh Located at Pope's Creek, Virginia

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Recommended Citation

Wilcox, Julia K., "Recent Vegetation and Area Changes in a Tidal Marsh Located at Pope's Creek, Virginia" (1989). *Dissertations, Theses, and Masters Projects.* Paper 1539617597.
https://dx.doi.org/doi:10.25773/v5-gm4r-p161

RECENT VEGETATION AND AREA CHANGES IN A TIDAL MARSH LOCATED AT POPE'S CREEK, VIRGINIA

A Thesis
Presented to
The Faculty of the School of Marine Science
The College of William and Mary in Virginia

In Partial Fulfillment
Of the Requirements of the Degree of
Master of Arts

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by
Julia K. Wilcox
1989

APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements for the degree of

Master of Arts

Julia K. Wilcox

Author

Approved, August 1989

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Walter I. Priest, III

DEDICATION

To my parents Larry and Kay,
for showing me that love is the best medicine.

ABSTRACT

Pope's Creek marsh has undergone a vegetation change since a 1976 tidal marsh inventory was conducted. *I. frutescens* comprised 90 percent of the plant cover at that time, the present study found that amount to be greatly reduced, with about 53 percent of the marsh being dominated by *I. frutescens*. *Spartina alterniflora*, *S. cynosuroides*, and *S.patens* all showing increased abundances since the 1976 inventory.

A change in relative sea level appears to be the mechanism responsible for the vegetation change. Elevation was not found to play a primary role in controlling vegetation distribution in the present marsh community. An accretion rate of 6.8 mm/yr obtained using the Cs-137 technique showed the study site to be accreting at a rate well above sea level rise estimates for the region.

A plausible mechanism for the vegetation change is erosion. The total area lost since 1937 is 1.83 Km^2 or about 50 percent. A large proportion of area loss has occurred in a portion of the marsh dominated almost exclusively by *I. frutescens*. This could result in a perceived change in marsh community, specifically a decrease in the apparent contribution of *I. frutescens*.

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ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my major professor, Gene Silberhorn for his encouragement and guidance throughout my graduate studies and for his undying enthusiasm for field work no matter what the temperature.

I would like to thank my committee members Carl Hershner, Woody Hobbs, Ken Moore and Walter Priest for there helpful suggestions in regard to my thesis work.

I wish to acknowledge the assistance provided by the staff of George Washington Birthplace National Memorial particularly John Frey, who originally brought the situation at Pope's Creek to the attention of the VIMS scientific staff, Dwight Stork, David Shockley, and John Karish.

I would also like to thank those hardy souls who assisted me with my field work, Lyn Cox, Pam Mason, and Eric Koepfler. A special thanks goes to the staff of the library particularly Susan Barrick and Diane Walker for their friendship and help throughout my graduate career.

Finally, I wish to express my deepest gratitude to my mother and father, Kay and Larry Wilcox, my brother, Geoff Wilcox and my fiance, Eric Koepfler for providing me with the love and support necessary to get through what sometimes seemed like an endless tunnel. I could not have done this work without them.

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INTRODUCTION

The area of brackish marsh surrounding the mouth of Pope's Creek, a tributary of the Potomac River located on the Virginia shore, appears to have undergone a recent change in vegetation composition. Mercer (1978) reported that the vegetation was composed almost exclusively of *Iva frutescens*. A small proportion, 5 percent each, was *Spartina cynosuroides* and *Kosteletskya virginica*; trace amounts of several other brackish species were also present. Anecdotal observations by local Park Service personnel from George Washington's Birthplace National Memorial indicated that the salt bushes (*Iva frutescens)* which had dominated the marsh community were dying. While other recent observations at Pope's Creek suggest that higher marsh species such as salt bushes are being replaced by marsh species typically associated with lower elevations.

One hypothesis is that the elevation of the marsh surface at the study site is becoming lower with respect to relative sea level. A change in elevation of the marsh surface could occur through several processes, such as local subsidence or erosion, and would result in a rise in relative sea level. Also a eustatic rise in global sea level would result in a rise in the relative sea level if sedimentation at this site were not occurring at a rate equal to or greater than the increase of sea level. Both of these processes could also work in concert to cause in a more rapid rise of relative sea level.

The objectives of this research were; (1) to define the marsh community presently at Pope's Creek; (2) describe changes which have taken place in the vegetation since the 1976 tidal marsh inventory; and (3) examine potential causitive mechanisms for the changes, specifically change in relative sea level and erosion.

LITERATURE REVIEW

SALT MARSH ZONATION

Plant zonation in tidal marshes is controlled by many factors. Frequently these factors work in concert complicating any ecological investigation of marsh zonation. One factor that is identified as dominant in many studies on salt marsh zonation is elevation. Elevation is easily measured and is directly related to tidal effects such as duration and frequency of flooding. These tidal effects frequently override or influence many of the other factors shown to affect zonation. Elevation may directly regulate factors which can affect plant zonation such as duration and frequency of tidal flooding, soil moisture, soil salinity and depth of water table (Adams, 1963; Mahall and Park, 1976; Disraeli and Fonda, 1979; Hutchinson, 1982). For these reasons elevation (or some measure of tidal inundation) is commonly the primary environmental variable measured in studies of salt marsh zonation but it is by no means considered the only factor contributing to plant distribution (Chapman, 1938).

Johnson and York (1915) conducted one of the early studies of salt marsh zonation. The study which was carried out in Cold Spring Harbor, New York included an investigation not only of emergent salt marsh vegetation but also of seagrasses and benthic algae. They found that salt marsh plants were distributed according to a number of environmental factors but many were directly related to elevation. They concluded that salt marsh species were found in a certain range of elevation where they were able to tolerate the time of emergence and submergence from the tide. The authors expressed this variable as an emergence-submergence ratio.

Chapman (1938) working on salt marshes in England concluded that the tide was the major factor related to plant zonation and that the water table, soil aeration, and soil drainage were greatly affected by tidal factors.

Hinde (1954) found that the distribution of the three major vegetation zones in California salt marshes dominated by *Spartina* *sp*., *Salicornia* *sp*., *Distichlis* *spicata* were closely related to elevation and submergence-emergence duration.

Kerwin and Pedigo (1971), working on brackish marsh plant distributions in Chesapeake Bay in Virginia, conducted one of the few studies available on distributions brackish marsh plant in the region. They found that their communities, defined as edge habitat, low meadow, meadow, and high meadow correlated with elevation differences as small as one to two inches (approximately 2.5 to 5 cm.). Reidenbaugh (1978) was able to relate each major species distribution in salt marshes on the Eastern Shore of Virginia to elevation as well as relating community zonation to elevation trends.

Many other studies have focused on the study of marsh zonation and have found some relationship between vegetation zonation and elevation or tidal inundation (Eleuterius and Eleuterius, 1979; Vince and Snow, 1984; Huq, 1986). Several studies involving the definition of wetlands by identifying the transition zone between wetlands and uplands have also found a relationship between elevation and species composition (Boon et al., 1977; Boon et al., 1978).

SEA LEVEL EFFECTS ON MARSHES

Tidal marshes hold an extremely tenuous position between land and sea, even a small change in relative sea level could profoundly affect the delicate balance that exists. Global sea level has been rising since the most recent retreat of the glacial ice sheet began, 17,000 to 15,000 years ago (Redfield, 1967). The information available indicates that the rise in global sea level was at first very rapid but began slowing about 4,000 years ago. This slowing in sea level rise marks the formation of many of our modern marshes. Prior to this, the formation of salt marshes occurred sporadically, coinciding with periods when the rate of sea level rise was believed to have slowed due to a cooler climate (Rampino and Sanders, 1981).

Sea level rise may be accelerating, resulting in increased stress upon salt marshes. Estimates range from a 56 cm rise to a 345 cm rise in sea level by the year 2100 with the most likely rise being between 114 and 216 cm (Titus, 1988).

Orson et al. (1985) found that salt marshes can respond in several ways to a rise in sea level. If sedimentation rates are sufficient, the marsh can accrete with the rise in sea level, expanding both laterally and vertically. The lateral expansion can occur by encroaching on bordering terrestrial vegetation, into the subtidal zone, or both. If the accretion rate does not equal the rate of relative sea level rise, eventually the vegetation dies, the marsh surface erodes and the marsh habitat can be converted to open water.

Baumann and DeLaune (1982) found that marshes in coastal Louisiana were being lost due to their inability to accrete sediment as rapidly as the rise in mean sea level. They attribute the situation to the combined factors of global sea level rise, high rates of subsidence and reduced sediment inputs. The inner portions of the salt marsh were found to be accreting at a rate less than the rate of coastal submergence while the levee portions of the marsh were accreting at approximately the same rate as coastal submergence. However, after the loss of the inner marsh the levee areas were eroded by wave action and also disappeared.

These same phenomena have been seen in the Chesapeake Bay area. The submerged upland marshes in Blackwater National Wildlife Refuge which were formed by the inundation of low-lying terraces are subsequently being lost to surface and creekbank erosion (Kearney and Stevenson, 1985; Stevenson et al 1985a). These marshes have low sediment inputs and high rates of coastal submergence working against them. If the conditions persist they eventually will be converted to open water.

Kearney et al. (1988) also found rapid wetland losses occurring along the Nanticoke estuary in Maryland. Most of the losses were in submerged upland marshes. Losses occurred through a combination of creek-bank erosion and interior ponding, which are factors that all of the marsh studies found to be significant. These marshes, like those in Blackwater National Refuge, have very little allochthonous sediment input and rely primarily on peat formation for accretion.

MEASUREMENT OF MARSH ACCRETION

Several methods have been used to measure accretion rates in marshes. Pb-210 dating and analyses of pollen horizons have been widely used in the Chesapeake Bay area to measure marsh accretion (Kearney et al., 1983; Stevenson et al., 1985b; Kearney and Ward, 1986). Both of these methods estimate average accretion rates for the last 150-200 years. Artificial marker horizons such as brick dust or glitter scattered on the sediment have been used to measure accretion rates over very short periods of time, such as several years (Harrison and Bloom 1977; Richard, 1978). This method is sensitive to sporadic sedimentation or erosion events such as storms and for that reason it may not be appropriate in determining an average accretion rate, but may be more useful in measuring seasonal and annual variability in accretion rate. These short-term methods also may overestimate accretion rates because little or no autocompaction occurs in the sediments over such a short period of time.

