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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
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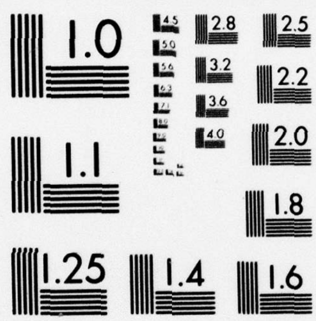

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TECHNICAL REPORT D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE GALVESTON BAY, TEXAS

APPENDIX D: PROPAGATION OF VASCULAR PLANTS AND POSTPROPAGATION MONITORING OF BOTANICAL SOIL, AQUATIC BIOTA, AND WILDLIFE RESOURCES

by

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June 1978
Final Report

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
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IN REPLY REFER TO: WESYV

31 July 1978

SUBJECT: Transmittal of Technical Report D-78-15, Appendix D

TO: All Report Recipients

1. The technical report transmitted herewith represents one of a series of research efforts (Work Units) undertaken as a part of the Habitat Development Project (HDP) of the Corps of Engineers' Dredged Material Research Program (DMRP). The HDP had as one of its objectives the testing and evaluation of habitat development as an alternative method of dredged material disposal.

2. This report, "Appendix D: Propagation of Vascular Plants and Post-propagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources," (Work Unit 4A13F) is one of four appendices relative to Waterways Experiment Station Technical Report D-78-15 entitled "Habitat Development Field Investigations, Bolivar Peninsula Marsh and Upland Habitat Development Site, Galveston Bay, Texas; Summary Report" (4A13K). The appendices to the summary report are studies that provide technical background and supporting data and may or may not represent discrete research products. Appendices that were largely data tabulations or that clearly have only site-specific relevance were published as microfiche; those with more general application were published as printed reports.

3. The purposes of this work unit were to establish and monitor marsh and upland vegetation at the Bolivar Peninsula Habitat Development Site and to evaluate the impact of habitat development on soil properties, plants, aquatic biota, and wildlife. Data from the report are best interpreted in the context of the series of ten work units that were conducted at Bolivar Peninsula (4A13A-J) and are synthesized in that site's summary report (4A13K).

John L. Cannon
JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report D-78-15	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MARSH AND UPLAND HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS; APPENDIX D: PROPAGATION OF VASCULAR PLANTS AND POSTPROPAGATION MONITORING OF BOTANICAL, SOIL, AQUATIC BIOTA, AND WILDLIFE RESOURCES	5. TYPE OF REPORT & PERIOD COVERED: Final report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J. W. Webb, J. D. Dodd, B. W. Cain, W. R. Leavens, L. R. Hossner, C. Lindau, R. R. Stickney, H. Williamson	8. CONTRACT OR GRANT NUMBER(s): Contract No. DACW39-76-C-0109
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Texas A&M University, Texas Agricultural Experiment Station, College Station, Tex. 77840	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DMRP Work Unit No. 4A13F
11. CONTROLLING OFFICE NAME AND ADDRESS: Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314	12. REPORT DATE: June 1978
	13. NUMBER OF PAGES: 772
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): U. S. Army Engineer Waterways Experiment Station, Environmental Laboratory, P. O. Box 631, Vicksburg, Miss. 39180	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

526 p.

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

WES TR-D-78-15-APP-D

18. SUPPLEMENTARY NOTES

Appendix A to this appendix was reproduced on microfiche and is included in an envelope inside the back cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic animals
Biota
Bolivar Peninsula
Dredged Material
Field investigations
Galveston Bay
Habitat development
Habitats
Marsh development
Marshes
Plants (Botany)
Vascular plants
Vegetation establishment
Wildlife

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A 2-1/2-year field investigation was conducted at Bolivar Peninsula, Galveston Bay, Texas, to test the feasibility and impact of developing marsh and upland habitat on dredged material. This report summarizes baseline information derived before habitat development operations and results of post-development operation.

Two marsh grass species and nine upland plant species including trees,

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Unclassified

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20. ABSTRACT (Continued).

shrubs, and grasses were planted in test plots on a dredged material site lying between the Gulf Intracoastal Waterway and Galveston Bay. Tests were conducted to measure plant survival and performance in response to different fertilizer treatments and planting methods. Plantings of the marsh grasses were made within an intertidal area protected from wave energies by a sandbag dike. Prior to and during plant development, information was collected to document changes in fish and wildlife communities.

Plantings were successful in both the marsh and upland. Marsh grasses surviving and performing well included smooth cordgrass (Spartina alterniflora) and saltmeadow cordgrass (Spartina patens). Upland plants demonstrating good survival and growth were live oak (Quercus virginiana) wax myrtle (Myrica cerifera), winged sumac (Rhus copallina), bitter panicum grass (Panicum amarum), and coastal bermuda grass (Cynodon dactylon var alecia).

Components of the habitat development site, consisting of the planted vegetation and sandbag dike, attracted insects, aquatic organisms, and birds. As the plants developed, the numbers of shore insects, mainly dipterans and beetles, increased greatly in the intertidal study area. Shorebirds associated with marshes moved onto the site and increased in density. The abundance of benthos was 1.5 times greater inside the diked area than outside, and within the diked area, the benthos in planted areas was 1.5 times as abundant as the benthos in bare areas.

After less than a year of development, the site provided heterogeneous habitats which tended to support greater use by fish and benthos than is generally associated with sandy shores along Bolivar Peninsula. The field investigation indicated that habitat development can be a feasible dredged material disposal alternative.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

SUMMARY

Establishment of marshland and upland communities on dredged material behind a sandbag dike was investigated at Bolivar Peninsula, Galveston Bay, Texas. Soil properties, aquatic biota, and wildlife were studied as the vegetation developed.

Spartina alterniflora sprigged in the summer of 1976 exhibited a trend of lower survival with increasing fertilizer applications. *Spartina patens* did not produce new growth after transplanting until September 1977. Following the July 1976 and January 1977 plantings, *S. patens* responded better at the higher elevations and *S. alterniflora* at the lower elevations. Survival at midelevations was low for both species. A comparison of January and May 1977 sprigging dates for *S. alterniflora* shows that survival was better for the May planting. However, density at the end of the year was better for the January planting because of the longer period of growth.

Sprigged *S. alterniflora* exhibited good survival, growth, and reproduction for all planting dates, particularly at lower elevations. Sprigged *S. patens* survived and did well only at elevations above mean high water (+1.6 ft msl). *S. alterniflora* and *S. patens* seeded in March 1977 germinated and grew only at elevation above 1.6 ft. Plants did not do well without the protection from waves afforded by the sandbag dike. Generally, fertilizer treatments did not result in significant changes in survival, growth, or reproduction of tillers.

An upland area was planted to three categories of plants: trees, shrubs, and grasses. All three categories appeared able to survive and grow. Survival for shrubs and trees planted in June and July 1976 was low. Survival for winter plantings of shrubs and trees was good, particularly for *Quercus virginiana*. *Croton punctatus* did not survive in the lower elevation block. In contrast, survival was 33 percent in the higher elevation blocks. *Pinus clausa* and *Tamarix gallica* had low survival at higher elevations and good survival at lower elevations. *Rhus copallina* and *Myrica cerifera* survived at all elevations. For the three grass species, survival of *Cynodon dactylon*

(alecia variety) and *Panicum amarum* was excellent. *Andropogon perangustatus* did not survive in the lower elevation block, and only slight survival was measured in the higher blocks. Responses of each species to three fertilizer treatments were evaluated. Second-year fertilizations of *C. dactylon* and *P. amarum* produced significantly more biomass and tillers than those plots fertilized only in 1976.

Avian censuses were conducted biweekly, and 135 species were recorded over the study period. Species composition at the experimental marsh changed as new species colonized the developing marshland. Population densities remained relatively low in all areas, but species diversity increased as the study progressed.

Nest searches revealed six species of birds breeding in the study area. One species, *Sterna albifrons*, was dependent on the unvegetated area of the experimental upland and showed a nest density of 9.8 nests per hectare.

Five species of small mammals and seven species of larger mammals were trapped or observed during the study period. *Sigmodon hispidus* was the most numerous mammal and was captured in all heavily vegetated areas. Mammals did very little damage to the planted vegetation.

Monitoring of changes in sediment composition and nutrient status of the site was accomplished by analysis of deep cores from selected plots as well as extensive sampling and analysis of surface sediments. Destructive sampling and analysis of plants from all plots where they were established were conducted in the late fall months of 1976 and 1977.

By the end of this investigation, the marshland site consisted of two distinct sediment zones separated by a zone of intermediate composition. The lower elevation marshland region (tier 1) was inundated much of the time. During the investigation, there had been a dramatic increase in clay content, organic matter, total Kjeldahl nitrogen, and extractable phosphorus. These components were largely confined to the surface horizons and decreased rapidly with depth. The buildup of these components in the lower marshland region was associated with sedimentation from clay- and silt-laden waters and with active algal growth.

Changes in sediment composition of the higher elevation portion of the lowland site (tier 3) were quite different over the study period. The chemical and physical composition of this area remained essentially the same for the last 2 years of the investigation, with only moderate fluctuations in these parameters being measured.

The region between tiers 1 and 3 was intermediate in physical and chemical properties.

Changes in the properties of the sediments at the site were largely controlled by elevation. Establishment and biomass production of the two grasses planted in the marshland, *Spartina alterniflora* and *Spartina patens*, were also associated with elevation. There was no relationship between sedimentation or chemical composition of the sediment and the presence of plants in the marshland. Chemical changes occurred in the unsprigged control plots at the same rates as in vegetated plots. Ammonia appeared to increase to some extent during the winter.

Photographs documented the growth of *S. alterniflora*, *S. patens*, and some volunteer plant species at the site. A variety of animal signs could be detected during the study, the predominant ones being fiddler crab holes and worm holes.

The aquatic biology data indicate that the period from July 1976 through June 1977 represents a modified baseline period. Significant changes in most parameters cannot be related to the presence or absence of marsh grasses, although some typical seasonal patterns were observed.

In excess of 22,000 individual vertebrate and macroinvertebrate organisms were collected from July 1976 through June 1977. Diversity may have been slightly affected by either the presence of the sandbag dike or the marsh grass planting, but the data do not demonstrate wide variations across the sampling site.

Six species of fishes were examined for food habits. With the exception of *Menidia beryllina*, the fishes examined fed primarily on benthic organisms or fish.

Benthic invertebrates were collected from a variety of families within the phyla Annelida, Mollusca, Crustacea, and Rhyncocoela.

Individual samples ranged from a complete absence of organisms to over 40,000 individuals per square metre. Polychaetes and one species of isopod dominated the intertidal samples, while insect larvae and pupae were dominant at the upper elevations. Diversity of the benthos was lowest in the zone which represented a transition between intertidal and supertidal. Little variation in the benthos either with location laterally across the site within elevation or within habitat type was observed.

Volatile solids levels were low throughout the study period, rarely averaging more than 1 percent of the sedimentary material by weight. Grain-size analyses revealed that the bulk of the material was within the range of 63 to 250 μm. Silt and clay represented approximately 10 percent of the total sedimentary material. There were no noticeable differences in grain size associated with elevation, habitat, or time during the study period.

Water quality data revealed values typical of Gulf of Mexico bays. Diurnal changes in temperature, dissolved oxygen, and salinity were apparent in many samples, as were seasonal trends.

PREFACE

This report presents the results of an investigation to describe quantitatively and monitor the botanical, soil, aquatic biota, and wildlife resources at the Bolivar Peninsula Marsh Development Site, Galveston Bay, Texas, following site development with vegetation plantings. The investigation was conducted as a part of the Corps of Engineers' Dredged Material Research Program (DMRP) under Contract No. DACW39-76-C-0109, entitled "The Propagation of Vascular Plants and Post-Propagation Monitoring of the Botanical, Soil, Aquatic Biota, and Wildlife Resources at the Bolivar Peninsula Marsh Development Site, Galveston Bay, Texas," dated 9 June 1976, between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., and the Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas. Contracting Officer was COL John L. Cannon, CE. The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was managed by the Environmental Laboratory (EL), WES.

Parts I, II, III, and IV were prepared by J. W. Webb and J. D. Dodd, Research Associate and Professor, respectively, in Range Science, Texas A&M University. B. W. Cain and W. R. Leavens, Assistant Professor and Research Assistant, respectively, in Wildlife and Fisheries Sciences, Texas A&M University, prepared Part V. "Sediment Chemistry," Part VI, was prepared by L. R. Hossner and C. Lindau, Associate Professor and Research Assistant, respectively, in Soil and Crop Sciences, Texas A&M University. R. R. Stickney and H. Williamson, Assistant Professor and Research Associate, respectively, in Wildlife and Fisheries Sciences, Texas A&M University, prepared Part VII.

The authors express appreciation to personnal of WES, particularly Hollis Allen, Jean Hunt, Scott Boyce, John Lunz, Ellis J. Clairain, Robert Huffman, and Robert Wells, for their assistance and cooperation during the investigation.

The contract monitor and site coordinator for WES was Hollis Allen, EL. Project Manager was Dr. H. K. Smith, Habitat Development Project, EL. Dr. John Harrison was Chief, EL.

COL John L. Cannon, CE, was Director of WES during the conduct of the investigation and preparation of this report. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
miles (U. S. statute) per hour	1.609344	kilometres per hour
gallons (U. S. liquid)	3.785412	cubic decimetres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9)(F - 32). To obtain Kelvin (K) readings, use: K = (5/9)(F - 32) + 273.15.

HABITAT DEVELOPMENT FIELD INVESTIGATIONS

BOLIVAR PENINSULA MARSH AND UPLAND

HABITAT DEVELOPMENT SITE

GALVESTON BAY, TEXAS

APPENDIX D: PROPAGATION OF VASCULAR PLANTS AND POSTPROPAGATION MONITORING OF BOTANICAL, SOILS, AQUATIC BIOTA, AND WILDLIFE RESOURCES

PART I: INTRODUCTION

1. This investigation is a part of the Dredged Material Research Program (DMRP) derived from the 1970 River and Harbor Act. In 1971 the U. S. Army Engineer Waterways Experiment Station (WES) at Vicksburg, Miss., was assigned to define and assess the problems of and develop a research program for the disposal of dredged material. The Texas Agricultural Experiment Station (TAES) at College Station, Texas, is concerned with that portion of the DMRP considering habitat development (marshland and upland) in dredged material along the upper Texas gulf coast.

2. The coastal marshes of Texas comprise about 774 km^2 and are an important land resource area on the Texas coast (Godfrey et al. 1973). Marshland is important to society for flood control and water quality. In addition, it provides wildlife habitat and can be a valuable source of nutrients for livestock and marine life [National Aeronautics and Space Administration (NASA) 1974]. An example of the importance of this region to Texas is illustrated by the occurrence of one third of the population and nearly one third of the industry of the State in this region (Fisher et al. 1972). The large population and industries have had a serious impact on the Texas gulf coast region. As industry and urbanization increase, a need exists for reestablishing marshes that were destroyed during development. Dredged material may provide such sites throughout the Texas gulf coast region.

3. This study involved the propagation of selected plant species on marshland and upland developed from the grading of dredged material. The purpose was to determine the field performance of selected plant species with various fertilizer treatments and propagation methods to grow, reproduce, and attract animals to a site composed of dredged material.

4. This study on propagation was complemented by companion studies of changes in soil properties, aquatic biota, and wildlife resources as the vegetation developed. The soils study was to relate the mineral-nutrient content of plants and the dredged material deposited on the study site to various cultural practices, experimental treatments, and temporal changes occurring on the site. The aquatic biota study was to document the qualitative and quantitative changes occurring in the macrobenthic faunal community and qualitative changes in nekton in both the experimental and reference areas. The wildlife study was designed to describe avian and mammalian utilization of the habitats developed and to document animal damage occurring in the experimental and reference areas.

PART II: DESCRIPTION OF THE AREA

5. The study area is located on Bolivar Peninsula along Galveston Bay, Texas (Figure 1). The peninsula forms the east end of a chain of sand barriers that extends almost 600 miles* along the Mexico and Texas coasts. It has developed as an offshore sandbar since the post Pleistocene rise in sea level about 4000 years ago (Lankford and Rehkemper 1969). Bolivar Peninsula is maintained by marine sedimentation processes, primarily on the gulf shore. However, some sediment is also transported by seawater washing over the barrier to the bay (NASA 1974). Apparently river-transported sediments are negligible (U. S. Army Engineer District, Galveston 1968).

6. Climate, tides, hurricanes, and the general soils have been previously described (Dodd et al. 1975, personal communication, Environmental Laboratory (EL), WES, Vicksburg, Miss. 1976). Included in these descriptions were composition of the vegetation, plant lists, and details of certain soil properties. Avian and mammalian species and populations were also discussed.

7. The actual study area is an 18-acre site between Marsh and Baffle Points near the west end of Bolivar Peninsula (Figure 1). The site is exposed to Galveston Bay on the north. A narrow land mass separates the site from the Gulf Intracoastal Waterway (GIWW) at mile 345. Elevation at the site ranges from -0.5 to about +10.0 ft mean sea level (U. S. Army Engineer District, Galveston 1975).** The tidal amplitude is narrow, ranging from about 0.76 to 1.81 ft, and the mean is about 1 ft. However, since Galveston Bay is shallow, winds can increase the tide by approximately 3 ft or decrease it by about 4 ft (Lankford and Rehkemper 1969). Disposal occurs about every 4 years. The last disposal on the study site occurred in August 1974.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 17.

** References to elevation hereafter refer to mean sea level (msl).

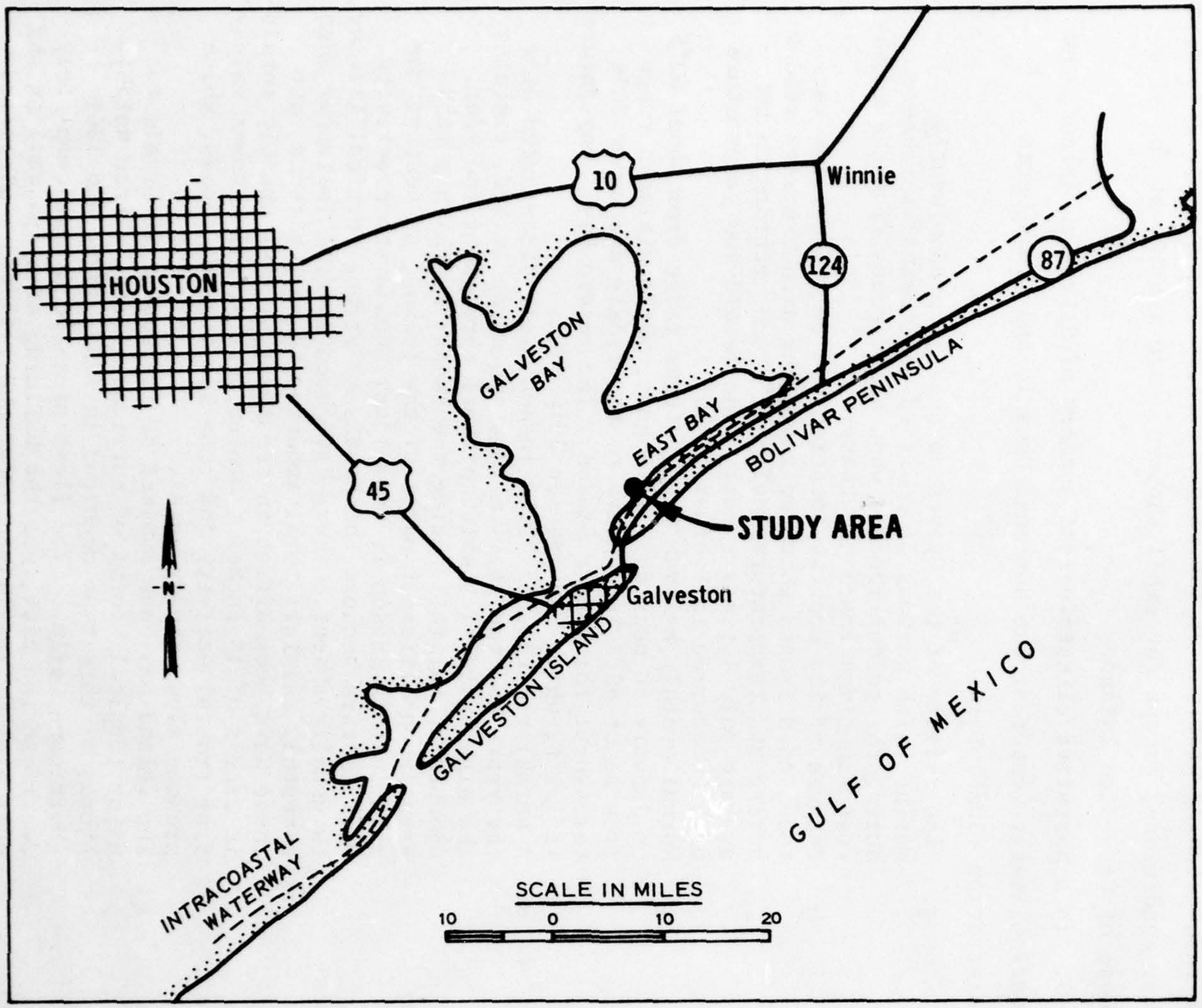

Figure 1. General location of the Bolivar Peninsula habitat development site, Galveston Bay, Texas

8. Available meteorological data were summarized from the U. S. National Weather Station located on Galveston Island approximately 13 km from the study site. In addition, precipitation was collected in eight rain-catching stations at the site. Because of the close proximity, weather conditions, except for small showers, were similar at the site to those of Galveston Island.

9. In a narrative climatological summary of Galveston Island, the National Climatic Center of the National Oceanic and Atmospheric Administration (1976) said:

> a. "The climate of the Galveston area is predominantly marine, with periods of modified continental influence during the colder months, when cold fronts from the northwest sometimes reach the coast.
>
> b. Because of its coastal location and relatively low latitude, cold fronts which do reach the area are very seldom severe and temperatures below 32°F are recorded on an average only 4 times a year. The record low temperature of 8°F occurred in February 1899.
>
> c. Normal monthly maximum temperatures range from about 60°F in January to near 88°F in August, while minimums range from about 49°F in January to the middle and upper 70's throughout the summer season. The record high temperature is 101°F, which occurred in July 1932.
>
> d. A normal rainfall of 42.20 inches, well distributed over the year, and the station location on an island, explains the high humidities which prevail throughout the year. Amounts of rainfall during the summer months may vary greatly on different parts of the island, as most of the rain in this season is from local thunderstorm activity. Hail is rare because the necessary strong vertical lifting is usually absent. There have been several instances when a monthly rainfall total amounted to only a trace, but these have been offset in the means by many monthly totals in excess of 15 inches. Winter precipitation comes mainly from frontal activity and from low stratus clouds, which produce slow, steady rains.
>
> e. The island has been subject at infrequent intervals to major tropical storms of hurricane force. Three notable storms of this type occurred in 1900, 1915, and 1961 (Hurricane Carla). The first of these almost completely destroyed the city, but the building of a sea wall on the gulf side of the island after the 1900 storm minimized the danger of direct wave and swell action associated with this type of storm."

10. Meteorological data are presented in Tables 1 and 2. Temperature means were 3 to 4°F below the average in January through March 1977.

Otherwise, temperatures were normal throughout the study period. Rainfall was slightly above normal in June and July 1976. However, during August 1976, precipitation was 8 cm below normal. During September, October, and November 1976, precipitation was normal, but, during December, rainfall was 9 cm above normal. During February and March 1977, half of the average rainfall was received. However, in April 1977, 10 cm above the average was received. Approximately 13 cm was received in a single 24-hour period. During May, rainfall was 6.5 cm below normal with only 1.7 cm being recorded in Galveston. During June 1977, rainfall was still 3.1 cm below normal in Galveston. However, rainfall recorded at the site was approximately normal. During July, precipitation in Galveston and at the site were dispersed with approximately 4.5 cm more rain at the Bolivar Peninsula site than in Galveston. Precipitation was 9.5 cm below normal in Galveston during July. During August 1977, precipitation was 5 cm above normal, while in September, precipitation again fell 1.8 cm below normal. During October 1977, precipitation was normal.

PART III: SITE PREPARATION

11\. The Bolivar Peninsula Marsh and Upland Habitat Development Site was constructed by the Galveston District. A conceptual design with specifications for the site were developed by WES. This development consisted of grading the dredged material to a specific slope (0.67%), constructing a U-shaped sandbag dike for wave stabilization, and constructing a "goat proof" fence around the area.

12\. Grading of the dredged material to the desired slope was initiated 29 January and completed 5 March 1976. Dike construction was initiated toward the completion of gradings to the desired slope. Thus, before completion of the dike, several areas within the study site were subjected to either tidal erosion or deposition and changes in elevation within relatively short distances. In addition, after grading, runoff from the upland surrounding the site resulted in both erosion and deposition, with corresponding changes (0.2 to 1.2 ft) in elevations. This latter problem was not anticipated.

13\. Sandbags were PVC-coated nylon bags 1.5 by 4.5 by 9.5 ft. They were filled in place with sand by pumping a sand and water slurry into the bags and letting the water drain out through bag pores. The primary dike was 1000 feet long and served as the main breakwater. In the primary dike, a base layer of two bags, which supported two stacked bags, was used in initial construction. Secondary dikes, 375 feet long, were constructed at both ends of the primary dike. They consisted of staggered single bags at elevations above approximate mean high water. Staggered bags of two bags each were placed from mean high water to the junction of the primary bags. Sinking of bags resulted in other designs and continuous placement of bags to maintain correct height of the dike. Maintenance was continued through June 1977 by the Galveston District.

14\. The "goat proof" fence extended all the way around the study site. It was completed by the Galveston District in October 1976. However, a temporary fence kept goats out during and after planting. A "rabbit proof" fence consisting of 18-in-high chicken wire with 1-in.

mesh openings was placed at the base of the "goat proof" fence in March 1977 by TAES personnel.

15. The interior of the area was developed by TAES in accordance with WES instructions into an experimental marshland, an upland area of small test plots, and an intertidal area (Figure 2). The purpose was to study species propagation and the effects of vegetation establishment on the developing ecosystems (marshland and upland).

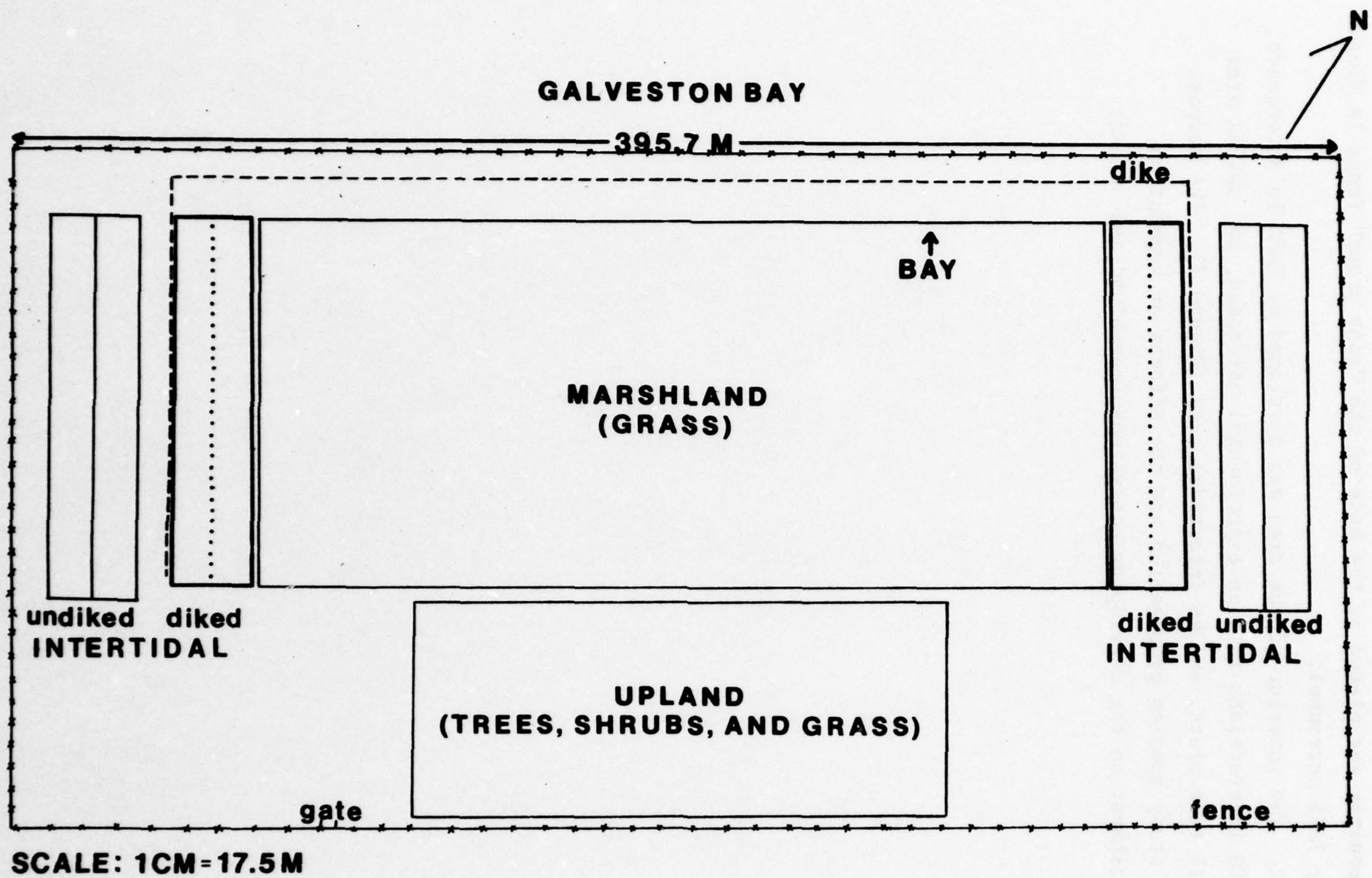

Figure 2. Schematic of the Bolivar habitat development site

PART IV: VEGETATION PROPAGATION

16. The purposes of this phase of the total research project were: to evaluate the feasibility of developing upland and marshland plant communities on dredged material found at the Bolivar Peninsula site through the use of various cultural practices, and to determine the field performance of selected plant species with various fertilizer treatments and propagation methods to grow, reproduce, and attract animals to a site composed of dredged material.

Methods

Seed collection, storage, and germination tests

17. Seeds of *Spartina alterniflora** and *S. patens* were collected from locally existing native stands. Seed heads were sparse and were collected with hand clippers.

18. *Spartina patens* collections were made from four sites during a period from late August to October 1976. Collection during this extended period insured seed maturity. Following collection, the material was air dried at ambient temperature. A small threshing machine was utilized from mid-October to mid-November for threshing. The threshed material was cleaned with a blower-type seed separator. The cleaned seeds were stored in sealed 3.79-ℓ containers. Approximately 50 percent was stored at ambient temperature, and the remainder was stored at about 4°C. A total of 113.7 ℓ of threshed seeds was collected. One hundred glumes were randomly selected from each container for determining percent fill. Glumes were considered filled if they contained a caryopsis. The range of fill was from 3 to 36 percent.

19. *Spartina alterniflora* seed collections were made from several stands in the local area. Again collection from several stands was required due to sparse seed production. Collection took place in late

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* Common and scientific names of plants and animals mentioned in this report are listed in Table 162.

November. Following collection the material was stored dry at 4°C for 2 weeks to allow after-ripening. Seeds were then dried at ambient temperature for about 2 weeks to facilitate threshing which was completed in early December. Threshing and seed-cleaning techniques were the same as employed for *S. patens*. Immediately following cleaning, seeds were placed in 19.0-ℓ containers with a saline solution. The solution utilized was recommended (personal communication, 21 October 1976, S. E. Broome, N. C. State University, Raleigh, N. C.) and consisted of 310 g NaCl (sodium chloride), 100 g $MgSO_4 \cdot 7H_2O$ (magnesium sulfate), 0.5 g $NaHCO_3$ (sodium bicarbonate), and 10 ℓ of distilled water. Adequate solution was added to each container to cover the seeds. The seeds were then stored at about 6°C. Approximately 257.7 ℓ of dry seed was collected. Five containers were randomly selected from the 17 for determination of glume fill. One hundred glumes were selected from each and examined for the presence of caryopses. The percent fill ranged from 8 to 13 percent.

20. The initial germination study was started on 25 October 1976 for *Spartina patens* and 14 January 1977 for *S. alterniflora*. Tests were initiated at approximately 2-week intervals. Each test included a total of 200 seeds per storage treatment.

21. The same procedures were used in the germination studies for both *Spartina patens* and *S. alterniflora*. However, two storage treatments were involved with the former (ambient temperature and 4°C). For each test, filter paper was placed in 8 petri dishes and 25 seeds were added. These seeds had been selected for the presence of caryopses in the glumes. The seeds and filter paper were moistened with 2 ml of distilled water, and the dishes were covered and placed in an incubator. The seeds were germinated in the dark at alternating thermal periods of 16 hours at 35°C ± 2°C and 8 hours at ambient temperature (18°C). The dishes were checked daily for germinated seeds, identified by emergence of shoot or radical. Germinated seeds were counted and removed. Approximately 2 ml of distilled water was added when the filter paper appeared dry. Each test was conducted for 40 days.

22. A test was conducted on *Spartina patens* seed planted in dredged

material. Three containers were filled with media. In one container 25 seeds were planted near the media surface; in another the seeds were placed 2.5 cm deep; and in the third at 5 cm. The media was moistened with distilled water as needed to keep it at or near field capacity.

Marshland propagation

23. Development of the study site into experimental plots resulted in the division of the site into three areas (marshland, upland, and intertidal) (Figure 3). The marshland was divided into three elevation tiers, and each tier was divided into three blocks. Each block was divided into 30 plots (6 by 10 m) with a 0.9-m buffer zone on two sides and a 3-m zone on the other sides. A zone 12.19 m wide was established between the lowest elevation marshland plots and the sandbag dike. This zone provided space for dike maintenance. A total of 270 plots were originally established in the marshland (Figure 3). Treatments were randomly assigned to plots (Table 3). Treatments included two species (*Spartina alterniflora* and *S. patens*), two propagules (seeds and sprigs), controls, and five fertilizer treatments for a total of 30 treatments. Each treatment was repeated within each block and tier. Control plots received fertilizer treatments but no plantings.

24. Marshland fertilization and sprigging of *Spartina patens* and *S. alterniflora* were initiated 22 July 1976 and completed 4 August 1976. Twelve rows of 20 culms each were planted in each plot (240 culms per plot). The spacing was 0.5 m.

25. Local sources of *Spartina patens* and *S. alterniflora* were utilized for planting material. *S. patens* was in the early flowering stage and no new tillers were evident. Clumps of *Spartina patens* were dug with a shovel. Each clump was separated by hand into smaller clumps of 5-8 stems with associated roots. Soil normally fell away from the roots during separation. Plants were placed into burlap bags after separation or placed directly into a jeep trailer. Since plants were dug within a few hundred meters of the planting site, transportation to the site was easily accomplished. When plants were not to be planted immediately, roots were covered with soil to prevent dessication. Plants were not held longer than one night before planting.

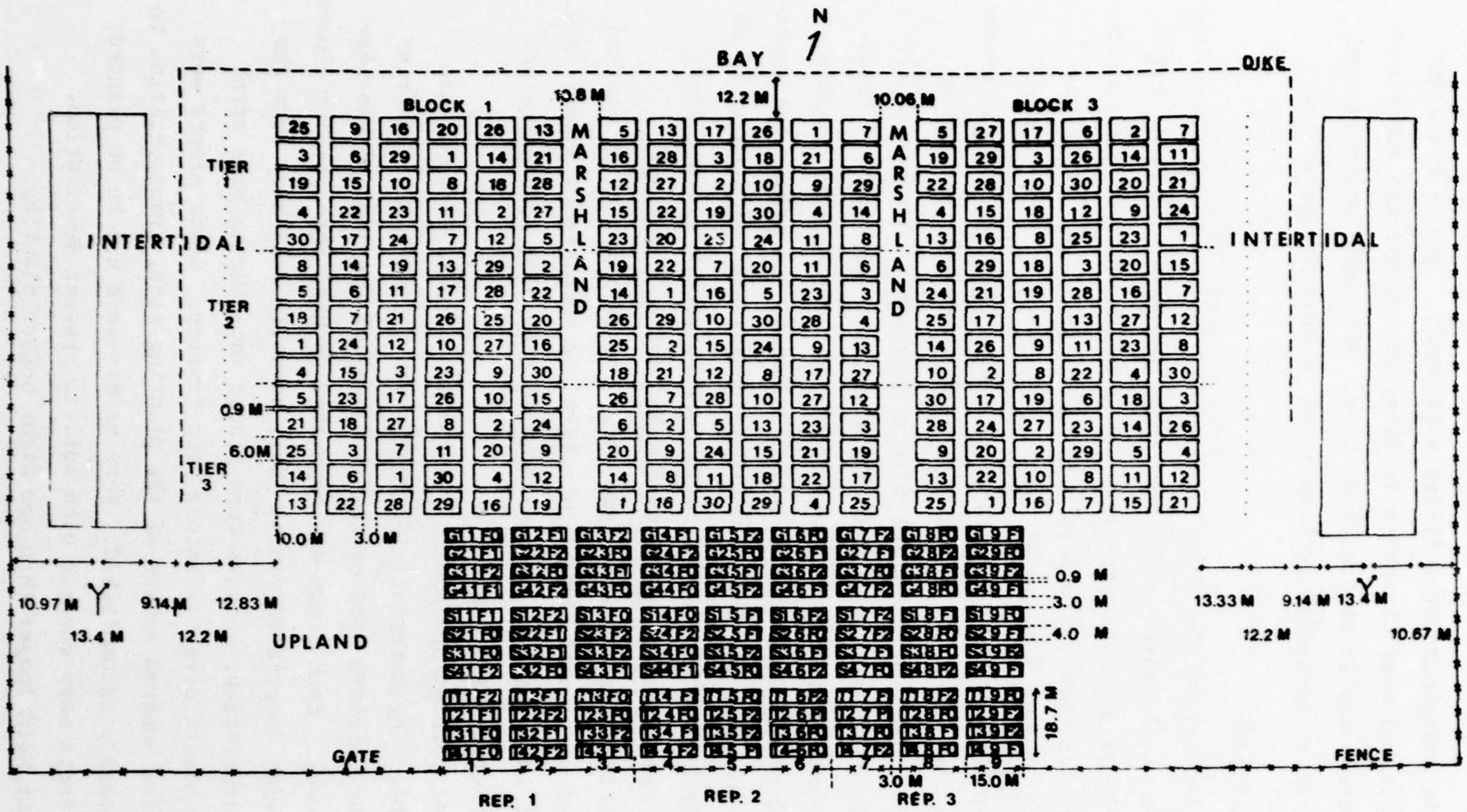

Figure 3. Map of Bolivar Peninsula study site showing marshland plots in three study blocks where photographs were taken monthly

26. *Spartina alterniflora* appeared to be in a rapid growth stage. Plants were loosened or dug with a shovel. Plants were immediately separated into individual stems with associated roots and rhizomes. Soil was generally washed or fell free from the roots during digging. Plants were wrapped in burlap bags and transported by truck, boat, and finally by jeep to the site. Plants were generally dug in the morning and planted during the remainder of the day. Care was taken to keep roots covered by wet burlap bags or to keep them covered with soil. Plants kept overnight were covered with soil to prevent root dessication.

27. Based on observations and reports in the literature, *Spartina alterniflora* culms for transplanting were collected from three elevations in a natural marsh, high, intermediate, and low. The total biomass of these culms was quite similar. However, culm heights ranged from about 78 cm at the low elevation to about 50 cm at the high elevation. This variation in height was in agreement with observations and published reports. Plants taken from each elevation were planted in the same general elevation in the experimental site.

28. Fertilizers utilized on marshland plots were: ammonium sulfate, $(NH_4)_2SO_4$ (21-0-0); triple superphosphate, P_2O_5 (0-46-0); and potassium sulfate, K_2SO_4 (0-0-50). For each plot the three fertilizers were weighed separately on a Mettler balance, mixed into a homogeneous sample, and sealed in a heavy-walled polyethylene bag to prevent caking prior to application. Fertilizer treatments were: F_0 - no fertilizer; F_1 - low rate, 122 kg N/ha, 122 kg P_2O_5/ha, and 122 kg K_2O/ha (122 g/m^2); F_2 - high rate, 244 kg N/ha, 244 kg P_2O_5/ha, and 244 kg K_2O/ha (244 g/m^2); F_3 - split application - low rate, and; F_4 - split application - high rate (Table 3).

29. During the 1976 planting, the experimental plots were prepared for fertilization by harrowing with a spring-toothed harrow in an east-west direction. The fertilizer was broadcast applied and the plots were harrowed in a north-south direction to mix the fertilizer with the soil. Fertilization of the marshland experimental plots was according to the specified rates (Table 3). The F_3 and F_4 plots received half of the

fertilizer prior to sprigging and the remaining half was applied after the sprigs had established. The initial fertilizer application was made on marshland plots on 22 July 1976. The split application following plant establishment was on 28 September 1976. In the second application, fertilizer was spread on the soil at low tide, and no attempt was made to incorporate it into the soil.

30. Following completion of planting, three sample quadrats (1 by 3 m) were located in each experimental plot of the marshland. The location of these quadrats was determined by dividing each plot into three equal parts. Each part was then subdivided into 1- by 3-m quadrats. One quadrat from each third was then selected at random for permanent sampling use. The northwest and southeast corners of each quadrat were staked.

31. Seed plots of *Spartina alterniflora* and *S. patens* were not established until the spring of 1977 because of nonavailability of seeds during the summer. Seeds were collected and stored during the fall of 1976.

32. Seeds were weighed for seeding plots to *Spartina alterniflora* and *S. patens*. A minimum of 100 viable seeds per metre square were required. Each seeded plot measured 30 m^2. Therefore, 3000 viable seeds were needed per plot. Weights were determined for 100 glumes of *S. patens*. In addition, the percent fill (36 percent) and percent germination (75 percent) were considered. This resulted in 270 viable seeds per 1000 glumes (1000 glumes weighed 1 g). Thus, 3000 viable seeds/270 viable seeds/g = 11.1 g of seeds per plot. The bulk was extremely small; so, glumes with 3 percent fill were utilized for an additional 25 viable seeds per m^2. The 25 seeds per m^2 were multiplied by 30 m^2 per plot. Thus, there was needed 750 viable seeds per plot. There were 22.5 g of viable seed per gram. Therefore, 750/22.5 g = 33.4 g of glumes were required per plot. These general calculations indicated that 125 viable seeds were planted per m^2.

33. Similar methods were utilized for *Spartina alterniflora*. However, weights were more difficult due to wet glumes. The weight of 1000 wet glumes was about 15 g. Fill was 10 percent and germination was considered as 55 percent, resulting in 55 viable seeds per 1000 glumes

(15 g). Thus, 3000/55 = 54.54 × 15 g = 818.2 g.

34. Plot seeding was done 21-23 March 1977 along with fertilization with a mixture of phosphorus and potassium fertilizers. *Spartina alterniflora* seeds were mixed with dry sand and spread on one half of the designated plots in all tiers. *S. patens* seeds were mixed with wet sand to prevent blowing. In tier 1 (lowest elevation), only 15 m^2 was seeded to *S. patens* in each plot. However, in tiers 2 and 3, 30 m^2 was seeded. All seeding was done at low tide.

35. Fertilizer rates used were the established F_0 to F_4 treatments for sprigged plots. The fertilizer was mixed with damp sand and broadcast on plots. After seeding, the seed and fertilizer were incorporated into the soil by a disc pulled behind a small tractor. A rubber pipe pulled behind the disc pushed into the sand. Seeds were generally considered to have been incorporated into the substrate at a depth of 1 cm. Seeded plots in the marshland were fertilized with nitrogen on 26-28 April 1977. Nitrogen was broadcast at low tides and was not mechanically incorporated into the soil. Seeded F_3 and F_4 plots were refertilized on 26 July 1977 with a mixture of nitrogen, phosphorus, and potassium fertilizer.

36. Three 0.1-m^2 quadrats were established in each third of the seeded plots. Corners of quadrats were marked with short 10-gage wire stakes. Number of emerging seedlings was counted at approximately 2-week intervals. Tide levels dictated times when counts could be made. Initial counts were delayed a week because seedlings were just emerging from the soil and were difficult to count. The first count was made on 13-15 April 1977. On 27 April a second count was made. A third count was made on 31 May 1977. On 27 June 1977 a total evaluation of number of stems per m^2, plant height, miscellaneous environmental effects, vegetative reproduction, and phenology was conducted. A final evaluation was conducted along with the other marshland plots on 2 September 1977. Destructive sampling was also performed on these plots along with sprigged plots.

37. Intertidal areas were developed on each side of the marshland experimental plots within the sandbag dike. Each of these areas consisted of two plots approximately 13 m wide orientated perpendicular

to the shoreline (Figure 3). One plot on each side was utilized for plant propagation, while the remaining plot on each side served as a control plot. Outside of the sandbag dike, two plots approximately 13 m wide orientated perpendicular to the shoreline were established on each side of the marshland plots. One plot on each side was used for plant propagation, while the remaining plot on each side served as a control.

38. A zone 9.14 m wide was established between the intertidal plots on each side of the marshland plots and the sandbag dike. The intertidal plots within the dike were about 13 by 101 m. The intertidal plots outside of the sandbag dike were about 13 by 108 m.

39. Planting of the intertidal plots to alternating rows of *Spartina alterniflora* and *S. patens* was begun 4 August 1976 and completed 5 August. The row and plant spacing in these plots was 1.0 m. The culms, regardless of species, were planted to a depth that corresponded to the ground line. Intertidal plots received no fertilizer.

40. Evaluations were made in sections within the four intertidal divisions (diked and undiked, east and west sides). Each section was established at successively lower elevations. Each section included 70 plants of *Spartina alterniflora* and 60 of *S. patens*. Fewer plants of *S. patens* occurred because one less row was planted than *S. alterniflora*. Similar parameters were measured in the intertidal plots at the marshland. During 1976 intertidal plots were evaluated on 22 August, 6 September, and 21 September. During 1977 intertidal plots were evaluated 27 June 1977.

41. Four nondestructive evaluations were made every other week on plants in each quadrat of the marshland experimental plots and three on all plants in the intertidal plots. In marshland plots, measurements were made on the 12 plants in each quadrat. In intertidal plots, measurements were made on all 70 *Spartina alterniflora* and 60 *S. patens* transplants per section.

42. A plant was considered surviving if any green could be observed. Percent survival was recorded by dividing the number of surviving plants by 12 (plants per quadrat) or 60 or 70 in intertidal plots, and multiplying by 100. Number of dead and absent plants was

also recorded. Plant height was recorded in cm on the tallest extended leaves of the three plants in the most western portion of each quadrat. An average of the three was taken and entered on the data sheet as height. In intertidal plots 10 measurements were randomly taken on each species and the average entered on the data sheets.

43. Density was recorded as the total number of stems at ground level in each quadrat or plot. Density was usually reported on a quadrat basis in the marshland. However, sometimes conversions were made to m^2 by dividing by 3. Stem numbers per plant were derived by dividing density by number of surviving plants per quadrat. Tillers per quadrat indicated the total number of new stems. Tillers per plant indicated the number of new stems that originated from the original planted stem.

44. A subjective sampling method was used to determine the number of stressed and stable plants. If an original transplant appeared brown-colored, badly withered, or small-stemmed, it was reported as stressed. The alternative to stressed was stable. The two numbers always added up to the number of surviving plants.

45. Plants with new tillers or new leaves were recorded as having new growth. Plants that had diseases were recorded. Animal plant damage to original transplants and their tillers was recorded. Missing leaves or parts of leaves or stems usually were indicative of animal damage. Animal tracks usually revealed the source of damage. Physical effects, such as wave action, erosion, wind, or sand burial damage to plants, were recorded.

46. Percent foliage cover was estimated based on preliminary baseline observations with a ten-point frame. Foliage cover was placed into 6 categories: < 1.0, 1.0-9.9, 10.0-24.9, 25.0-49.9, 50.0-74.9, and 75.0-100 percent cover of the ground by leaves, stems, and seed stalks.

47. The number of transplants with flowers or seed heads was recorded. The number of dormant plants or plants beginning new growth after winter dormancy was also recorded. The actual stage of growth of plant was recorded separately based on the number of plants in each stage recorded. The stages were: normal growth, flowering, seed

initiation, seed distribution, bud formation, dormant, and new spring growth. Number of invading species and the number of invading plants were recorded in each marshland quadrat.

48. Evaluation dates for the marshland were: 22 August 1976, 6 September 1976, and 4 October 1976. On 9 November 1976 all marshland plots were again nondestructively evaluated. The end-of-growing-season destructive sampling was initated in November 1976 and completed in December 1976. Initially 10 plants were removed from marshland experimental plots for total biomass determinations. These plants were selected at random with three plants taken from each third of a plot, except for one of these thirds from which four were taken. None of these plants were removed from the quadrats used for nondestructive sampling. It was obvious that the removal of 10 plants was detrimental to the stand. In conference with WES scientists, it was determined that three plants would be removed from each plot. A plant for removal was selected at random in each third of a plot. No plants were removed from the permanent quadrats.

49. It was also determined with WES scientists that no plants would be removed from plots with less than 20 percent survival. Most experimental plots sprigged to *Spartina alterniflora* exceeded 20 percent survival. However, *S. patens* did not survive in tiers 1 and 2 and only limited survival occurred in tier 3.

50. Four more evaluations of the marshland sprigged plots were conducted during 1977. A winter evaluation was conducted 24 February and a spring evaluation on 2 May 1977. This evaluation was not completed because of high tides over an extended period. On 27 June 1977 a summer evaluation was performed. A final nondestructive evaluation was made 11-14 October 1977.

51. Seed heads of *Spartina patens* were collected from 1-10 August 1977 from marshland plots. Spikelets of seeds were separated from the rachis and the spikelets weighed.

52. Destructive sampling was initated on 12 October 1977. Plant biomass was measured in a soil core taken by a circular frame 35.6 cm in diameter and 25 cm deep (0.1-m^2 surface area). The cylinder was driven into the ground around randomly selected plants, and the soil

and plant were removed with the cylinder. The roots were washed free of soil. Root and shoot biomass were determined after drying at 83°C for 30 hours to a constant weight. Root:shoot ratios were determined.

53. *Spartina patens* transplants in tier 1 at the 4-9 November 1976 evaluation showed no signs of growth. Based upon physical examination of excavated plants, it was determined that the transplants were dead. In addition, few *S. patens* transplants were alive in tier 2. Survival exceeded 20 percent in only two plots. One plot had 25 percent survival and the other 22 percent.

54. Survival of *Spartina patens* in tier 3 was good in only the 3 rows of plots at the highest elevations. It was not consistently above 20 percent in these three rows in all three blocks. In this tier the initial die back of aboveground parts (stems and leaves) was followed by new leaf growth. This was an indication that *S. patens* was planted too late in the life cycle and that atmospheric temperature was probably too high for survival.

55. Based upon the above data and observations, dead transplants in one half (east side) of *Spartina patens* plots in tiers 1 and 2 were removed, and new *S. alterniflora* plots were established in 1977. Many plots of *S. patens* were not destroyed since they were not needed in the new experimental plots. The remaining half of each *S. patens* plot was left for future observations. Existing *S. alterniflora* sprigged plots were not altered.

56. Five plots were established in each row within each block of the original plots (Figure 4). The new design consisted of five fertilizer treatments. Fertilizer rates corresponded to the rate previously utilized on that plot.

57. Each new plot occupied one fourth of the original plot (divided on a north-south line) (Figure 5). However, some new plots were located between plots and blocks utilizing the 3-m buffer. Since new plots were 6 by 2.5 m, they fit between plots in the buffer zones.

58. The 1977 planting of new plots (one fourth size of original plots) utilized sprigs of *Spartina alterniflora* in tiers 1 and 2. Plantings were accomplished on 1-4 February 1977 for a winter planting

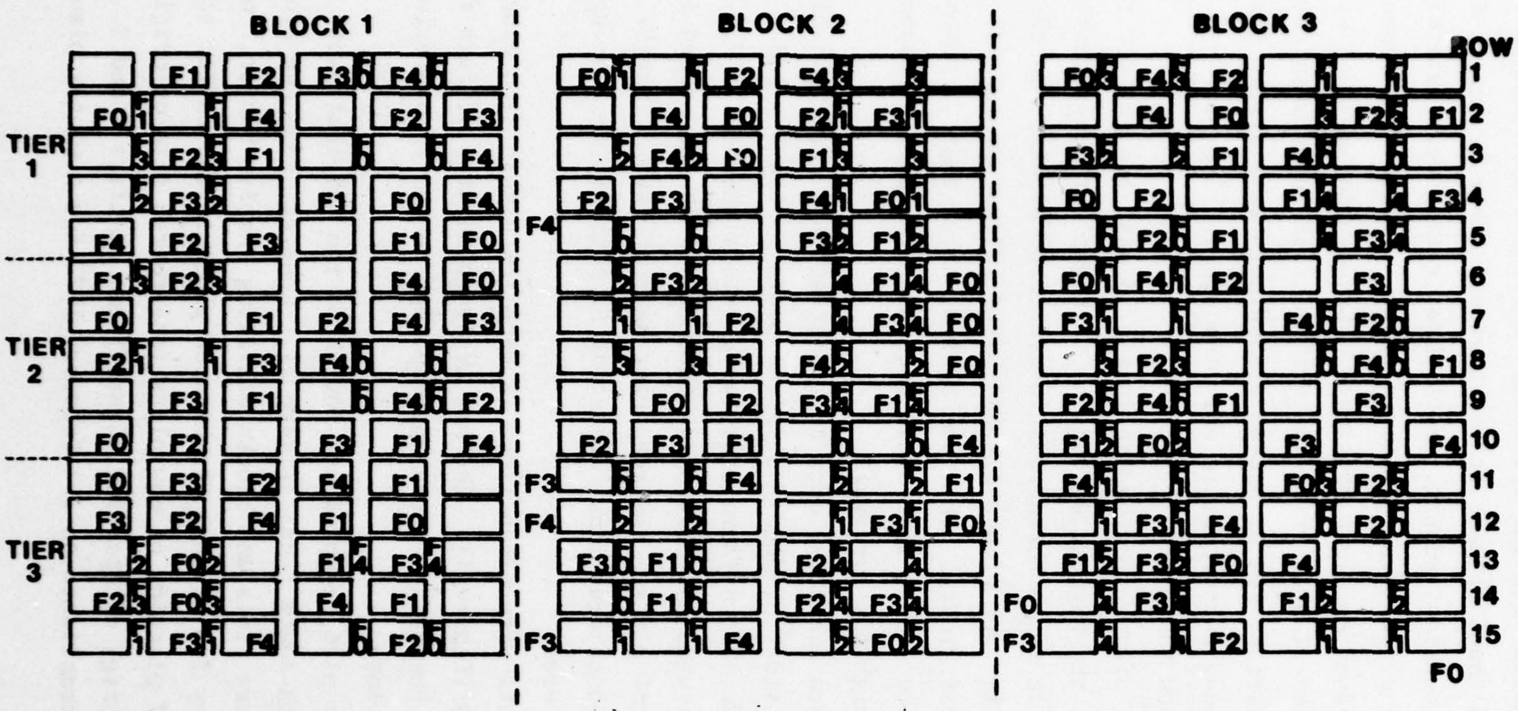

Figure 4. Design for plots and areas planted to *Spartina alterniflora* and *Spartina patens* in 1977. The F subscripts denote fertilizer treatments. Tiers 1 and 2 were planted to *Spartina alterniflora* in winter and spring 1977. Tier 3 was planted to *Spartina alterniflora* and *Spartina patens* in winter 1977

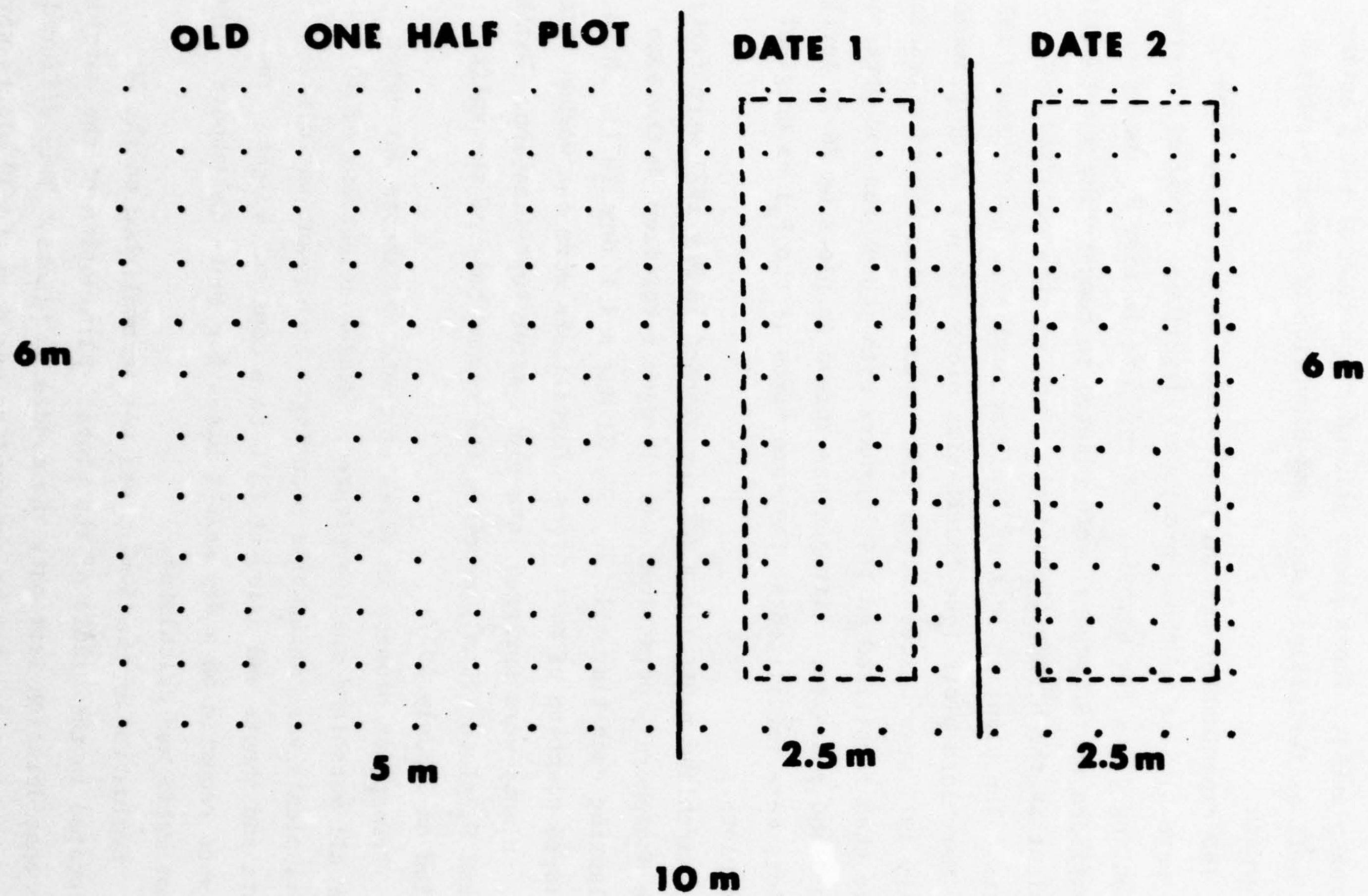

Figure 5. Design of plots and subplots and sampling scheme for plots planted in winter (date 1) and spring 1977 (date 2)

and 11-12, 30-31 May 1977 for a spring planting. With 2 dates, 10 rows, 3 replications, and 5 fertilizer rates, there was a total of 300 plots (18,000 transplants). These plots allowed comparison of two planting dates, as well as fertilizer rates, and elevation of plant establishment and growth.

59. The experimental design, plot size, and evaluation methods in tier 3 were similar to those previously described. However, instead of two planting dates for *Spartina alterniflora* in tier 3, two species (*S. alterniflora* and *S. patens*) were planted to compare the adaptability of each plant at the higher elevations. Each species required 4500 transplants. The planting in tier 3 was accomplished 1-4 February 1977.

60. Marshland plots (one-fourth-size plots, 15 m^2) to be planted in February 1977 were disced with a disc harrow pulled behind a tractor. Plots were then fertilized on 1-4 February with phosphorus and potassium fertilizers and redisced. Nitrogen was spread on plots on 26-28 April 1977. Plots were fertilized at the same rates (F_0 to F_4) as original marshland plots.

61. Marshland plots (15 m^2) to be planted in May 1977 were fertilized with phosphorus, potassium, and nitrogen fertilizer on the same day of planting each tier (11, 12, 30, 31 May and 1 June 1977). High tides delayed planting of most tiers. Fertilizers were not worked into the soil. Plants were sprigged into plots after fertilization. Marshland F_3 and F_4 plots (15 m^2) received the second half of the split application on 26 July 1977.

62. Transplant biomass in terms of roots and shoots was determined for all marshland species planted. Random selections of 40 individual plants were made while planting. Each plant was divided into roots and shoots and dried at 83°C to a constant weight. The results were reported on a dry weight basis for roots and shoots. The root:shoot ratio was calculated.

63. Evaluation of the 15-m^2 plots was accomplished on the 30 plants located in the middle of the plots. Elimination of the outside rows for consideration left only the middle 30 plants. This differed from original plots in that no subsampling was done and 30 plants were utilized per plot versus 36 in original plots. Evaluations included

the same parameters measured on whole marshland sprigged plots.

64. The February planting was evaluated 2 months after planting on 27-28 April 1977. The May planting also was evaluated 2 months after planting on 21-22 July 1977. All one-fourth size plots were evaluated 11-15 November 1977.

65. Eighteen cages, 2 by 2 m, were constructed in August 1976 to determine if depredation by birds and mammals occurred. The locations are shown in Figure 3. Cages were 2 by 2 m. They were constructed of metal pipes driven at each corner which supported 2-in.-mesh chicken wire 48 in. high. The tops were also covered with chicken wire.

66. Adjacent uncaged plots (2 by 2 m) were staked at corners. Six caged and uncaged plots in the intertidal area contained 2 transplants each of *Spartina alterniflora* and *S. patens*. All other cages were placed outside established plots. Comparisons of vegetation parameters, which were the same as measured on marshland and upland plots, were made between caged and uncaged plots.

Upland propagation

67. The upland was divided into three elevational tiers and each tier was further divided into four elevational rows of plots (4 by 15 m) (Figure 3). Three rows of plots in each tier were utilized for plant propagation, while the fourth row was not planted and was considered as a control. The upper tier (highest elevation) was utilized for planting trees. The four rows of plots in the middle tier were planted to shrubs. The lower tier (lowest elevation) of the upland was planted to three grass species. Each row of plots was divided into three replications of three plots each. The three plots in each replication were utilized for two fertilizer treatments and a control (Table 4). A total of 108 experimental plots were established on the upland.

68. The four corners of all experimental plots were staked with 5- by 5-cm wooden stakes, 152 cm in length. Staking was initiated on 10 June 1976 and completed in about 2 weeks. Originally 60 cm of each

stake were to be left exposed. However, due to the hard substrate and difficulty in driving stakes, 75 cm were left exposed. Boundaries of the intertidal plots were marked in the same manner.

69. Prior to preparation of the experimental plots for fertilization, the dense stand of *Sesbania drummondii* on the west portion of the upland plots was removed by hand. This removal was necessary to reduce competition for nutrients, soil moisture, and light with the species to be planted.

70. Planting of the upland plots was initiated on 29 June 1976 and completed on 8 July 1976. Although most material was from local sources, it was necessary to secure some from nurseries in Louisiana and Georgia. All local material was dug manually to insure healthy plants with as many roots as possible (Table 5).

71. During 1976 the grass species planted in the lower tier were *Panicum amarum* (bitter panicum) (Gould 1975) in the lowest elevational row, *Cynodon dactylon* (bermuda grass-alecia variety) in the middle row, and *Andropogon perangustatus* (bluestem) in the higher row (Table 4). Gould (1975) taxonomically combined *Panicum amarum* and *P. amarulum*, which were originally recognized as two separate species, into *P. amarum*. The growth form or variety utilized in this study was *P. amarum* (Hitchcock 1971). The growth form was rhizomatous with single stems.

72. The plots planted to grasses (lower elevation tier) contained 8 rows with 30 plants per row and a 0.5-m spacing. A total of 2160 grass plants were utilized for each species. For *Panicum amarum* and *Andropogon perangustatus*, single culms which included culm base and roots were planted. Depth of planting corresponded to the ground line on the plant. Clumps of plants were dug and separated into single culms of *Panicum* and 5-8 stems of *Andropogon*. Plants were then wrapped in burlap bags and transported to the site. A shovel was used to dig clumps of *Cynodon* sod with roots attached. The sod was loaded onto a truck for transportation to the boat launch on Bolivar Peninsula. Sod was transported to the site in a boat and then separated into small sprigs. Sod was kept overnight underneath a tarpaulin before planting. Spring planting depth was approximately 7.5 cm.

73. Grass plants were in various stages of development at the time of collection. *Cynodon dactylon* sprigs were healthy. However, *Andropogon perangustatus* culms were in the early flowering stage and no new tillers were evident. *Panicum amarum* culms were in the active growth stage.

74. Upland tiers containing shrubs and trees were planted at the rate of 2 rows per plot with 8 plants per row. A spacing of 2 m was used and a total of 144 shrubs and trees were planted for each species. All shrubs and trees were planted at a depth corresponding to the ground line evident on the specimens. The four rows of plots in the middle tier were utilized (in order of decreasing elevations) for control, *Rhus copallina* (winged sumac), *Prunus* sp. (plum), and *Croton punctatus* (gulf croton) (Table 4). Two size classes of *Prunus* sp. were planted. The tall plants (mean height 35 cm) appeared to have more roots than the recently mowed shorter plants (mean height 18 cm). Collected plants of *Rhus copallina* were in good condition with large crowns and many roots. The *Croton punctatus* plants were all in good condition with extensive root systems. All plants were dug with a shovel, loaded directly onto a vehicle, and transported to the site. *Rhus copallina* and *Prunus* were covered with soil and a tarp and transported the same day. These two species were "heeled in" for one day prior to plantings. *Croton* was planted immediately after digging.

75. The upper tier (highest) elevation was utilized for plantings of *Pinus elliottii* (slash pine), *Pinus clausa* (sand pine), control, and *Tamarix gallica* (salt cedar) in order of decreasing elevation (Table 4). *Pinus elliottii* were obtained in January from Louisiana and were planted in 3.79-ℓ containers. However, all plants died prior to the June planting. *Tamarix gallica* cuttings were utilized for planting. *Pinus clausa* had been in cold storage for over 90 days prior to planting. Thus, these plants were considered to be in poor condition (fungus, dead terminal buds) for planting and survival.

76. Transplant biomass in terms of roots and shoots was determined on 20 plants for each upland species planted. Random selections of plants were made while planting. Wet and dry weights

were determined for each species. While planting both the upland and marshland plots, a reduced soil layer was evident in most plots. Depth to this layer and depth to planting for each species were measured in each plot to facilitate correlation of this soil layer with plant survival. This layer was present at the soil surface of all plots in the lowest elevational tier. It was present in most plots in the western half of the upland.

77. Fertilizers (purchased and weighed by Soils Personnel) utilized on the upland were: ammonium sulfate, $(NH_4)_2SO_4$, (21-0-0); triple superphosphate, P_2O_5 (0-46-0); and potassium sulfate, K_2So_4, (0-0-50). Fertilizer mixtures for each upland monotypic plot were weighed to the specified rate of fertilizer. For each plot the three fertilizers were weighed separately on a Mettler balance, mixed into a homogenous sample (except nitrogen was applied separately in 1977), and sealed in a heavy-walled polyethylene bag to prevent caking prior to application. The samples were again mixed at the site just prior to application.

78. During the 1976 plantings, the experimental plots were prepared for fertilization by harrowing with a spring-toothed harrow in an east-west direction. The fertilizer was broadcast applied and the plots were harrowed in a north-south direction to mix the fertilizer with the soil.

79. Initial fertilization rates for the upland were: F_0 - no fertilizer; F_1 - low rate, 25 kg N/ha, 50 kg P_2O_5/ha, and 40 kg K_2O/ha; and F_2 - high rate, 25 kg N/ha, 100 kg P_2O_5/ha, and 80 kg K_2O/ha (Table 4). After the plants established, a second application was applied. The rates were: F_1 - low rate, 100 kg N/ha; and F_2 - high rate, 200 kg N/ha. The initial fertilizer application was made on the upland plots on 30 June 1976. The second application was on 27 September 1976.

80. Poor survival of many species in 1976 resulted in the replanting of many upland plots. Three species of trees, *Quercus virginiana* (live oak) transplants, *Pinus clausa* (sand pine) transplants, and *Tamarix gallica* (salt cedar), were planted in the upland area in 1977. Sand pine and salt cedar were replanted in the same plots as 1976 (Table 4).

Live oak was planted as a substitute for *Pinus elliottii* (slash pine). Sand pine was planted on 19 January 1977 and salt cedar on 24 January. Cuttings of the latter were inserted into the ground to a depth of approximately 15 cm.

81. Live oak was purchased and delivered in 3.79-ℓ containers. Soil and roots were removed intact from the containers and planted so that soil just covered the root and soil mass. Planting was accomplished on 9 February 1977. The lower limbs were pruned after planting.

82. In the shrub category, *Rhus copallina* (sumac) was replanted except for a few surviving plants. *Myrica cerifera* (wax-myrtle) was substituted for *Prunus* sp. It was dug locally from a frequently flooded pasture. Plants were loaded directly onto a truck, covered with a canvas, transported to the site, and planted the same day. Dead plants of *Croton punctatus* were replaced with seedling plants of that species. Seedlings were dug and planted immediately. The 3 plots of *Croton* in replication 1 were completely replanted. *Andropogon perangustatus* was completely replanted (2160 plants) on 21 January 1977. The other grass species had established and replanting was not necessary.

83. Upland plots that were completely replanted in 1977 were harrowed with a spring-toothed harrow on 18 January. They were then fertilized on 19 January with a mixture of phosphorus and potassium fertilizers and reharrowed. Phosphorus as P_2O_5 was applied at the rate of 25 kg/ha and 50 kg/ha at the low and high rates, respectively. Potassium as K_2O was applied at 20 and 40 kg/ha, respectively. Control plots received no fertilizer. Nitrogen was applied 15 April 1977 as $(NH_4)_2SO_4$ at 50 and 100 kg/ha, respectively. Replanted plots received a second application of the above fertilizer rates on 27-28 July 1977. Fertilizer was broadcast on the surface and was not incorporated into the soil.

84. A top dressing of $(NH_4)_2SO_4$ was applied to 1/2 of the bermuda and bitter panicum plots. Fertilization was accomplished 15 April 1977 by broadcasting the nitrogen on the surface of the plots.

85. Vegetation that volunteered into shrub and tree plots was mowed by lawnmower. Some vegetation also was chopped by hoe around

shrubs and trees. This was done to decrease competition from invading herbaceous plants.

86. Nondestructive evaluations were taken in upland grass plots by quadrats. Quadrats were 1 by 3 m randomly located in each third of a plot. Measurements included: survival, plant height on three randomly selected plants in each quadrat (same plants measured each evaluation), miscellaneous environmental effects, vegetative reproduction, phenology, animal damage, percent foliage cover, and number of invading species and plants per quadrat. Evaluations taken on shrubs and trees included all plants in each plot.

87. Nondestructive evaluations of upland plots were taken 2 September and 9 November 1976. Destructive sampling was done in transplanted grass plots but not in shrubs and trees. With only 16 original trees per plot, few were available to sample, and the remaining trees were left for tests of growth rates. Only certain plots of *Andropogon Andropogon perangustatus* were sampled because of less than 20 percent survival in other plots.

88. Destructive sampling consisted of randomly selecting three transplants, placing a 35.6-cm-diam by 25-cm-deep cylinder over the plant center, and driving it into the ground. The cylinder with its plant material and soil core was dug out of the ground. Roots were washed free of soil with a stream of water from a 12-V water pump on the site. Water was pumped from 50-gal drums on a trailer. The washed plant was placed in the plastic bag, sealed, and carried to the lab. Roots were separated from shoots. Roots and shoots were then dried at 83°C for 30 hours and weighed. Root:shoot ratios were determined.

89. Upland plots were nondestructively evaluated on 21-22 June and 22 September-5 October 1977. Destructive sampling was initiated on 22 September and completed 6 October 1977 in grasses, shrubs, and trees.

Results

Initial transplant biomass

90. During the 1976 planting, total biomass and root:shoot ratios

varied between species (Tables 6 and 7). The range for total biomass, based on dry weight, ranged from a low of 0.9 g for *Croton punctatus* to a high of 32.0 g for *Rhus copallina*. When wet weight was considered, the low, 2.0 g, was from *Andropogon perangustatus*, and *Tamarix gallica* had the high, 65.0 g.

91. In general, the wet and dry root:shoot ratios were similar for a species (Tables 6 and 7). Exceptions were *Prunus* sp. (short), *Cynodon dactylon*, and *Spartina alterniflora* (high). Root:shoot ratios, based on dry weight, ranged from 0.14 for *Croton punctatus* to 1.40 for *Prunus* sp. (short). Other species near or above 1.0 included *Rhus copallina* (0.95), *Cynodon dactylon* (1.36), and *S. alterniflora* (high) (1.29). Because of an oversight transplant biomass data were not collected for *S. patens*.

92. Transplant root and shoot weights as well as height were determined for species planted in the upland during winter 1977 (Table 7). The same data were collected for both winter and spring marshland plantings (Table 6). The root:shoot ratio in *Rhus copallina* was much higher than those collected in 1976 (Table 7). The wet root:shoot ratio was 4.25, but the dry root:shoot ratio was about half of that. *Pinus clausa* and *Andropogon perangustatus* both had low root biomass compared to shoot biomass. In the marshland the root:shoot ratio increased two fold from the February to the June plantings.

Seed germination

93. Storage conditions appeared to have little influence on the germination of *Spartina patens* (Table 8) in the initial test. About 2 weeks after storage, data indicated a higher germination rate for cold storage than for ambient. However, as time of storage increased, no consistent difference in germination among treatments was obvious.

94. As time of storage, regardless of conditions, for *Spartina patens* increased, the percent germination decreased (Table 8). However, in mid-March about 5 months after storage, a sharp decline was noted. This decline was followed by an increase in percent germination in the tests conducted in late March. However, a uniform decline occurred from early April until the tests were terminated in mid-May. Under cold storage conditions the overall germination range was from a high

of 82 percent in test 1 to a low of 32.5 percent (cold storage) in the last test. Under ambient temperature storage, the range was from a high of about 80 percent in test 4 to a low of 36 percent in the last test. Although each test was conducted for 40 days, germination was completed in 30 days.

95. Germination tests for *Spartina alterniflora* were initiated about 1 month following storage (Table 8). During the period from initial tests (mid-December) to late February, the percent germination varied from about 60 to 70 percent. However, with the test initiated on 12 March (approximately 3 months after storage), germination declined to less than 20 percent and did not exceed 27 percent during the remaining tests. The lowest germination, 9.5 percent, occurred in the last test (initiated 23 April) from seeds collected at the south jetty.

96. In the tests on *Spartina patens* planted in dredged material, only 1 seedling emerged in the shallow planted container. In contrast, 13 emerged from the 2.5-cm planting depth. A total of 4 emerged from the 5-cm depth.

Marshland

97. At evaluation 1, mean survival for *Spartina alterniflora* sprigs, regardless of tier, was similar (about 60 percent) for most treatments (Table 9). An exception was the low survival (49.1 percent) for high rate fertilizer. In contrast, *S. patens* survival was lower in all treatments. The range of survival was from a low of 30.6 percent to a maximum of 44.1 percent.

98. *Spartina alterniflora* height was not significantly different among treatments, ranging from a low of 47.2 cm (F_0) to a high of over 54 cm (F_1) (Table 9). Significant differences were evident for *S. patens*. The range was from 45.3 cm (F_1) to over 66 cm (F_4). New growth from plants in the permanent quadrats was low, but similar for *S. alterniflora*, regardless of treatment. New growth by *S. patens* was generally lower than for *S. alterniflora* with the lowest number, 0.5 plants per quadrat, in treatment F_4.