The method chosen for this study, Cesium-137 (Cs-137), measures the average accretion rate over the last 25 years and has been successfully utilized in the marshes of the Mississippi Deltaic Plain (Hatton, 1976) and Delaware coastal marshes (Brickman, 1978). Radioactive Cs-137 was released into the atmosphere during open air nuclear testing which began in 1954. The testing peaked slightly in 1959 and reached a maximum in 1963. This technique uses the major peak of Cs-137 activity deposited in the sediment record as a marker horizon for the year 1963. It has the advantage of being a simple and straightforward method for calculating average accretion without being quite as sensitive to storm activity as other short-term methods. Several accretion studies in lakes have successfully used the Cs-137 technique (Pennington et al., 1973; Robbins and Edington, 1975; Mitchell et al., 1983; Melieres et al., 1988), but the use of this technique in marshes is controversial.

The Cs-137 method assumes little or no migration of the isotope occurs after deposition in the sediments. Whether this assumption is met depends on the adsorption character of the isotope to the sediment particles. Adsorption is inversely related to grain size and makes this technique most useful in sedimentary environments high in clay and silt (Brickman 1978). Warinner (1962) found that adsorption of Cs-137 onto clay particles was also inversely related to salinity. This characteristic may affect the actual concentration of Cs-137 adsorbed, but should not displace the peak of activity unless a dramatic change in salinity, such as channel dredging might cause, occurs. Casey et al. (1986) working in Virginia Eastern Shore marshes found a high annual variability in marsh pore water salinity due to desiccation occurring throughout the summer and periodic storms. Thus this technique may be of limited use in high salinity environments.

Another potential problem with this technique exists in marshes due to mixing and bioturbation of the sediments particularly that caused by benthic fauna (Schaffner et al., 1987). Mixing is most likely to result in a very weak peak or complete obliteration of the peak, and thus would make calculating an accretion rate impossible.

The method also may overestimate accretion rates as in other artificial marker horizon techniques (Stevenson et al., 1986). The Cs-

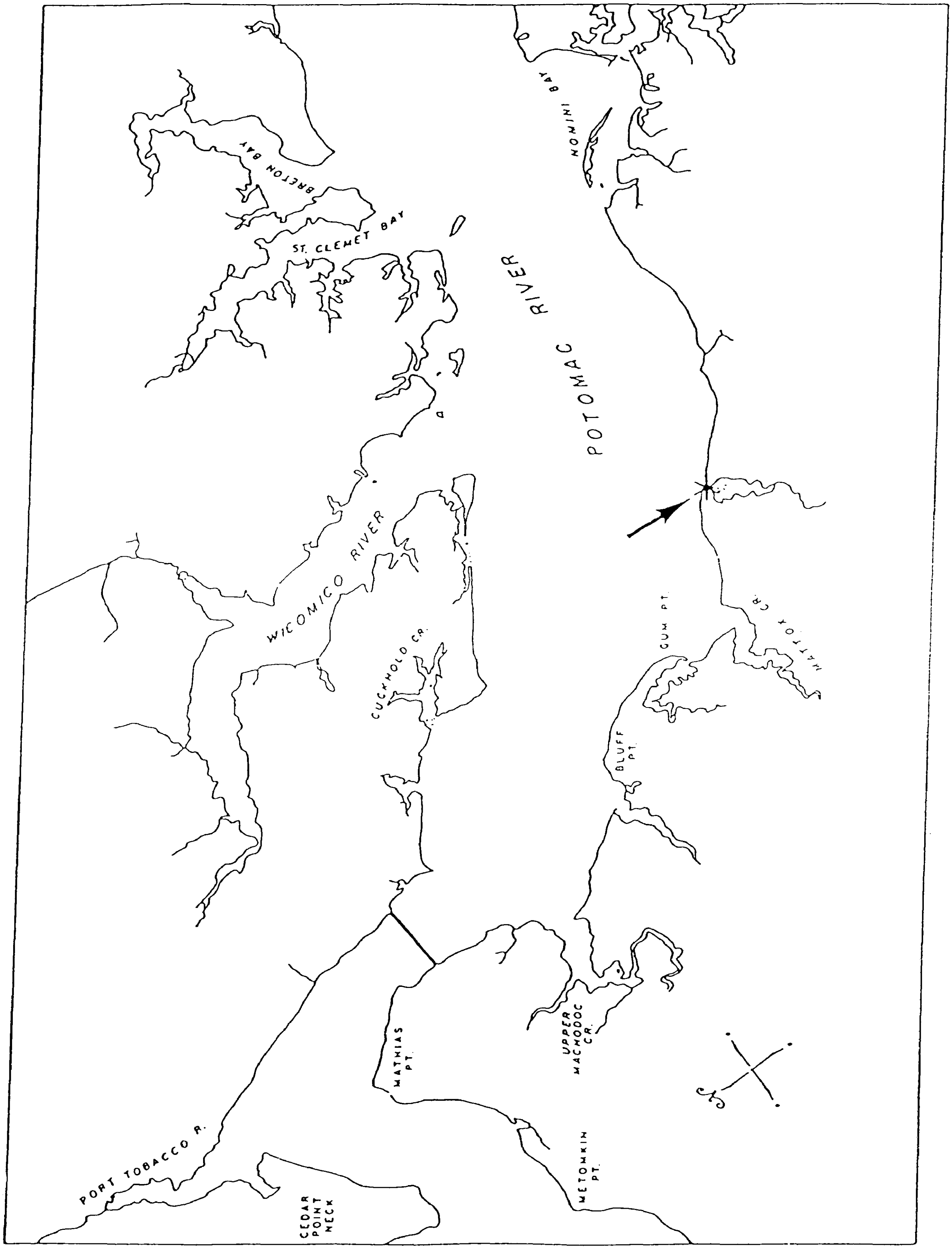
137 method measures only recent accretion and thus does not allow for the eventual autocompaction that occurs in the sediments, which in sediments high in organic matter and moisture may be substantial (Kaye and Barghoorn, 1964).

METHODS

A detailed vegetation map of the present plant community was prepared using a Bausch and Lomb™ zoom transferscope and aerial photography taken in October 1985, by the U.S. EPA. Distinct communities were determined by differences in textural appearance. These communities were identified and confirmed by field studies. Frequently a community was not dominated by a single species. In these cases co-dominants were assigned. The area of each community then was computed using a Numonics™ digitizer. In comparing these data to the 1978 tidal marsh inventory and other aerial photography all communities that had Iva frutescens as a dominant or co-dominant were defined as salt bush community or high marsh. Salt bushes are usually found above mean high water in the zone flooded only by spring tides (Marcellus, 1972).

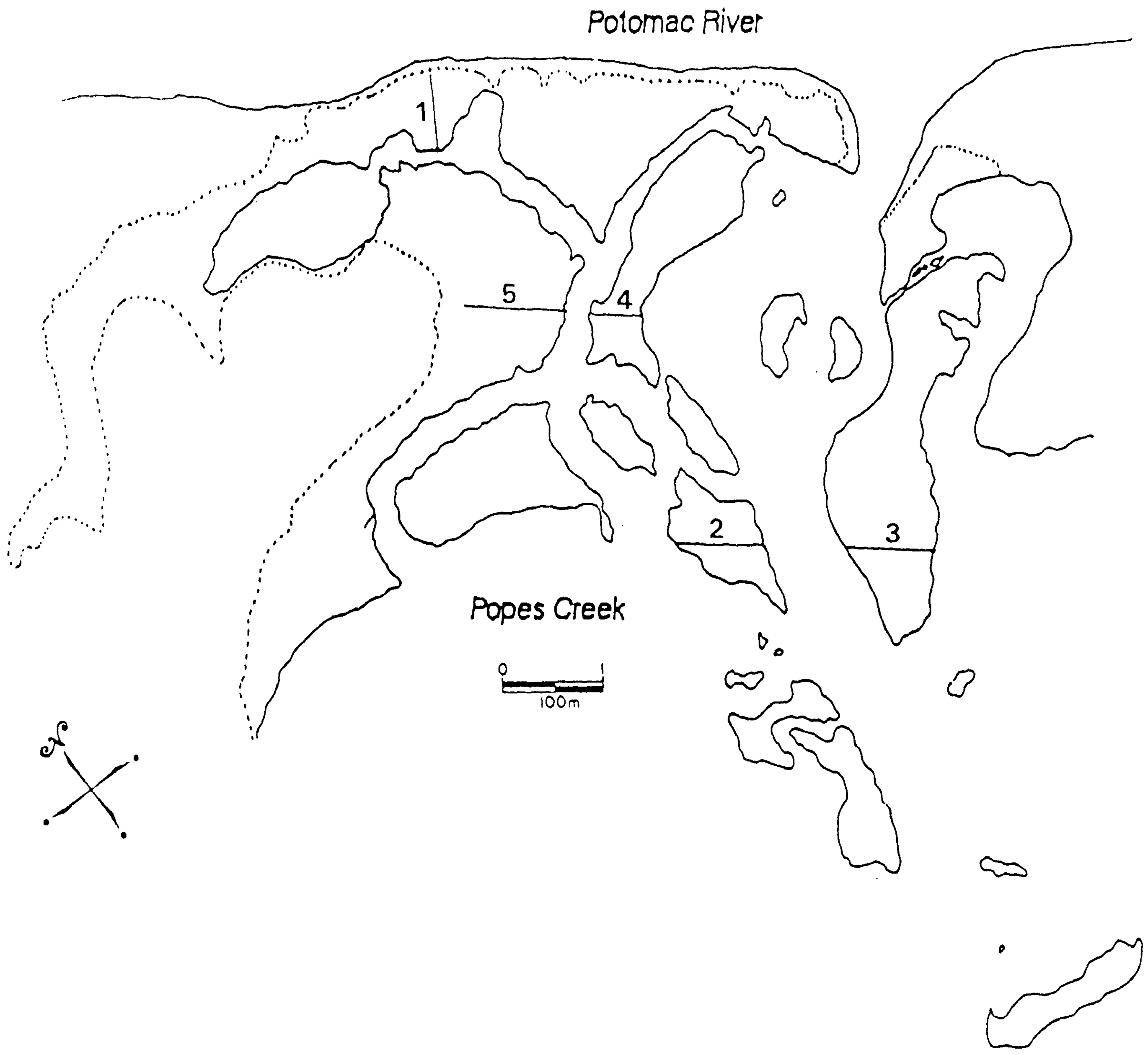
Determinations of vegetation cover at Pope's Creek marsh located on the Potomac River (figure 1) were made during July, August, and September of 1985. Five transects approximately 1 meter wide were set up in the main body of the marsh (figure 2). The transects were oriented perpendicular to the creek bank crossing from streamside marsh to back marsh. 1 m^2 samples were taken randomly from 1 to 6 meters to the right or left of the center line of the transect at 5 meter intervals. Samples on each survey date were taken from the same quadrat, initially determined on the first sampling date. Within each sample area vegetation cover was estimated using an adaptation of the Braun-Blanquet scale (Braun-Blanquet 1932) of percent cover as follows: x = trace, 1 = 1-10 %, 2 = 10-25 %, 3 = 25-50 %, 4 = 50-75 %, 5 = 75 -

Figure 1. Pope’s Creek Study Site.