99. There were no significant differences in plant density within species regardless of treatments (Table 9). However, stems per surviving plant ranged from over 1 in most treatments to over 6 (F_0) for *Spartina alterniflora*. In general, stems per surviving plant for *S. patens* was about 1. Animal damage was generally low.

100. Survival of *Spartina alterniflora* was higher than for *S. patens* at evaluation 2 (Table 10). The range for *S. alterniflora* was from 40 percent to over 63 percent. In contrast, the range for *S. patens* was about 12 to over 24 percent. Heights were generally similar, regardless of species or treatment.

101. *Spartina alterniflora* transplants had more new growth than *S. patens* (Table 10), ranging from 3.9 to 6.6 plants per quadrat. The range for *S. patens* was 0.6 to 3.6. Plant density and stems per surviving plant were similar within species, regardless of treatment. However, they were higher for *S. alterniflora* than for *S. patens*. Animal damage and foliage cover were low, regardless of species or treatment.

102. Survival showed a wide range at evaluation 3 (Table 11). The range for *Spartina alterniflora* was from about 41 to over 60 percent. In contrast, it ranged from about 9 to about 20 percent for *S. patens*. Plant heights varied only slightly among species and treatments.

103. There was a significant difference in *Spartina alterniflora* plants with new growth (Table 11). The range was from 4.6 (F_2) to 7.0 plants per quadrat. The number of plants with new growth per quadrat was less for *S. patens* (range 0.4 to 3.6) than for *S. alterniflora*. In general, the same relationship existed for plants with new tillers. *S. alterniflora* (range 5.1 to 6.5) had more plants with tillers than *S. patens* (range 0.0 to 4.4). This relationship was also observed for number of tillers per quadrat and number of tillers per plant that initiated new tillers.

104. Animal damage was generally low (Table 11). However, treatment F_2 had suffered greater damage than any other treatment, regardless of species or treatment. Foliage cover was low.

105. Survival for *Spartina alterniflora* was much higher at evalua-

tion 4 than for *S. patens* (Table 12). Survival was less than 15 percent for all *S. patens* treatments. In contrast, it exceeded 37 percent for all *S. alterniflora* treatments. Plants with new growth were similar for *S. alterniflora*, except for treatment F_2, and all treatments exceeded that for *S. patens*.

106. Density for *Spartina alterniflora* ranged from 6.6 to 9.0 (Table 12). This was considerably higher than for *S. patens* (1.3 to 4.7). Plants with tillers and number of tillers per quadrat were higher for *S. alterniflora* than *S. patens*. Tillers per plant ranged from 2.5 to 3.4 for *S. alterniflora* and from 1.0 to 3.7 for *S. patens*.

107. Stems per surviving plant were generally similar, regardless of treatment or species (Table 12). Exceptions were for fewer stems on *Spartina patens* treatments F_2 and F_4. Animal damage was generally low, except for *S. patens* treatments F_2 and F_3 and *S. alterniflora* treatment F_4. Foliage cover was still low.

108. <u>End of growing season evaluation</u>. The end-of-season evaluation (5) showed that survival for *Spartina alterniflora* exceeded that for *S. patens* (Table 13). The range for the former was from 37.3 to 56.2 percent, and for the latter it was 3.4 to 14.2 percent. Plant heights were significantly different between species. The range for *S. alterniflora* was from 51.9 to 65.3 cm. In contrast, the range for *S. patens* was 35.4 to 51.9 cm. Plants with new growth were similar within a species, but differences existed between species. More new growth occurred in *S. alterniflora* than *S. patens*.

109. Plant density ranged from 11.7 to 16.0 stems per m^2 for *Spartina alterniflora* (Table 13). A wider range (1.4 to 23.9) was measured for *S. patens*. Plants with tillers differed significantly among treatments for both *S. alterniflora* and *S. patens*. However, the former had more tillers than the latter. In general, the number of tillers per quadrat was similar among species and treatments. Exceptions were the large number in treatment F_1 and the low number in treatment F_4.

110. Stems per surviving plant ranged from 4.8 to 7.3 for

Spartina alterniflora and from 2.0 to 9.6 for *S. patens* (Table 13). In general, the number of plants with animal damage was relatively low, regardless of species or treatment. Foliage cover did not exceed 1 percent on any treatment.

111. Belowground biomass for *Spartina alterniflora* ranged from 3.9 g (treatment F_0) to 5.5 g per 0.1 m^2 (treatment F_1) (Table 13). The range for *S. patens* was 3.2 g (treatment F_2) to 6.3 g per 0.1 m^2 (treatment F_0). Because of low survival, destructive samples were not collected for *S. patens* from treatment F_4. Aboveground biomass exceeded belowground biomass, regardless of species or treatment. The root:shoot ratio was similar for species and treatments, ranging from 0.4 to 0.7. Only limited seed production occurred in these recently sprigged plots. Invading plants were rare in all treatments, except for *S. patens* treatments F_2 and F_3.

112. Percent survival for each species declined at each evaluation during 1976, regardless of fertilizer treatment (Table 14; Figures 6 and 7). Percent survival was much higher in *Spartina alterniflora* than *S. patens* at all evaluations (Figure 8). Data for evaluations 3 and 4 occupied positions between 2 and 5. The inclusion of all plots in calculations, regardless of elevation tier, lowered the overall mean survival for *S. patens*. Survival for *S. patens* was low in tier 1 at evaluation 4 (Table 14, Figure 9). By evaluation 5 only a few *S. patens* plants were still alive in tier 1. *S. patens* also exhibited low survival in tier 2 by evaluation 5, but averaged about 22 percent survival in tier 3. An exception was the F_4 treatment. Survival was almost zero.

113. At evaluation 5 (8-9 November 1976) *Spartina alterniflora* survival was best in elevation tiers 1 and 2 (Figure 10). Survival was generally 50 to 60 percent in tier 1 and 60 to 80 percent in tier 2, except at fertilizer treatment F_4. Survival was below 40 percent in this treatment. Survival was also below 40 percent in elevation tier 3. Response of the two species to fertilizer rates was different. Best survival for both species was in treatment F_3 (Figure 10). *S. alterniflora* survival at rate F_0 was higher than for the remaining

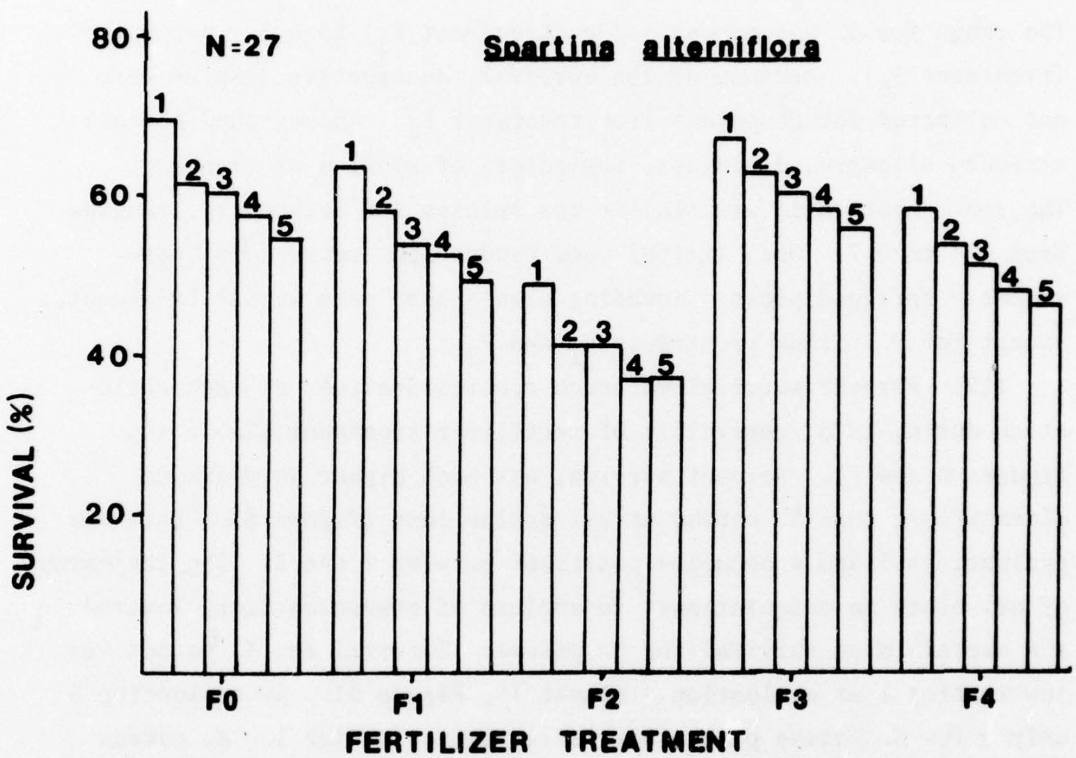

Figure 6. Mean survival (percent) for *Spartina alterniflora* by fertilizer treatment, showing evaluations 1 through 5 as indicated by numbers on bars

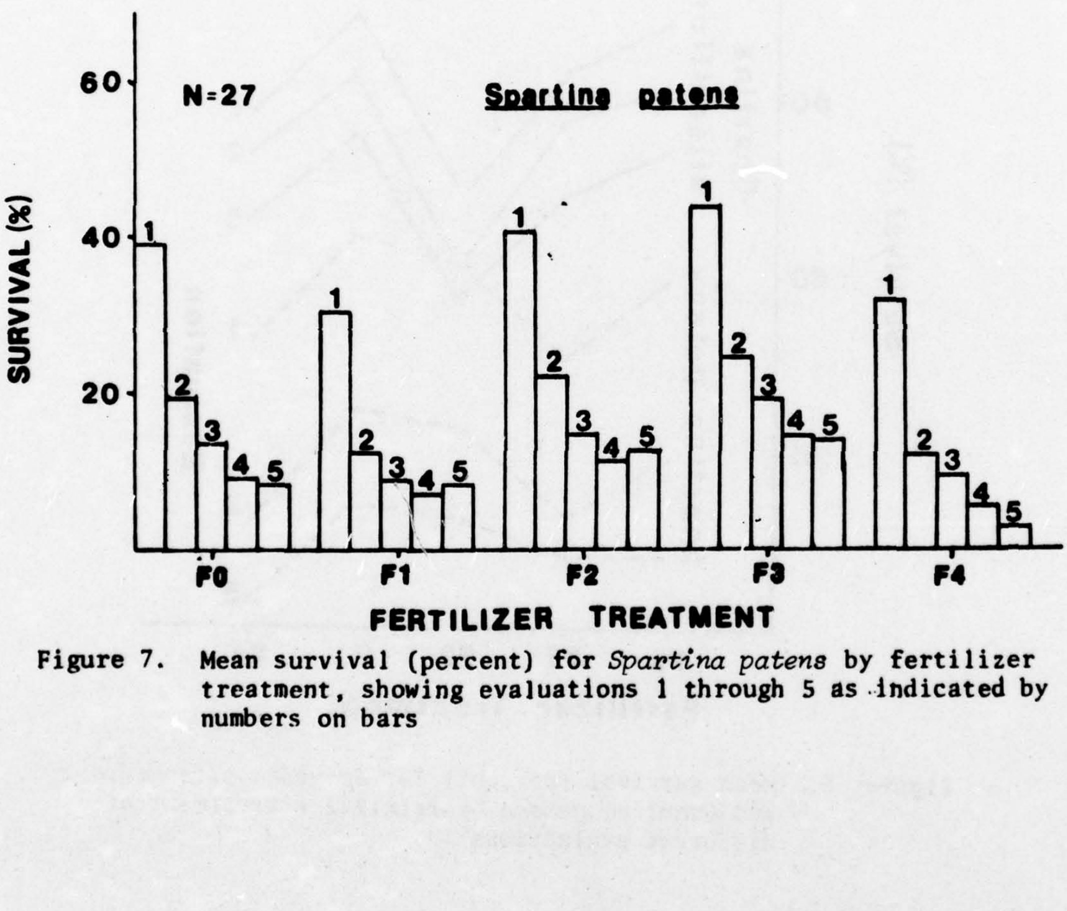

Figure 7. Mean survival (percent) for *Spartina patens* by fertilizer treatment, showing evaluations 1 through 5 as indicated by numbers on bars

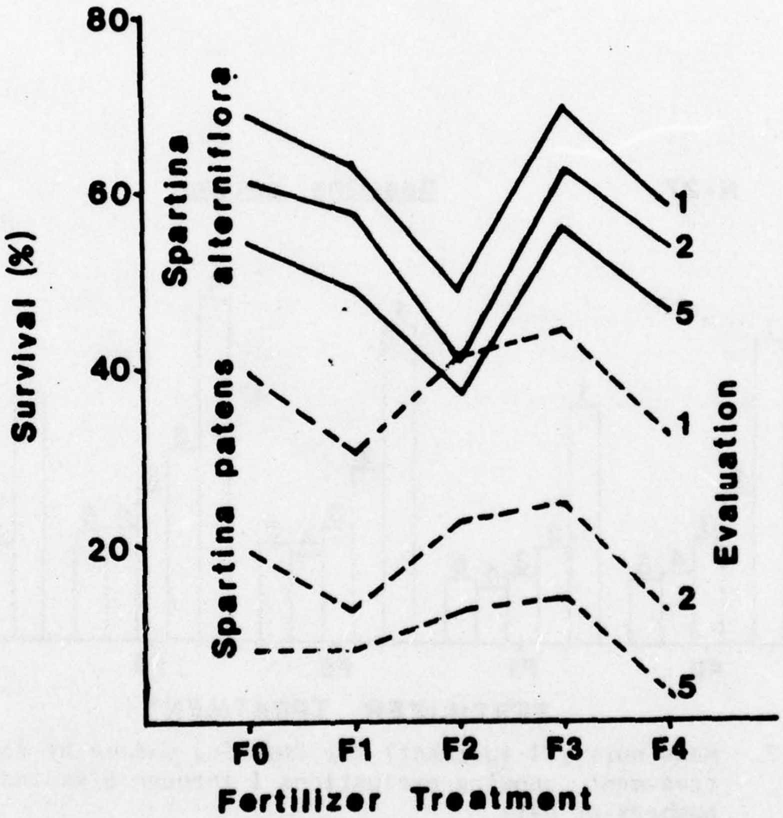

Figure 8. Mean survival (percent) for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment at different evaluations

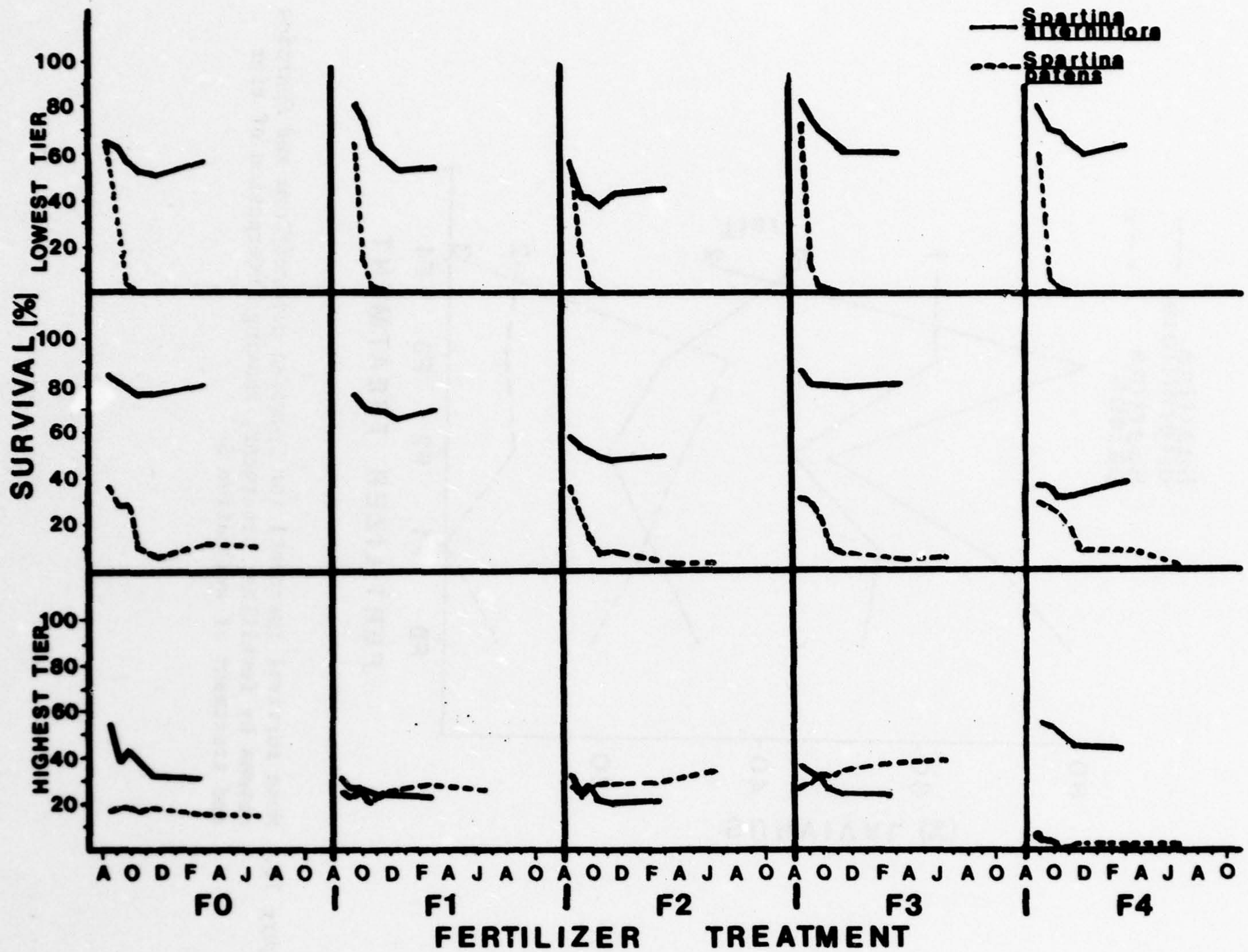

Figure 9. Mean survival (percent) for *Spartina alterniflora* and *Spartina patens* by tier and fertilizer rates at each evaluation

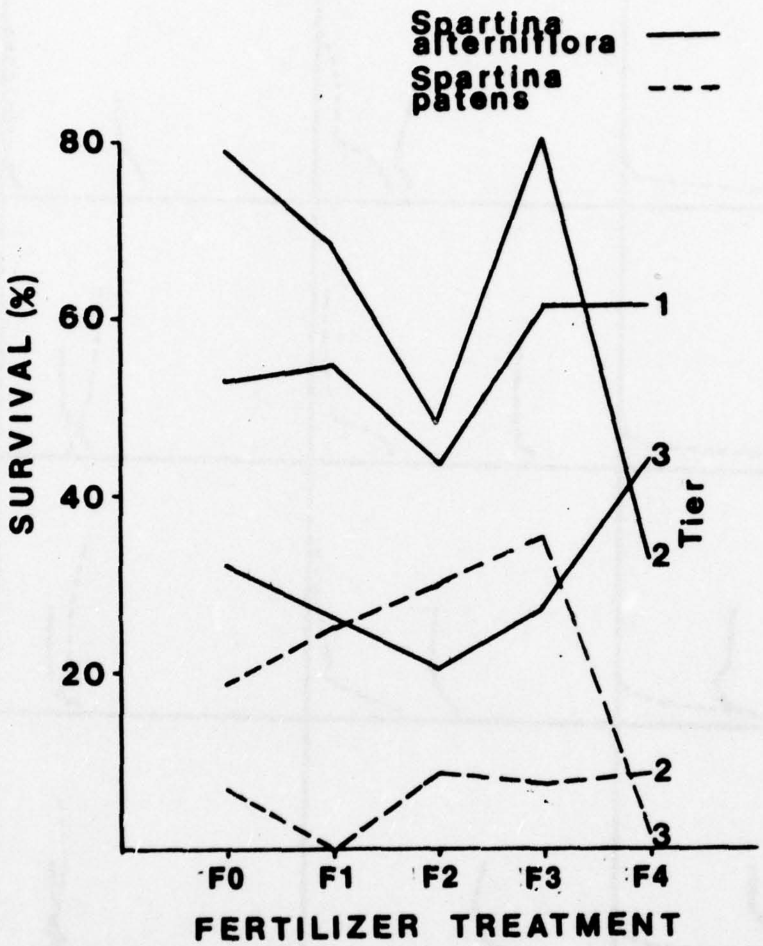

Figure 10. Mean survival (percent) for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment, showing interaction of tier and treatment at evaluation 5

fertilizer treatments. The lowest survival for all *S. alterniflora* plots occurred at rate F_2. In contrast, *S. patens* survival was higher at the F_2 rate than the F_1 rate. Survival for both species was lower at the F_4 rate than at F_3 (Figure 8).

114. *Spartina alterniflora* survival was better when the total fertilizer applied was by split applications rather than a single application (Figures 6 and 8). In *S. alterniflora*, mean separation tests (Student-Newman-Keuls' multiple-range test) indicated that the F_3 rate had significantly better survival than F_2. With *S. patens* better survival occurred at the F_3 rate than with F_1 (Figure 7). The lowest survival of all *S. patens* plots occurred at the F_4 rate. Survival in F_1 and F_4 was similar initially. Before the second fertilizer application was made prior to the fourth evaluation, F_1 and F_4 plots were receiving the same fertilizer rates.

115. Response of each species to fertilizer varied by elevation tier. At the F_4 rate, survival of *Spartina alterniflora* was low in tier 2 and high in tier 3 at evaluation 5 (Figure 10). Survival by tiers was similar in response at F_1, F_2, and F_3 rates. Survival at the F_0 rate was lower in tier 3 than in the other 2 tiers, indicating tier and treatment interaction (Figure 10). In *S. patens*, at evaluation 5, there was no survival in tier 1. In tiers 2 and 3 there was a sharp difference in survival at rate F_4.

116. Significant differences in height existed among treatments during the first two evaluations ($P < 0.05$) (Tables 9 and 10; Figure 11). At evaluation 4 the differences in height were significant at $P < 0.20$ (Table 12). Data from evaluation 5 showed that differences were significant ($P < 0.01$) (Table 13). *Spartina alterniflora* was consistently taller than *S. patens*. Nonfertilized plots of *S. alterniflora* were shorter than fertilized plots. Treatments F_1, F_2, and F_3 of *S. alterniflora* were slightly taller than F_4 and F_0. *S. patens* did not establish a similar trend. Slight differences did exist due to fertilizer treatment. Rates F_0 and F_4 were

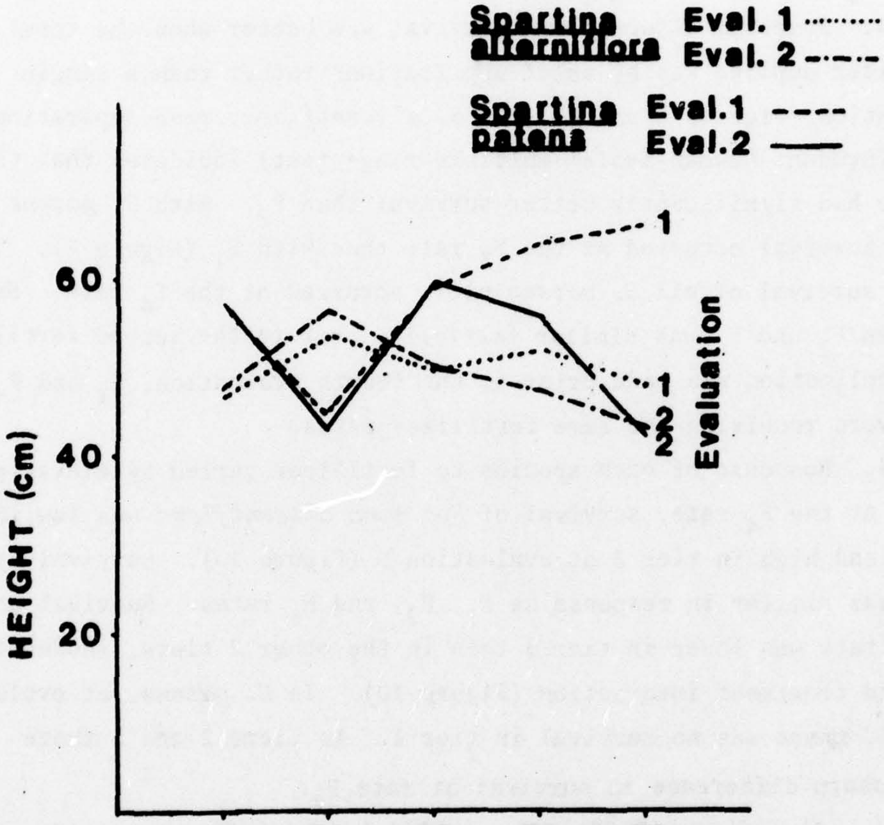

Figure 11. Mean heights for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment, at evaluations 1 and 2

slightly taller than F_1, F_2, and F_3.

117. Significant interactions between tiers and treatments occurred at evaluations 1 and 5 (Figures 12 and 13). The interaction at evaluation 1 was primarily due to death and slow growth of plants in elevation tier 2. Primary differences at the two evaluations occurred as a result of death of some *Spartina patens* plants in tiers 1 and 2 at the latter evaluation (Table 15). At evaluation 5 the shortest plants of *S. alterniflora* occurred in tier 3 and the tallest in tier 1.

118. New leaf and tiller growth of *Spartina patens* was slower than for *S. alterniflora* (Figure 14). New growth appeared after the initial evaluation for *S. alterniflora*. However, growth of *S. patens* generally did not occur until late September. Significant differences existed among treatments until 5 October (Tables 6-11). However, part of the difference was due to the greater percent survival of *S. alterniflora*. When the percent new growth of surviving plants was analyzed, differences among treatments were only significant at $P < 0.10$ for evaluation 2 (Table 10). At evaluation 3 differences were highly significant ($P < 0.001$) among treatments (Table 11).

119. Differences in new growth appeared to be related to fertilizer treatments (Figure 15). At the high single application (F_2), the percentage of plants with new growth was lower than for other treatments in *Spartina alterniflora*. The lower rates of application (F_1 and F_3) appeared to enhance growth in *S. patens* (Figure 15). The high split rate (F_4) appeared to greatly reduce new growth of *S. patens* at evaluations 1 and 2. However, since the second application had not been applied, the applied rate was equivalent to the low single application (F_1).

120. *Spartina alterniflora* and *S. patens* responded differently in terms of new growth to fertilizer treatments in each tier (Figure 16). A significant interaction between tiers and treatments for

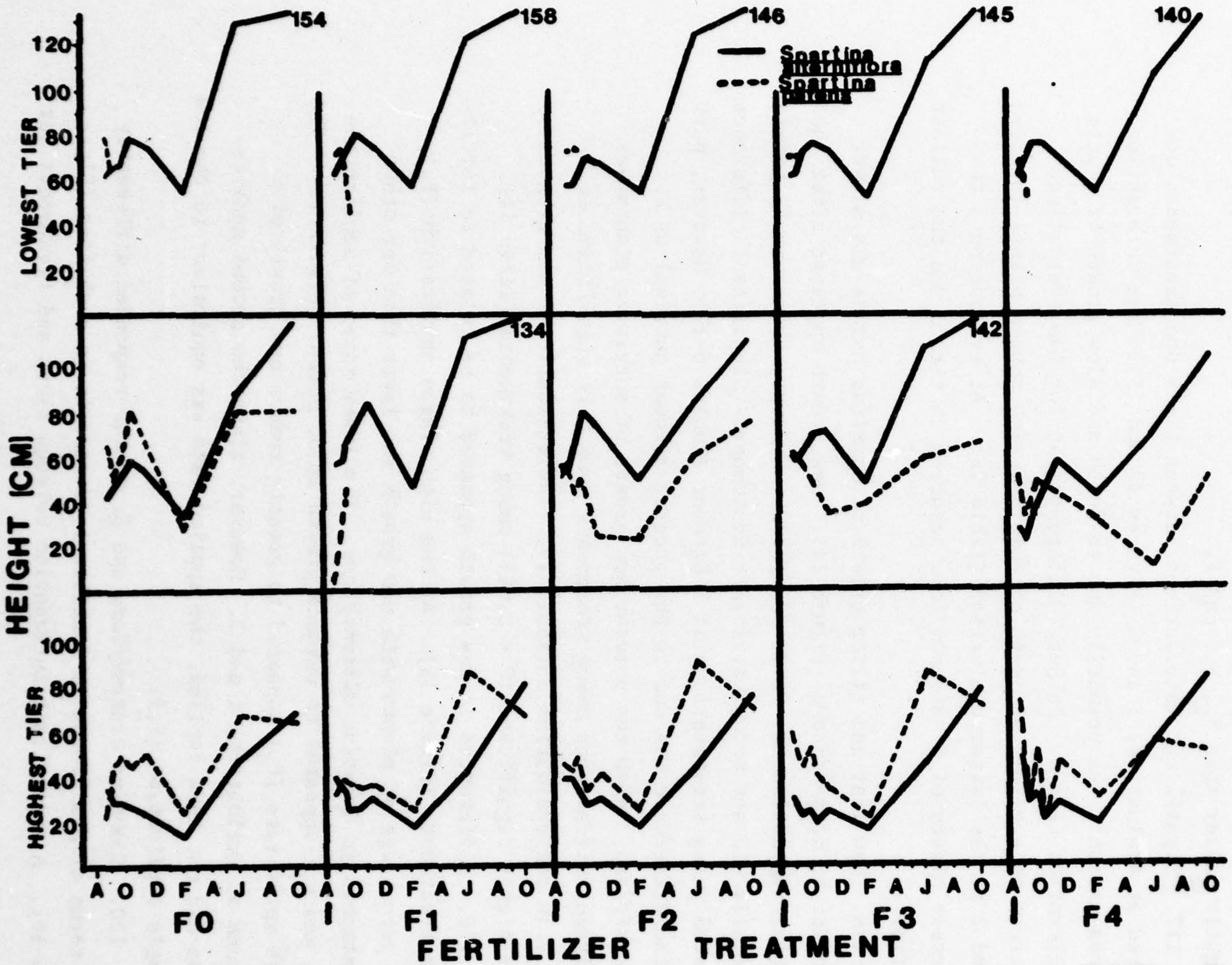

Figure 12. Height (cm) of *Spartina alterniflora* and *Spartina patens* by tier and fertilizer rates at each evaluation

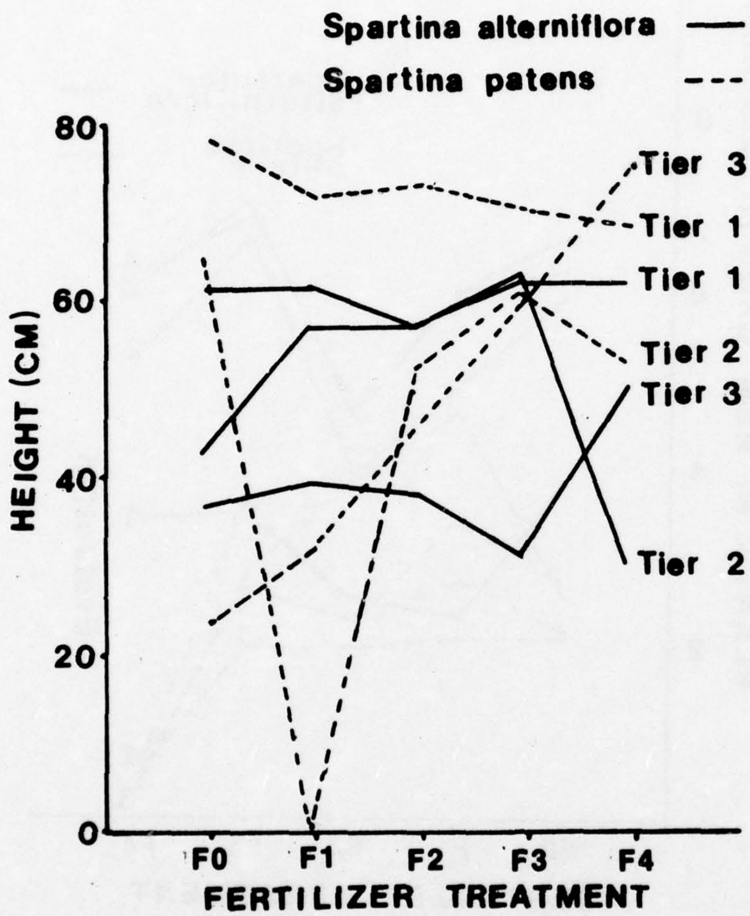

Figure 13. Mean heights for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment showing interaction of tiers and treatments at evaluation 5

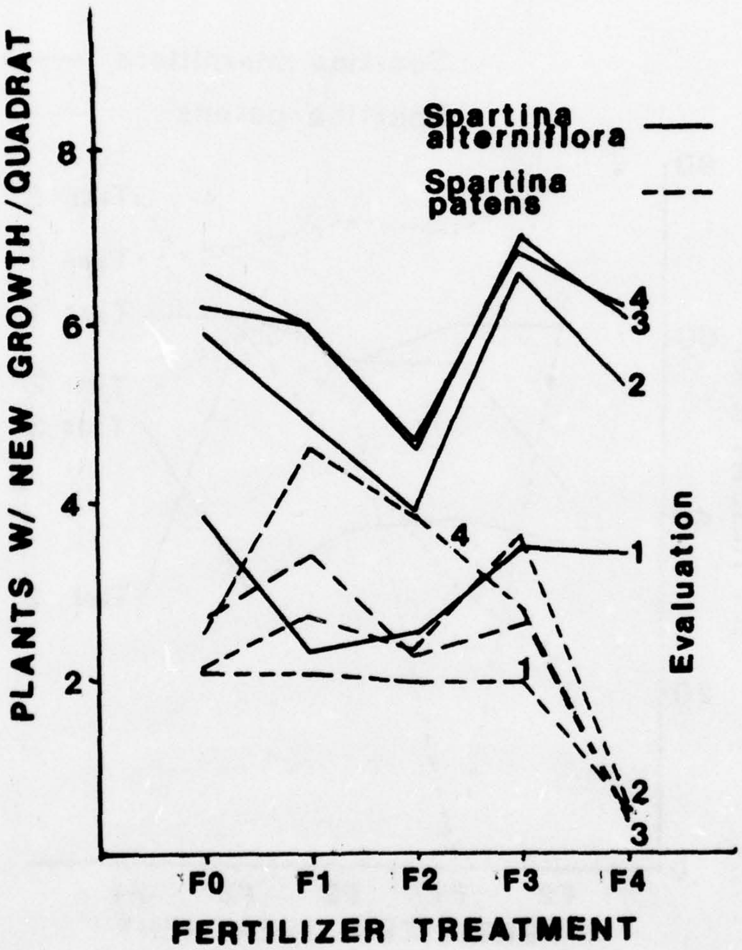

Figure 14. Means for plants with new growth for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment at four evaluations

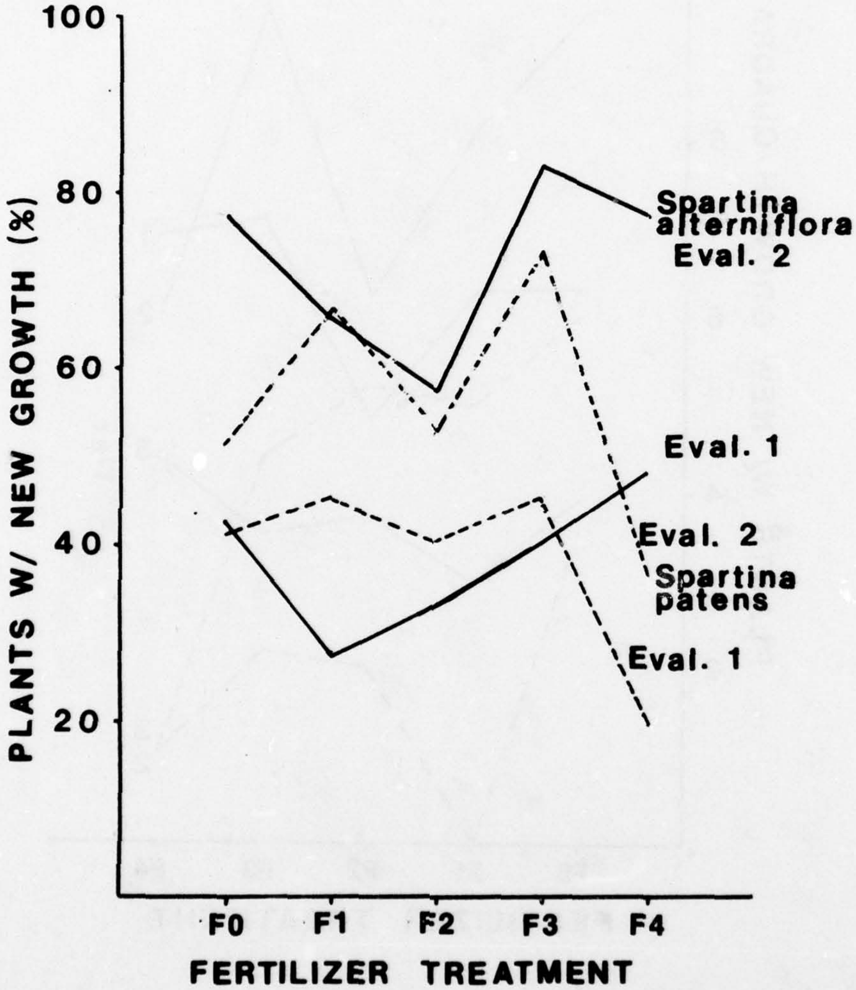

Figure 15. Means for percent plants with new growth for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment at two evaluations

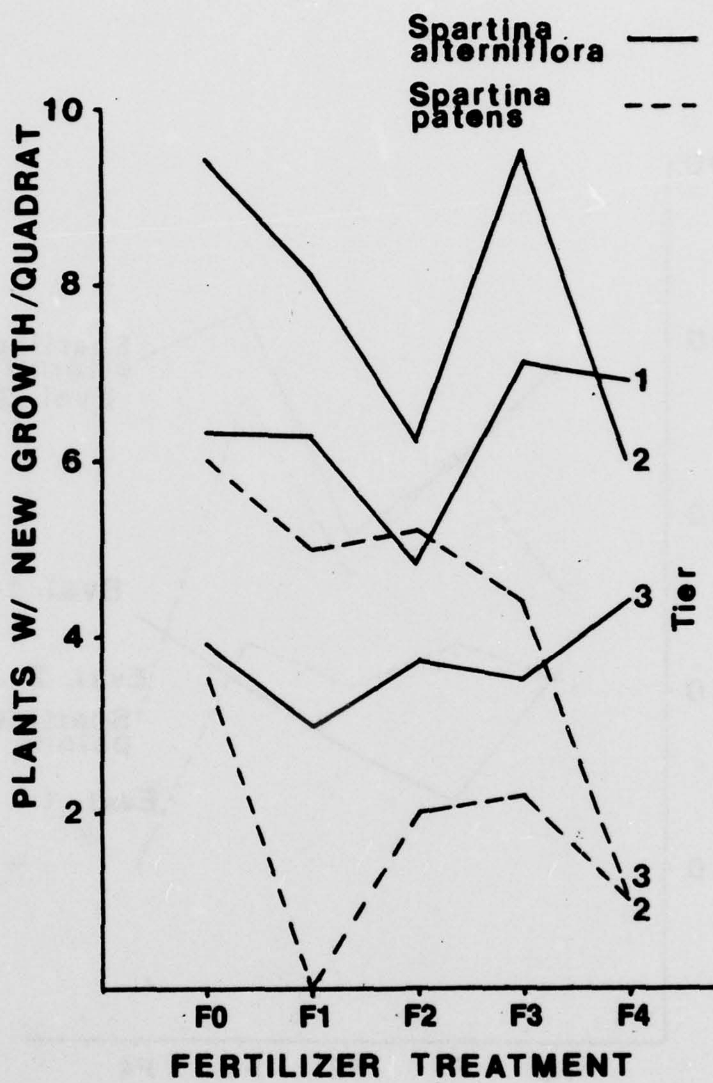

Figure 16. Means for plants with new growth (*Spartina alterniflora* and *Spartina patens*) by fertilizer treatment, showing interaction of tier and treatment at evaluation 5

plants with new growth occurred at evaluation 5. Differences occurred primarily at the high split rate (F_4).