NOMINI BAY
BRETON BAY
ST. CLEMET BAY
POTOMAC RIVER
WICOMICO RIVER
GUM PT.
MATTOX CR.
CUCKHOLD CR.
BLUFF PT.
UPPER MACHODOC CR.
MATHIAS PT.
METOMKIN PT.
PORT TOBACCO R.
CEDAR POINT NECK

Figure 2. Transect locations.


Potomac River
1
5
4
2
3
Popes Creek
0
100m
N

100 %

The Braun-Blanquet scale was then converted to percent abundance using the mid-point of the range (Wikum and Shanholtzer, 1978). To eliminate temporal variability in species abundance the mean of the three sampling dates was calculated for each sample area. Information on the presence or absence of Dodder, Cuscuta sp. was also recorded. Dodder, a leafless and rootless parasitic vine, is a destructive parasite almost totally lacking chlorophyll and survives by extracting nutrition from other plants (Johnson, 1931; Smith, 1977).

Relative elevation data for each quadrat were collected in the spring of 1986 using a Nikon™ surveyor's level and stadia rod. The relative elevation was referenced to a 2 meter steel rod driven in at the upland edge of the marsh. This permanent reference point was arbitrarily assigned an elevation of 3.0 meters (10 feet) so that relative elevation measurements in the marsh could be represented by positive values.

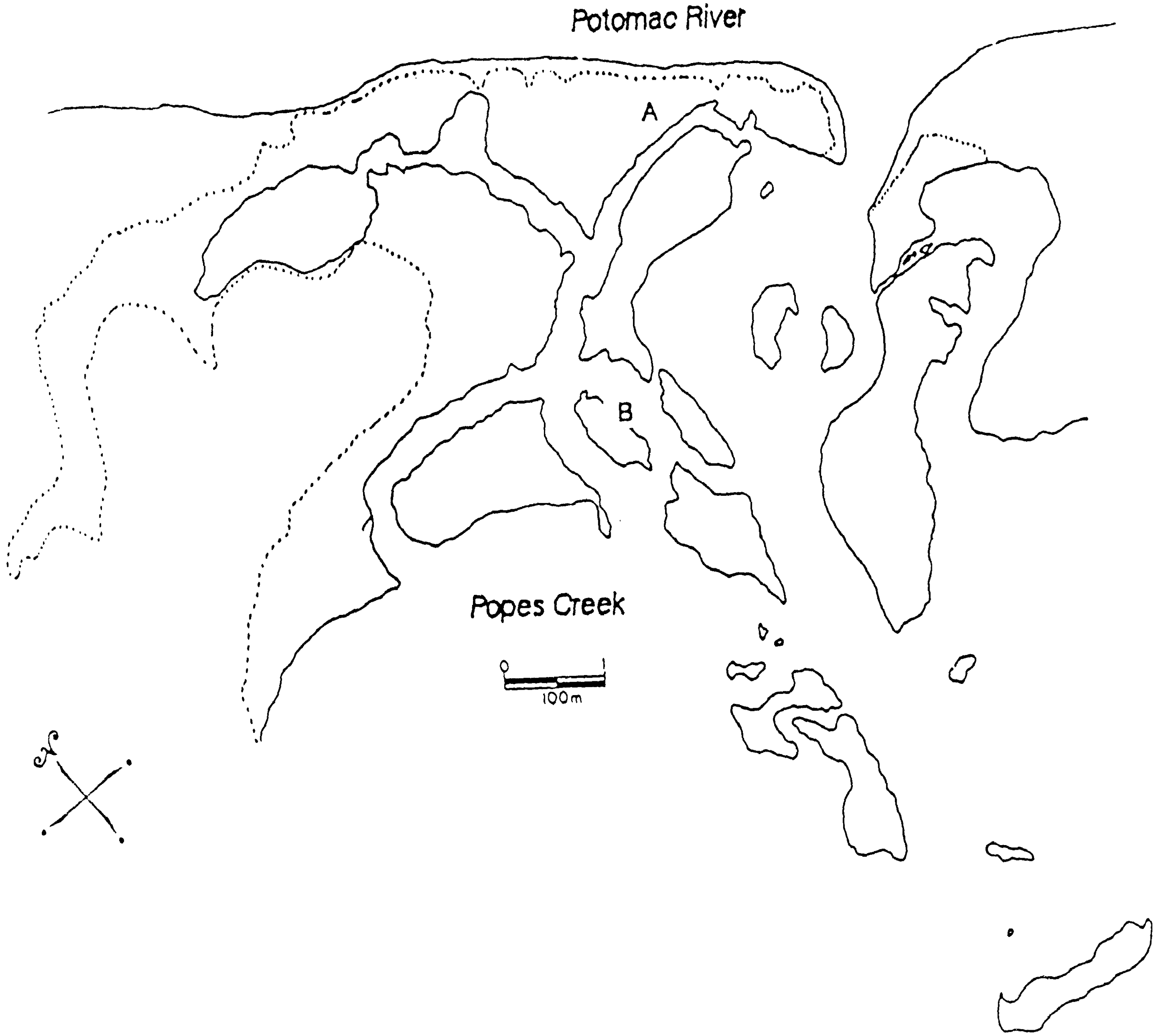
Analysis of the vegetation data was performed by Detrended Correspondance Analysis (DCA) using the FORTRAN program DECORANA from the Cornell Ecology Program Series (Hill, 1979). Detrended Correspondance Analysis has been widely used in ecological studies to identify spatial patterns among biota and physical/chemical parameters (Clark, 1986; Huq, 1986; Whittier et al., 1988). It was developed as an improvement of the Reciprocal Averaging (RA) technique. DCA eliminates the two main problems found in RA; the "arch effect", which is a mathematical artifact caused by the strong quadratic relation of the second axis to the first axis, and the compression of samples near the ends of the axes.

The axes generated by DCA simultaneously rank samples based upon their species composition and species based upon the samples in which the occur. This process is achieved by the simultaneous ordination of species and samples. In the present study analysis was based upon sample scores along four axes, according to their species composition. Samples with similar species composition have similar axes scores and cluster together in the output.

Successive ordinations were performed on the vegetation data during which samples that caused severe skewing of the axes and resulted in a compression of the data were removed. This enabled patterns in the remaining data to be analyzed. The Statistical Package for the Social Sciences (SPSSX) was used to graph ordination axes. Pearson product-moment coefficient of correlation was used to test for significant correlations between elevation and all ordination axes.

Sediment cores were collected in spring 1988 to determine accretion rates from two sites (figure 3). To obtain 100 gm. of sediment that was needed for each depth increment, it was necessary to take multiple cores at each sampling site and pool corresponding layers. A total of seven cores were obtained from each sampling site. The cores were collected using a 7.5 cm diameter aluminum cylinder. Compaction for each core was measured and a correction was made on each 2 cm interval. Cores were carefully extruded in the field onto a large sheet of plexiglass and cut into appropriate depth increments. Care was taken to locate coring sites so that there was no chance of a core being taken in a previously disturbed area.

Figure 3. Cesium-137 sample locations.


Potomac River
A
B
Popes Creek
0
100m
N

In the lab the sediments were dried, ground and weighed. Cesium-137 activity was measured using an ORTEC™ multi-channel analyzer. Each subsample was counted for 24 hours and net counts with the region of interest were calculated. Background activity was determined by a mean subsample was counted for 24 hours and net counts with the region of interest were calcualted. Background activity was determined by a mean of the net counts of the background at the beginning and end of the sample processing. These values differed by less than 0.5 percent. Background activity was subtracted from the sample net counts. Resultant values were converted to counts per minute per kilogram of sediment. Cesium-137 activity was plotted with depth to determine the layer of maximum activity. This layer becomes the marker for 1963. The depth of sediment above this layer was then divided by the number of years that have elapsed since 1963 to determine an average accretion rate.

Changes in total marsh area at Pope's Creek were calculated using aerial photography from 1937, 1953, and 1985. These photographs were analyzed using a Bausch and Lomb™ zoom transferscope. Total areas were computed using a Numonics™ digitizer.

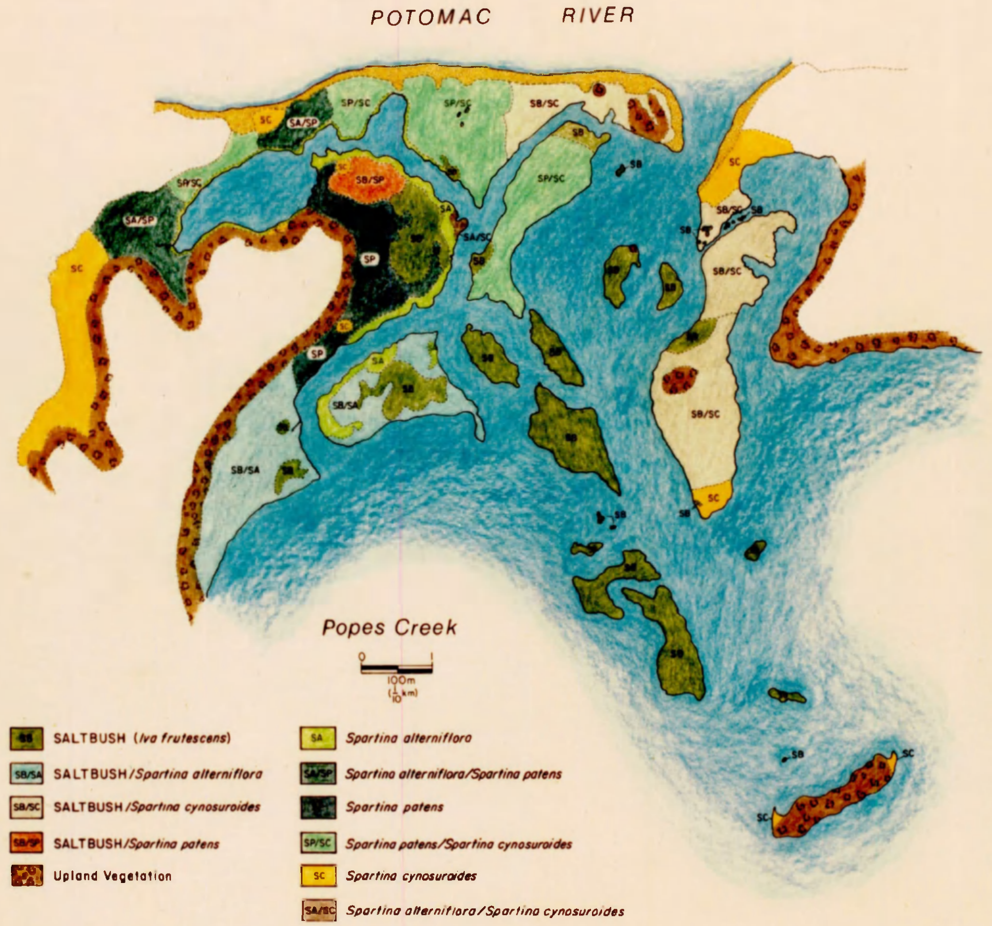
RESULTS

The vegetation map of Pope's Creek marsh (figure 4) compiled from aerial photography taken in 1985 and field studies conducted in 1986 indicates that a change in vegetation composition has occurred since the tidal marsh inventory in 1976 (Mercer, 1978). Iva frutescens presently is the dominant or co-dominant species in 53 percent of the marsh. This is a substantial decrease from the 90 percent cover reported by Mercer. Spartina alterniflora and Hibiscus moscheutos were reported in abundances of 5 percent each. Results of the present study indicate increased abundance of S. alterniflora which was a co-dominant species in 11 percent of the marsh and formed monospecific stands in 5 percent of surveyed marsh area. H. moscheutos was sparsely distributed in the marsh and was not found in any of our vegetation samples which focused on the main body of the marsh. Other species that were reported in trace amounts in the 1976 inventory include: S. cynosuroides, Kosteletzkya virginica, S. patens, Typha sp., Amaranthus cannabinus, Echinochloa walteri, Rumex verticillatus. S. cynosuroides, K. virginica, S. patens, and A. cannabinus all have shown increased abundances since 1976. K. virginica and A. cannabinus are still present in low abundance in the vegetation community, never dominating the vegetation. S. cynosuroides and S. patens presently dominate or co-dominate the vegetation in 53 percent and 33 percent of the marsh respectively. Classifying all areas that were dominated or co-dominated by I. frutescens as high marsh and all other areas as low marsh reveals a decrease in high marsh from 1976 to 1986 of 90 percent to 53 percent.

Figure 4. Pope's Creek vegetation map.

VEGETATION MAP OF POPES CREEK

by JULIA WILCOX



Dodder was patchily distributed throughout the marsh and was predominantly found clinging to Iva frutscens. When it was present it formed extremely dense colonies and the host plants's viability appeared greatly reduced.

Figure 5 is a plot of the sample scores of the first two DECORANA ordination axes. Axis 1 and axis 2 account for 58 percent and 41 percent of the variation in vegetation data. The major species show distinct areas of concentration. Samples with a high percentage of live I. frutescens have low values on both axis 1 and axis 2. S. patens displayed high values on axis 1 with intermediate values on axis 2. Samples composed of a fairly high percentage of Dead I. frutescens were distributed with intermediate values on both axis 1 and axis 2. A. cannibinus displayed high values on axis 2 and low values on axis 1. Samples dominated by S. alterniflora had intermediate values on axis 1 and intermediate to high values on axis 2.

Figures 6 and 7 show plots of axis 1 and axis 2 with axis 3. Major species concentrations are again shown with the addition of a sample concentration dominated by Pluchea purperescens which displayed intermediate to high values on axis 3 and intermediate values on axis 1 and axis 2.

Correlation analysis between all ordination axes and elevation data showed a positive correlation with axis 3 and elevation ($p<0.05$). However axis 3 is responsible for only 21 percent of the variation in vegetation data. Because only elevation was measured in this study, the variation resulting from the first two ordination axes must be attributed to some undetermined environmental or biological variable.

Figure 5. DECORANA output for Axis 1 and Axis 2.

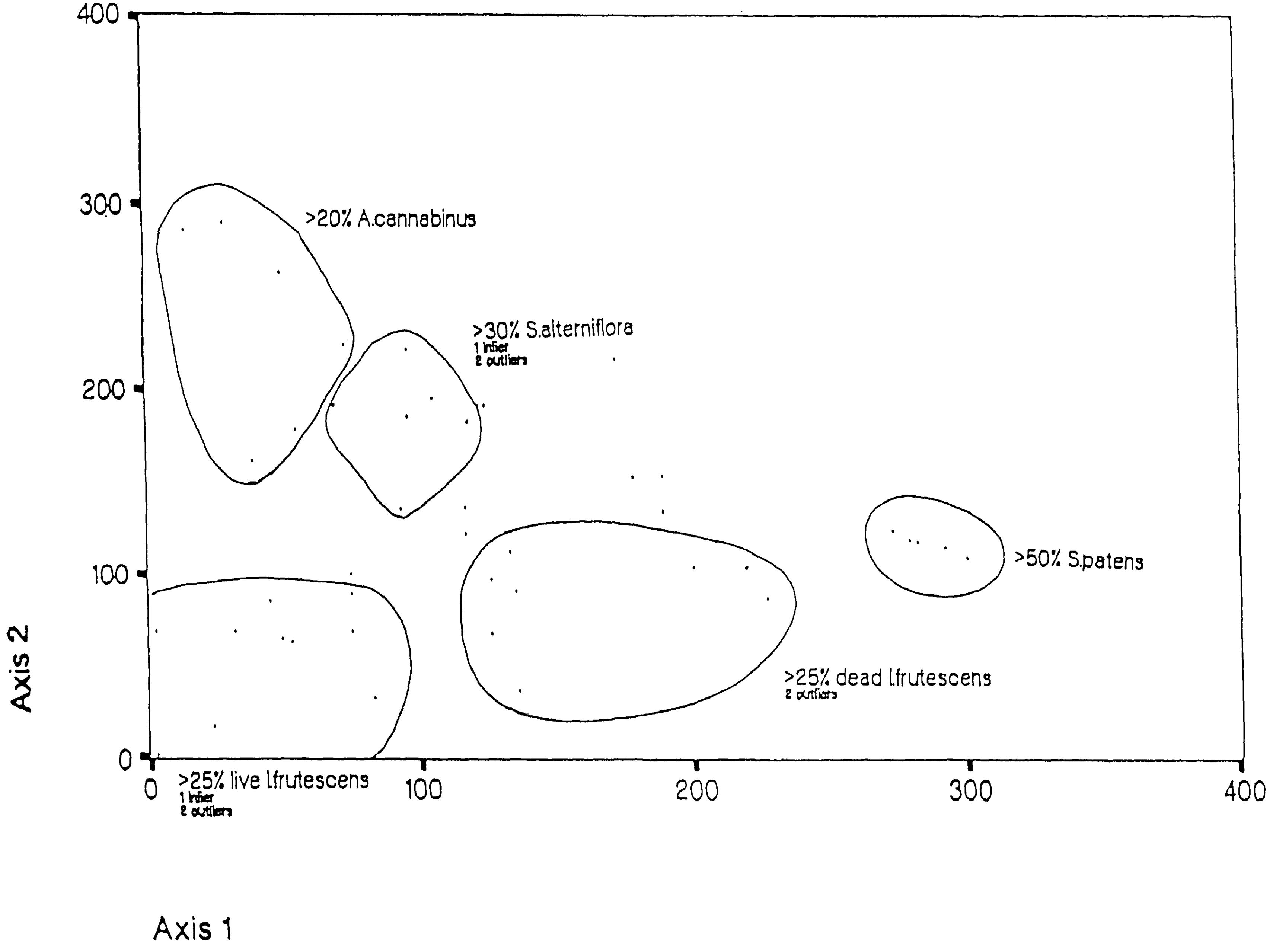
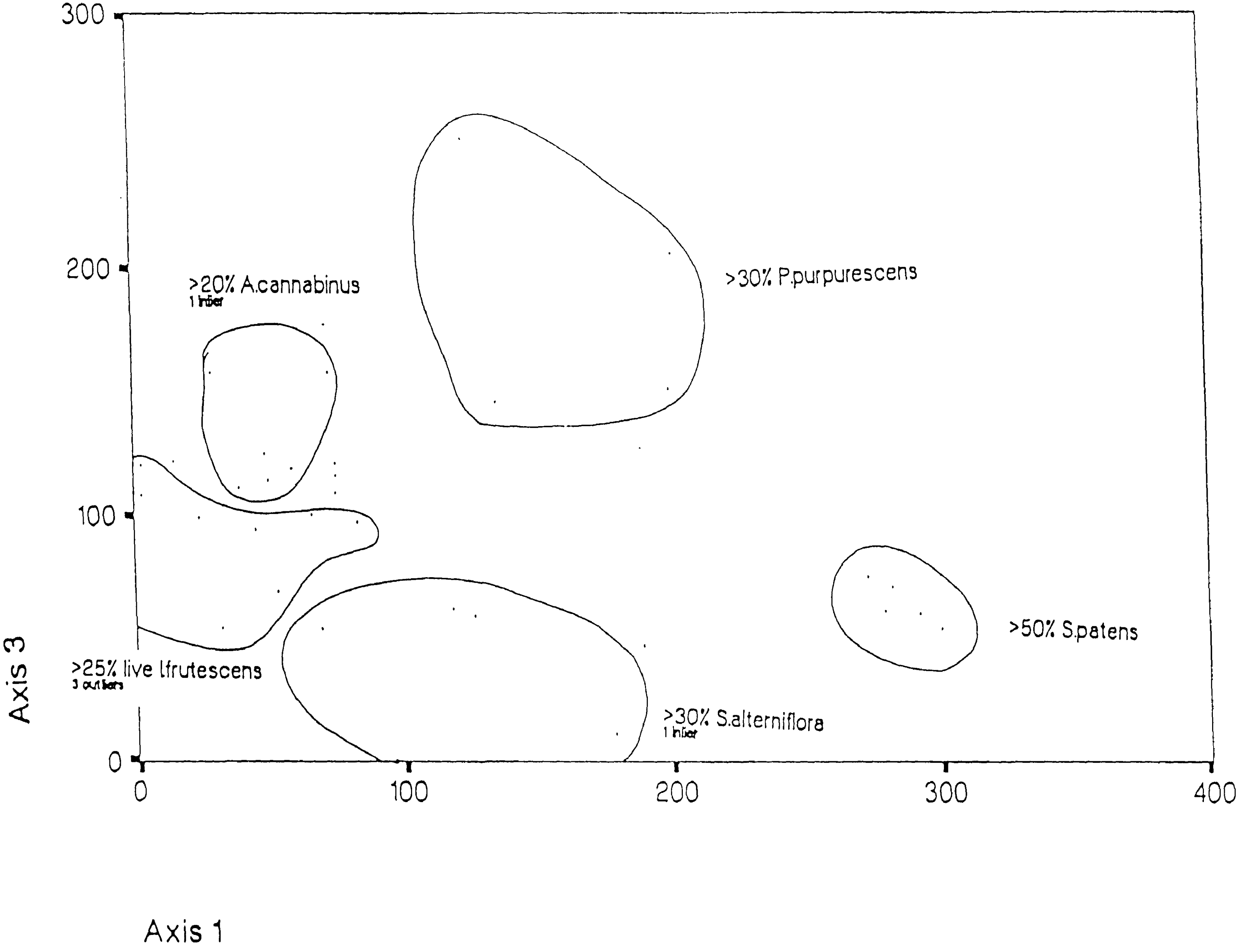
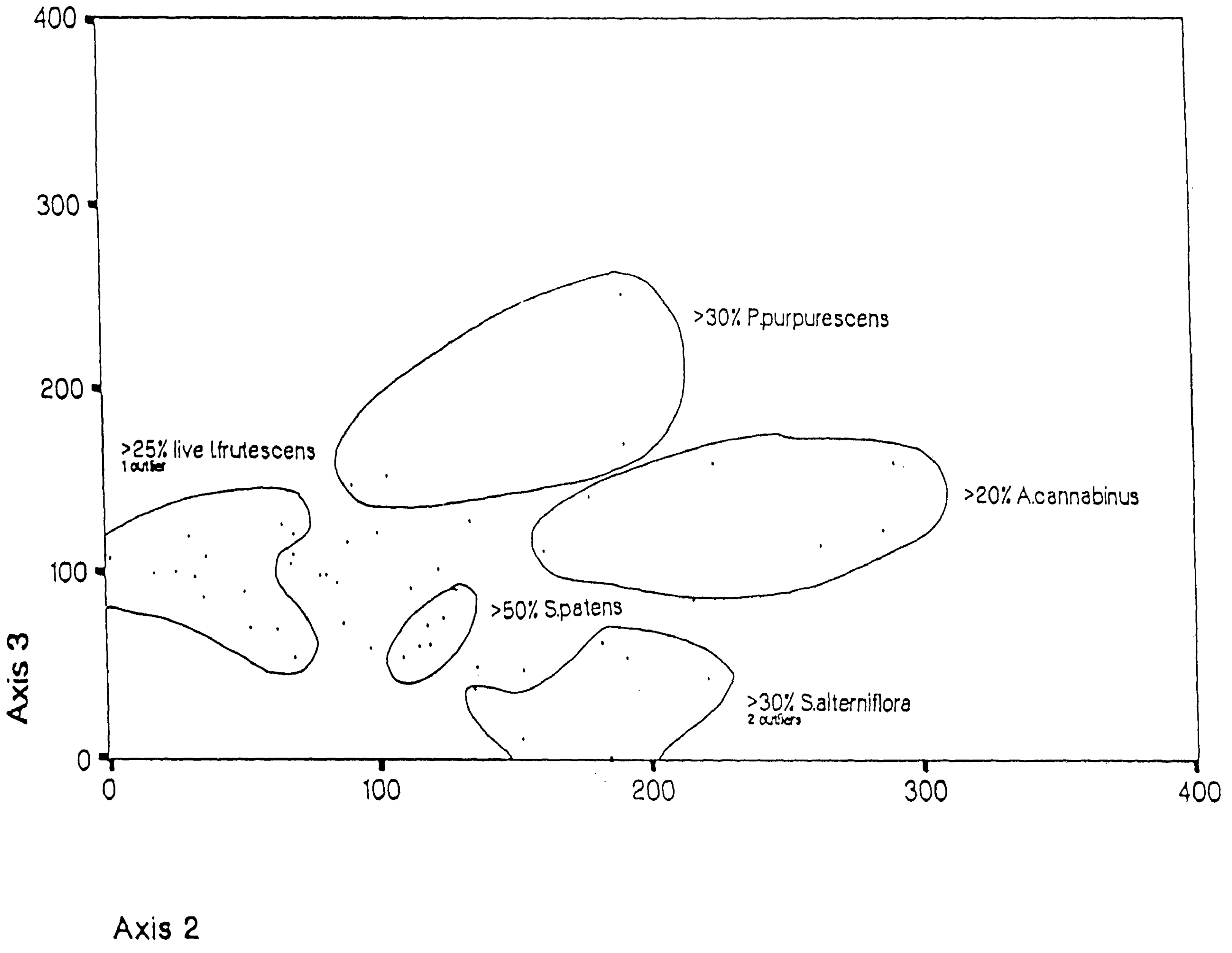