121. Differences in stems per m^2 (density) existed from evaluation 1 to evaluation 4. However, significant differences among treatments were not evident from mean separation tests. *Spartina alterniflora* increased in density at each evaluation. Fertilizer rates did not appear to make any difference in rate of increase (Table 17, Figure 17). *S. patens* showed little increase in density until the fifth evaluation (Table 16, Figure 18). Between 5 October and 9 November, the number of tillers on *S. patens* greatly increased, except for treatment F_4 where no increase was measured (Figure 18). Similar trends in regards to fertilizer rates were exhibited at all density evaluations for *S. alterniflora*, but the magnitudes differed (Figure 19). In contrast, no trend in density was evident for *S. patens*.

122. The density of each species responded differently to fertilizer treatments in each elevation tier (Figures 20-22). *Spartina alterniflora* density was low in tier 2 in treatment F_4 (Figure 23). The response of *S. patens* density in tier 2 was best at F_0 and F_1 rates. In general F_0, F_1, and F_2 treatments resulted in higher plant density than F_4 (Figure 23).

123. Stems per surviving plant reflected more accurately the number of tillers produced than density (Tables 9-13). In contrast to density, no significant differences in the number of stems per surviving plant occurred due to treatments. Stems per surviving plant generally increased at each evaluation (Table 17). *Spartina alterniflora* tillering was slow in elevation tier 3 (Figure 24).

124. Significant differences existed by treatment in the number of plants with tillers at each evaluation (Tables 9-13). As with density, this was a reflection of percent survival. Differences existed among species at each evaluation (Figure 25). They also existed among treatments in *Spartina patens*. The number of *S. alterniflora* plants with tillers was always higher than for *S. patens*. Treatment F_4 of *S. patens* had a lower number of plants with tillers than any other treatment. The highest number occurred in treatment F_1.

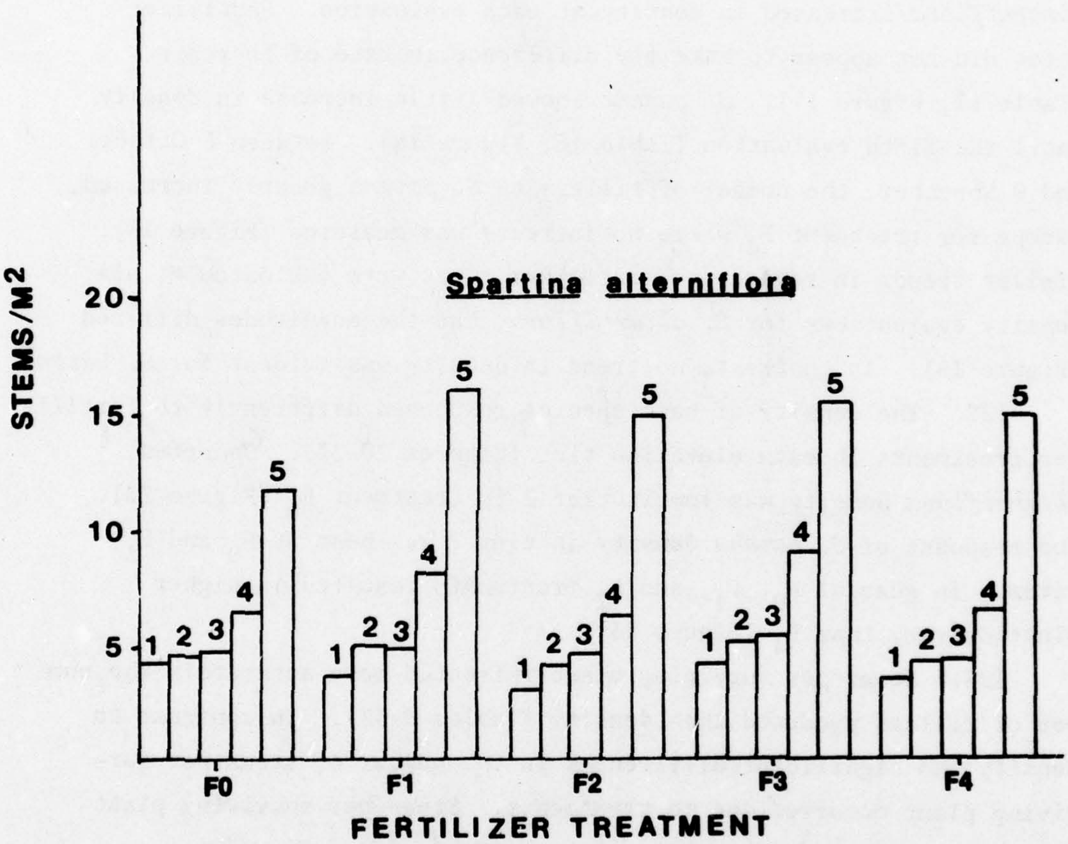

Figure 17. Mean densities for *Spartina alterniflora* by fertilizer treatment at five evaluations

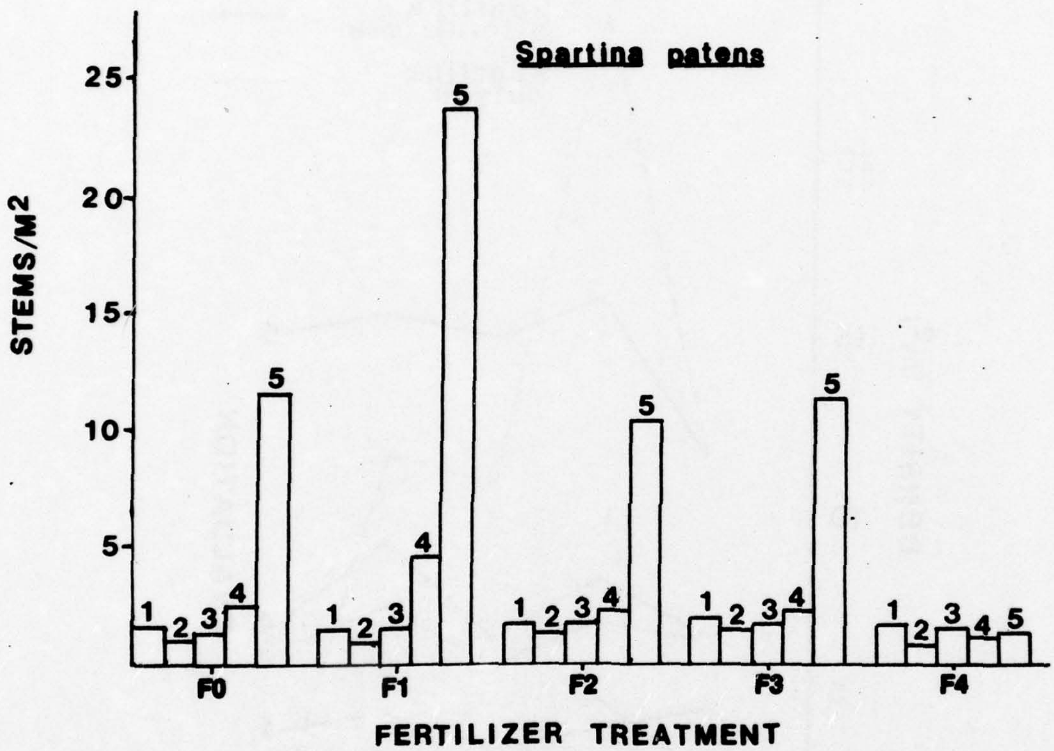

Figure 18. Mean densities for *Spartina patens* by fertilizer treatment at five evaluations

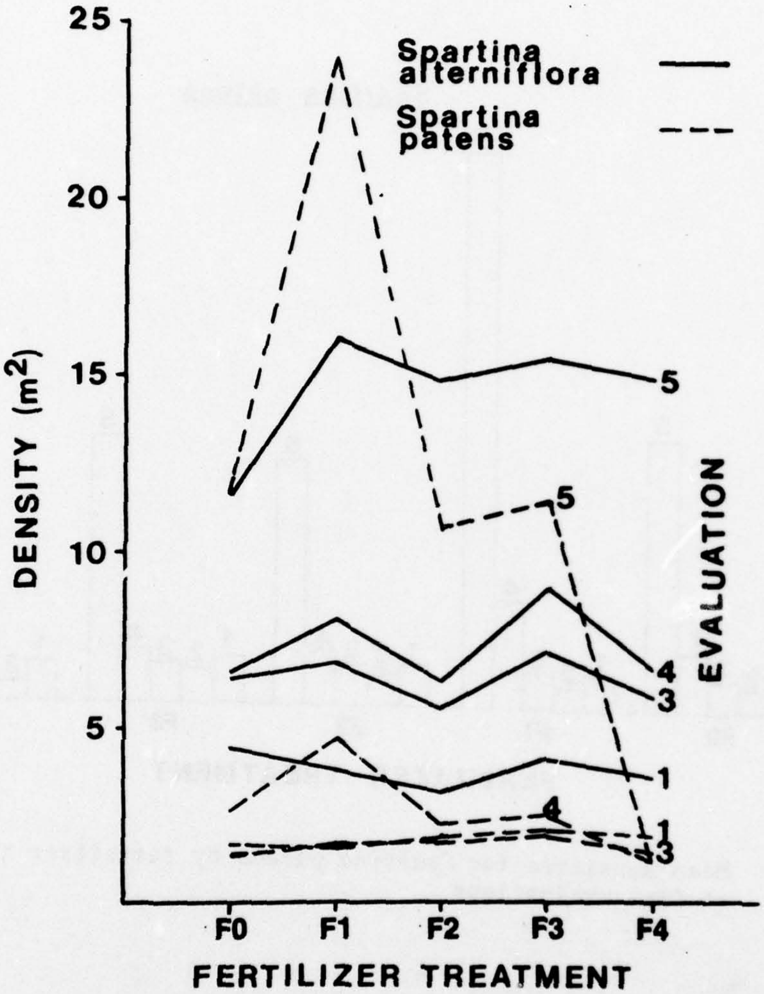

Figure 19. Mean densities for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment at evaluations 1, 3, 4, and 5

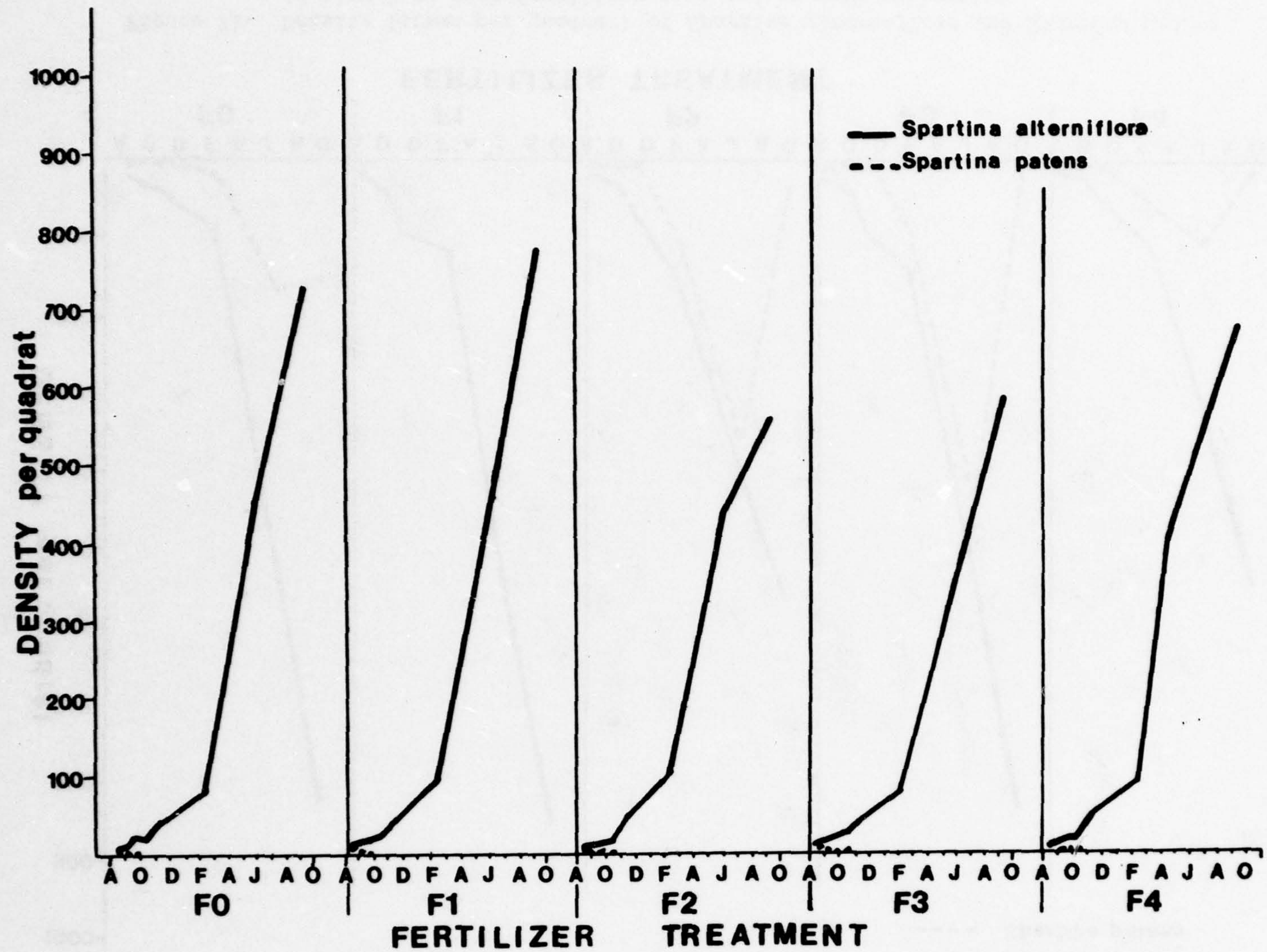

Figure 20. Density (per quadrat) of *Spartina alterniflora* and *Spartina patens* in tier 1 at each fertilizer rate and at each evaluation

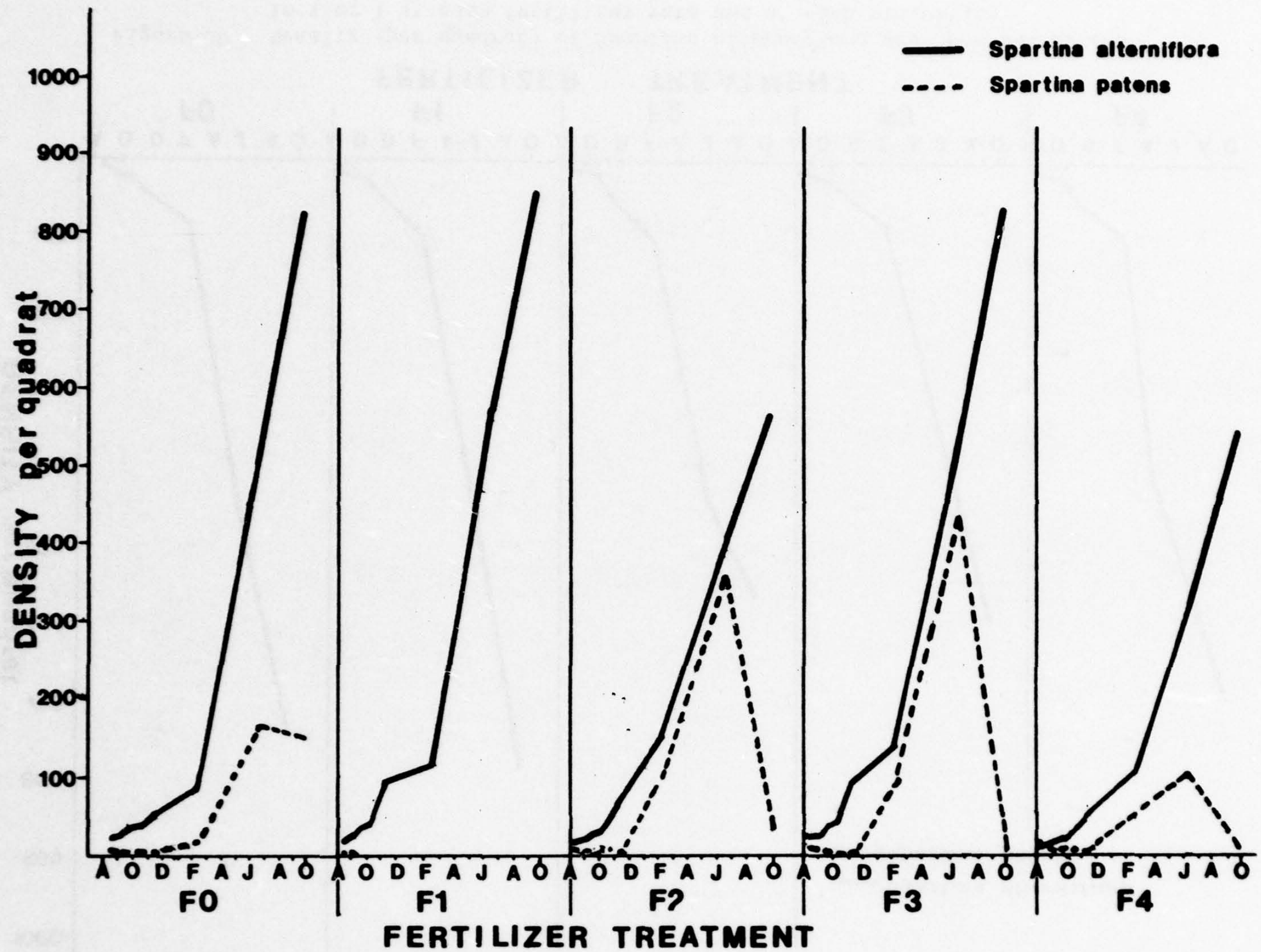

Figure 21. Density (stems per quadrat) of *Spartina alterniflora* and *Spartina patens* in tier 2 at each fertilizer rate and at each evaluation

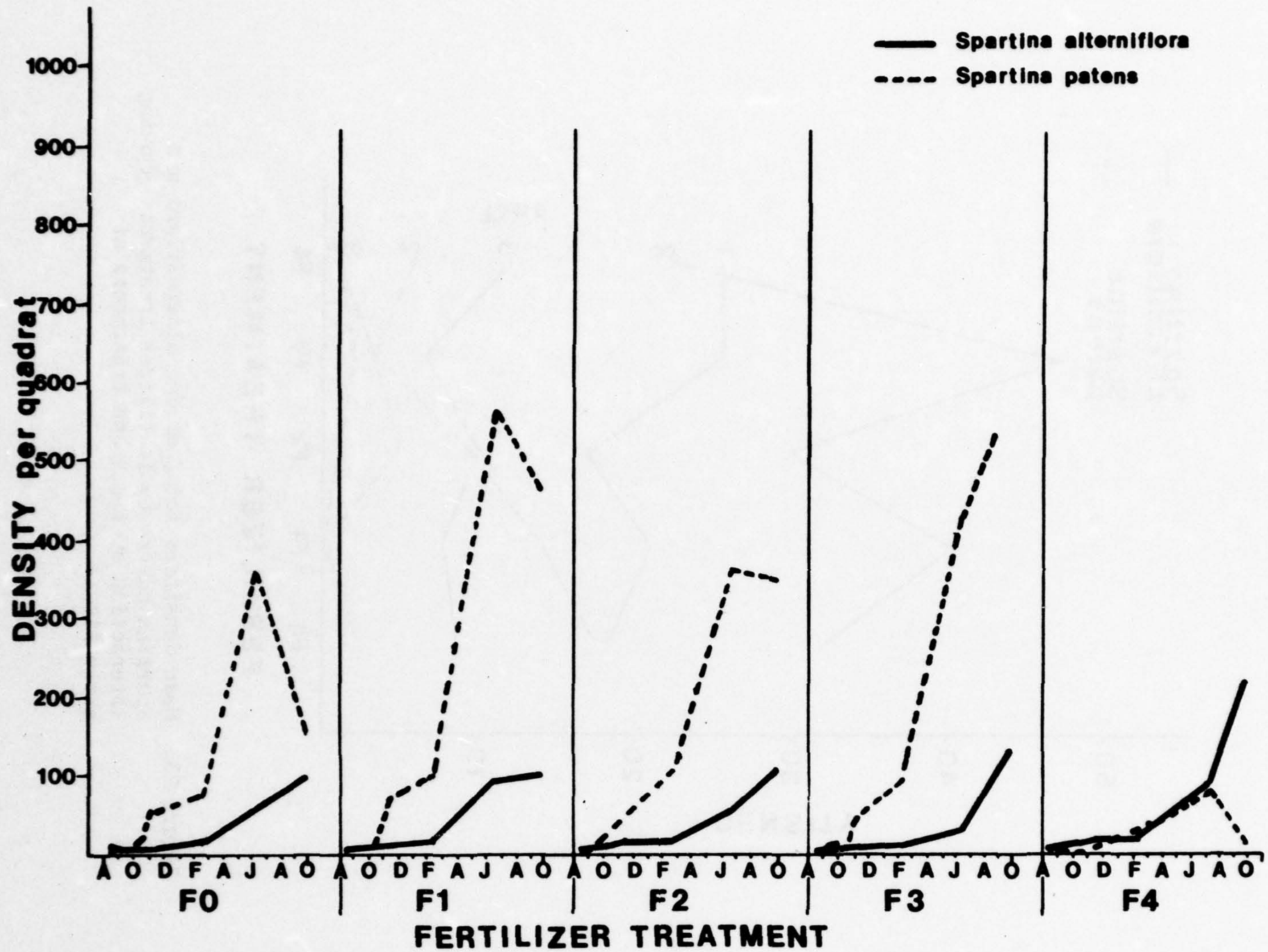

Figure 22. Density (per quadrat) of *Spartina alterniflora* and *Spartina patens* in tier 3 at each fertilizer rate at each evaluation

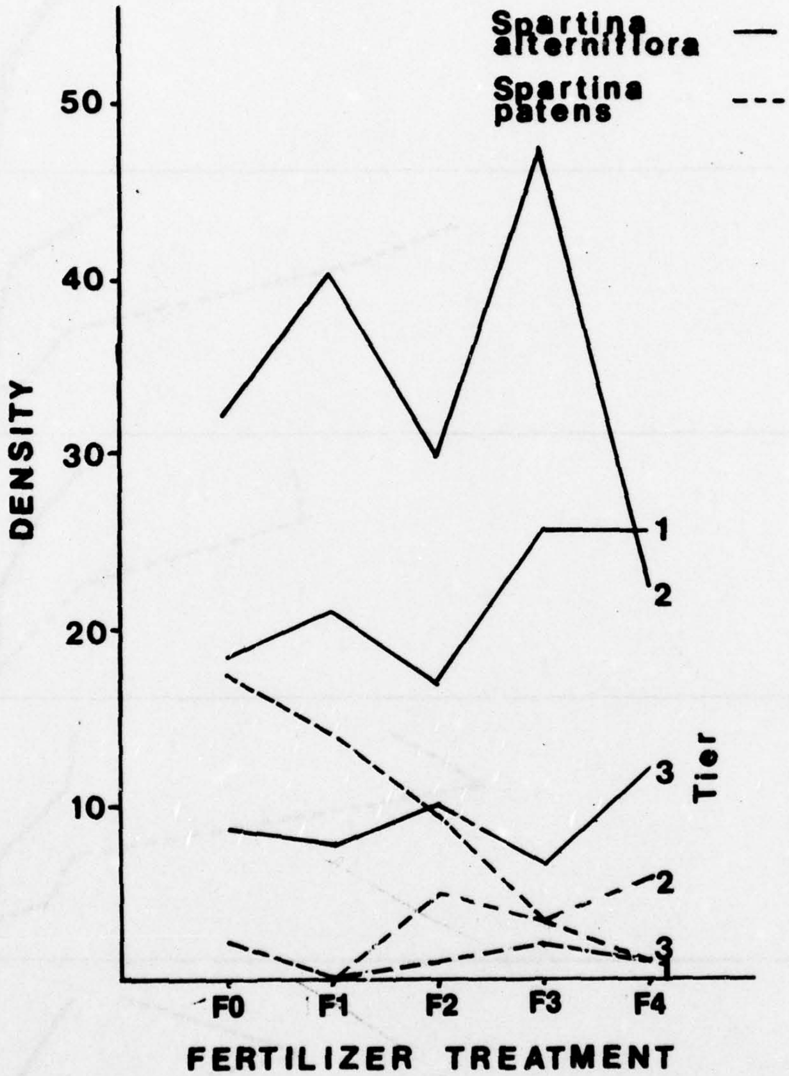

Figure 23. Mean densities for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment showing interaction of tiers and treatments at evaluation 4

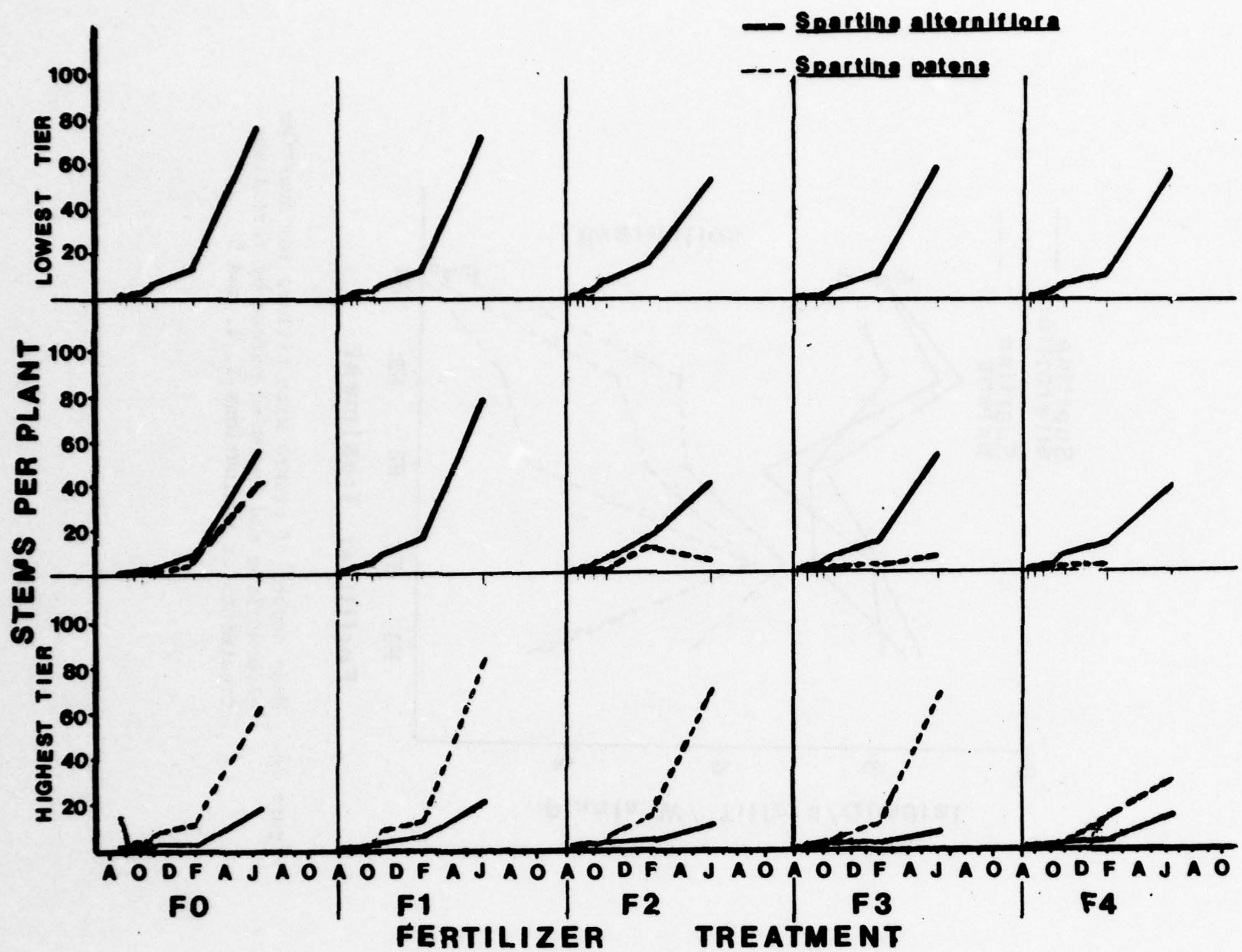

Figure 24. Stems per surviving plant of *Spartina alterniflora* and *Spartina patens* by tier and fertilizer rate

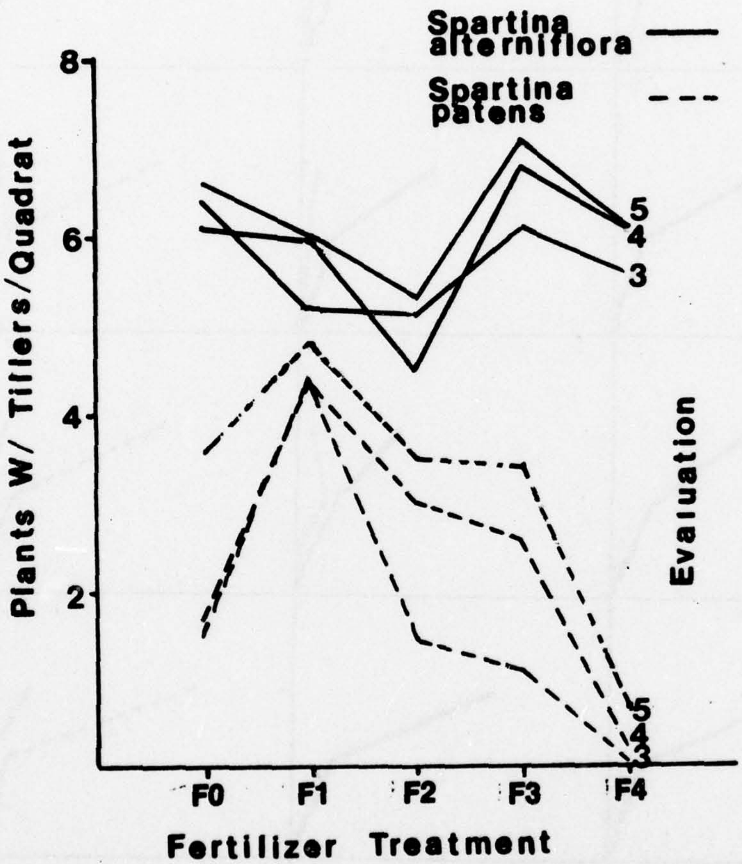

Figure 25. Mean number of plants with tillers for *Spartina alterniflora* and *Spartina patens* by fertilizer treatments at evaluations 3, 4, and 5

125. When the percentage of surviving plants with tillers was compared by treatments, differences existed only at evaluation 3 ($P < 0.10$). There were no significant differences among treatments in the number of tillers produced by plants producing tillers (Tables 10-12). There was a significant ($P < 0.20$) interaction among tiers and treatments at evaluation 5.

126. The number of tillers per quadrat also reflected percentage survival within treatments, regardless of species. Differences in the number of tillers per quadrat was significant ($P < 0.05$) in evaluations 3 and 4, but not 5 (Figure 26). *Spartina alterniflora* produced more tillers than *S. patens*, regardless of treatment. An interaction among tiers and treatments occurred in evaluations 3, 4, and 5. Death of *S. patens* in tier 1 lowered tiller numbers between evaluation 3 and 4 in F_0 and F_1 treatments.

127. Initially, animals damaged *Spartina alterniflora* more than *S. patens* (Figure 27). The damage was primarily due to rabbits. Tracks of nutria and raccoons also were found in many plots. Damage to *S. alterniflora* occurred more frequently in the F_0 treatment. An interaction among tiers and treatments was present in most evaluations (Tables 9-12). At evaluation 1, *S. alterniflora* received the heaviest damage in elevation tier 3 (Figure 28). However, some plots of tier 1 also were damaged. Significant differences in animal damage among treatments also occurred at evaluation 4.

128. Percent foliage cover was estimated to be less than 1 percent at all evaluations. There were no significant differences due to treatments in number of invading plant species or total number of plants.

129. Data from destructive sampling in November 1976 showed no significant differences by treatment in belowground biomass, aboveground biomass, total biomass, or root:shoot ratios, regardless of species (Table 13). A significant difference ($P < 0.05$) did exist in grams of seed produced by each species (Table 13). No seeds were produced by *Spartina patens*.

130. Invading plant species and invading plants, regardless of

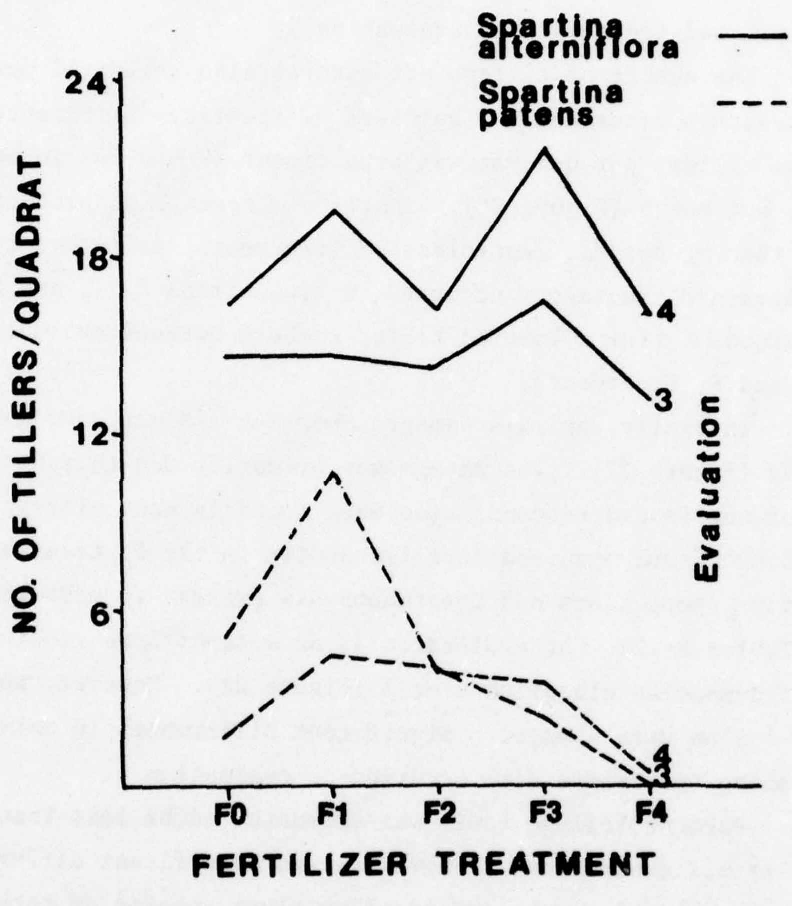

Figure 26. Mean number of tillers for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment at evaluations 3 and 4

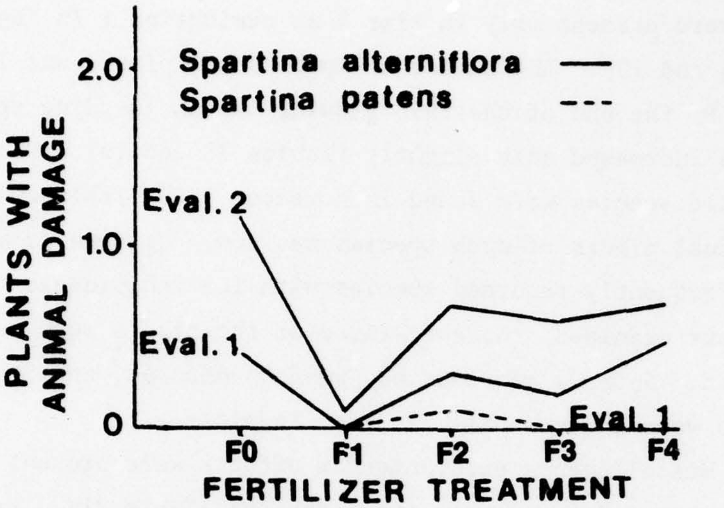

Figure 27. Mean number of plants with animal damage for *Spartina alterniflora* and *Spartina patens* by fertilizer treatment at evaluations 1 and 2

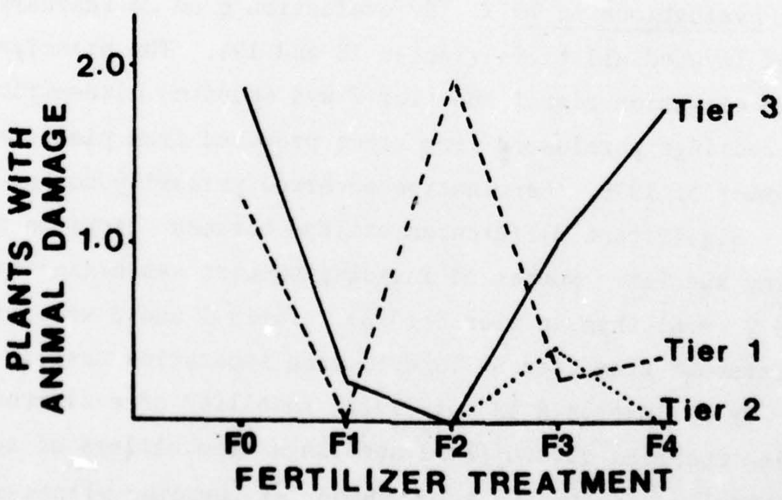

Figure 28. Mean number of plants with animal damage for *Spartina alterniflora* by fertilizer treatment, showing interaction of tiers and treatments at evaluation 1. Only slight damage had occurred to *Spartina patens*

species, were present only in tier 3 at evaluation 1 in August 1976 (Tables 18 and 19). The number of species and plants was low.

131. By the end of the 1976 growing season invading species and plants had increased only slightly (Tables 18 and 19). Only six identifiable species were found in November 1976 (Table 20). Number of individual plants of each species was low. *Cyperus esculentus* was the most frequently recorded species with 108 individuals throughout the quadrats examined. Seventy-three of the plants were recorded in one quadrat. *Scirpus americanus*, *Cynodon dactylon*, and *Sporobolus virginicus* were infrequently recorded in plots.

132. Miscellaneous environmental effects were present in a number of plots scattered throughout the marshland (Table 21). Predominant problems originated from waves washing across plots because of low spots in the dike. Erosion was severe in a few plots where ditches developed near the corners of the dike. Several erosion ditches developed in the middle of the lowest tier because of low places in the dike. Repairs to the dike eliminated erosion in these ditches. Erosion also was recorded in a few plots at the upper elevations. Erosion in the upper plots was primarily due to runoff from rainfall.

133. Evaluations in 1977. By evaluation 6 on 24 February 1977, plants had invaded all tiers (Tables 18 and 19). The principal invader in elevation tier 1 and tier 2 was *Spartina alterniflora* seedlings. Seedlings germinated from seeds produced from plants sprigged in the summer of 1976. Germination occurred primarily during early February. Significant differences existed between tiers in number of invading species. Number of invading species was higher in tier 1 (0.5) and 2 (0.6) than in tier 3 (0.3). Tiers 1 and 2 were significantly different from tier 3 (Tukey's mean separation test).

134. By evaluation 8 in July 1977, inability of evaluators to distinguish *Spartina alterniflora* seedlings from tillers of sprigged plants generally resulted in a low number of invading plants and species in elevation tiers 1, 2, and 3. Each tier was significantly different from the other in number of invading species (Tukey's mean separation test). The range was from 1.0 invading species per quadrat in tier 1, followed by 0.4 in tier 2, and 0.7 in tier 3. Num-

bers of invading plants in tiers 2 and 3 were each significantly different from tier 1 ($P < 0.05$ - Tukey's mean separation test).

135. From November 1976 to 24 February 1977 survival in marshland plots remained approximately the same in all plots at all elevations (Figure 9; Tables 14 and 22). Overall survival was still much higher in *Spartina alterniflora* (49.9 percent) than *S. patens* (9.8 percent) for 24 February 1977. For *S. alterniflora* highest percent survival (56 percent) occurred in F_3 and F_0 plots (Table 23). Lowest survival (39.8 percent) occurred in the high single application of fertilizer (F_2) followed by the high split rate (F_4) at 47.8 percent.

136. In *Spartina patens* the lowest survival (3.7 percent) occurred in F_4 (high split rate) plots. However, one of the highest survival rates (12.3 percent) recorded occurred in F_2 plots, which received the high rate single application. Highest survival was in F_3 plots (15.1 percent). Differences in survival due to fertilizer were not significant.

137. At evaluation 8 on 27 June 1977 (Table 24), survival could not be determined in many plots of *Spartina alterniflora* because of the high density of stems. Therefore, analyses of survival for *S. alterniflora* were not conducted.

138. Density had increased astronomically for *Spartina alterniflora* in elevation tiers 1 and 2 at the 27 June evaluation. Density was 386 to 486 in the lower tier at each fertilizer treatment (Figure 20). Density ranged from 321 to 579 in tier 2 (Table 25, Figure 21). Density also increased considerably for *S. patens* in tier 3 (Figure 22). Significant differences did not exist in density as a result of fertilizer treatments.

139. Height of plants decreased between 4 November 1976 (Table 13) and 24 February 1977 (Table 23). However, by 27 June (Table 24) height was, in general, twice that measured in February. Height of both species in each elevation tier seemed to follow the same pattern of decrease during the winter, followed by a large increase in height in spring (Figure 12). Largest increase in height for *Spartina alterniflora* occurred in tier 1. Tier 2 was next largest (Table 26,

Figure 12). In tier 1 *S. alterniflora* exceeded 100 cm in each fertilizer treatment. In tier 2 *S. alterniflora* was about 100 cm. In tier 3, however, height was generally less than 50 cm. Except for F_0 plots for *S. patens*, height was always greater in tier 3 than tier 2. Differences in height between tiers were highly significant ($P < 0.005$).

140. Differences in height among fertilizer treatments were significant ($P < 0.10$). Tallest plants for species were in F_1 plots (low single fertilizer application). *Spartina alterniflora* was measured at 96.6 cm and *S. patens* 86.2 cm in F_1 plots. F_3 plots were next in height in *S. alterniflora*. F_2 and F_3 (80.6 and 78.1 cm, respectively) were next in *S. patens*.

141. Number of stems per surviving plant continued to increase at each evaluation (Table 27, Figure 24). At evaluation 8, survival for *Spartina alterniflora* was not determined because of the high density of stems, which prevented determination of original transplants. The assumption was made in the case of *S. alterniflora* that new tillers were derived from original surviving transplants. Therefore, stems per surviving plant was based on survival recorded at evaluation 6.

142. For *Spartina patens* number of stems per plant increased to over 72.1 except for F_4 plots, for which it was about 31. Best growth was achieved in tier 3.

143. For *Spartina alterniflora* the greatest number of stems per plant occurred in elevation tier 1, regardless of fertilizer treatment (Table 27). An exception was the F_1 treatment where tier 2 was greater than tier 1. The highest number of stems per plant was recorded in the F_0 plots of tier 1. However, there was little difference among F_0, F_1, and F_2 plots (77.4, 72.6, and 74.2, respectively). The smallest number of stems was in tier 3. Tremendous increases in number of stems per plant occurred between the 6th and 8th evaluations (Figure 24).

144. Although the number of *S. alterniflora* plants with animal damage was approximately four per quadrat in February (Table 23), this number decreased to less than 1 on 27 June (Table 24). No dam-

age to *Spartina patens* was recorded on 27 June (Table 24). Damage in February varied from 0.3 plants damaged in F_4 quadrats to 2.8 in F_2 and F_3 quadrats (Table 23). Animal damage to all plants was attributed to rabbits and possibly nutria.

145. Foliage cover increased from less than 1 percent recorded in November 1976 (Table 13) to 1 to 10 percent at evaluations 6 and 8 (Tables 23 and 24).

146. No plants in flower were recorded in February 1977 (Table 23). By 27 June 1977, 54.3 percent (F_2 plots) to 95.8 percent (F_0 plots) of *Spartina patens* were in flower (Table 24). Seeds matured during July and were clipped in quadrats on 9-11 August 1977. Flowers in *S. patens* plots seeded 22-23 March were not present on 27 June. However, immature to mature seed heads in seeded *S. patens* plots were clipped 7 September 1977.

147. Seedling establishment. Three weeks following the seeding of marshland plots, mean seedling emergence per m^2 varied from zero in F_3 and F_4 fertilizer plots of *Spartina patens*, to 16.2 in F_3 treatments of *S. alterniflora* (Table 28). The overall mean was 9.8 per m^2 in *S. alterniflora* and 2.0 for *S. patens*. This difference between species was highly significant ($P < 0.05$).

148. The difference in seed germination by species was still significant ($P < 0.05$) at the second evaluation, approximately 5 weeks after seeding. Best survival was in elevation tier 3. Number of *Spartina alterniflora* seedlings in the middle tier had declined considerably by the second evaluation. No survival was recorded in tier 1. Differences in number of seedlings in each tier were significantly different in both evaluations 1 and 2.

149. The largest number of seedlings to emerge in any plot was 15.9 per m^2 in the F_3 treatment of *Spartina alterniflora* in elevation tier 3. *S. patens* never exceeded 11 seedlings per m^2.

150. The lowest two tiers were not evaluated at the third evaluation because of high water. Germination of *Spartina patens* appeared to be several weeks behind *S. alterniflora*.

151. Germination was not recorded for either species in elevation tier 1 at any evaluation. This was in marked contrast to the invasion

by seedlings of *Spartina alterniflora* on 24 February in tier 1.

152. Differences in tides were recorded during the period in which natural seedling invasion occurred and during 5 weeks of evaluation following seeding. During the period 1 January to 20 March 1977 mean low water was 0.04 ft msl and mean high water was 0.86 ft msl (Figure 29). In contrast during the period 21 March to 27 April, mean low water was 0.71 ft, which was approximately the same as the mean high water of the earlier months, and mean high water was 1.56 ft. There was a difference of 0.7 ft in the mean high water of the two time periods. Percent of time of inundation at each elevation was considerably greater during the latter time period (Figure 29).

153. No seedling germination or survival was recorded below 1.2 ft in elevation (Figure 30). The lowest survival occurred at about 1.4 ft above msl, where survival was recorded in six plots (Figure 30). At this elevation inundation occurred about 36 percent of the time during the period 21 March to 27 April 1977.

154. At the 27 June evaluation for seedlings, differences in seedling density still existed by species (Table 29). Height was generally the same for each species. Animal damage to plants was much more significant to *Spartina alterniflora* (18.4 per m^2) than *S. patens* (1.2 per m^2) ($P < 0.05$). Percent foliage cover was less than 1 percent for both species. No flowers or seed heads were present on 27 June.

155. Differences in density still existed by elevation tiers on 27 June (Table 30). Tier 3 was significantly greater than tier 2 or 1 but tier 2 was not greater than tier 1 (Tukey's mean separation test). No differences in height were detected between tiers or fertilizers. A slight difference ($P < 0.10$) existed in fertilizer treatments in number of plants stressed. Animal plant damage was greater in tier 3 than tier 2 or 1. Tier 2 was not greater in animal damage than tier 1 ($P < 0.05$ - Tukey's mean separation test).

156. For *Spartina alterniflora* density was least in F_4 plots (Table 31). However, differences due to fertilizer treatments were not significant. Only in number of plants stressed did there appear to be a fertilizer response. Stress seemed to be due to the heavy single

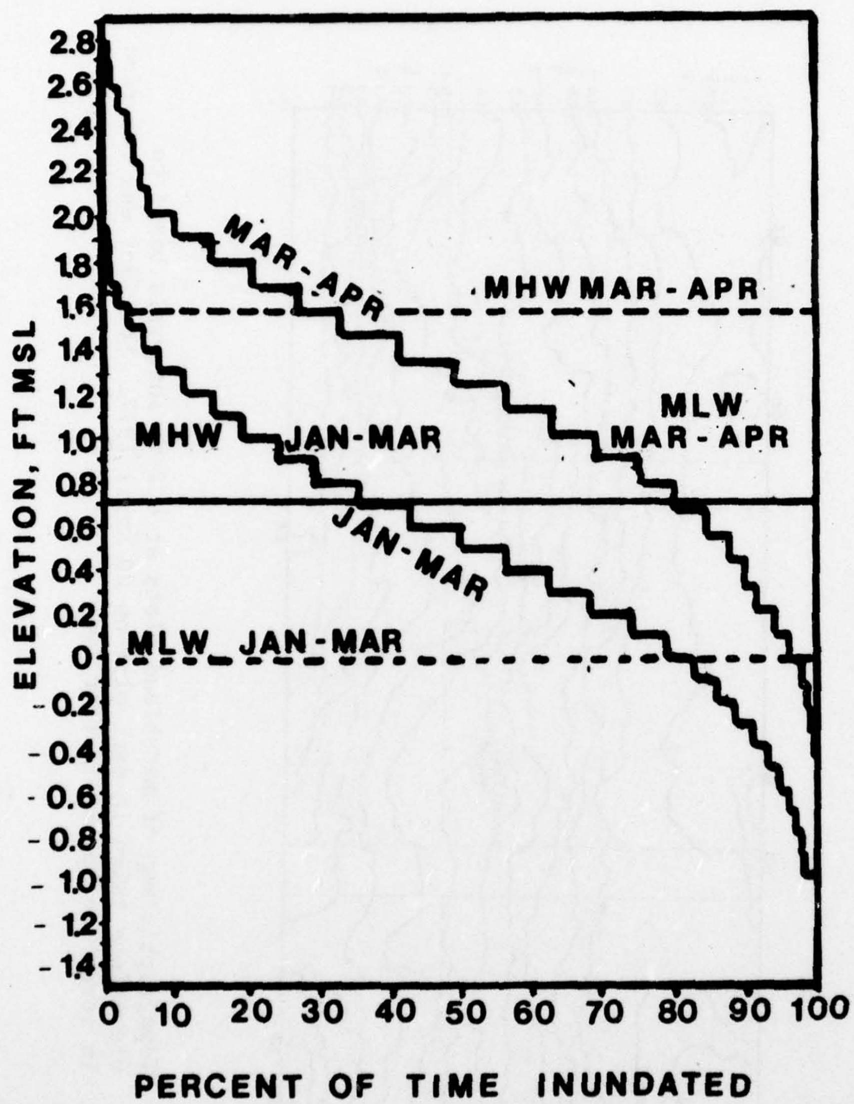

Figure 29. Percent of time each elevation was inundated during seedling establishment in marshland plots. Period of time of monitoring was 1500 hours 1 January to 2400 hours 20 March 1977 and 1500 hours 21 March to 0900 hours 27 April 1977

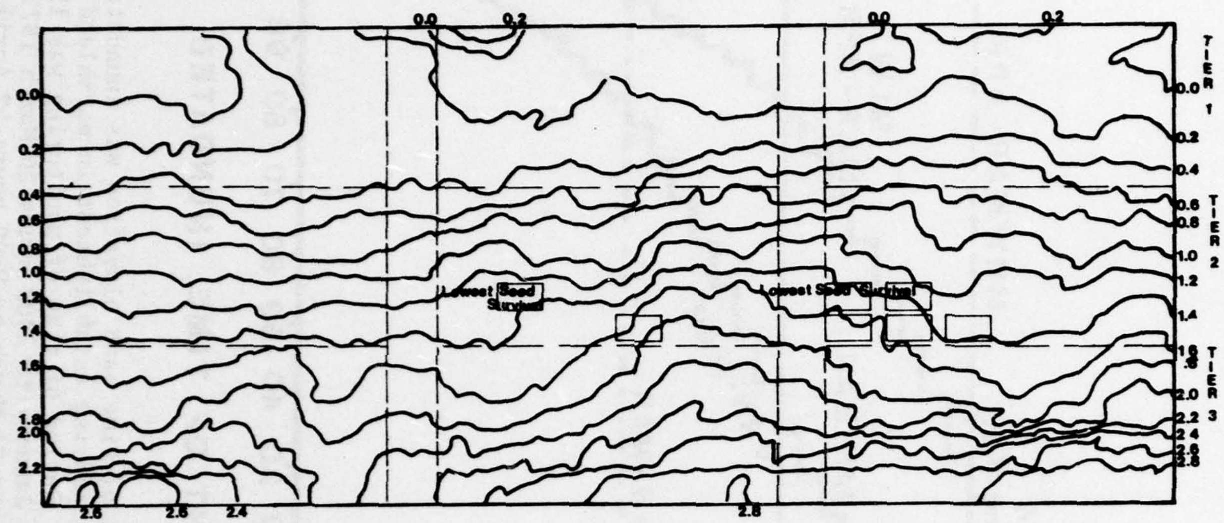

Figure 30. Topographic map of marshland plots at 0.2-ft intervals based on elevations taken in each plot on 20 April 1977. Survival was recorded in seven seed plots in tier two

application of fertilizer.

157. At evaluation 9 the density and height of *Spartina alterniflora* in sprigged plots was much greater than *S. patens* (Table 32). Density varied from 411 to 576 stems per quadrat for *S. alterniflora*. It was only 4.1 stems per quadrat in F_4 plots of *S. patens*. The highest *S. patens* density, 178.5 stems, was still less than half the number in *S. alterniflora* quadrats. Height varied from 108 cm to 130 cm for *S. alterniflora*. In *S. patens* height did not exceed 72.2 cm (Table 32).

158. Animal damage to plants at evaluation 9 was negligible. Foliage cover was generally 10 to 25 percent for *Spartina alterniflora*. In general, *S. patens* foliage cover never exceeded 10 percent (Table 32).

159. Individual randomly selected clumps of *Spartina patens* produced as much biomass in some fertilizer plots as *S. alterniflora*. Root biomass average was 135 g per 0.1 m^2 in *S. alterniflora* and 128 g per 0.1 m^2 in *S. patens*. Shoot biomass was 124.1 g per 0.1 m^2 in *S. alterniflora* and only 85.3 g in *S. patens*. *S. alterniflora* and *S. patens* shoot, root, and total biomass was 40 to 50 fold higher than the original weight (Table 6). Initial shoot or root weight for both species never exceeded 4 g. Weight gain was primarily due to new tillers and associated roots. Gain in weight from November 1976 was ten fold or better (Table 13).

160. The root:shoot ratio was always greater than 1 in both species at evaluation 9. It varied from 1.1 to 1.9 (Table 32). This ratio was in contrast to the ratios of initial transplants. Initially the ratio for transplants at intermediate and low elevation for *Spartina alterniflora* and *S. patens* in one-fourth-size plots was less than 1 (Table 6). Root:shoot ratios were also less than 1 in all fertilizer treatments for both species in November 1976 (Table 13).

161. Seed production on *Spartina alterniflora* was measured on quadrats as well as the 0.1-m^2 areas. Except for F_4 plots seed production was generally around 7 g per 0.1 m^2. Only 1.7 g was produced in F_4 plots (Table 32). For *S. patens*, measurements were taken only on quadrats.

162. Stem density per quadrat had continued to increase at evaluation 9 for *Spartina alterniflora* (Table 25). Over 500 stems per 3 m^2 was recorded in all tier 1 and 2 fertilizer treatments, except in the F_1 treatment in tier 2 (Figures 20 and 21). Over 800 stems per quadrat were present in the middle tier in F_0 and F_3 plots. Density of stems was much lower in tier 3 for *S. alterniflora* (Figure 22). Approximately 100 stems per quadrat were recorded in all fertilizer treatments in tier 3, except the F_4 treatment. Over 200 stems were present in this treatment.

163. No survival was recorded in tier 1 for *Spartina patens*. Growth of *S. patens* in tier 2 was variable. Zero to 128 stems per quadrat were recorded in the fertilizer treatments (Figure 21). In the highest elevation tier stem densities of 534 occurred in the F_3 treatment (Figure 22). However, only 7.9 stems were recorded in the F_4 treatment (Table 25). Fewer stems were recorded at evaluation 9 than 8 in F_0, F_1, and F_4 plots.

164. For *Spartina alterniflora* at evaluation 9 the tallest plants occurred in the lowest elevation tier (Figure 12). Height varied from 139.7 to 157.7 cm (Table 26). The shortest height for each fertilizer treatment was always in the highest elevation tier (Figure 12). Height varied from 67.8 to 83.4 cm. Fertilizer treatments did not appear to make any difference in height for *S. alterniflora*.

165. For *Spartina patens* height was generally the same in the middle and high elevation tiers (Figure 12). Height varied from 47.5 cm in F_4 plots to 80.6 in the F_0 plots.

166. In seeded plots in the marshland at evaluation 9, density for 3 m^2 varied between plots. A low of approximately 8 stems per 3 m^2 was recorded in the F_4 *Spartina alterniflora* treatments and the F_1 treatments of *S. patens* (Table 33). Over 200 stems were recorded for *S. alterniflora* in the F_3 treatments. The highest density recorded in any seeded plot on 27 June 1977 was 40 (Table 31). Density was considerably less than that in sprigged plots. However, density (where survival did occur in higher elevation tiers) was higher than for sprigged plots evaluated in November 1976 (Table 13).

167. Height doubled from June 1977 to October 1977 (Tables 31 and

33). However, height of both species was still less than in sprigged plots. Foliage cover was still less than 10 percent in all treatments. Average shoot biomass was 19.1 g per 0.1 m^2 for *Spartina alterniflora* and 43.5 g for *S. patens*. Root biomass was 32.5 g per 0.1 m^2 and 45.7 g for *S. alterniflora* and *S. patens*, respectively. This exceeded the biomass in the sprigged plots in November 1976 (Table 13).

168. At evaluation 9 in the *Spartina patens* plots, the only invading species recorded in the lowest two tiers was *S. alterniflora* (Table 34). *S. alterniflora* also was more numerous (5900 plants) than any other species in the highest elevation tier. *Sporobolus virginicus* contributed 892 plants. *S. patens* and *Scirpus americanus* were recorded over 100 times in marshland plots. *Fimbristylis castaneum* and *Cyperus esculentus* were frequently encountered at the highest elevations. *Salicornia* spp. were numerous before the occurrence of high tides from Hurricane Anita in September. After the high tides most *Salicornia* spp. plants died. Therefore, they were not recorded during the October evaluation.

169. No invading species were recorded in *Spartina alterniflora* plots in the lowest two tiers at evaluation 9 (Tables 18 and 19). However, 10.8 plants were recorded in F_0 plots of *S. patens* in tier 1. From 24.3 to 35.0 individual plants were recorded in tier 2 plots for *S. patens*. Tillers from adjoining *S. alterniflora* plots and tillers from *S. alterniflora* seedlings that invaded *S. patens* plots were the only plants recorded. The absence of invasion of *S. alterniflora* in its own plots was due to inability of the investigators to distinguish invading stems of *S. alterniflora* from tillers of original transplants.

170. Number of invading species per quadrat generally did not increase between evaluations (Table 18). The number of plants of each species did increase over time, particularly at evaluation 9 (Table 19). A four-fold increase occurred in most treatments.

171. Rows 1-15 planted 1-4 February 1977. In one-fourth-size plots planted 1-4 February 1977 to *Spartina alterniflora* and evaluated 28 April, significant differences ($P < 0.05$) between the 15 rows occurred in all variable tests except number of tillers per surviving plant. However, differences between replications also were highly

significant. Fertilizer treatments were not significantly different except in number of invading species. Elevations were obviously different between replications (Figure 30).

172. Using elevations taken in each plot, ten elevational zones (0.25-ft increments) were set up. Analyses were run on *Spartina alterniflora* using elevational zones in place of rows. Thus, replications were the same by elevation. As with rows the zones were significantly different ($P < 0.05$) in all variables except number of tillers per surviving plant and number of invading plants. Replications were no longer significantly different except in percent survival, number of stable plants, percent plants with new growth, and number of invading species.

173. Percent survival was greatest at the lowest (77.9) and highest elevations (84.5) (Table 35). The lowest zone was below 0.50 ft. The highest zone was all elevations above 2.5 ft. Survival declined in successive zones approaching the middle 1.25- to 1.49-ft zone. At this elevation percent survival was 19.8 percent. Mean high water for the period 1 February to 27 April was 1.21 ft. Inundation was 18.5 percent of the time at mean high water (Figure 31).

174. Density, which reflected survival, was lowest in the 1.25-to 1.49-ft and 1.50-to 1.74-ft zones (21.0 and 17.6 plants per plot, respectively). Number of stems per surviving plant varied from 1.3 (1.50-to 1.74-ft zone) to 3.3 (0.50-to 0.74-ft zone), but differences were not significant.

175. Height of plants was greatest (62.9 cm) at the lowest elevation zone and shortest in the 1.50-to 1.74-ft zone (25.1 cm). Tillers per plant were greatest (11.0 tillers) in the 0.75-to 0.99-ft zone. Animal plant damage was greatest at the highest elevations.

176. Within the analysis by zones, fertilizer treatments were significantly different in percent plants with new growth ($P < 0.01$), animal plant damage ($P < 0.05$), and number of invading species ($P < 0.01$). Percent plants with new growth was slightly greater in F_1 plots (Table 36). Animal plant damage was least in F_1 plots. Number of invading species was greatest in F_0 plots.

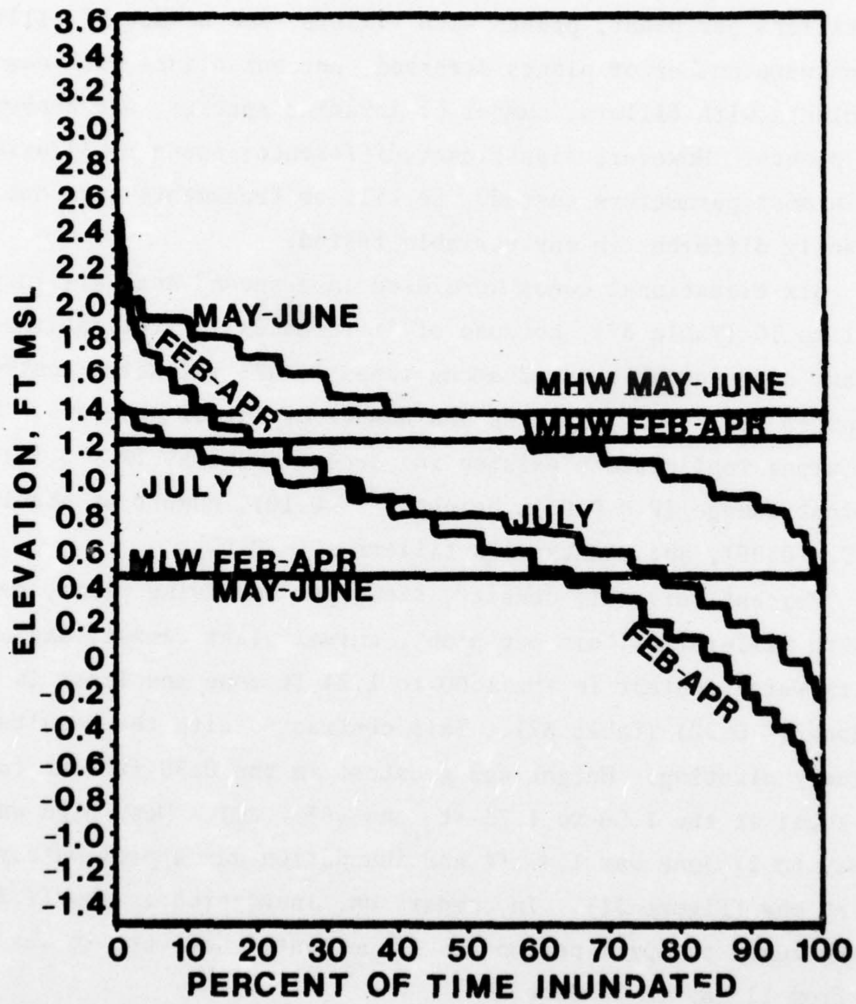

Figure 31. Percent of time each elevation was inundated in marshland one-quarter-size plots during initial 2-month establishment. Period of time of monitoring was 0900 hours 1 February to 0900 hours 27 April 1977 and 1200 hours 11 May to 1700 hours 27 June 1977

177. Rows 1-10 (tiers 1 and 2) planted 11 May - 1 June 1977. The ten rows of *Spartina alterniflora* planted in May-June 1977 and evaluated 21-27 July were significantly different ($P < 0.05$) in percent survival, animal plant damage, density, height, stems per plant, number of stable plants, tillers per plant, plants with tillers, and number of tillers. Exceptions were number of plants stressed, percent plants with new growth, percent plants with tillers, number of invading species, and number of invading plants. However, significant differences among replications existed in most parameters tested. Fertilizer treatments were not significantly different in any variable tested.

178. Six elevational zones were used in a second analysis in place of rows 1 to 10 (Table 37), because of differences in replications. Significant differences existed among zones in all variables tested except number of invading species and number of invading plants. Differences among replications existed in percent survival ($P < 0.10$), animal plant damage ($P < 0.05$), height ($P < 0.10$), number of stable plants ($P < 0.05$), and plants with tillers ($P < 0.05$).

179. Percent survival, density, stems per surviving plant, percent plants with tillers, tillers per plant, animal plant damage, and number of tillers were greatest in the 1.00- to 1.24-ft zone and least in the lowest zone (< 0.50) (Table 37). This contrasted with the results of the February planting. Height was greatest in the 0.50-ft zone (84.0 cm) and least at the 1.50- to 1.75-ft zone (57.7 cm). Mean high water for 11 May to 27 June was 1.47 ft and inundation was approximately 30 percent at mhw (Figure 31). In comparison, inundation at mhw (1.21 ft) for the February to April period was 18 percent. However, it was 58 percent from 11 May to 27 June.

180. Differences in fertilizer treatments were present in percent survival ($P < 0.10$), density ($P < 0.05$), tillers per plant ($P < 0.01$), percent plants with tillers ($P < 0.05$), and number of tillers ($P < 0.05$). Survival was slightly greater in F_4 plots (79.8 percent) (Table 38). Lowest survival occurred in F_1 (72.1 percent) and F_2 (73.4 percent) plots. Density was greatest in F_4 plots (133.0) and lowest in F_0 plots (109.9). The lowest number (4.5) of tillers per plant occurred in F_0

plots. Little difference among fertilizer plots was evident in tillers per plant. The range was 5.2 to 5.6 tillers. Number of tillers was also lowest in F_0 plots.

181. Comparison of planting dates at the end of 2 months. Evaluations were made 2 months after each planting. In the analysis of variance on the lowest 10 rows, date × row interactions and differences between replications were highly significant ($P < 0.05$) in density, number of tillers, height, and animal plant damage. Therefore, elevational zones at 0.25-ft intervals were used to run analyses in place of rows. Six zones were compared. Differences by dates (2 months after each planting) occurred in all parameters except tillers per plant, foliage cover, number of invading species, and number of invading plants (Table 39). Survival was significantly higher (75.8 percent) in the spring planting (May-June) than the February planting (60.0 percent) ($P < 0.05$). Density was twice as great in the spring planting (126.7) as in the February planting (58.6). Mean height in the spring planting was 26 cm taller than the February planting. Heights were 78.3 cm in the May-June planting and 52.1 cm in the February planting.

182. Differences by zones and in date × zone interactions were significant in all parameters except percent plants with new growth, tillers per plant, and percent foliage cover (Table 39). Interactions of zone and date indicated different plant responses by planting date to each elevational zone. Differences in percent of time of inundation at each elevation were evident during the two time periods (Figure 31). Inundation was 18 percent at elevation 1.21 ft in February through April but 58 percent in May and June.

183. Fertilizer treatments without date × fertilizer interactions were significant ($P < 0.05$) only in number of plants stressed (Table 40). Significant differences among fertilizer treatments with date × fertilizer interactions also occurred in density, percent of plants with new growth, and number of tillers per plots.

184. Comparison of planting dates at 11-15 November evaluation. By 11-15 November 1977 density of plots planted in February exceeded 1100 plants in all zones below 1.24 ft msl (Table 41). From 0.50

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to 0.99 ft, stem density was above 1500 stems per plot. Only in the 1.00-to 1.24-ft zone was stem density above 1000 stems in the May-June planting. In the lowest zone (< 0.50 ft) for the May-June planting stem density was only 389. Differences in density between the two dates was almost significant ($P < 0.10$). The date × zone interaction was highly significant ($P < 0.01$). Greater density in May- June plots than in the February planting occurred in the highest 2 zones (1.25 to 1.49 ft, 1.50 to 1.74 ft). This reversal of the trend of greater density of February planted plots resulted in the significant interaction.

185. Height followed the same trend as density. Height was greater in February planted plots in the lowest 4 zones but less than May-June plots in the highest 2 zones. Differences were not significant ($P < 0.10$) (Table 41).

186. No plants were recorded with animal damage in plots of either planting date. For the 0.50- to 0.99-ft zone foliage cover was from 25 to 50 percent in February planted plots. In February planted plots below 0.50-ft elevation, foliage cover was 10 to 25 percent. All other zones, regardless of planting date, had less than 10 percent foliage cover. Number of invading species and individual plants was small (Table 42).

187. Differences in density in fertilizer treatments were not significant at $P < 0.10$. At both planting dates greatest density occurred in F_2 and F_4 plots (Table 42). Density was 1062 stems per plot in the F_2 treatment and 1161 in the F_4 treatment in the February planting. However, density in the F_1 treatment in February plots was 883, only 278 stems less than the highest density. Similar differences occurred in May-June planted plots.

188. Height was not different between fertilizer treatments. Percent foliage cover exceeded 10 percent only in F_4 February planted plots. Differences in number of invading species and number of invading plants due to fertilizer treatments did not exist.

189. <u>Comparison of *Spartina alterniflora* and *S. patens* in rows 11-15 (tier 3)</u>. In rows 11-15 of one-fourth-size plots planted 1-4 February 1977 and evaluated 27-28 April, *S. alterniflora* and *S. patens* were similar in percent survival. Survival was 54.1 percent in *S. alterniflora*

and 51.1 percent in *S. patens* (Table 43). Density, stems per surviving plant, and number of tillers were greater in *S. patens*. The differences were significant at $P < 0.05$. However, differences were probably due to the larger number of stems normally present in *S. patens* plants as compared to *S. alterniflora*.

190. More plants were stressed in *Spartina patens*. Accordingly, more plants were stable in *S. alterniflora* plots than *S. patens*. Differences were significant at $P < 0.05$ (Table 43).

191. No differences among fertilizer treatments in *Spartina alterniflora* and *S. patens* plots were found except in number of invading species and plants. Differences were significant at $P < 0.10$ for these two parameters.

192. Differences between rows and row-species interactions occurred. Survival was better for *Spartina alterniflora* (31.3 percent) than *S. patens* (11.3 percent) in row 11 (Table 43). Survival increased for each species in each successively higher elevation row. Survival was within 5.6 percent in rows 12-14. Survival was 90 percent for *S. patens* and 80.2 percent for *S. alterniflora* in row 15.

193. Density and stems per plant increased for each species at each successively higher elevation row, except for *Spartina alterniflora* in row 15 (Table 43). Tillers per plant for *S. patens* were most numerous in rows 13-15. Height increased for *S. patens* with each successively higher row.

194. Animal plant damage to *Spartina alterniflora* was greatest in row 15 (9.0) and least in row 11 (0.3). *S. patens* received no damage.

195. Number of invading species was greatest in row 15 for both species. Number of invading plants was greatest in row 15 for *Spartina patens*. Although row 11 was lowest in number of invading plants for *S. alterniflora*, the other four rows varied considerably in numbers of invading plants.

196. At the 11-15 November 1977 evaluation, survival increased in each successively higher elevation row for *Spartina patens*. Percent survival was 11.3 in row 11, and 91.5 in row 15 (Table 44). Survival could not be determined in *S. alterniflora* plots since numerous stems prevented distinquishing original transplants.

197. Density was significantly greater ($P < 0.01$) in *Spartina patens* plots than *S. alterniflora*. Density increased in each successively higher elevation (row) for *S. patens*. Density per plot increased from a low of 203.5 in row 11 to 2185.8 stems in row 15. Density of *S. alterniflora* also increased from 522 in row 11 to 960 in row 14. However, in row 15 density decreased sharply to 397 stems per plot (Table 44).

198. Height was significantly greater ($P < 0.01$) in *Spartina alterniflora* (101.4 cm) than *S. patens* (76.0 cm). In all rows but row 15, *S. alterniflora* exceeded *S. patens* in height. In row 15 height was 87 cm for both species.

199. Only slight animal damage occurred in *Spartina alterniflora* plots and none in *S. patens* plots. Foliage cover was less than 10 percent in all rows, regardless of species. Number of invading plants was significantly greater in *S. patens* plots (Table 44). Many of the invading plants were *S. alterniflora* tillers from seedlings and adjacent sprigged plots. The invaders were not recorded in *S. alterniflora* plots since they could not be distinguished from tillers of transplants.

200. Tidal inundation from 1 February to 31 August. During the period of tide monitoring, February was the month of lowest tides (Figure 32). This corresponded with the strong north winds that pushed bay waters into the Gulf of Mexico. May was the month of highest tides. Tides were approximately the same for March, April, June, and July. At average mlw for the entire monitoring period, present inundation was approximately 50 percent in February, 96 percent in May, and 80 to 90 percent the other months. At mhw inundation was approximately 15 percent in February and 50 percent in May. The average mhw for the Bolivar Peninsula site was 1.21 ft from 1 February to 31 August 1977.