>20% A.cannabinus
>30% S.alterniflora
1 inlier
2 outliers
>50% S.patens
>25% dead I.frutescens
2 outliers
>25% live I.frutescens
1 inlier
2 outliers
0
100
200
300
400
0
100
200
300
400
Axis 2
Axis 1

Figure 6. DECORANA output for Axis 1 and Axis 3.



300
200
100
0
Axis 3
0
100
200
300
400
Axis 1
>20% A.cannabinus
1 inlier
>30% P.purpurescens
>25% live I.frutescens
3 outliers
>30% S.alterniflora
1 inlier
>50% S.patens

Figure 7. DECORANA output for Axis 2 and Axis 3.



400
300
200
100
0
Axis 3
0
100
200
300
400
Axis 2
>25% live I.frutescens
1 outlier
>30% P.purpurescens
>20% A.cannabinus
>50% S.patens
>30% S.alterniflora
2 outliers

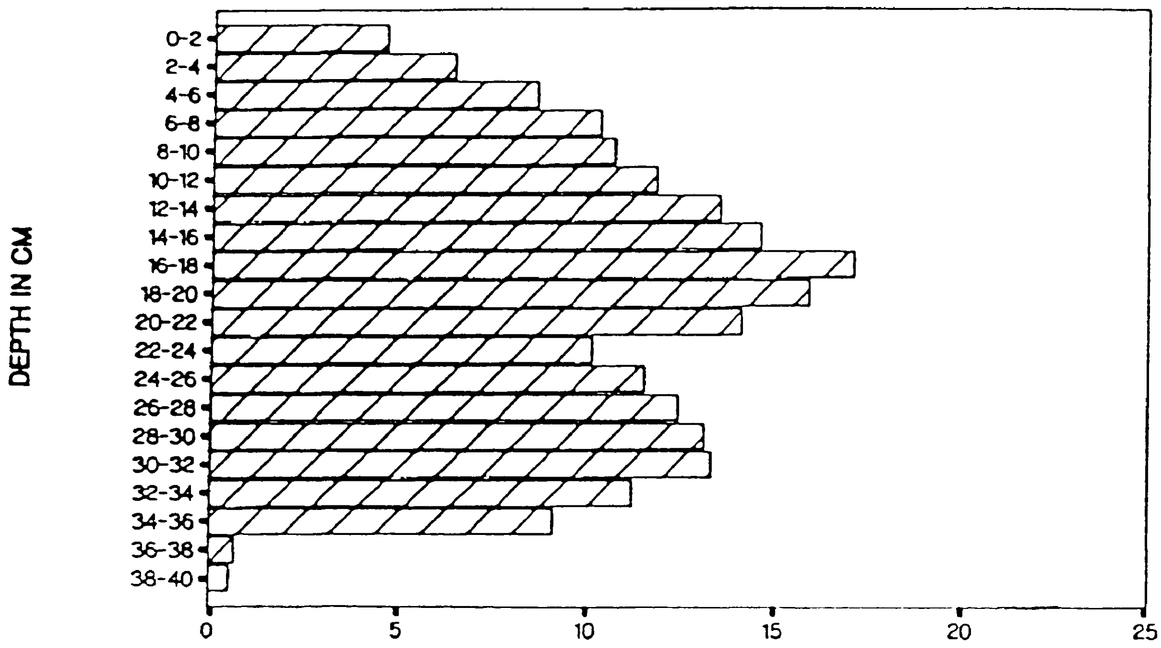
The results of the Cs-137 analysis are presented in figure 8. The peak of Cs-137 activity was located in the 16-18 cm layer at both the A and B sites. The average accretion rate using 17 cm as the marker horizon for 1963 is 6.8 mm per year. This rate is well above the estimates for relative sea level rise (sea level rise + subsidence) which has been reported to be approximately 2.6 mm per year (Davis, 1987). These data indicate that the marsh is accreting at a level at least equal to sea level rise and therefore does not appear to meet the criteria for the "drowning marsh" scenario (Orson et al., 1985)

Examination of aerial photography indicated that a change in area of the marsh has occurred since 1937. The total area in 1937 was 3.66 km^2 (figure 9). Aerial photography from 1953 indicates that 2.80 km^2 (figure 10) of marsh was present. In 1976 when the tidal marsh inventory was conducted the area was reported at 2.10 km^2 (Mercer, 1978). The present area of the marsh from 1985 aerial photography is approximately 1.83 km^2 (figure 11), half the area in 1937. Marsh area remaining plotted against time (figure 12) shows that the loss rate is almost linear, indicating a steady decrease in area over the last 50 years. The majority of the area loss is concentrated in the central island portion of the marsh (figure 13). Aerial photography from 1937 indicated that these islands were dominated (ca. 92 percent vegetation cover) with _I_. _frutescens_.

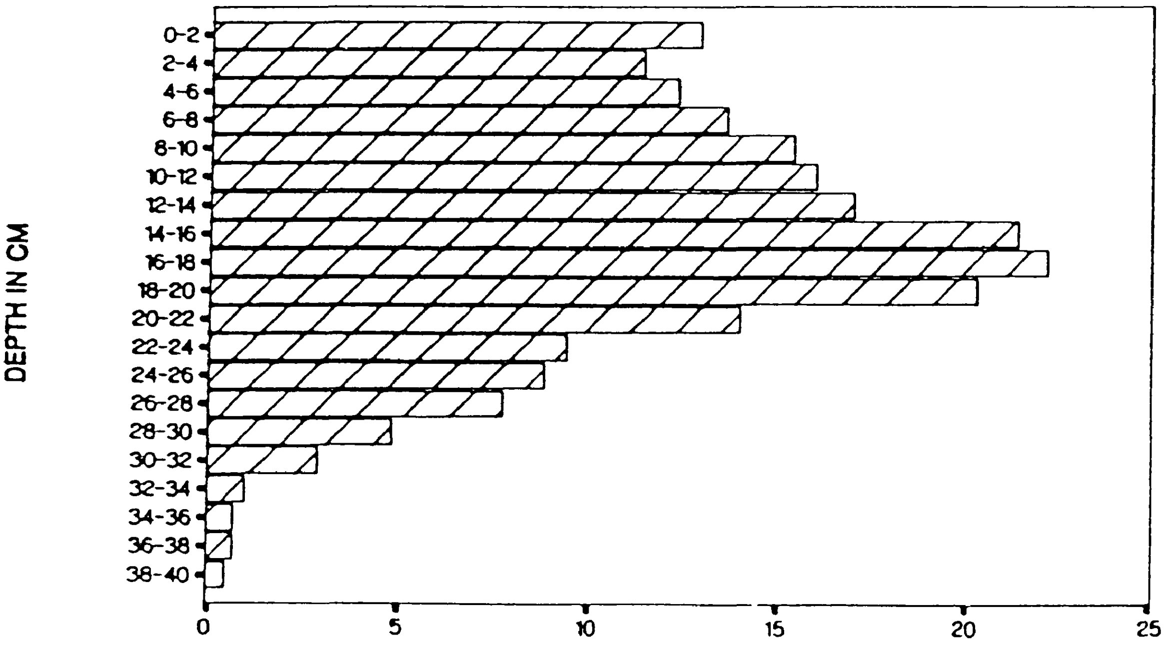
Figure 8. Cesium-137 distribution in sediment at marsh sites A and B.