Upland

201. Grasses. Of the three grass species planted 1-8 July 1976, there was no significant difference in percent survival between *Panicum amarum* (79.6 percent) and *Cynodon dactylon* (96.0 percent) on 2 September 1976 (Table 45). *Andropogon perangustatus* had significantly lower survival (9.3 percent) than the other two species. Since survival was

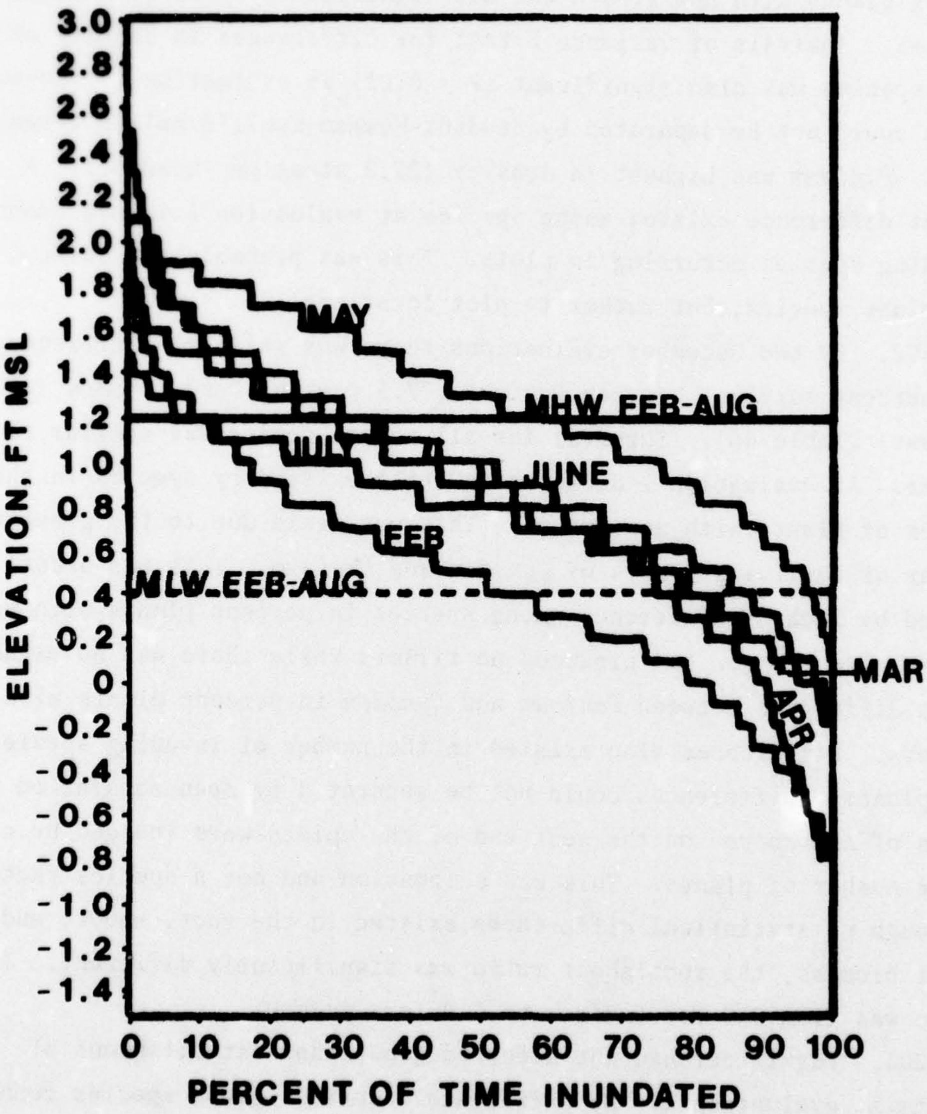

Figure 32. Percent of time of tidal inundation by month at each elevation in marshland plots

much higher in *Panicum* and *Cynodon*, the number of plants per quadrat with new growth, 8.6 and 11.5, respectively, was significantly higher ($P < 0.01$) than for *Andropogon* (1.0). However, the percentage of surviving plants with new growth was not significantly different among species. Analysis of variance F-test for differences in density of each species was also significant ($P < 0.01$) at evaluation 1. However, means could not be separated by Student-Newman-Keuls's multiple-range test. *Panicum* was highest in density (22.2 stems per quadrat). A slight difference existed among species at evaluation 1 in the number of invading species occurring in plots. This was probably not related to the plant species, but rather to plot locations.

202. By the December evaluations there was still no difference in the percent survival between *Panicum* (77.5 percent) and *Cynodon* (98.1 percent) (Table 46). Survival for all three species was similar to September. At evaluation 2 differences still existed by species in the number of plants with new growth. This was again due to the greater number of surviving plants of *Cynodon* and *Panicum*. This was ascertained by lack of difference among species in percent plants with new growth. *Andropogon* had produced no tillers while there was no significant difference between *Panicum* and *Cynodon* in percent plants with tillers. Differences also existed in the number of invading species and plants. Differences could not be separated by mean separation tests. Plots of *Andropogon* on the west end of the upland were invaded by a large number of plants. This was a location and not a species factor. Although no statistical differences existed in the root, shoot, and total biomass, the root:shoot ratio was significantly different. The range was from 0.5 for *Panicum* to 1.9 for *Cynodon*.

203. Fertilizer had not affected growth and establishment of plants at evaluation 1. No difference occurred (grass species combined) in percent survival, number of plants with new growth, and density due to fertilizer treatment (Table 47). Percent plants with tillers was significantly different by fertilizer treatment ($P < 0.05$) at evaluation 2 (Table 48). F_2 plots produced fewer tillers than F_1 and F_0 plots. Plants with new growth also were different among species ($P < 0.10$). However, this parameter reflected the lower percent sur-

vival in *Andropogon*.

204. Within each species there were no significant differences in percent survival, plants with new growth, or density due to fertilizer treatment at evaluation 1 (Tables 49, 50, and 51). At evaluation 2 there were still no differences in parameters measured on *Panicum amarum* that were caused by different fertilizer treatments (Table 52). In *Cynodon* at evaluation 2, there was a significant difference in shoot biomass due to fertilizer treatment (Table 53). The highest fertilizer rate (F_2) caused a significant increase in shoot weight over the other two rates. No other significant differences occurred in parameters measured due to fertilizer. In *Andropogon*, no differences due to fertilizer were found in the three parameters measured (Table 54).

205. Percent survival of *Panicum amarum* appeared to increase slightly to 84.7 percent by 22 June 1977 (Table 55). *Cynodon dactylon* survival had decreased to 81.3 percent. *Andropogon perangustatus* survival was only 5.4 percent after replanting in January 1977.

206. Most surviving plants of all three grasses had put out new growth (Table 55). Over 6.7 tillers per surviving plant of *Panicum* were recorded. Tillers were not recorded in *Cynodon* because of its growth form. *Andropogon* tillers were too difficult to count because of the dense growth of invaders.

207. No differences in survival due to fertilizer treatments were found in the three grasses. The lowest percent survival of *Panicum* and *Cynodon* was 74.1 percent in *Cynodon* F_2 plots (Table 56). Some plots in replication 1 were lower in elevation and survival was as low as 38 percent in some plots. Elevations in replication 1 were approximately 0.5 ft lower than elevations in replication 2. Elevations in replication 2 were generally lower than replication 3 by 0.2 ft to 0.5 ft. Some differences did exist within replications, particularly replication 1. In this replication about a 0.5-ft difference in elevation existed between plots.

208. Large differences in color occurred in fertilized *Cynodon dactylon* plots in 1977. Refertilized plots turned dark green after fertilization. The initial response of *Cynodon* to fertilizer was obvious.

209. On 19 May five 0.1-m^2 quadrats were clipped in each half of each plot of *Panicum amarum* and *Cynodon dactylon*. Dry weight of herbage was computed. Dry biomass production in *Cynodon* plots fertilized in 1976 and again in 1977 was twice as great in F_1 plots and 3 times as great in F_2 plots as those fertilized only in 1976 (Table 57). The difference was significant at $P < 0.10$. There was little difference in F_0 plots between years. The overall mean was 42.4 g per m^2 for plots fertilized in 1976 and 99.9 g per m^2 for plots refertilized in 1977.

210. *Cynodon dactylon* responded better to the 1977 heavy fertilizer application rates at the highest elevations within the 9 plots. However, with F_1 applications response was better at the lowest elevations. In fact, there appeared to be a negative response to the F_2 treatment at the lowest elevation plots with the 1977 application. A replication × year interaction was significant ($P < 0.10$).

211. In *Panicum amarum* plots differences in biomass production between fertilizer application dates (1976 versus 1976 & 1977) were not significant. However, in F_1 plots refertilized in 1977, biomass production was almost four times greater than in plots fertilized only in 1976 (Table 57). The standard error of the mean was almost half the value of the mean itself. The level of probability for differences between times of application was $P < 0.20$.

212. When fertilizer treatments (dates combined) were compared, F_2 plots of *Panicum amarum* contained over 3 times as much biomass as F_0 and F_1 plots. This was highly significant ($P < 0.05$). Biomass was 82.9 g per 0.1 m^2 in the F_2 treatment and 23.6 and 26.9 g in F_0 and F_1 plots, respectively (Table 58).

213. At the 26 September 1977 evaluation for *Panicum amarum* the additional application of fertilizer in 1977 resulted in highly significant differences ($P < 0.05$) in density and height (Table 59). Density was 88.9 stems per quadrat in refertilized plots versus 63.9 in plots fertilized only in 1976.

214. In measurements on 1977 refertilized plots (1976 plots not considered) of *Panicum amarum*, significant differences in density ($P < 0.10$), height ($P < 0.05$), root biomass ($P < 0.05$), shoot biomass ($P < 0.10$), and total biomass ($P < 0.10$) existed (Table 60). F_2 plots

had the largest and F_0 plots the smallest measurements in each parameter, except root:shoot ratio. The root:shoot ratio and seed production were not significant ($P < 0.10$).

215. Significant differences ($P < 0.10$) in shoot biomass of *Cynodon dactylon* occurred between times of fertilizer application (Table 61). Shoot biomass was 40.5 g per quadrat in refertilized plots and 29.0 g in plots fertilized in 1976 only. Total biomass was 137.2 g with the 1977 application and 99.7 g for 1976 only. Root biomass was 96.7 and 70.7 g per quadrat for refertilized plots and plots fertilized in 1976, respectively. Root:shoot ratio was greater than 2 in both treatments.

216. Fertilized plots of *Cynodon dactylon* produced greater biomass than unfertilized plots. F_1 plots produced more root biomass (133.6 g per quadrat) than F_2 (100.9) and F_0 plots (55.6) (Table 62). However, shoot biomass was greater in F_2 plots. Total biomass reflected the greater root biomass. Therefore, total biomass was greater in F_1 plots. However, none of the parameters examined were significantly different ($P < 0.10$).

217. In the upland grass evaluation in September-October 1977, differences in density and height between *Panicum amarum* and *Andropogon perangustatus* were not significant (Table 63). However, there were 63.9 stems of *Panicum* per quadrat as opposed to 22.1 for *Andropogon*. Density and height were not measured for *Cynodon dactylon*.

218. Root biomass was significantly different ($P < 0.05$) among the three species. *Cynodon dactylon* averaged 70.7 g of roots per 0.1 m^2. *Panicum amarum* averaged 35.6 g and *Andropogon perangustatus* 10.6 g. Shoot biomass was not significantly different between species. Weight was 48.6 g per 0.1 m^2 for *Panicum*, 29.0 g for *Cynodon*, and 26.7 g for *Andropogon*. Total biomass was 99.7 g per 0.1 m^2 for *Cynodon*, 84.2 g for *Panicum*, and 37.2 g for *Andropogon* per 0.1 m^2.

219. Parameter means for *Andropogon perangustatus* as a result of fertilizer treatments were not significantly different (Table 64). Survival was only 6.5 percent in F_0 and F_1 plots and 0.9 in F_2 plots. Total biomass of surviving plants sampled was 31.7 g per 0.1 m^2 in F_1 plots and approximately 46 g in F_0 and F_2 plots.

220. <u>Shrubs and trees</u>. For the shrubs and trees, there were

significant differences in percent survival at the first evaluation (Table 65). *Prunus* sp. had a lower survival rate (0.7 percent) than any other shrub or tree. *Croton punctatus* had the highest survival rate (54.9 percent) followed by *Rhus copallina* at 11.8 percent. Due to water accumulation in replication 1 of the upland, *Croton* survival was limited. Thus, the survival rate in replication 2 and 3 was higher than 54.9 percent. There was no difference in the effect of the fertilizer treatments on the shrubs and trees as a combined unit. Analyses were not run for each species on the fertilizer effect.

221. At evaluation 2 there was an apparent effect of fertilizer on the survival of all shrubs and trees (Table 66). However, this effect did not appear to be the same for each species. Survival (percent) was the same as the first evaluation for each species, except *Rhus copallina* had declined slightly from 11.8 to 9.0 percent.

222. For the trees and shrubs planted in January 1977 and evaluated 22 June 1977, percent survival was significantly ($P < 0.05$) different among species. Greatest survival occurred in *Quercus virginiana* (94.4 percent) followed by *Rhus copallina* with 72.9 percent (Table 67). One replication of *Croton punctatus* that was low in elevation had almost no survival. Thus, the overall percent survival of *Croton* was lowered to 20.8 percent. *Pinus clausa* and *Tamarix gallica* both had about 34 percent survival. Differences by fertilizer treatments were not significant ($P < 0.10$) in the combined species.

223. Height was significantly ($P < 0.01$) different among species. *Tamarix gallica* was tallest (90.2 cm) followed by *Quercus virginiana* (81.0 cm). Differences in height by fertilizer treatment in combined species were not significant ($P < 0.10$). However, a species × fertilizer interaction was present. Analyses for each tree and shrub species were not run for the 22 June evaluation.

224. At the 26 September 1977 evaluation, survival in *Quercus virginiana* had risen slightly to 96.5 percent. Apparently one tree believed to be dead in June had survived. *Rhus copallina* survival had dropped to 66 percent (Table 68). Survival in *Myrica cerifera* was 62.9 percent. Survival in *Pinus clausa* and *Tamarix gallica* dropped slightly to 28.4 percent and 31.9 percent, respectively. *Croton punctatus* sur-

vival remained above 20 percent.

225. Height on 26 September 1977 was about the same in *Quercus virginiana* (78.9 cm), *Pinus clausa* (25.2 cm), *Rhus copallina* (39.3 cm), and *Myrica cerifera* (36.8 cm) as in June. It had increased to 106.9 cm in *Tamarix gallica* and to 41.7 cm in *Croton punctatus*.

226. Root biomass for *Pinus clausa* increased from 0.7 g at time of transplanting to 2.4 g per plant in September 1977. Shoot biomass had increased from 3.0 to 4.2 g. In *Tamarix gallica*, no roots were present initially. In September root biomass was 25 g per individual. However, part of the rooted stem was included in this weight. Shoot biomass had increased from 65.0 g to 80.1 g. In *Quercus virginiana* root biomass had increased from 26.0 to 69.8 g per plant. Shoots had increased from 25.6 g to 48.6 g. In *Rhus copallina* root biomass increased from 23.5 g to 42.9 g per plant. Shoot weight had increased from 9.8 g to 20.7 g. In *Croton punctatus* root weight was only 0.1 g initially versus 24.9 g in September 1977. Shoot weight was initially 0.8 g and had increased to 393 g in September. *Myrica cerifera* root weight had increased from 5.3 to 37.5 g. Shoots had increased from 5.9 g to 39.2 g (Table 68).

227. Significant differences in survival due to fertilizer treatments in shrubs and trees were found only in *Myrica cerifera*. Greatest survival was found in F_0 plots (87.5 percent) (Table 69). Next highest was F_1 plots (62.5 percent) and lowest was F_2 plots (38.8 percent). Similar trends were evident in *Rhus copallina*, *Quercus virginiana*, and *Pinus clausa*. However, these differences were significant.

228. High fertilizer rates significantly increased height in *Pinus clausa* (Table 70). *Croton punctatus* height followed a similar trend, but no significant differences were measured. Root biomass (Table 71) and shoot biomass (Table 72) in shrubs and trees were not significantly affected by fertilizer treatments. Root:shoot ratios in none of the species were different as a result of fertilizer treatments (Table 73). No significant difference ($P < 0.10$) in total biomass was found as a result of fertilizer treatments (Table 74).

229. <u>Invading plant species</u>. The upland tiers planted to grass did not change much between 2 September and 9 November 1976 (Table 75).

From 0.3 to 2.4 species occurred on the average in each fertilizer treatment in each grass. The number of invading plants (species combined) doubled in *Andropogon perangustatus* plots between 2 September and 9 November 1976 (Table 76). Number of invading plants remained about the same in *Panicum amarum* and *Cynodon dactylon* plots.

230. The largest invasion of species and plant numbers occurred in the highest elevation tier (Table 77). *Cyperus esculentus* was the most numerous invading species in control plots. It was found in all three tiers of the upland. *Scirpus americanus* was the next most numerous species and occurred in all three tiers and in about 50 percent of the quadrats. *Ambrosia psilostachya* (western ragweed) and many unknown forb seedlings were found in the shrub and tree control plots. *Sporobolus virginicus* and *Spartina patens* were frequently encountered in all tiers. Some members of the nightshade (Solanaceae) family were present in some tree plots. *Fimbristylis castaneum* was frequently counted in the grass tier but was not recorded in any other tier. Most other species were not recorded frequently.

231. On 19 May 1977 weight of invading plants was not significantly different due to rate of fertilizer on either *Cynodon dactylon* or *Panicum amarum* plots (Table 58). Weight of invaders also was not significantly different due to time of application (1976 versus 1976 & 1977) in *Cynodon* plots. However, in *Panicum* plots significant differences ($P < 0.10$) existed in weight of invading plants between once-fertilized and refertilized plots (Table 57). There were 10.2 g per m^2 in refertilized plots and 3.4 g per m^2 in plots fertilized only in 1976.

232. Miscellaneous environmental effects. No miscellaneous environmental effects were recorded in trees or shrubs at evaluation 2 of the upland (Table 78). Erosion and drowning of plants by the wetness of soil occurred at the western end of *Panicum amarum*, *Cynodon dactylon*, and *Andropogon perangustatus* plots. Sand burial by blowing sand also occurred in the eastern end of *Cynodon dactylon* plots.

233. Except for sand burial and wet soil in the plots, environmental effects on plants were negligible during the rest of the study period. An exception was the high tides created by Hurricane Anita,

which moved westward across the Gulf of Mexico in early September. Tides reached into the lower replications of *Panicum amarum*, *Cynodon dactylon*, *Andropogon perangustatus*, and into parts of the second tier of shrubs. *Cynodon* was burned by the salt water. Brown color of the grass indicated that 3 plots on the western end of the study area had been affected. This brown color was later replaced by green as the plants recuperated. *Panicum* apparently was not affected by the tide. No plants were still alive in *Andropogon* and shrub plots on the western side of the experimental area to evaluate effects.

Discussion

Marshland

234. Of the parameters measured in the plots, density should not be overemphasized in initial analyses. Density was related to the total biomass produced, but it was not a good index of tiller production by each plant. Instead, density reflected plant survival. With greater survival, greater density occurred. In evaluations near the end of the study, plant density still reflected initial plant survival. However, after survival could no longer be measured, density was the only parameter to adequately reflect tiller production.

235. Individual transplants could still be located through the winter 1977. However, by the end of spring 1977, tiller production was so numerous and widespread, original transplants could not be identified, and survival could no longer be recorded. To still account for low survival in some plots, the number of stems per quadrat was divided by the number of surviving plants in that quadrat at evaluation 6. That allowed further evaluation of production for original transplants. This gave another parameter in addition to plant density for evaluation purposes.

236. The number of stressed and stable plants was based on subjective measurements. However, the measurements indicated treatments that resulted in depressing plant establishment prior to actual death. Some severely stressed plants did recover. In fact, some plants

recorded as dead at one evaluation would produce new shoots at later evaluations. This was reflected in increased survival reported for *Spartina patens* in at least 2 evaluations. Surviving plants were recorded as either stable or stressed. Therefore, plants that were marginal were placed in one of the two categories. A third category considering the marginal plants may have been of benefit in the analyses.

237. Slight differences in elevations among treatments within the same tier and block hampered statistical analyses of original marshland plots. Differences in plant response within a single treatment due to elevation were sometimes obvious. In some instances, fertilizer response may have been masked by elevation response.

238. Response of each species to fertilizer treatments varied by tier. This response was to both fertilizer treatments and small changes in elevation within each tier. Survival was particularly erratic in elevation tier 2. Tier 2 of original plots corresponded in part to elevation 1.50 to 1.75 ft in one-fourth-size plots. Survival and density of *Spartina alterniflora* in that zone in the July evaluation were less than in the lowest elevational zones. Similar differences in survival by elevation were found in the May-June planting. Some of these zones still corresponded to tier 2 of original plots. The one-fourth-size plots were analyzed by elevation zones to eliminate elevational differences. Differences by fertilizer treatments were not biologically significant in this analysis.

239. Elevation did appear to affect each species differently. *Spartina patens* was better adapted to elevations not inundated by tides except at infrequent intervals. In contrast, *S. alterniflora* appeared adapted to grow at all elevations, except at approximate mhw. This zone of low survival appeared to be related more to season of the year than elevation. Since tide charts did show wide ranges in mhw and percent of inundation in each month, the movement of the "kill" zone was understandable. Apparently, the growing-limiting parameter or parameters fluctuate in relation to the tide. Soils analyses indicated that ac-

cumulation of salts at approximately mhw was affecting plant survival and growth.

240. Plant survival declined over time. The initial 5 evaluations detected the ability of some plants to remain alive for long periods before death occurred. New tillers and new growth of *Spartina alterniflora* in August 1976 indicated that this species could be transplanted during summer months with no problems. However, *S. patens* transplants in July did not develop new growth until the 21-22 September evaluation. After the February plantings, growth occurred as soon as the temperature was adequate. This indicated that summer planting of *S. patens* resulted in limited growth and vegetative reproduction until the weather cooled and precipitation increased in September.

241. Survival and new growth of *Spartina patens* was lowest in F_4 plots. However, this was probably the effect of elevation and not fertilizer. Initially, differences between fertilizer rates had to be anomalies, because F_4 and F_1 rates were the same until the second application in the F_4 treatment. *S. patens* F_4 plots were generally situated at lower elevations than other treatments. Thus, the lower elevations were reflected in the lowered survival in F_4 plots.

242. The initial lower survival of *Spartina alterniflora* transplants during July in F_2 treatments plus higher survival in F_0 treatments indicated an adverse fertilizer effect on *S. alterniflora* transplants. Plants in one-fourth-size plots probably did not show a similar adverse effect in survival to fertilizers because of the cool weather and consequently slower absorption of nutrients. Marshland plants did retain green color throughout the winter 1976, but the seed stalks did mature. Thus, limited growth did occur during this period even though a lower mean plant height was measured.

243. From laboratory tests it appeared that ideal planting depth for *Spartina patens* was 2.5 cm. The planting of seeds with the disc and tractor resulted in the placement of seeds from the soil surface to a depth of approximately 2.5 cm. With 125 viable seeds per m^2 enough seeds should have been placed at proper planting depth to prevent planting depth from becoming the limiting factor in seedling establishment.

244. Seeds produced in fall 1976 from July transplants of *Spartina alterniflora* fell into the mud beneath plants. Tidal fluctuation moved many of the seed to other locations and seed germination occurred throughout the entire marshland in January 1977. Apparently, low winter tides coupled with occasional warm temperatures encouraged germination and establishment of seedlings. Bay waters are generally too salty to allow photosynthesis by terrestrial plants with leaves beneath the water. Clay and silt particles also tended to coat plant leaves. Wave action, because of low tides, was not detrimental to seedling establishment during January. Thus, tide conditions were probably more satisfactory for germination and establishment in winter than during spring (March) when planting was conducted. Seed germination (from sprigged plants) in December 1977 at all elevations of the marshland indicated that prolonged cold storage of seeds was not required to break dormancy.

245. Most seeds planted in March 1977 germinated. However, continuous high water prevented some observations at lower elevations. It appeared that seedlings could not survive when covered by silty water. The high tides also resulted in waves washing plants from the soil. The dike was not maintained at an elevation high enough to prevent fairly rigorous wave action. Plants were able to establish only where inundation and wave action were infrequent or did not occur. Dry conditions at the highest elevations also prevented seedling establishment. Plants at some of the higher elevations remained in the 1- or 2-leaf stage several weeks before dying.

246. In comparing January and March tides, mlw for the 6-week seedling evaluation period was approximately where the hlw level was during the period of volunteer seedlings in January. In past, tides only covered the lower 3 to 4 rows of plots for short periods of time in January. In contrast, tides covered most of the lower 8 to 10 rows of plots during the evaluation period.

247. Tidal ranges varied from month to month and season to season. Apparently, this affected the elevation at which sprigged plants survived and grew. Comparisons of the February and May-June one-fourth-size plot plantings indicated that the higher tides in May-June allowed

good survival and growth at higher elevations than previously evident from the original plots. This was particularly evident for *Spartina alterniflora.*

248. Plant density in seeded plots with good survival was greater than in sprigged plots at equivalent evaluation periods. However, the inability to establish seeds at all elevations without the possibility of failure due to tide level makes the use of sprigs more feasible. Establishment of plants from seed may be possible at all elevations under the proper tidal regime.

249. Animal damage occurred only at higher elevations. This seemed to reflect rabbit habits. They seldom enter water or mud to feed. The rabbits were observed to venture into lower elevations only during extended periods of low tide.

250. Monitoring of caged and uncaged plots did not prove to be of value. Geese, ducks, and other birds that might severely damage vegetation did not utilize the Bolivar Peninsula site. Rabbits were excluded by the perimeter fence and those inside the fenced area were removed. With death of some or all of the four plants sprigged into caged plots, statistical comparison of caged versus uncaged plots was not possible.

Upland

251. Large differences in elevation within and among replications affected the analysis of species adaptability and fertilizer effects. Plots in replication 1 of grasses and *Croton* were particularly affected by abnormally high tides and drainage following precipitation. Survival and growth of all three grass species and *Croton* were both severely affected. The large standard error of the mean of F_2 plots of *Panicum amarum* in 1976 and 1977 indicated the large variability within the data.

252. Elevation and undulating terrain may be critical factors in plant establishment in upland areas. Generally, too much water, which may occur in depressions or from high tides, should be avoided for most species. *Tamarix gallica* could be an exception. It appeared to establish equally well in xeric and mesic habitats.

253. Invading plants were probably prevented from growing in many *Cynodon dactylon* plots by the thick ground cover. In *Panicum amarum*

plots the open areas between plant stems allowed more invaders. Invaders did appear more in fertilized plots than unfertilized plots of both species. F_2 fertilizer rates apparently promoted establishment by invaders.

254. Time of planting did not seem to matter with the grass species. However, slightly better survival was attained in *Andropogon perangustatus* planted in January than in July. In trees and shrubs, timing of plantings could be critical. During dormancy of trees and shrubs, planting shock is much less severe. Soil moisture, air temperature, and phenology usually favor winter planting over summer.

255. Cutting and removing invading plants around transplants may be necessary. *Sesbania drummondii* was a prolific plant. As a result, available soil moisture, nutrients, and sunlight to transplants may have been absorbed by this plant. If transplants did survive, growth would probably have been reduced. Other invading species, particularly grass species, may not need to be removed. However, in this experimental study, every effort was made to evaluate effects of fertilizer on each transplant without outside variables. Therefore, invaders were removed in transplant plots. The vegetation on control plots was not disturbed. This facilitated evaluation of invaders.

256. Since tree and shrub species are normally slower growing plants than grass species, the effects of fertilizer on parameters other than survival may not be noticeable until the plants have grown for several years. Thus, repeat fertilization each year would be necessary to document effects.

257. Analyses of root, shoot, and total biomass on 0.1-m^2, 25-cm-deep samples may result in erroneous conclusions. Although samples were taken as randomly as possible, living plants were selected. By selecting plants rather than areas, estimates of the total biomass for the entire plot cannot be made. The unvegetated areas were not sampled. Actual analyses were of biomass produced by surviving plants in each plot. However, this technique will provide valuable data when the plant density has stabilized.

258. Analyses among species other than survival also may be

misleading. The growth habits of each species are different and comparing such parameters as height and biomass of different species may be of limited value. Comparsions within species is valuable.

259. Emphasis in upland planting appeared to be placed on fertilizer response. More considerations should probably be given to elevational ranges of each species. Limited survival of some species seemed to occur at lower, wetter elevations and at the higher, drier elevations. Planting across elevational ranges may be necessary to adequately predict survival and growth of at least some of the species.

260. Rabbits and large mammals are detrimental to *Panicum amarum* and probably other species. Initial protection of plants may be necessary for adequate survival and growth and to provide erosion control.

Conclusions

Marshland

261. *Spartina patens* seeds can be stored at ambient temperatures. However, viability of seeds declines sharply after 5 months of storage. *S. alterniflora* seed viability also declines sharply after 5 months of the recommended cold-wet storage.

262. Successful seeding of marshland areas is apparently dependent on continuous or frequent low tides. Emergent seedlings of either *Spartina patens* or *S. alterniflora*, below mhw, are prevented from establishing due to washing of soil from around seedlings and by silt particles in the water reducing light needed for photosynthesis. Establishment of natural seedlings during low tides in January 1977 and 11 months later in December 1977 indicated seedlings can establish if low tides and warm temperatures occur concurrently.

263. Sprigs of *Spartina alterniflora* were extremely successful or partially successful at all elevations of the marshland. A zone at approximate mhw affected survival. Below this zone survival and growth of *S. alterniflora* was good. Best survival, growth, and tiller production was at approximately 0.50 to 1.00 ft below mhw. Above mhw *S. alterniflora* survival was slightly limited. In addition, plant height

and number of stems was less than at the lower elevations.

264. *Spartina patens* survived and grew successfully only at elevations above mhw. Best survival and growth was achieved at the highest elevations in the marshland plots.

265. Fertilizer treatments did not result in significant differences in survival, tiller production, height, or seed production in either species. In fact, fertilization at time of planting may have been slightly harmful to transplant survival. Best results of fertilizer treatments were generally from split applications. From an economic as well as biological standpoint, initial fertilization of transplants probably is not necessary.

266. Better survival, tiller production, and growth of *Spartina alterniflora* can be achieved by planting in months of warm weather. However, winter plantings produce a denser stand of stems by the end of the growing season despite lower initial survival. Thus, a protective vegetative cover can be attained in marshland rapidly with either late fall or winter plantings. Tiller production is normally numerous the following spring. If immediate plant cover is not required, warm weather planting may be more easily accomplished.

267. Tides fluctuate by seasons of the year. The amount of inundation at each elevation affects plant establishment. Limited growth of *Spartina alterniflora* and *S. patens* can be expected at the mhw mark.

268. Rabbits and nutria utilized *Spartina alterniflora* and to a lesser extent *S. patens*. Protection of recent transplants may be necessary to allow rapid establishment.

269. Protection from wave action is essential in the establishment of *Spartina alterniflora* and *S. patens*. Only limited establishment can be expected in high wave energy areas. Sandbag dikes can be effective wave stabilizers, but may be economically unfeasible. Some scouring and channel formation should be expected in newly established marshlands. Increased elevation due to silt deposition also should be expected, particularly adjacent to the dike.

270. Single stems of *Spartina alterniflora* and 5-8 stems of *S. patens* with associated roots appeared to be satisfactory transplant material. Single stems of *S. alterniflora* and small clumps of *S.*

patens can be more easily handled and are more economical than larger masses of transplant material.

271. Invading species at low elevations was limited to *Spartina alterniflora* seedlings, established from seeds produced from original transplants. At elevations above mhw invading species may include local plants adapted to the marshland environment.

Upland

272. *Cynodon dactylon* and *Panicum amarum* are well adapted for survival and growth in sandy dredged material along Bolivar Peninsula. However, survival of *Cynodon* is prevented by tidal inundation and frequently flooded or wet soil. *Andropogon perangustatus* did not survive well after transplanting in the summer of 1976 and again did poorly in the January 1977 planting. Although this species grows under similar natural conditions, transplantation does not seem feasible.

273. *Cynodon* and *Panicum* both grew better with fertilization. Repeated applications each year are desirable for better growth and production. For *Cynodon* F_1 rates were better at all elevations than F_2 rates. F_2 rates may have been harmful at lower elevations. For *Panicum* F_2 rates produced the best growth and production.

274. The establishment of invading species is inhibited due to rapid growth of *Cynodon* and *Panicum* . Invader species varied by elevation. Greatest invasion occurred at intermediate elevations. Too wet or too dry conditions prevented invasion of plots.

275. Winter plantings of trees and shrubs is better suited for survival and growth than summer plantings. Elevations are critical elements of survival for each species. *Tamarix gallica* cuttings require moist substrate for initial survival and growth. *Pinus clausa* grew better with moist soil. Dry conditions eliminated this species. *Croton punctatus* could not survive in wet soil but grew well in dry soil. *Quercus virginiana*, *Rhus copallina*, and *Myrica cerifera* appeared to have the widest tolerance range to soil moisture conditions. These three were the best adapted tree and shrub species utilized.

276. Fertilizer apparently lowered survival initially in tree and shrub species. However, the effects were not highly significant.

Fertilizer did seem to promote growth after the initial establishment for most species.

PART V: FAUNA

277. The objective of the terrestrial vertebrate study was to describe the avian and mammalian utilization of the wetland and upland habitats developed at the Bolivar Peninsula field site. Data collected on population densities and diversities were compared to similar data collected from nearby reference and control areas.

278. Terrestrial vertebrates in the Texas coastal marshes have not been studied in the past unless they were of game or other economic value (Lynch 1967, Chabreck 1972). Recent studies provided data on population estimates and occurrence of vertebrates within a limited portion of the available coastal marshes along the upper Texas coast (Stutzenbaker 1970, Lee 1976). Lee's (1976) research was conducted in an area adjacent to the present field site.

Methods

Small mammal populations

279. Small mammals were trapped for four consecutive nights on five occasions between September 1976 and August 1977. Fifty Sherman live traps were placed in three different grids and baited with hen scratch (1:1, corn:milo). The grids in the experimental (E) area and the control (C) area (Figure 33) were five rows of ten traps spaced so that the area covered was 1.67 and 0.95 ha, respectively. The reference (R) area contained 50 traps placed 15 m apart in five rows of ten traps and covered 0.81 ha.

280. The vegetation of the control area was predominately *Sesbania drummondii* with an understory dominated by genera of the family Compositae. There was also a small, unvegetated area of sand and shell, and some stands of *Spartina patens*. The reference area was mostly a *S. patens-Andropogon perangustatus* marsh. There were also some areas of *Sesbania drummondii* with a Compositae understory.

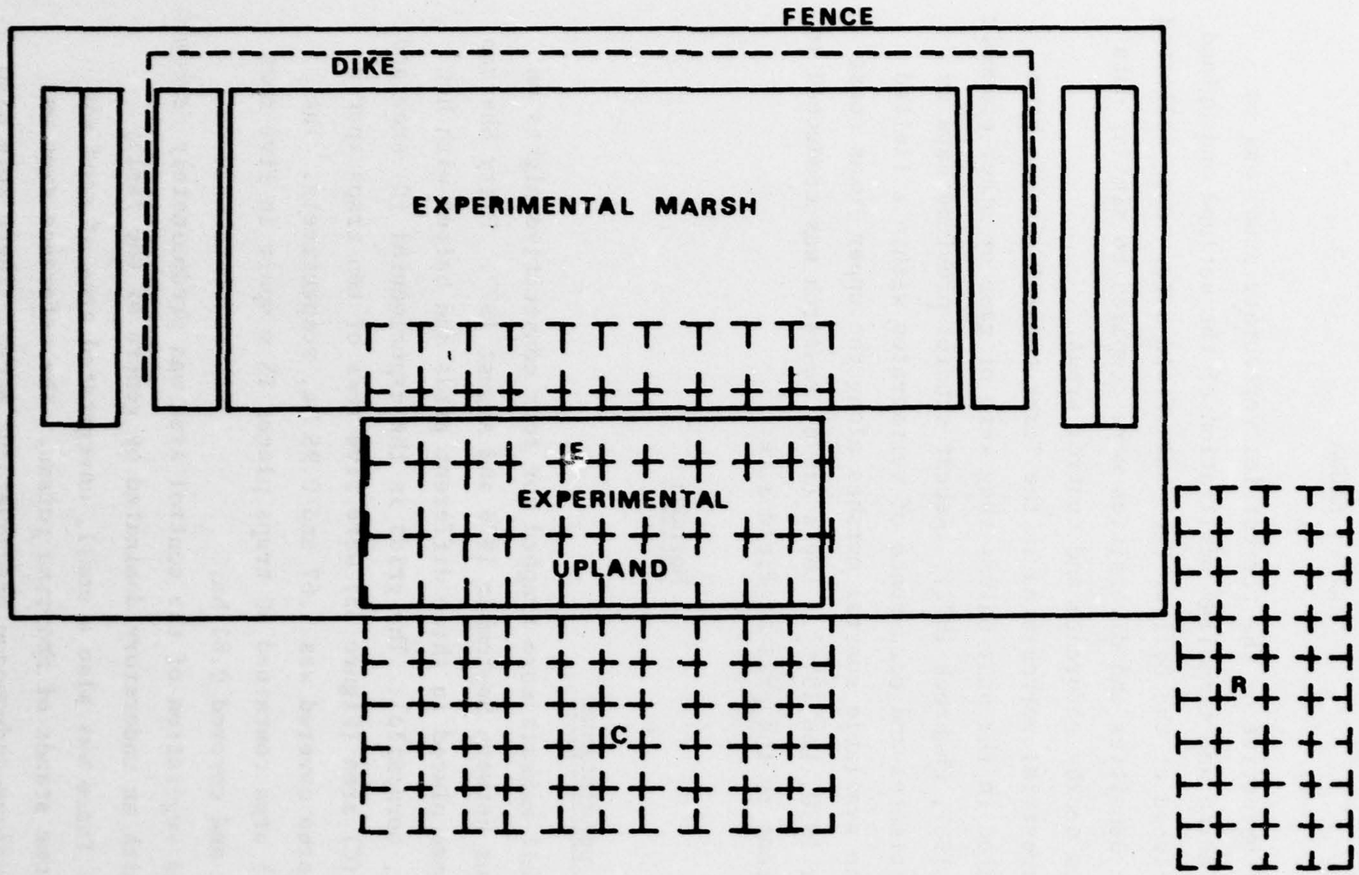

Figure 33. Field location of small mammal grids in the experimental, reference and control areas on the Bolivar Peninsula study site. E = experimental, C = control, and R = reference area

281. Small mammals captured in the live traps were identified to species according to Davis (1974). Taxonomic nomenclature followed Jones et al. (1975). Animals captured were weighed, sexed, aged, and toe clipped for later identification before release at the site of their capture. Small mammals captured on the experimental grid were removed to reduce damage to the planted vegetation. Animals captured are reported as number trapped.

Larger mammal populations

282. Larger animals (*Procyon lotor, Didelphis virginiana*) were caught with large live traps (Tomahawk Co., Tomahawk, Wisconsin) baited with dead fish. Any mammal captured was removed from the island to reduce interference with the small mammal trapping efforts. *Sylvilagus* sp. were hunted during the day and at night with use of a head lamp, and were removed from the experimental area as collected. Observations of tracks and scats were used to detect other mammals on the study site, which were not recorded in trapping efforts. No population estimates were made on these data.

Reptiles and amphibians

283. Any reptile or amphibian seen in the marsh or upland habitat was identified according to Conant (1975) and its presence recorded. These data were not analyzed for population estimates.

Avian populations

284. A general survey of the bird species present on the study site was conducted in July 1976, before actual sampling began, to acquaint the observer with the bird species present. Beginning in August 1977 the avian community in the marsh and upland habitats was sampled using transects with 10-minute observation points spaced equidistant as described by Anderson (1970) and Bond (1957). Birds seen while the observer was at an observation station were recorded as to the section of the transect the bird occurred on. The width of

all transects was determined by the experimental design of the planted area and the length of marsh transects was determined by tide levels (Figure 3).

285. The study site was surveyed using four transects for the August 1976 to December 1976 period (Figure 34). The openness of the study area allowed the observer to see every bird on the area with 10X binoculars and assign the spotted bird to its position on the study area. During January and February 1977, nine transects were used to more thoroughly sample the study area. In March 1977 two transects (two and six) were eliminated since the habitat being sampled *(Sesbania drummondii)* was the same as the control area, but not representative of the experimental area (Figure 35).

286. Bird densities for each species were reported as number per ha of each habitat type within the study area. Due to the openness of the area the birds seen on the census trips represented a total count of the number present. Density was thus calculated by adding up the total of birds per species seen on each transect within a habitat type and dividing this by the number of census trips per season in each habitat type. The resulting value is the average number of birds per species seen in each habitat per season. Dividing that number by the area of the habitat censused provided the density per ha per season for any species considered. The area of two habitat types (experimental and reference marsh) changed as the tides changed because the transect length would increase or decrease. The area of each habitat type per season is presented in Table 79.

287. Diversity was also calculated from the average number of birds per species on each transect each season. The Shannon index, in base 2, was computed from tables prepared by Lloyd et al. (1968).

288. The censuses were generally conducted on two consecutive mornings twice a month. The census period began one half hour after sunrise and lasted no more than two hours. This time period would not allow all transects to be walked in one morning, so as many as possible were run the first morning and the remainder the following morning. The order in which the transects were walked was randomly selected.

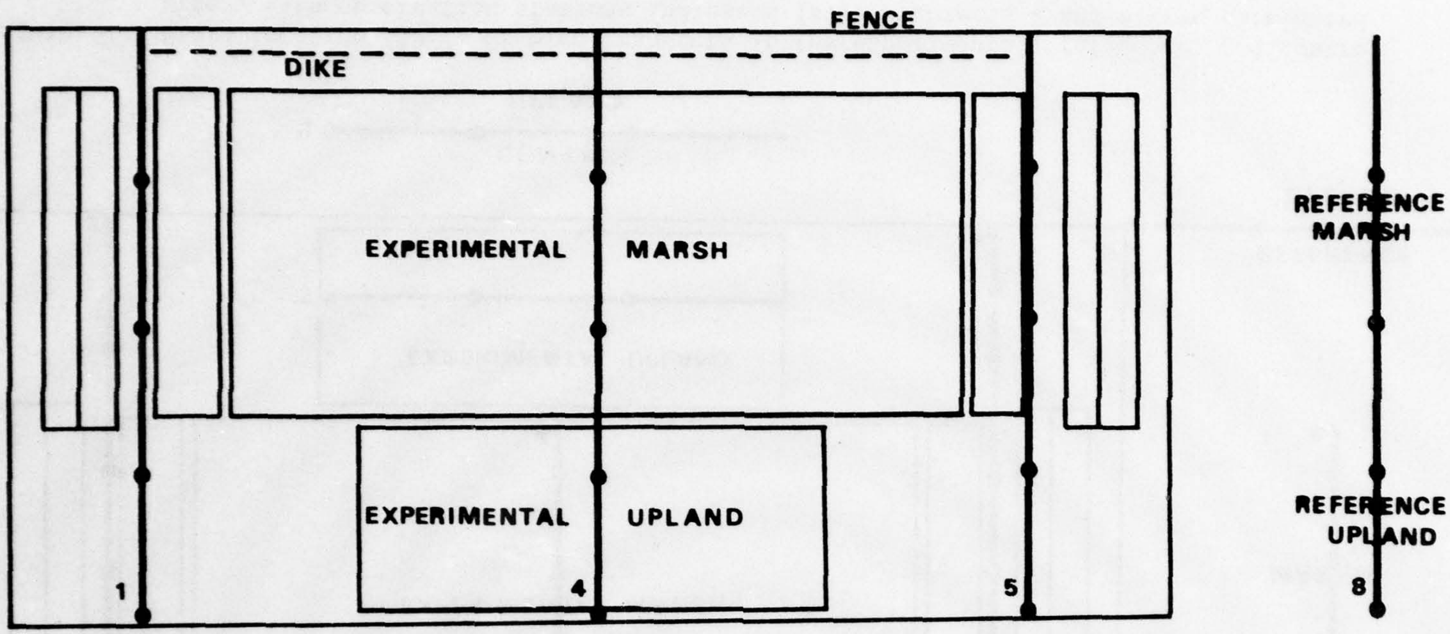

Figure 34. Field location (1976) of bird transects in the experimental and reference areas, with observation stations indicated (●)

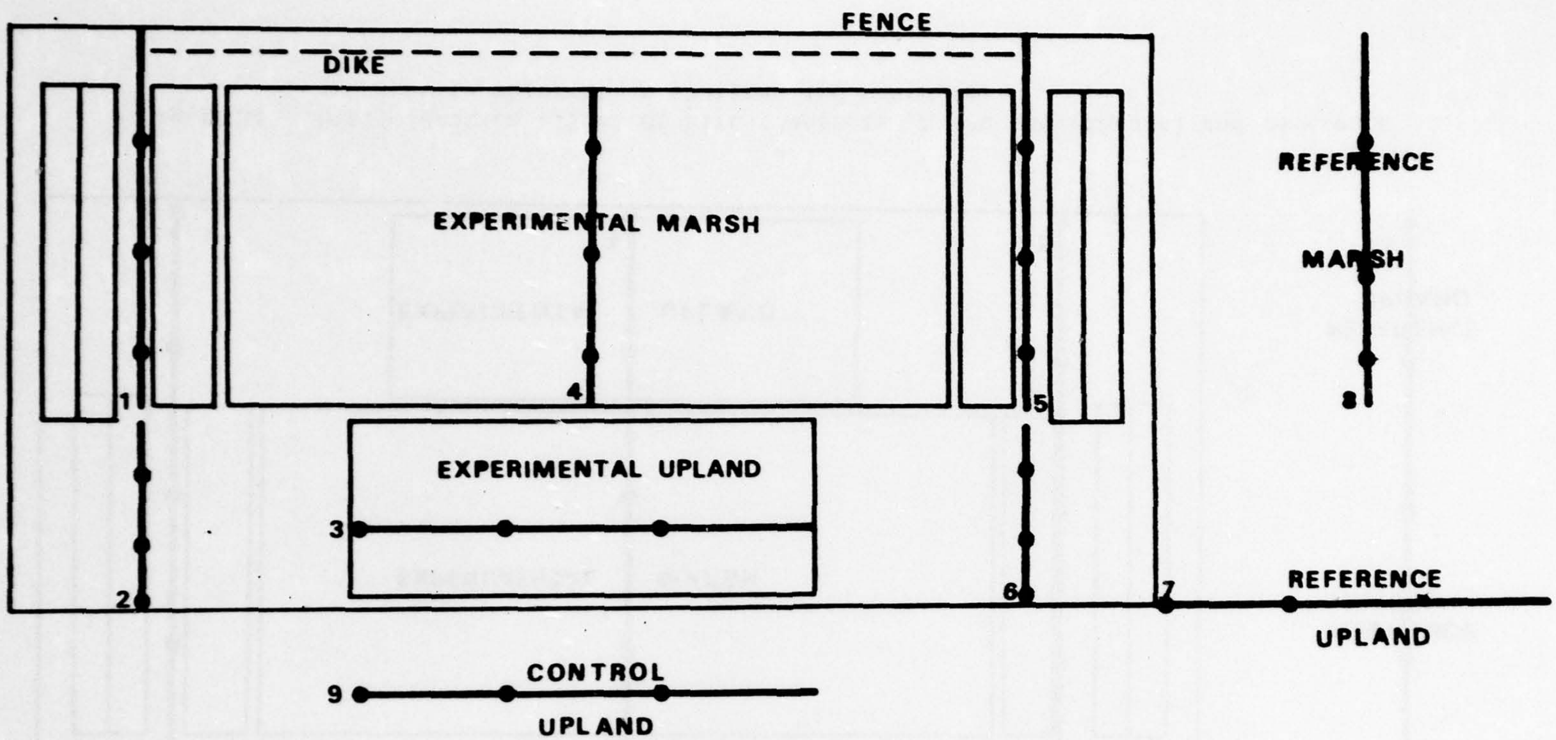

Figure 35. Field location (1977) of bird transects in the experimental, reference, and control areas, with observation stations indicated (●). Transects 2 and 6 were eliminated in March 1977

If two observers worked, then all transects were walked in a single morning.

289. Birds seen on the study site were also recorded at times other than the census periods. These data represent birds that are found along the upper Texas coast and provided an indication of the migration patterns and season designations for this study. The seasons chosen were June-July, summer; August-November, fall; December-February, winter; and March-May, spring.

290. Nest searches in the experimental, control, and reference areas were conducted at 2-week intervals from March through June 1977. Plots were chosen from the existing mammal grids with trap station stakes marking the corners of the plot (Figure 33). A 1 m path along the perimeter and two diagonals of each plot were searched for nests on the ground or in the vegetation. The area covered in each plot was approximately 100 m^2. Five plots on each area were searched at 2-week intervals, with all plots being searched at least once. Birds nesting in sparsely vegetated areas were often detected by noting bird activity at or near the nest site. All nests and scrapes found were identified, marked, and revisited at least twice. Data collected from the nests included species, number of eggs, number of young, days to fledging, and success of the nest.

Results

Small mammal populations

291. Twelve species of mammals were either captured or seen on the study site, excluding domestic livestock (Table 80). The *Vulpes vulpes* recorded was seen on the peninsula about 2 km south of the study area. Other coastal areas in Texas have been recorded as having as many as 25 mammal species (Blair 1950).

292. The results of the small mammal trapping indicate that *Sigmodon hispidus* was the dominant small mammal in the reference area during all seasons (Table 81). It was captured in the control

area during seasons when the vegetation, especially *Sesbania drummondii* and its associated ground cover, was dense, but was captured in very small numbers during the dormant plant season (February). *Sigmodon hispidus* moved into the experimental upland area in August 1977.

293. *Mus musculus* was more frequently captured in the control area. Slightly more captures of *M. musculus* occurred in the experimental upland than the reference area, while only one *M. musculus* was captured in the experimental marsh. Except for the September 1976 trapping period, the *M. musculus* population appeared to exhibit an inverse relationship to the *S. hispidus* in the control area. *M. musculus* seemed to prefer less heavily vegetated areas.

294. The other two species of small mammals, *Oryzomys palustris* and *Rattus norvegicus*, were rarely captured. *R. norvegicus* was only captured at the beginning of the trapping in September 1976 and was not trapped in succeeding trapping periods. *O. palustris* was more frequently captured in the reference area, although occasional captures occurred in the control area. A single *O. palustris* was captured in the experimental marsh at the end of the study (Table 81).

Larger mammal populations

295. Larger mammals in the marsh habitat consisted of four species: *Myocastor coypus*, *Lutra canadensis*, *Dasypus novemcinctus*, and *Sylvilagus floridanus* (Table 82). All except *S. floridanus* were seen on rare occasions within the experimental area. There were 29 *S. floridanus* and three *S. aquaticus* collected and removed from the experimental upland during this survey (Table 82). Seven *Procyon lotor* were trapped from the experimental area and removed from the island. *P. lotor* are numerous on Bolivar Peninsula (Lee 1976); however, they did not interfere with the small mammal trapping. On the control and reference areas, *Sylvilagus* sp. were numerous and signs of *Procyon lotor*, *Didelphis virginiana*, and *Capra hircus* indicated these species were common on the island.

Reptiles and amphibians

296. Population estimates on reptiles and amphibians were not made, but records were kept of sightings or indirect evidence of their presence. No reptiles or amphibians were noted in the marsh habitats. In the upland areas, *Terrapene ornata*, *Heterodon platyrhinos*, *Lampropeltis getulus*, and *Phrynosoma cornutum* were the only reptiles observed (Table 82). Several other reptiles are known to occur in this area (Lee 1976).

Avian populations

297. A total of 135 avian species were observed either on the Bolivar Peninsula study site or flying over the site (Table 83). Many of these species were observed at times other than the census periods. The lowest number of species recorded (27) occurred in July 1977; the highest number (54) was recorded in April 1977. The average number of species observed each month was 36.3. The summer and winter seasons showed the lowest average species numbers; a slight increase occurred during the fall, and a marked increase was noted during the spring season (Figure 36).

298. Table 84 is an indicator of the type of habitats available on the field site. For example, Ciconiiformes and Charadriiformes, both water-dependent groups, had greater than 60 percent representation. However, only 18 percent of the Anseriformes were recorded on the study area. Many tree-dependent orders (Piciformes, Strigiformes) were poorly represented, but normally tree-dependent Passeriformes were seen on the site during spring migration.

299. The data in Tables 85-89 indicate the experimental marsh was important to resident as well as migratory species. It contained more species than the reference marsh in all seasons. Two new species were observed for the first time on the experimental marsh in December 1977. These were *Cistothorus platensis* and *Ammospiza maritima*. The experimental upland was not preferred over the reference uplands.

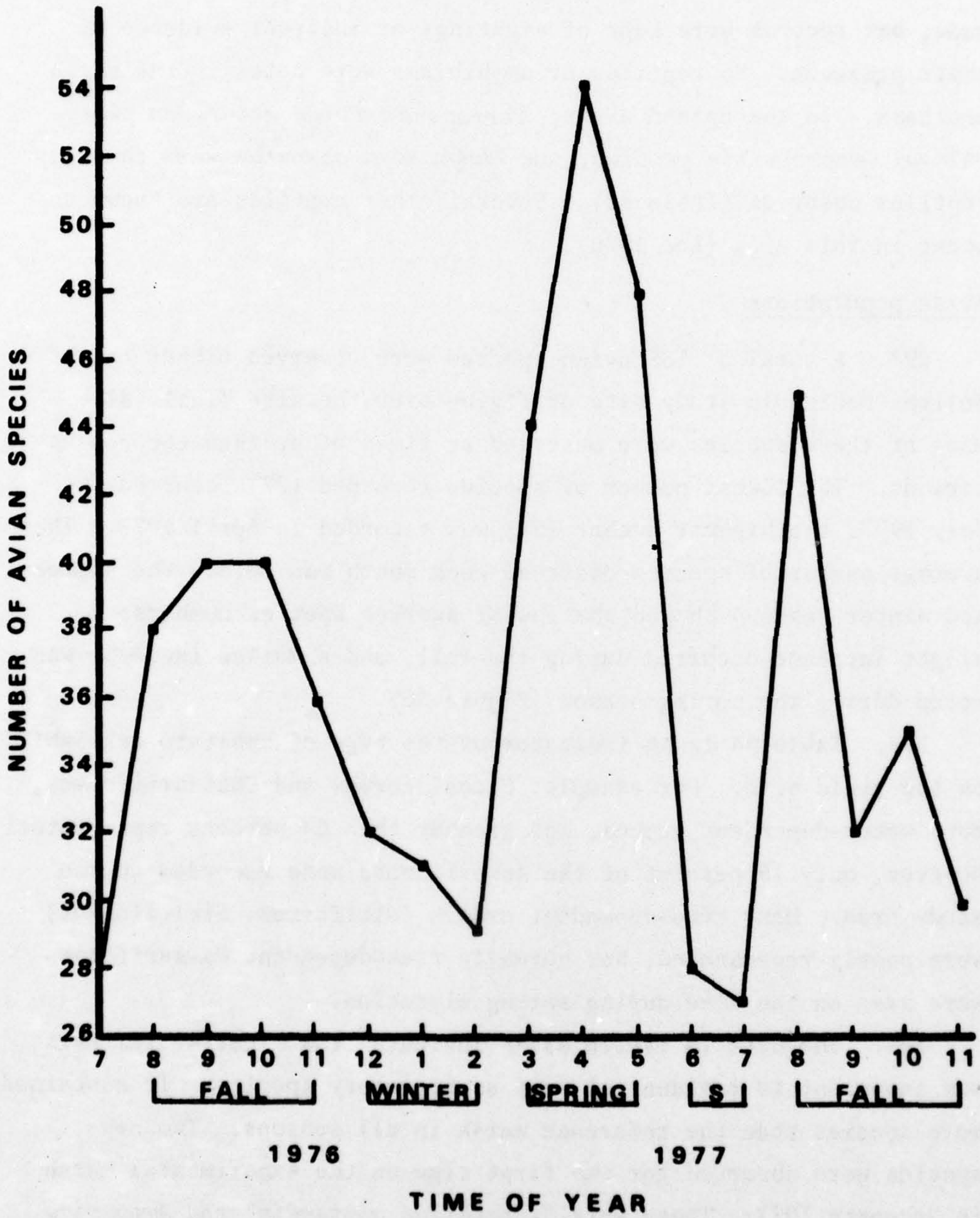

Figure 36. Total number of species seen each month on the Bolivar Peninsula study site

300. Density of birds within a habitat is an important factor in the understanding of avian ecology. This may be approached as number per ha of habitat or number of ha per individual bird in those species with large territories. Generally, densities on the study area were low (Table 85-89). High species densities were usually seen only in gregarious species (*Larus atricilla, Agelaius phoeniceus*).

301. Bird densities were higher in the fall of 1977 (Table 86) than the fall of 1976 (Table 85) except on the experimental upland. The lowest average densities of birds recorded in the marsh habitats were in the 1976-1977 winter season (Table 87). However, the experimental upland showed its highest density during the winter season. The spring 1977 season showed an increased average density in all habitats except the experimental upland (Table 88). Densities again increased in the summer of 1977 (Table 89), except on the experimental marsh, where they remained near the spring level.

302. The diversity data for each transect during this study indicate that the spring 1977 season showed the greatest diversity for all transects except the control upland (Table 90). In general, figures for the experimental marsh transects showed an increased diversity as the marsh developed from the fall 1976 season. Transect four showed the greatest increase and reached the highest diversity figure (Table 90). The upland transects showed lower diversity figures both for the experimental transect (three) and the reference transects (seven and nine). The density of the birds and the diversity on each transect and at each station were calculated for the different months of the study (Appendix A', Tables A1-A14).

<u>Bird nesting activities</u>

303. The highest total nest density was 12.4 nests per ha in the experimental upland habitat (Table 91). Three species bred in this area: *Charadrius vociferus, C. wilsonia,* and *Sterna albifrons. S. albifrons* nested heavily in the sparsely vegetated sandy area of the upland, and of 23 scrapes the average success was 90 percent, based on the number of eggs hatched. This protected area had a

S. albifrons nest density of 9.8 per ha.

304. Three species of birds bred in the experimental marsh habitat (Table 92). Two *Agelaius phoeniceus* nests, one containing a *Molothrus ater* egg, were successful. Four nests of *Sterna albifrons* showed only 60 percent success. No nests were found in the reference marsh.

305. There were no successful nests on the reference and control uplands (Table 91). On visits subsequent to nest discovery, the eggs were always missing. The revisits were done early enough so that the eggs could not have hatched and the resulting young fledged. It is assumed most nests were the victims of reptile predation, possibly *Lampropeltis getulus*, since broken eggshells were only found under the *Muscivora forficata* nest.

306. Nest searches east and west of the study site revealed mostly *Agelaius phoeniceus* nests. Specific searches for *Sterna albifrons* on suitable sandy areas revealed only one active scrape.

Discussion

Small mammal populations

307. Mammal diversity was low on the Bolivar Peninsula study site relative to other Texas coastal marshes. Lee (1976) considered the low diversity to be a reflection of the low habitat diversity of the area. In her study, she recorded three species not seen in the present study: *Felis rufus, Spilogale putoris,* and *Blarina brevicauda.* This increases the cumulative mammal list to 15 species, excluding livestock.

308. *Sigmodon hispidus* prefers areas of heavy vegetation (Davis 1974). The reference area, always heavily vegetated even in winter, showed consistently large *S. hispidus* populations. The control area was utilized most when the vegetation was heaviest. The experimental upland was not inhabited until August 1977 when the vegetation was very dense. During that trapping period, three of the four *S. hispidus* captured were in the *Cynodon dactylon* plots, probably because of the dense ground cover of that grass. Lee (1976) reported highest

S. hispidus populations in October and November and lowest estimates in February and March. The discrepancy between Lee's results and the current study may be due to naturally occurring population fluctuations (Davis 1974). Lee also mentioned that construction of the marsh may have affected her February and March trapping data.

309. *Mus musculus*, as mentioned, prefers less heavily vegetated areas. This would explain the inverse relationship with *Sigmodon hispidus*. *M. musculus* is also closely associated with man and his activities, as evidenced by the large numbers of *M. musculus* captured in September 1976 when human activity was near its peak.

310. *Rattus norvegicus* is also a commensal species (Davis 1974). The two *R. norvegicus* caught in September 1976 may have reached the site with the heavy equipment and manpower transported from Galveston.

311. *Oryzomys palustris* was not reported by Lee (1976). It was first captured when the reference area was very wet and had some areas of standing water. Davis (1974) reports *O. palustris* is semiaquatic and prefers marshy areas. *O. palustris* was captured in the *Spartina alterniflora* of the experimental marsh in August 1977. This area is subject to frequent tidal inundation. The *O. palustris* captured in the control area was near a low-lying area just south of the grid site.

Larger mammal populations

312. *Sylvilagus floridanus* and *Procyon lotor* were the most important larger mammals on the experimental site. During the winter of 1976-1977, *S. floridanus* moved into the experimental marsh to feed on *Spartina alterniflora* and *S. patens*, the only green vegetation available. They did little lasting damage to those plants. *P. lotor* began using the experimental marsh to feed in the late fall of 1977. Many tracks were seen near the sandbags, where water remains after the tide has receded.

Avian populations

313. The seasonal variation was obvious in the number of bird species on the field site. Summer residents were either breeding

birds or non-breeding individuals that did not complete their northward migration (*Pluvialis squatarola*).

314. Very few species (*Asio flammeus, Mergus serrator*) were seen exclusively in the winter. Most winter birds were permanent residents (*Larus atricilla*). Anseriformes are common winter residents on the upper Texas coast (Feltner and Pettingell 1974), but were rarely seen on the study area. During the 1976-1977 winter, the marsh was sparsely vegetated, the tide was very low (beyond the fence), and human activity was moderately heavy. These factors may have deterred Anseriforme use of the area.

315. Many spring migrants on the study area were members of the Charadriiformes or Passeriformes, and many were seen only once. Most of the Passeriformes prefer wooded habitats, but during migration they were seen in *Sesbania drummondii* which seldom grows higher than 10 ft. Since many spring migrants fly non-stop across the Gulf of Mexico (Pettingill 1970), they stop at the first opportunity, regardless of the long-term suitability of the habitat.

316. The 1976 fall season showed a gradual rise and fall in species numbers, while fall 1977 was erratic. This discrepancy between the two years occurred because the observer no longer lived near the study site after August 1977.

317. The experimental marsh always had more species than the reference marsh, but this is misleading since the experimental marsh was censused by three transects and contained three times as much area. In addition, the species composition of the two areas was different. Many members of Laridae used the less vegetated reference marsh as a loafing area, while those species preferring more dense marsh vegetation such as *Cistothorus platensis* used the experimental marsh.

318. Birds did not show a preference for the experimental upland, except in the fall of 1976. This initial selection was probably in response to the recently tilled soil. After this season the fewer species may have been due to the lack of the taller *Sesbania drummondii* in the experimental upland. Bird selection of taller vegetation is supported by the fact that many birds were seen perched on the fence line or on plot stakes.

319. Since average bird densities were so low on all areas, any influx of birds during a census period would be reflected in the density figures for that season. For example, the average density of the reference marsh in the fall of 1977 was 6.6 birds per ha. If *Larus atricilla* had not been on the area the density would have been only 3.6 birds per ha. In other words, density on all areas seems to reflect random sightings of large flocks of gregarious species.

320. Diversity figures reflect both number of species and number of individuals. Thus, the high spring diversities reflect both the influx of many species, and the larger number of individuals seen. It is misleading that the upland control transect (nine) did not show a higher diversity since many spring migrants were sighted there at times other than the census period. The low number of species during the summer season would imply a lower diversity than was actually recorded. However, the equitability component of the diversity index was obviously high enough to compensate for the low species number.

Bird nesting activities

321. *Sterna albifrons* bred in the experimental upland in the summer of 1976, during the peak of human activity. The area at that time was very sparsely vegetated. In May 1977, when the first scrapes were found, the vegetation was much denser, especially at the west end of the upland. Although there was less suitable breeding area, there were more birds attempting to breed. In fact, the amount of area seemed to limit the number of active scrapes. In June, one month after the first scrapes were begun, new scrapes were found. These had to be new nests, since the May nests had just hatched and the parents were still feeding the fledglings. With area a limiting factor, it is surprising that only one scrape was found outside the experimental area. *Capra hircus* was a potential threat outside the fence, but the fence was not completed during the 1976 season. The experimental upland may be a traditional nesting ground for *Sterna albifrons*. This is supported by the site tenacity shown during the 1976 summer. At this time, plots were being staked and some eggs were actually relocated to prevent being destroyed by the spring tooth harrow.

322. *Sterna albifrons* also nested in the upper tier of the experimental marsh. The success rate was lower in the marsh because the area was not suitable for ground nests. The substrate color was too dark to properly camouflage the eggs, and a higher than normal tide washed away several eggs. Since the marsh was not used until the June nesting, this leads to the conclusion that the lateness of the season and the limited amount of proper habitat forced some birds to nest in this unsuitable area.

323. *Agelaius phoeniceus* attempted to breed in two areas. Initial nest attempts in May 1977 were in the *Sesbania drummondii* of the control upland. None of these nests were successful. In June 1977 the first nests were found in the experimental marsh, woven into the *Spartina alterniflora*. These nests were successful. This supports the theory that *Lampropeltis getulus* predation was the factor that prevented nest success in the *Sesbania*. No *Lampropeltis* were ever seen in the marsh.

Conclusions

Small mammal populations

324. Four species of small mammals were captured on the Bolivar Peninsula study site. *Sigmodon hispidus* was captured in all trapping areas, but only when these areas were heavily vegetated. *Mus musculus* populations were inversely related to *S. hispidus* populations, since *M. musculus* prefers less heavily vegetated areas. *Rattus norvegicus* was only captured in September 1976, when human disturbance was at a maximum. *Oryzomys palustris* was recorded in the reference areas when they were very wet, and in the experimental marsh when the *Spartina alterniflora* had grown dense enough.

Large mammal populations

325. *Sylvilagus floridanus* and *Procyon lotor* were the dominant large mammals in the study site. *S. floridanus* were removed from the experimental area to limit animal damage to the planted vegetation, and *Procyon lotor* were live-trapped and removed to reduce interference

with small mammal trapping. Two semi-aquatic species, *Lutra canadensis* and *Myocastor coypus*, were seen infrequently in the experimental marsh.

Reptiles and amphibians

326. Reptiles and amphibians were not considered in any quantitative aspect, and only four species were encountered during the study period: *Terrapene ornata*, *Heterodon platyrhinos*, *Lampropeltis getulus*, and *Phrynosoma cornutum*.

Avian populations

327. A total of 135 species were recorded during the study, and the great majority of these were migrants. The number of species present during any month ranged from a low of 27 in July 1977 to 54 species recorded during spring migration (April 1977). During the last months of the study marsh-dependent species began to colonize the experimental wetland. No such influx was noted in the experimental upland, because of the slower growth rate of the shrubs and trees.

328. Density and diversity figures were low throughout the study, although there were slight increases in the spring and toward the latter part of the study.

Bird nesting activities

329. Six species of birds bred on the study site. *Sterna albifrons*, *Charadrius vociferus*, and *C. Wilsonia* were ground nesters. *Muscivora forficata* nested in *Sesbania drummondii*, *Agelaius phoeniceus* nested in *Sesbania* and *Spartina alterniflora*, and *Molothrus ater* parasitized the nests of *A. phoeniceus*. *Sterna albifrons* seemed to depend on the experimental area, breeding there in 1976 during peak human disturbance and again in 1977 when the vegetation was heavier than *S. albifrons* normally prefers.

PART VI: SEDIMENT CHEMISTRY

Methods

Field methods

330. Following the site preparation and prior to fertilization, core samples were taken for analysis. A total of 18 cores were collected from the research area to be used for initial characterization of the site. The plots from which the cores were taken are shown in Figure 37. A core was taken from the center of each plot. After the initial characterization of the site was completed, an extensive soil sampling program was initiated. Soil samples from each of the 270 marshland plots and the 36 intertidal reference plots were taken at the middle and at the end of each growing season. In addition, nine deep cores were also taken at the same time from the center of each high-fertility *Spartina alterniflora* plot.

331. Nine shallow cores (0 to 30 cm) were taken from the site. They were obtained using 30-cm-long by 7.6-cm-diameter polyvinylchloride pipe. Six of the cores were taken from plots located in the marshland area: three of these plots were commonly under water and three were from the plots which were intermittently submerged. The final three shallow cores were taken in the upland area. The PVC pipe was driven into the ground to a point where the top was just flush with the surface. The PVC pipe with the soil core inside was then removed from the ground, capped at both ends, and taped with electrical tape to prevent contamination with air. The cores were frozen with dry ice and transported to the laboratory for chemical and physical analysis. Each 30-cm core was sectioned into the 0-to 15-cm and 15-to 30-cm depths and analyzed separately.

332. Nine deep cores (0 to 105 cm) were also taken for analysis. Sampling locations are also shown in Figure 37. The locations from which the deep cores were taken were the high-fertility *Spartina alterniflora* plots (plot 13) in the marshland area. Soil cores from these plots were divided into 15- to 105-cm increments.

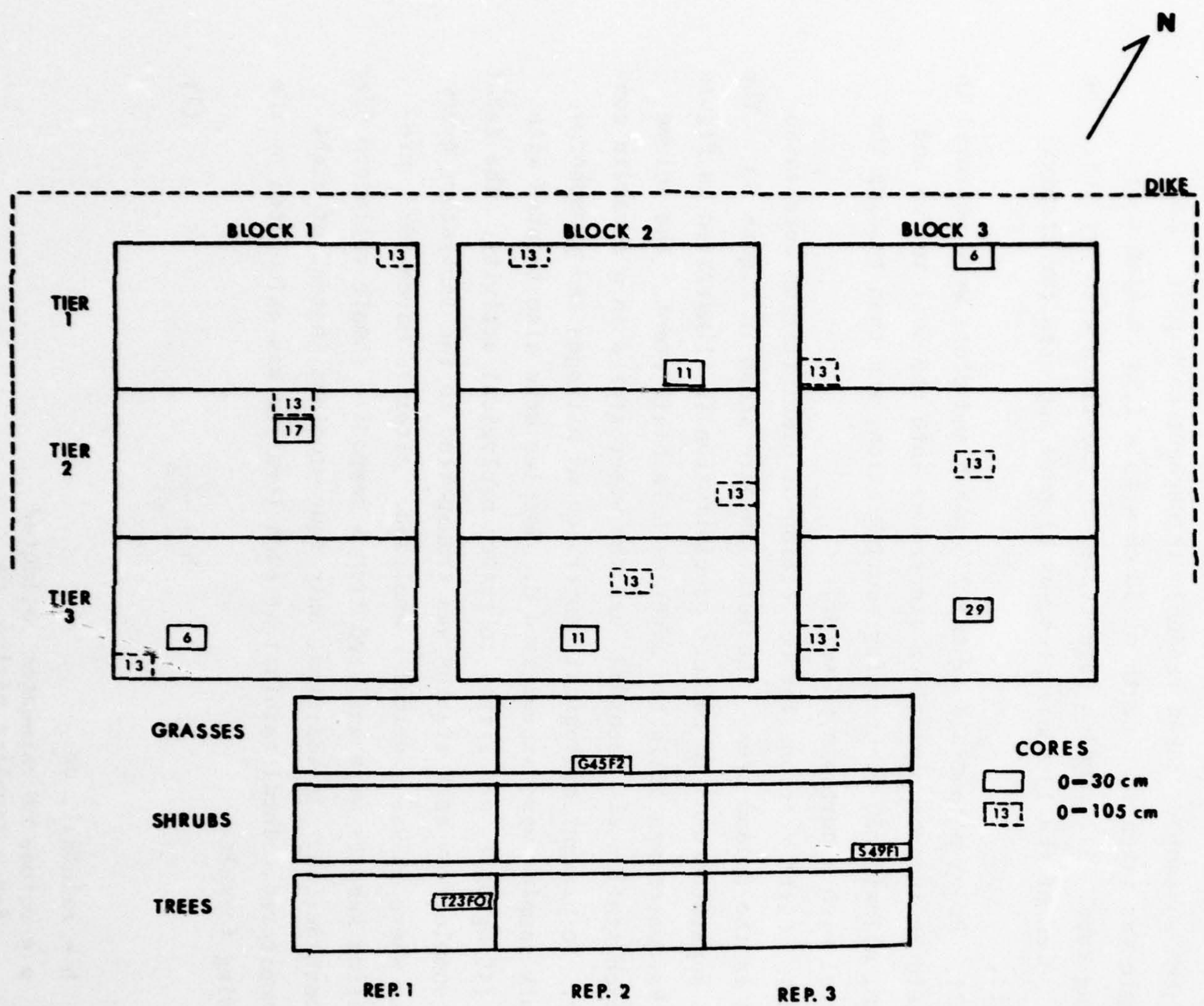

Figure 37. Locations of cores taken prior to fertilization of the Bolivar Peninsula site

333. A total of 306 composite samples (270 marshland plots and 36 exclosures, Figure 38) were taken for chemical analysis at the middle and end of each growing season. Each soil sample was a composite of ten subsamples taken randomly throughout each plot. Each subsample was taken to a depth of 30 cm with a 2.54 cm-diam soil sampling tube. All samples were frozen in the field with dry ice. The entire 30 cm of the 10 subsamples was blended and used for chemical analysis.

334. Redox potentials of the 270 marshland plots were measured in the field by inserting platinum electrodes into the soil to 7.5 and 22.5 cm, allowing 30 minutes for equilibration, and then reading the potential with a portable pH meter.