CESIUM 137 DISTRIBUTION IN SEDIMENT

A CORE



B CORE



CESIUM IN COUNTS PER MINUTE PER KG

Figure 9. Pope's Creek marsh shoreline from 1937 aerial photography.

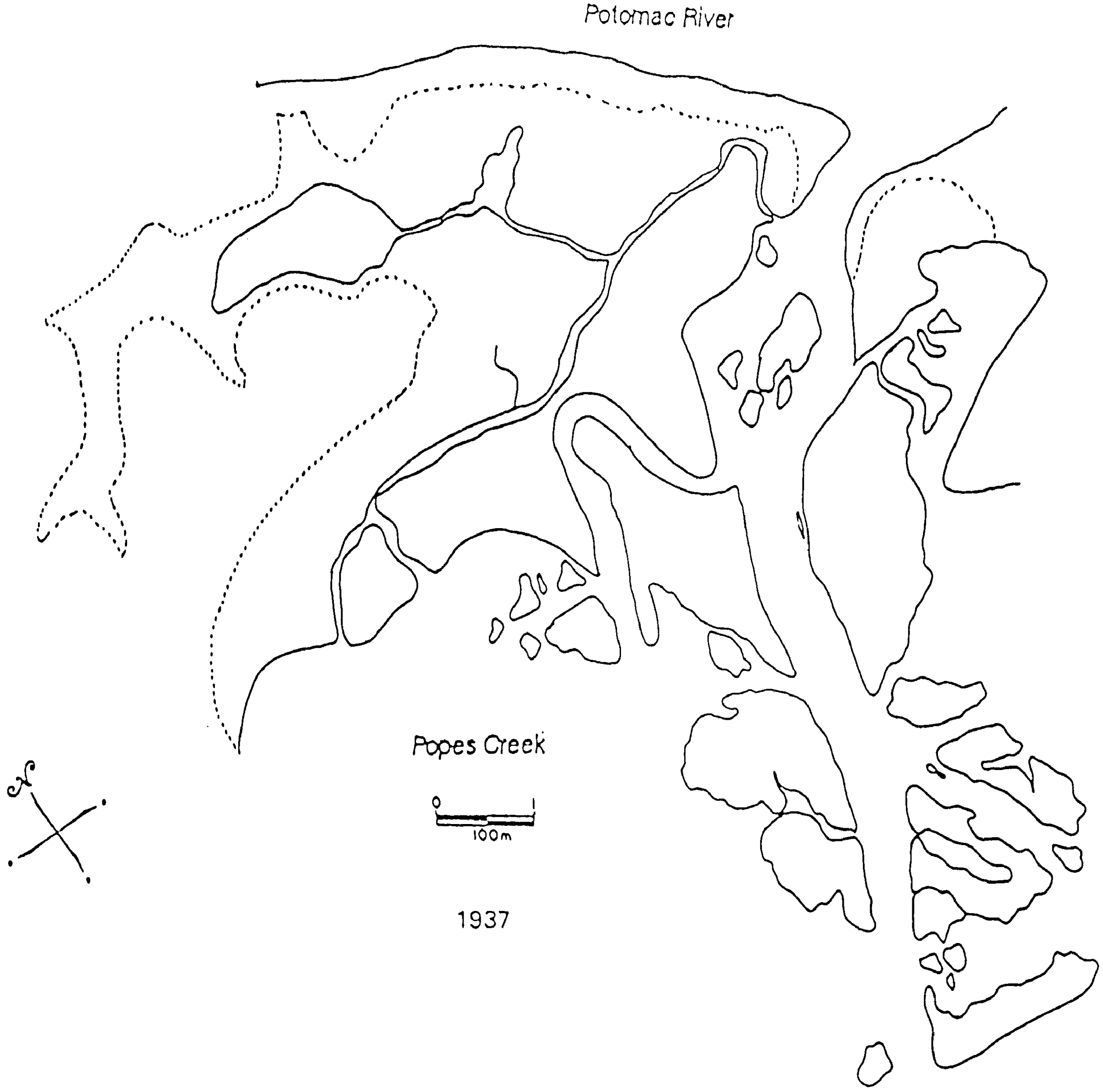

Potomac River
Popes Creek
0
100m
1937
N

Figure 10. Pope's Creek marsh shoreline from 1953 aerial photography.

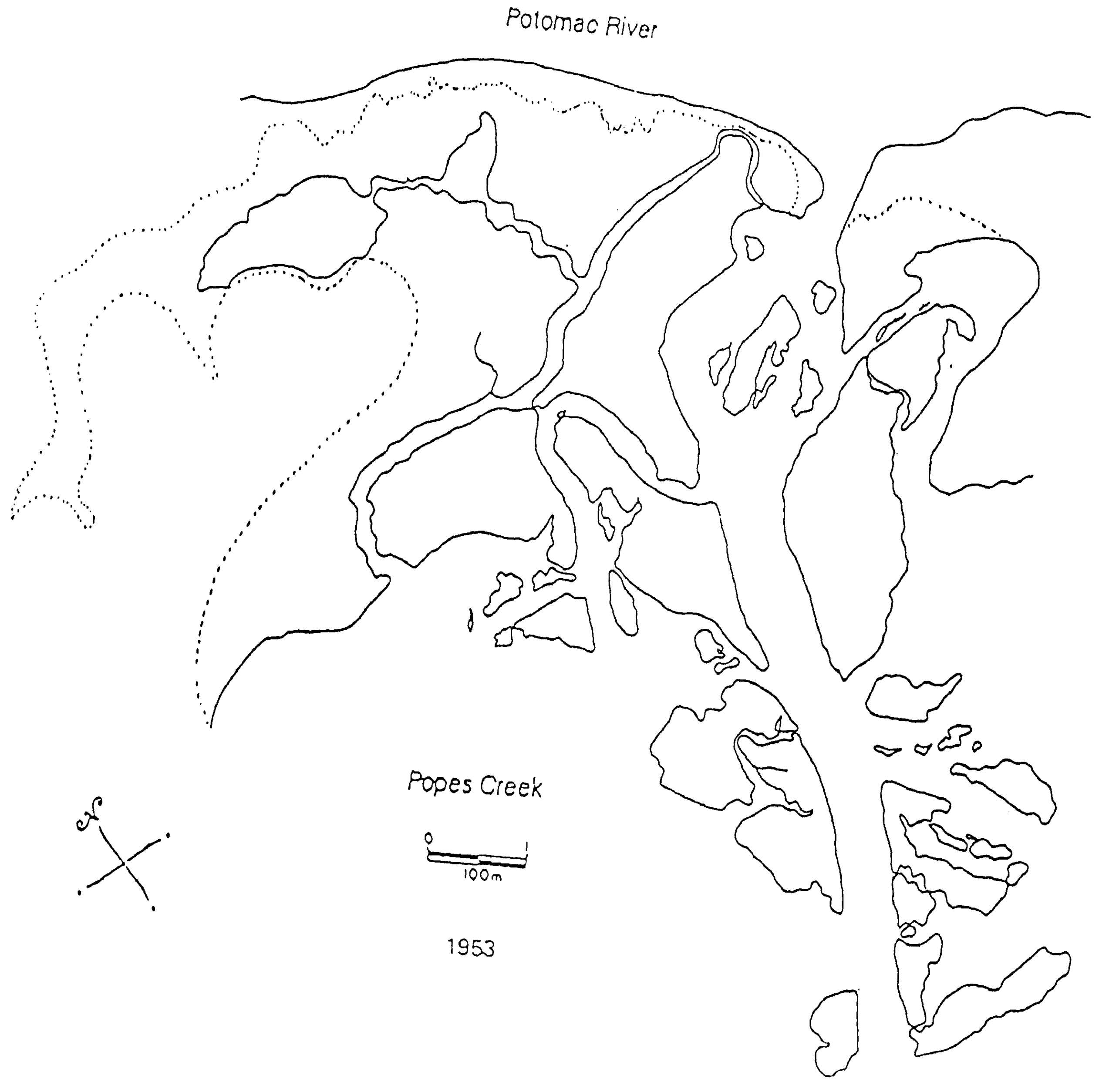

Potomac River
Popes Creek
N
0
100m
1953

Figure 11. Pope's Creek marsh shoreline from 1985 aerial photography.

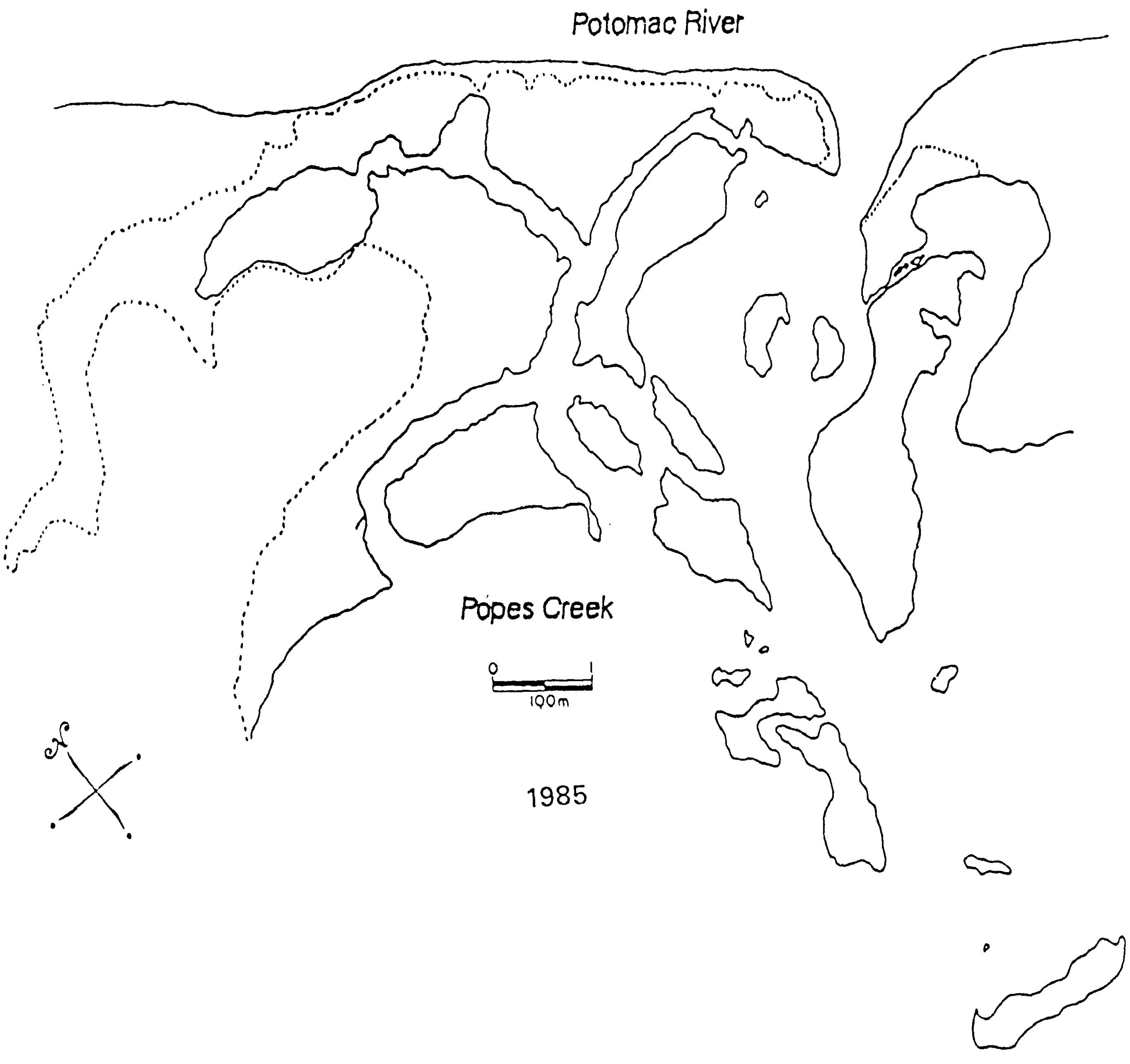
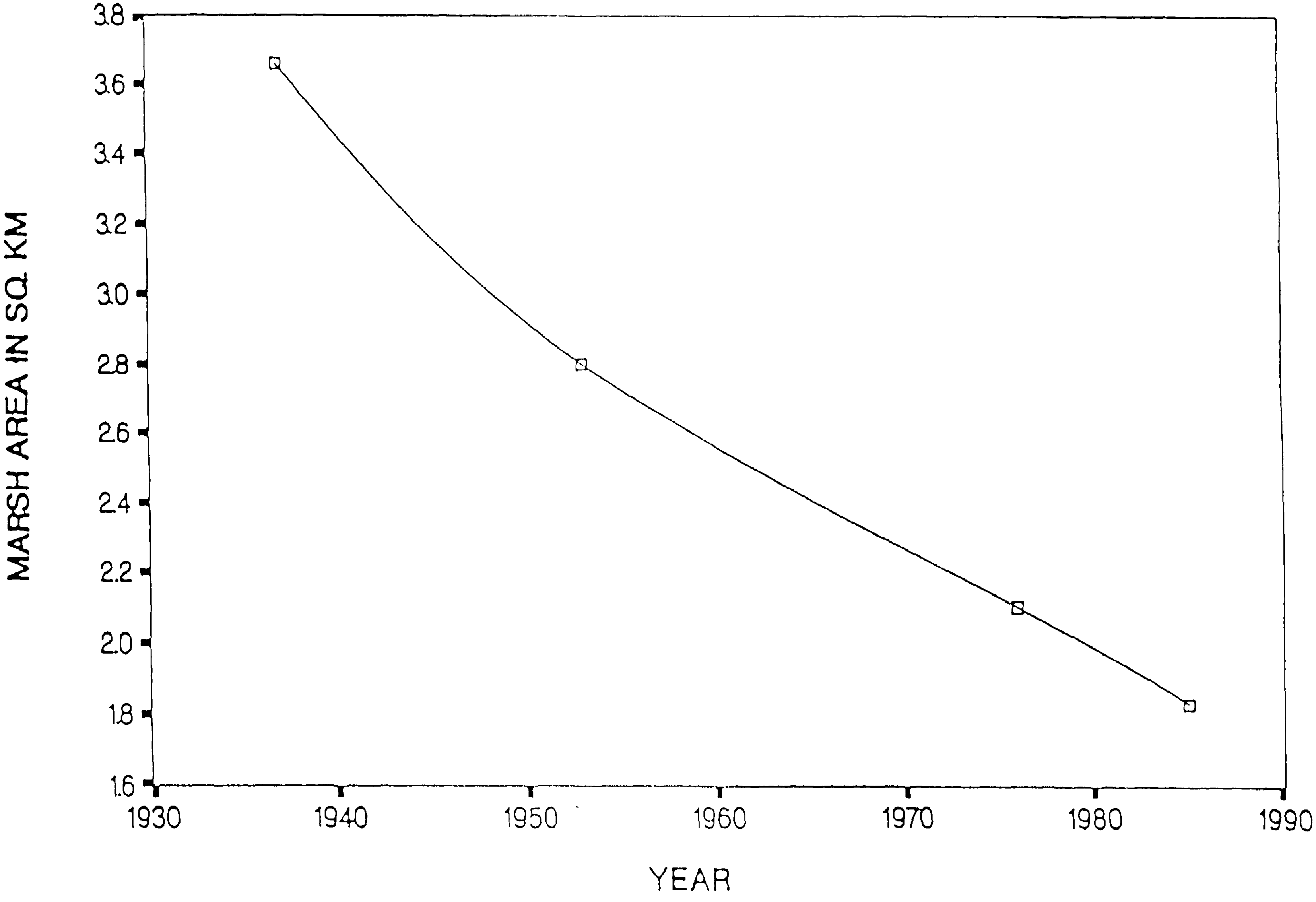
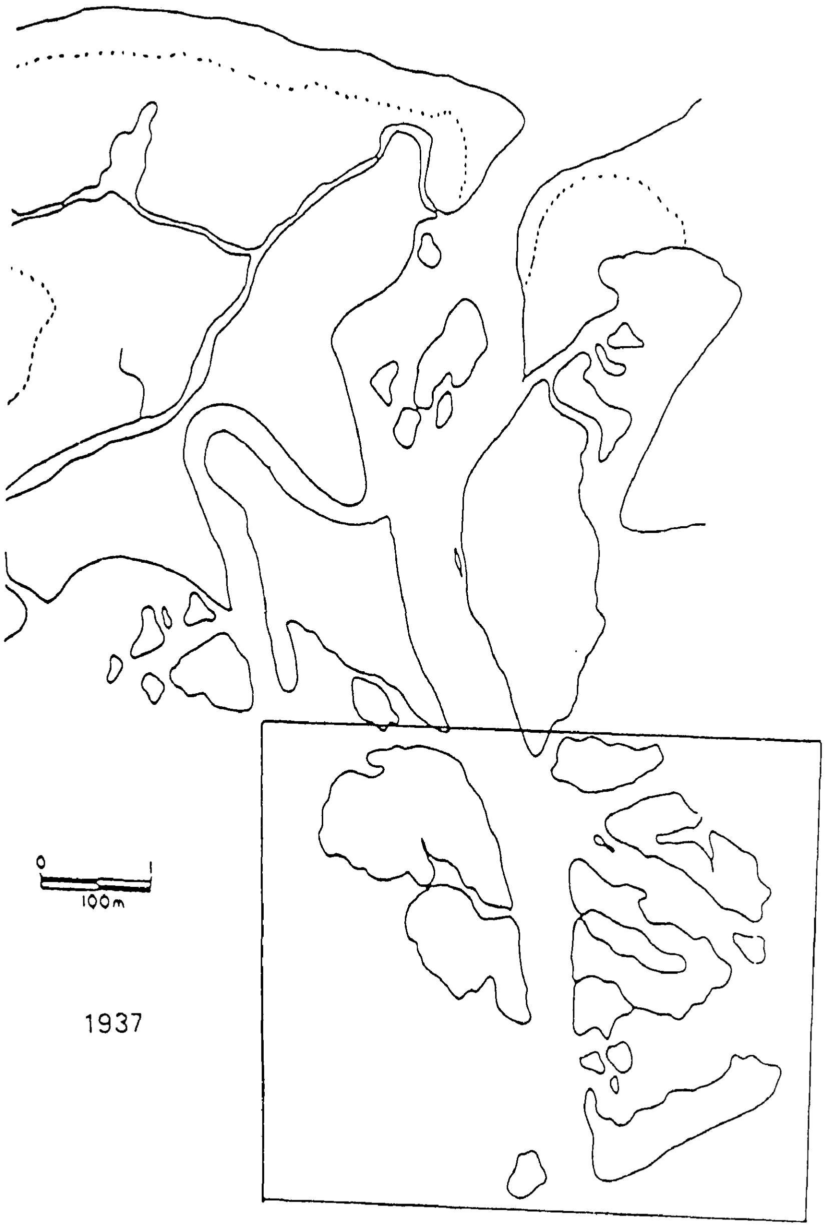

Potomac River
Popes Creek
0
100m
N
1985

Figure 12. Pope's Creek marsh area remaining versus year.

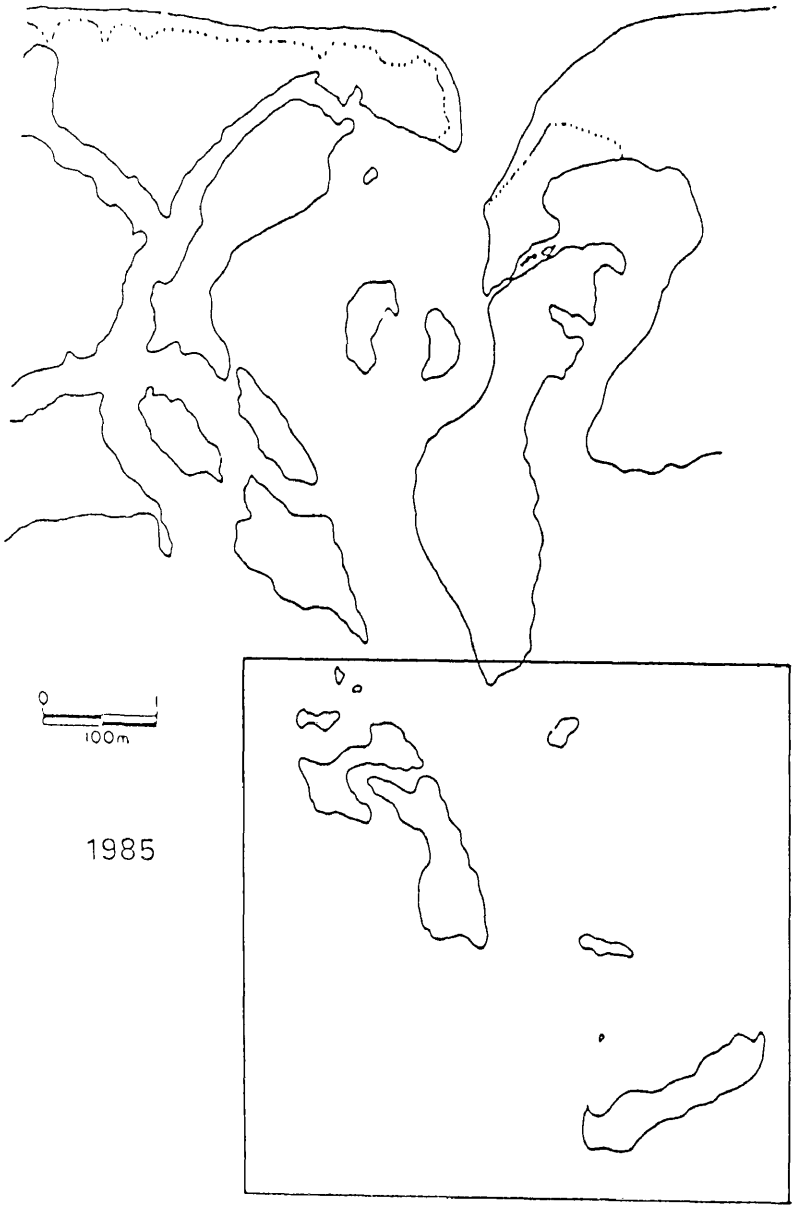


MARSH AREA IN SQ. KM
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1930
1940
1950
1960
1970
1980
1990
YEAR

Figure 13. 1937 and 1985 shorelines of island portions of Pope's Creek marsh



1937



1985

DISCUSSION

A comparison of the present vegetation community with that documented during the 1976 tidal marsh inventory (Mercer 1978) supports the hypothesis that a change in marsh vegetation has occurred. The 1976 inventory reported that 90 percent of vegetation cover was I. frutescens. Results of this study indicate that the I. frutescens cover has been reduced to 51 percent. Other plant species have increased in abundance, for example S. cynosuroides, S.alterniflora, and S. patens represented less than 5 percent of percent cover during the 1976 tidal marsh inventory. This study did not estimate direct percentage cover of species for the entire marsh but instead delineated communities and assigned dominants or co-dominants for the communities, so a direct comparison is difficult, but these species now dominate or co-dominate in 53 percent (0.94 km^2), 16 percent (0.29 km^2), and 33 percent (0.59 km^2) respectively. This suggests an increase in relative abundance has occurred with respect to these species.

A change in vegetation type may be due to several mechanisms which were pursued. The vegetation trend seems to indicate a change from I. frutescens, which is primarily associated with high marsh, to Spartina sp. which are associated with lower elevations. The first mechanism examined was a change in relative elevation with respect to sea level. To determine if this mechanism could be important in vegetation community change, elevation was examined as a controlling factor of plant distribution in the present community.

Analysis of elevation and species abundance data using DECORANA indicated that elevation does not appear to play a primary role in determining vegetation zonation at this study site. Elevation did correlate positively with axis 3 but this axis was responsible for only a small percentage of the variation seen between samples. The trend that is indicated by the DECORANA output (figure 5) shows *S. alterniflora* at the lowest elevations with *S. patens* and *I. frutescens* located just above, as expected. Unexpectedly, samples that were dominated by *A. cannibinus* and *P. purpurescens* were associated with the highest elevations. A possible explanation for this may be due to sampling error when elevation readings were taken due to the high variability in elevation within some quadrats. When elevation data were collected in a quadrat that contained hummocks and ditches, a median level was approximated for the placement of the stadia rod. This could result in an overestimation of the elevation in one portion of the quadrat and an underestimation in the other portion where each portion may have had a distinct vegetation community.

The results of the Cs-137 analysis indicated an average accretion rate of 6.8 mm/yr. This is within the range of values reported for marsh accretion rates in the literature of 2.5 mm/yr to 8.1 mm/yr (Stevenson et al., 1986). This range, however includes values for Louisiana deltaic marshes which have unusually high accretion rates. Despite high accretion rates, marshes in Louisiana appear to have an accretionary deficit, where relative sea level rise is outpacing the ability of the marsh to accrete.

Alteration in the vegetation pattern at Pope's Creek could indicate that an accretionary deficit exists, however this hypothesis is not supported by the accretion rate determined which is well above estimates for relative sea level rise for the area of approximately 2.6 mm/yr (Davis, 1987). Stevenson et al. (1986) have criticized the Cs-137 technique because it may overestimate long-term accretion rates. This is of particular importance in some studies where the measured Cs-137 accretion rate was very close to estimates of relative sea level rise. The results of this study indicate that even with some overestimate of accretion rate the areas sampled do not display an accretionary deficit. Accretion rates determined in this study and results of previous analysis of vegetation-elevation relationships indicate a change in relative elevation with respect to sea level is probably not the mechanism responsible for vegetation community change at Pope's Creek.

Zonation has been shown to depend strongly upon elevation in salt marshes (Johnson and York, 1915; Chapman, 1938; Hinde, 1954; Hutchinson, 1982; Vince and Snow, 1984; Huq, 1986), but many other factors may also play a role. Other environmental factors which were not measured in this study could be responsible for the variation in species composition that was seen. Salinity (Adams, 1963), pH (Stevenson and Emery, 1958), drainage (Chapman, 1940), soil type (Johnson and York, 1915; Gallagher et al., 1977), and soil nutrient chemistry (Huq, 1986) have all been cited as factors which play some role in determining zonation. In addition to environmental controls of zonation there can also be biological controls. The lower salinities found in brackish marshes allow an increase in the species diversity and thus competition between species may also increase and override environmental factors as a controlling factor in zonation. While it is difficult to measure competition between species, a serious shortcoming of this study was that only one environmental variable was measured. This resulted in only a minimum of information being obtained from the DECORANA analysis.

A second mechanism which might play a role in the vegetation change observed is erosion. While erosion would not directly cause a change in vegetation, it may cause what is perceived as a change if there is a difference in erosion rates of vegetation communities. Examination of aerial photography showed that a loss of marsh area has occurred. Since 1937, 1.83 km^2 have been lost, with 53 percent of the loss (0.97 $km^{2)}$ occurring since 1978.

This loss due to erosion has occurred principally through widening of tidal creek channels and a substantial reduction in the central island portion of the marsh. Many of these islands have been greatly reduced in size or have completely disappeared (figure 13). They differ from other areas of the marsh because they are almost exclusively covered with I. frutescens. Aerial photography from 1937 shows that the central island area was 92 percent I. frutescens marsh and it is these marsh islands that have accounted for about 22 percent of the total area loss occurring from 1937 to 1985. This resulted in a large decrease in I. frutescens abundance due loss, not from a change in community structure. The net effect on the marsh community would be an decrease in the apparent contribution of I. frutescens and an increase in the apparent contribution of other species.

The substantial loss of area focused in the island section of the marsh may be attributed to a combination of vegetation type and high shoreline to area ratios. The latter condition results in increased exposure to wave and current action. As the shoreline erodes, tidal channels enlarge, resulting in further increases in erosion. No research has been done comparing the erosion control capacity of different species of marsh plants but Silberhorn (1978) classified the salt bush community's potential erosion buffer ability as " not structurally suited as an assimilator of sediment and flood waters, it serves somewhat as a buffer to erosion on sand berms that often front small pocket marshes. ". Vegetative erosion control projects (Hardaway, et al., 1984) primarily use _S. alterniflora_ and _S. patens_ to revegetate shorelines. The morphology of these grasses is such that a dense root and rhizome mat is formed which is very effective at controlling soil erosion. A large portion of the plant's biomass, as much as 50 percent or more (Good et al., 1982), is dedicated to these underground structures since they represent a major reproductive pathway. No research has been done comparing the aboveground and belowground biomass of _I. frutescens_ or shrub vegetation, but field observations demonstrated that even large bushes could easily be pulled from the soil indicating a root system that is probably less effective at controlling soil erosion than the dense root system found in grass species.

There are other potential factors which may specifically play a role in the decrease of _I_. _frutescens_. These include the presence of dodder, _Cuscuta_ sp.. Its distribution was limited in the marsh but it was found exclusively on _I_. _frutescens_. Where it occurred it profoundly affected the vigor of the host plant with most of the bush appearing dead. In addition, another potential factor in decreasing _I_. _frutescens_ abundance could be caused by a die-off of mature bushes. Priest (1977) found that when _I_. _frutescens_ reached a main stem diameter of approximately 2.5 cm the main bush died off and young side shoots were put out. If a large proportion of bushes reached this stage at the same time it would decrease the contribution of _I_. _frutescens_ to the marsh community temporarily.

CONCLUSIONS

Marsh vegetation changes have occurred at Pope's Creek. The marsh is shifting from vegetation dominated by _I. frutescens_ to vegetation dominated by grass species such as _S. cynosuroides_, _S. patens_, and _S. alterniflora_.

Vegetation zonation in salt marshes has been frequently attributed to elevation or some tidal factor related to elevation. The present study did not find a strong relationship between elevation and species distribution. Because only elevation was measured, the environmental or biological factor(s) responsible for controlling zonation at Pope's Creek are unknown.

Accretion rates determined using Cs-137 analysis indicate that the marsh is accreting at a rate approximately two times relative sea level rise estimates for the area. This further supports the lack of change in relative elevation with respect to sea level as a mechanism for the observed vegetation change.

A substantial area loss of 1.83 km^2 or about 50 percent of the marsh has occurred over the last 50 years. This loss may be one mechanism responsible for the vegetation change via a selective loss of areas dominated by _I. frutescens._ This may be due to differential erosion rates of various marsh communities. Morphology of the marsh may also play a role in increasing erosion due to the prevalence of islands and dissected areas which are exposed to more wave and current action.

Additional biological factors such as parasitic plants and age structure could be directly affecting the abundance and vigor of _I. frutescens_ and contributing to vegetation change.

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