335. Eight stations for collection of precipitation were established in the upland area. The locations are shown in Figure 39. The simple apparatus used to collect precipitation is illustrated in Figure 40. Rainwater was collected after each rainfall event. The volume from each station was recorded and the water stored in a separate container. To prevent biological conversion of nitrogen and phosphorus, the bulk samples were stored at $4^{o}C$. Samples were also treated with $HgCl_2$ (40 mg $HgCl_2$ per litre) to retard biological activity. The total water sample from each station was transported to the laboratory every 2 weeks where it was chemically analyzed. After 15 March 1977, precipitation samples were analyzed from a composite sample collected over a 2-month period. In addition, only four stations instead of eight were monitored. Total rainfall at each location was calculated by the following formula:

$$h = \frac{v}{\pi r^2} \quad (1)$$

where:

h = rainfall, cm

v = volume of rainwater collected for a sampling period, cm^3

r = radius of funnel, cm

π = 3.14

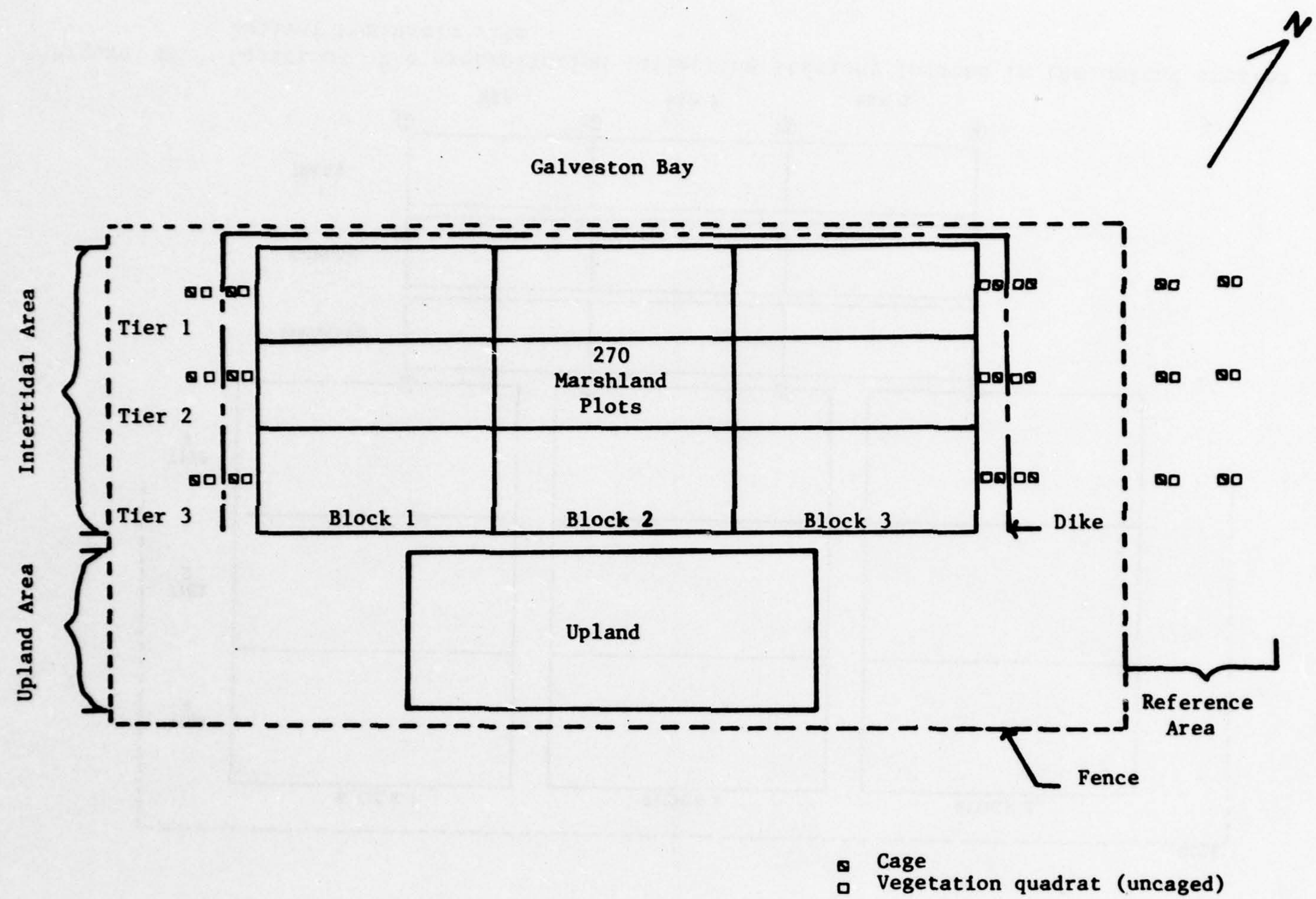

Figure 38. Field location of the 36 intertidal reference plots (cage-quadrat pairs)

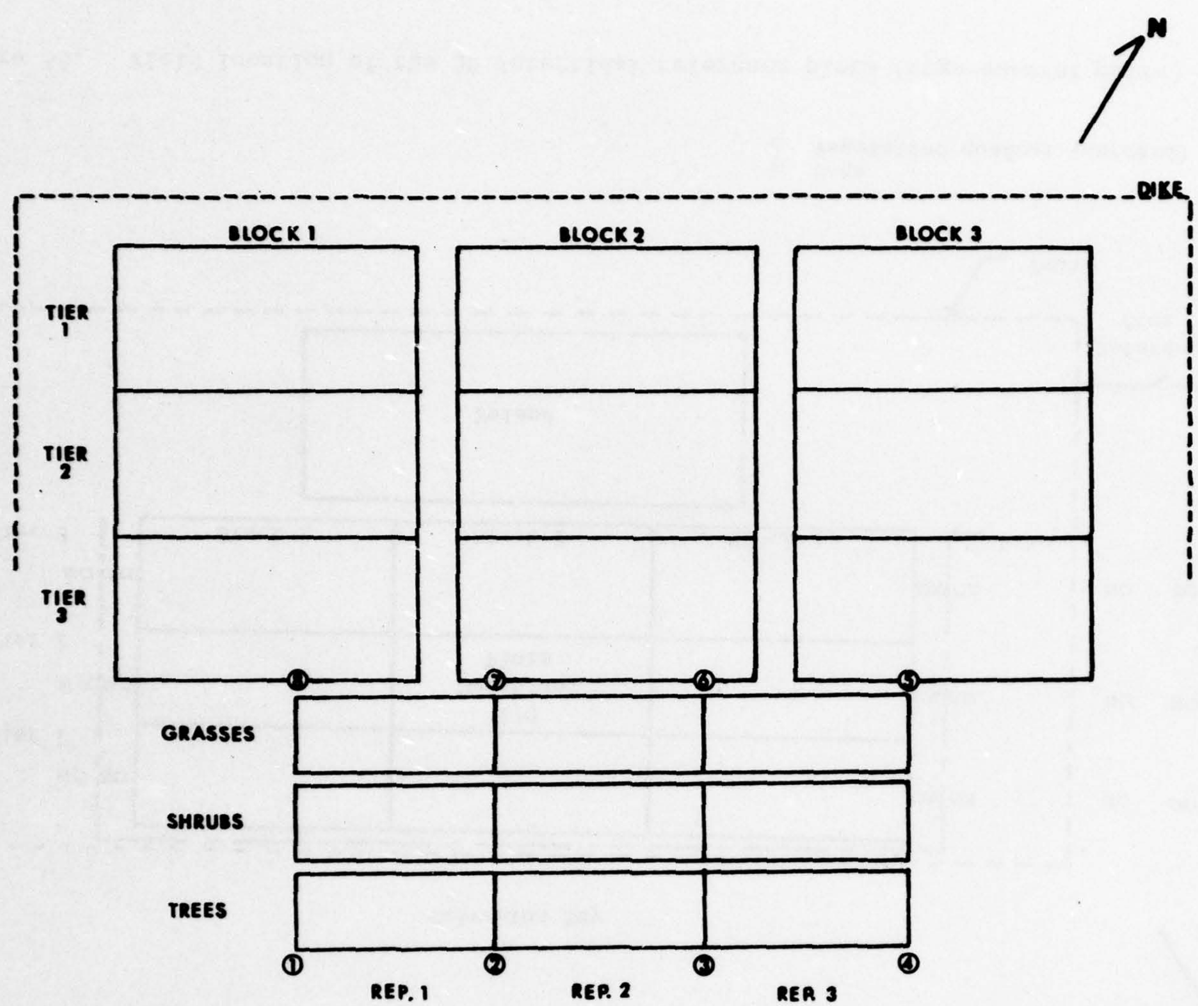

Figure 39. Locations of 8 precipitation collection stations located in the upland area of the Bolivar Peninsula site

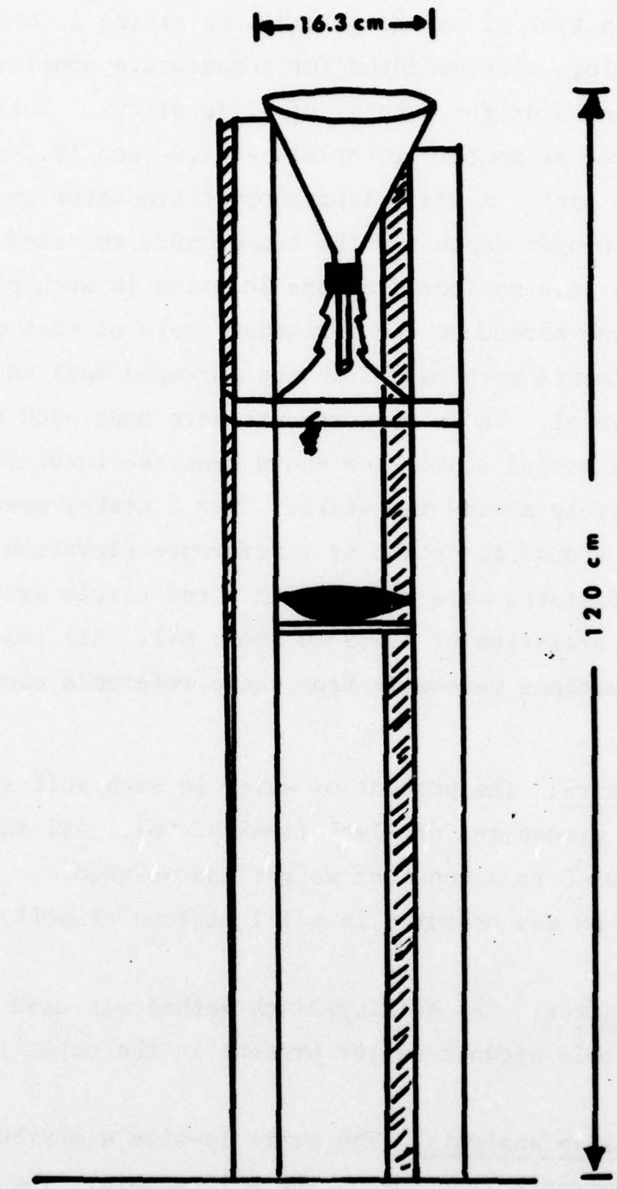

Figure 40. Precipitation collection station

336. Soil temperature monitoring stations were randomly located in the marshland and upland areas (Figure 41). Twelve plots were randomly selected in each tier of the marshland area giving a total of 36 observations. Four plots were selected for temperature monitoring in each tier of the upland area for a total of 12 locations. Soil temperatures were monitored at monthly intervals at 2.5- and 10.0-cm depths in the center of each plot. A glass laboratory thermometer was inserted into the soil to the proper depth and the temperature recorded.

337. Elevations were monitored at one location in each plot. A reference elevation was marked on the northeast stake of each plot in the lowland. Measurements were made from the surveyed mark on the stake to the ground level. These measurements were made each month. Stakes in tier 1 were marked at 76.2 cm above mean sea level (msl) with a black circle completely around the stake. Tier 2 stakes were marked with a yellow circle around the stake at a reference elevation of 91.4 cm above msl. Tier 3 stakes were marked with a red circle around the stake at a reference elevation of 121.9 cm above msl. All calculations regarding ground elevations were made from these reference elevations.

Laboratory methods

338. Soil moisture. The percent of water in each soil sample was determined using the procedures of Black (1965:92-96). All samples were oven dried at 105°C to a constant weight and weighed.

339. pH. Soil pH was measured in a 1:1 mixture of soil and water (Black 1965:922-923).

340. Organic matter. The Walkley-Black method was used to determine the oxidizable organic matter present in the cores (Black 1965:1272-1276).

341. Particle-size analysis. The particle-size distribution was determined on the inorganic fraction of the soil sample. The procedure used a combination of sedimentation and wet and dry sieving techniques (Black 1965:552-562).

342. Cation exchange capacity (CEC). The sodium saturation method was used for determining CEC (Black 1965:889-900).

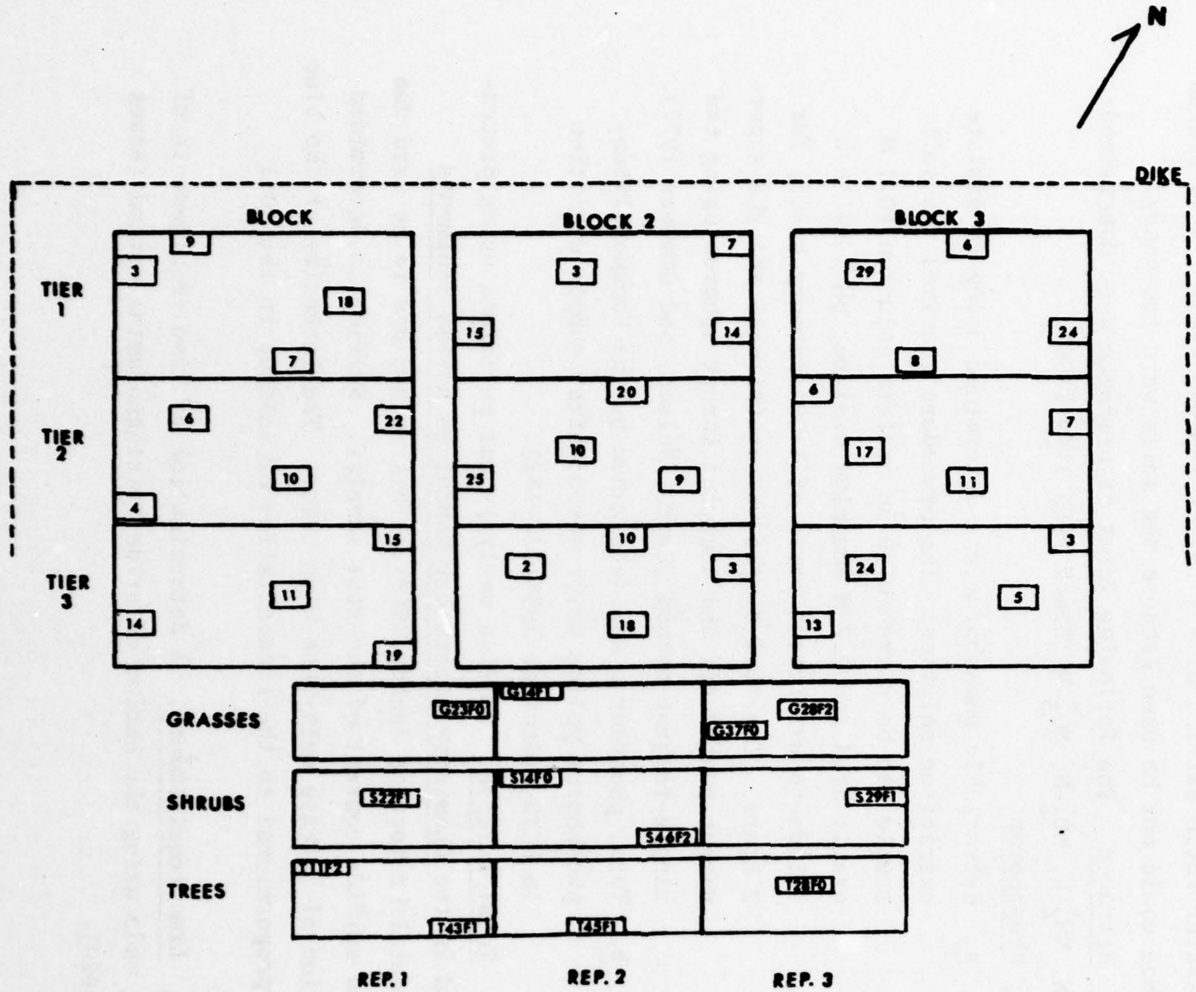

Figure 41. Locations of randomly selected plots from which soil temperatures were monitored at 2.5 and 10.0 cm at the Bolivar Peninsula site

343. Exchangeable bases. The method of Toth and Ott (1970) was used to determine exchangeable bases.

344. Soil Salinity. Salinity of the soils was determined using a soil-to-water ratio extract of 1:1 (Black 1965:933-940). A saturated paste method could not be used because the soils were too sandy.

345. Nitrogen. The following forms of nitrogen were determined: Kjeldahl N, NH_4^+-N, NO_2^--N, NO_3^--N (Black 1965:1149-1254).

346. Phosphorus.

a. Extractable phosphorus was determined using an oxalate extraction solution. The procedure requires the soil samples to be shaken with an oxalate solution (0.1 M oxalic acid and 0.2 M ammonium oxalate, pH 3.5) in a solids-to-extractant ratio of 1:20 (ovendry basis) for 2 hours. The soil sample was centrifuged and the supernatant poured off and analyzed for phosphorus using the single-reagent method (Owens, Nelson, and Sommers 1977).

b. Total phosphorus was determined by the Vanadomolybdophosphorus yellow color method after sample digestion in $HClO_4$ (Jackson 1958:134-182).

347. Total sulfide. Sulfide analysis was performed using procedures found in the Chemistry Laboratory Manual on Bottom Sediments (Environmental Protection Agency 1969). This method had to be used due to the low sulfide content of the soil samples. Sulfide is determined by formation of intense methylene blue color. The intensity of the blue color is proportional to the concentration of sulfide in the soil sample.

348. Lime requirements. A determination of lime requirements of soils was made using the barium chloride triethanolamine method (Black 1965:928-929).

Results and Discussion

Amount and nutrient composition of precipitation

349. Rainfall on the research site between 8 September 1976 and 15 September 1977 was 120.8 cm. Monthly precipitation at the Bolivar site is plotted in Figure 42 along with mean monthly rainfall at Galveston (National Oceanic and Atmospheric Administration, 1976) for comparison. Rainfall at the Bolivar site from January to May 1977 was well below the Galveston mean monthly precipitation.

350. Nitrogen, phosphorus, Ca^{++}, K^{+}, and Na^{+} were determined in the rainwater. The total quantity of these components reaching the site based on precipitation analysis is presented in Table 93. Concentrations of these components in the rain were generally low and below detectable limits in many instances, particularly for the nitrogen and phosphorus forms.

351. In determining the total quantity of an element reaching the site, only those periods where an element was present in detectable amounts were summed. On this basis, only 3.5 kg/ha of inorganic nitrogen (NH_4^+ + NO_3^- + NO_2^-) was deposited on the site during this 14-month period. Organic nitrogen collected was 8.9 kg/ha, but a large portion of this is thought to be contributed by insects in the collection bottle. A trace of phosphorus and 2.1 kg/ha of potassium were found. Calcium totaled 6.8 kg/ha and sodium 21.6 kg/ha.

Sediment temperature

352. Average sediment temperature at 2.5- and 10-cm depths is plotted in Figures 43 and 44 and recorded in Table 94 for the upland and marshland. Temperatures were taken on fifteen dates beginning with 15 October 1976. Temperature data for September 1977 were lost. Each point on the graph represents a mean of all observations taken for the upland or marshland areas on that date. Temperatures in October in both the upland and the marshland were about 24°C with the highest temperature at 2.5 cm. At the upland site, the November and December temperatures at 2.5 cm were less than at 10 cm, but on 20 January 1977

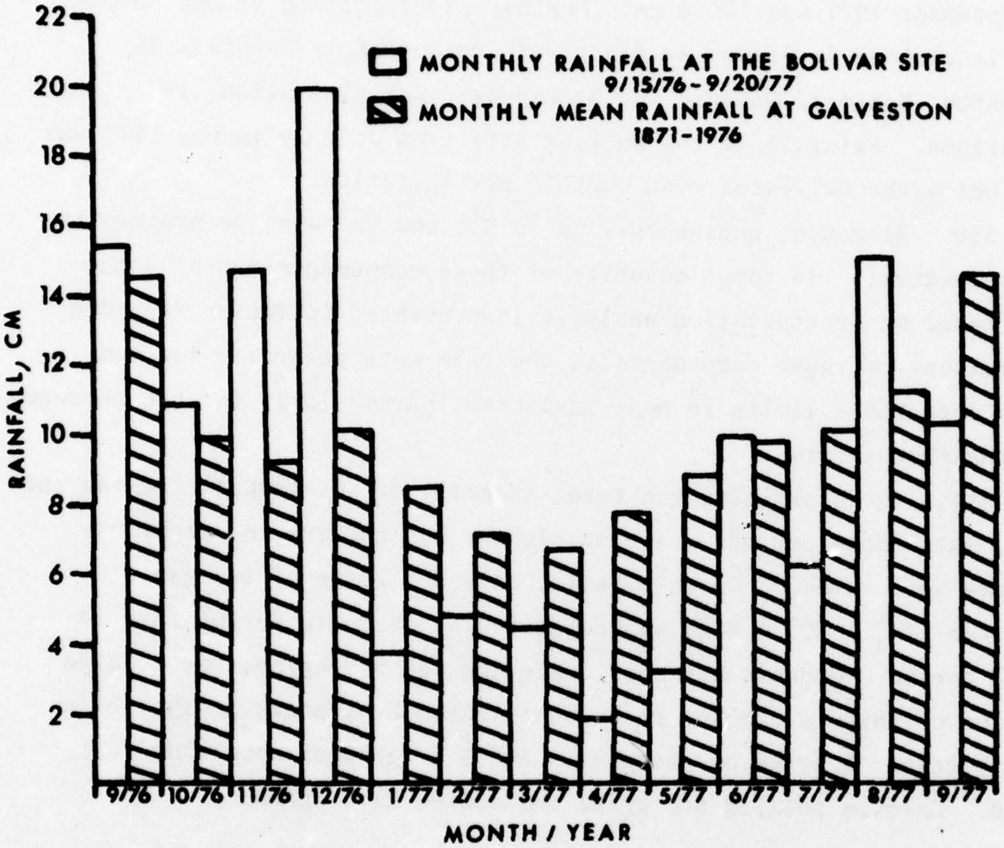

Figure 42. Mean monthly rainfall at the Bolivar Peninsula site from 15 September 1976 to 20 September 1977 compared to the long-term average rainfall at Galveston, Texas

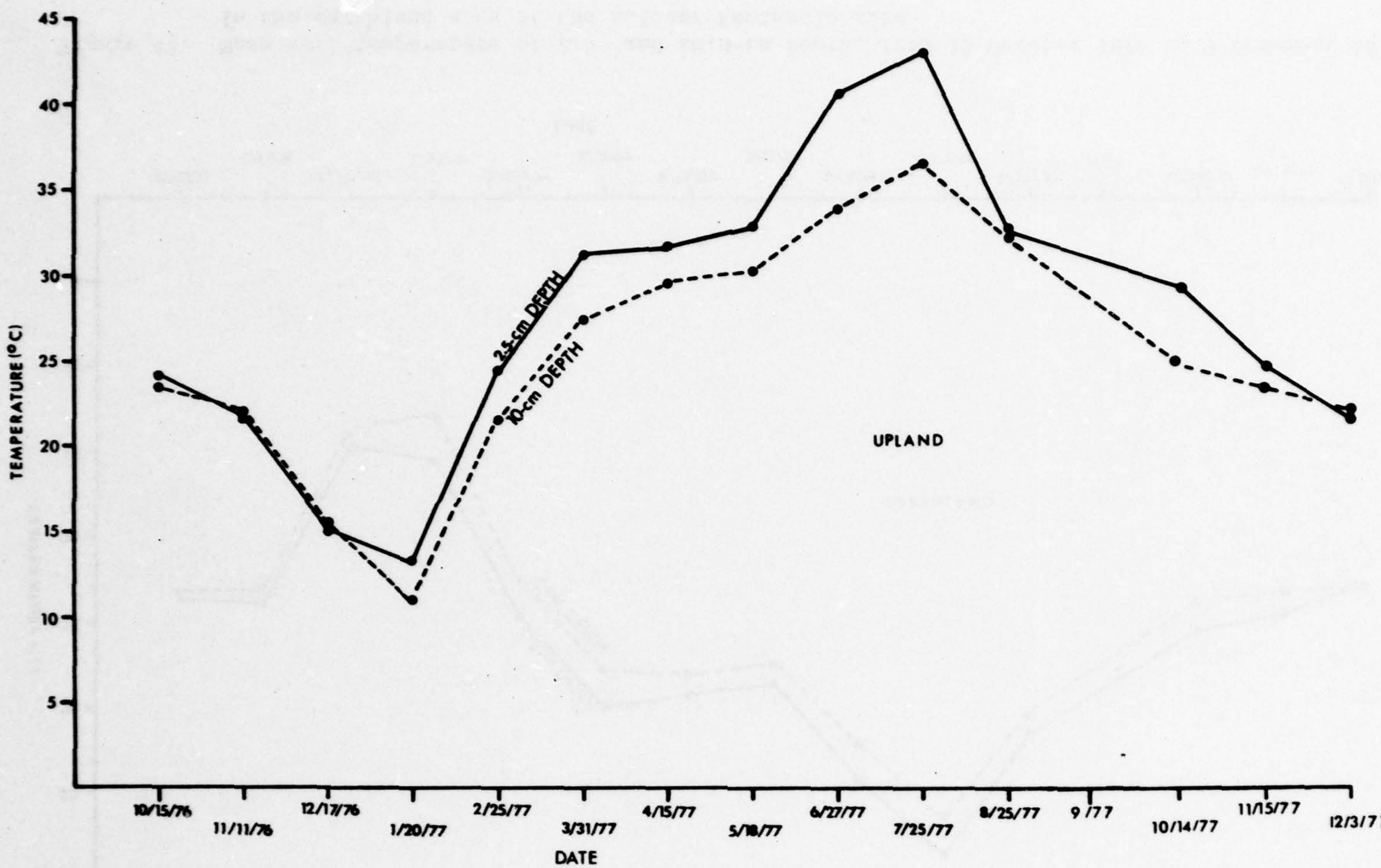

Figure 43. Mean soil temperature at 2.5- and 10.0-cm depths from 15 October 1976 to 3 December 1977 in the upland area of the Bolivar Peninsula site

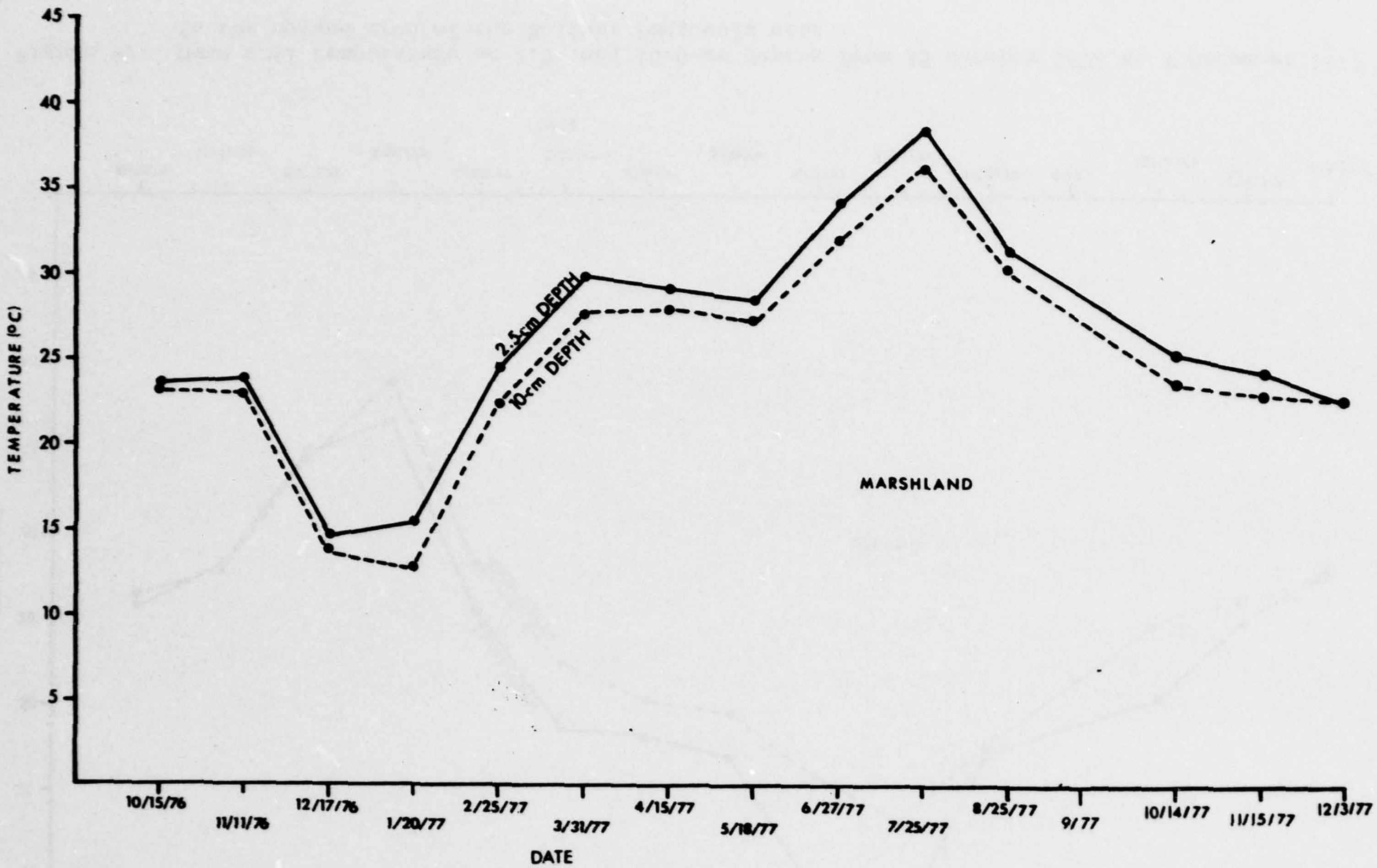

Figure 44. Mean soil temperature at 2.5- and 10.0-cm depths from 15 October 1976 to 3 December 1977 in the marshland area of the Bolivar Peninsula site

the surface temperature was greater. This reflects the effect of the ambient temperature on the upper few centimetres of sediment on the drier upland site. In the marshland the 2.5-cm temperature was always about 0.5°C warmer than the 10-cm depth. The lowest temperature measured in the upland was 11°C at the 10-cm depth in mid-January. The lowest sediment temperature in the marshland was about 14°C. After January the sediment temperature in the marshland increased to around 30°C in March and then decreased about 2 degrees until the middle of May. From the middle of May to late July 1977 the temperature increased to a maximum of about 39°C at the 2.5-cm depth. Sediment temperatures began decreasing in late July. Temperature at the 10-cm depth for the marshland area was always less than the 2.5-cm depth but only by a degree or so.

353. Sediment temperature of the marshland gradually decreased to about 23°C in December 1977 for both the 2.5- and 10-cm depths. The 10-cm depth temperatures were the same as the 2.5-cm depth for the December 1977 sampling date.

354. A similar temperature trend was seen for the upland area. The temperature increased from late January to a maximum of 43°C in late July followed by a gradual decrease in temperature from August 1977 to the last sampling date in December 1977. Sediment at the 2.5-cm depth was again warmer by a few degrees compared to the 10-cm depth.

355. A comparison of the soil temperatures from the upland and marshland shows that both areas were about the same from October 1976 to early April 1977. After the middle of April the upland plots were always a few degrees warmer than the marshland area. This was due to the greater heat energy absorbing capacity of the seawater in the marshland area as opposed to the rapid heating by the sun of the relatively dry soil in the upland plots.

Elevations

356. Elevations were measured four times. Because of a misunderstanding regarding which stake to measure, the earliest two measurements were discarded. The elevations recorded for 18 September

and 30 November 1976 were taken from the surveys conducted by the Galveston District. The last two sets of elevation data were taken by Texas A&M University personnel. Elevation data for the four dates are presented in Figures 45 to 48. All elevations are reported as ground elevations with respect to mean sea level datum.

357. A number of elevations seem to be in error since Texas A&M and Corps of Engineer values do not coincide. The plots that did not coincide were resurveyed by the Corps of Engineers and remeasured by Texas A&M personnel. Only two plots now exist that do not coincide with respect to elevation. These were T1-B3-14* and T3-B2-7 plots located in the marshland. At this point in time Texas A&M personnel discontinued monitoring the marshland elevations since the Galveston District office was monitoring the same plots at quarterly intervals with better equipment.

358. With a few exceptions, where erosion or deposition was occurring, there had been very little change in ground level elevation. Changes had been on the order of a few centimetres for most of the area over a 4-month period. However, there were areas where as much as a 5- to 10-cm change had taken place.

Shallow core analysis

359. Nine shallow cores were taken on 29 June 1976. A visual description of the cores (0 to 30 cm) is given in Table 95. Color was related to the standard Munsell charts. Other physical features were noted in the field description. Sediments were all very sandy across the area. Some pockets of shells were observed.

360. Chemical and physical analyses of the 0- to 15- and 15-to 30-cm sections of the nine cores are presented in Table 96. Moisture content of the sediment was dependent on the location of sample. The two upland cores, no. 1 (T-23-FO) and no. 2(S-49-F1) were taken from the top part of the upland area. Moisture content ranged from 13.1 to 16.8 percent. The lower moisture content of core no. 3 (G-45-F2), 5.2 to 5.7 percent, was apparently due to the large shell fragments associated with the sample. The moisture content of those sediments from the marshland region was variable and ranged from 17.5 to 26.3 percent.

* T = tier 1; B3 = block 3; 14 = plot 14.

N

	BLOCK 1						BLOCK 2						BLOCK 3					
TIER 1	25	9	16	20	26	13	5	13	17	26	1	7	5	27	17	6	2	7
	-5	-4	-1	8	8	1	3	2	6	1	9	7	3	13	8	10	1	-9
	3	6	29	1	14	21	16	28	3	18	21	6	19	29	3	26	14	11
	-2	-3	1	4	5	4	4	7	6	3	4	3	0	2	7	8	-3	-1
	19	15	10	8	18	28	12	27	2	10	9	29	22	28	10	30	20	21
	2	0	2	5	5	8	8	8	9	5	4	5	6	7	5	5	6	2
	4	22	23	11	2	27	15	22	19	30	4	14	4	15	18	12	9	24
	6	6	5	7	10	8	10	8	12	8	9	11	12	11	10	11	7	2
	30	17	24	7	12	5	23	20	25	24	11	8	13	16	8	25	23	1
	10	12	10	10	11	13	12	14	16	11	12	15	16	19	16	10	10	7
TIER 2	8	14	19	13	29	2	19	22	7	20	11	6	6	29	18	3	20	15
	14	17	15	12	16	18	20	19	27	21	25	25	26	26	24	20	16	6
	5	6	11	17	28	22	14	1	16	5	23	3	24	21	19	28	16	7
	19	23	23	19	22	21	30	26	32	32	34	35	34	30	29	27	25	23
	18	7	21	26	25	20	26	29	10	30	28	4	25	17	1	13	27	12
	29	31	27	29	28	28	35	32	40	41	41	43	37	34	37	30	32	27
	1	24	12	10	27	16	25	2	15	24	9	13	14	26	9	11	23	5
	36	35	34	37	34	35	43	37	47	52	49	50	43	37	41	39	40	33
	4	15	3	23	9	30	18	21	12	8	17	27	10	2	8	22	4	30
	41	41	40	40	35	41	44	42	55	58	58	51	47	42	41	43	48	43
TIER 3	5	23	17	26	10	15	26	7	28	10	27	12	30	17	19	6	18	3
	48	46	47	52	46	47	46	47	61	63	61	59	49	46	44	45	54	52
	21	18	27	8	2	24	6	2	5	13	23	3	28	24	27	23	14	26
	52	51	54	55	50	55	48	53	64	66	65	63	54	51	47	50	61	58
	25	3	7	11	20	9	20	9	24	15	21	19	9	20	2	29	5	4
	56	54	62	58	53	58	52	58	64	69	72	67	60	56	58	59	66	67
	14	6	1	30	4	12	14	8	11	18	22	17	13	22	10	8	11	12
	62	62	66	69	59	62	64	63	70	72	77	75	73	68	79	82	79	79
	13	22	28	29	16	19	1	16	30	29	4	25	25	1	16	7	15	21
	82	87	78	70	62	68	76	78	85	85	87	91	88	81	90	95	102	91

Figure 45. Elevation data of the marshland plots taken 18 September 1976. Ground elevations of each plot are given in centimetres below each plot number with respect to mean sea level

N

	BLOCK 1						BLOCK 2						BLOCK 3					
TIER 1	25 / -2	9 / 1	16 / 4	20 / 16	26 / 15	13 / 12	5 / -2	13 / 12	17 / [illegible]	26 / 2	1 / 9	7 / 8	5 / 5	27 / 12	17 / 14	6 / 11	2 / 6	7 / 2
	3 / 2	6 / 1	29 / 5	1 / 11	14 / 14	21 / 16	16 / 8	28 / 12	3 / 9	18 / 3	21 / 4	6 / 5	19 / 7	29 / 1	3 / 11	26 / 10	14 / 4	11 / 0
	19 / 4	15 / 5	10 / 5	8 / 10	18 / 11	28 / 13	12 / 11	27 / 12	2 / 9	10 / 5	9 / 7	29 / 3	22 / 8	28 / 8	10 / 9	30 / 7	20 / 8	21 / 5
	4 / 8	22 / 6	23 / 8	11 / 10	2 / 12	27 / 14	15 / 12	22 / 15	19 / 9	30 / 9	4 / 8	14 / 11	4 / 11	15 / 10	18 / 13	12 / 10	9 / 9	24 / 8
	30 / 11	17 / 13	24 / 11	7 / 13	12 / 17	5 / 16	23 / 14	20 / 15	25 / 12	24 / 11	11 / 13	8 / 17	13 / 19	16 / 20	8 / 19	25 / 12	23 / 12	1 / 11
TIER 2	8 / 16	14 / 17	19 / 15	13 / 13	29 / 18	2 / 21	19 / 22	22 / 19	7 / 19	20 / 21	11 / 24	6 / 26	6 / 26	29 / 26	18 / 27	3 / 24	20 / 20	15 / 14
	5 / 23	6 / 23	11 / 26	17 / 22	28 / 23	22 / 23	14 / 31	1 / 27	16 / 28	5 / 33	23 / 34	3 / 35	24 / 34	21 / 28	19 / 31	28 / 28	16 / 28	7 / 25
	18 / 27	7 / 30	21 / 27	26 / 31	25 / 29	20 / 29	26 / 36	29 / 33	10 / 31	30 / 42	28 / 41	4 / 44	25 / 37	17 / 32	1 / 32	13 / 32	27 / 33	12 / 28
	1 / 36	24 / 35	12 / 33	10 / 35	27 / 35	16 / 34	25 / 44	2 / 38	15 / 41	24 / 51	9 / 50	13 / 51	14 / 44	26 / 37	9 / 42	11 / 41	23 / 41	5 / 35
	4 / 41	15 / 41	3 / 41	23 / 40	9 / 42	30 / 41	18 / 44	21 / 43	12 / 47	8 / 55	17 / 54	27 / 53	10 / 48	2 / 43	8 / 41	22 / 47	4 / 48	30 / 44
TIER 3	5 / 47	23 / 47	17 / 48	26 / 54	10 / 45	15 / 47	26 / 45	7 / 48	28 / 55	10 / 61	27 / 60	12 / 58	30 / 51	17 / 47	19 / 44	6 / 47	18 / 56	3 / 82
	21 / 51	18 / 50	27 / 54	8 / 56	2 / 50	24 / 52	6 / 48	2 / 53	5 / 61	13 / 65	23 / 65	3 / 63	28 / 55	24 / 50	27 / 48	23 / 51	14 / 62	26 / 58
	25 / 56	3 / 54	7 / 61	11 / 59	20 / 54	9 / 58	20 / 49	9 / 59	24 / 63	15 / 69	21 / 71	19 / 67	9 / 61	20 / 58	2 / 58	29 / 58	5 / 67	4 / 66
	14 / 63	6 / 62	1 / 66	30 / 62	4 / 59	12 / 62	14 / 64	8 / 65	11 / 70	18 / 74	22 / 77	17 / 76	13 / 73	22 / 69	10 / 78	8 / 83	11 / 80	12 / 78
	13 / 82	22 / 87	28 / 76	29 / 71	16 / 59	19 / 67	1 / 77	16 / 77	30 / 36	29 / 83	4 / 87	25 / 91	25 / 88	1 / 81	16 / 88	7 / 94	15 / 94	21 / 90

Figure 46. Elevation data of the marshland plots taken 30 November 1976. Ground elevations of each plot are given in centimetres below each plot number with respect to mean sea level

N

Tier	Block 1						Block 2						Block 3					
Tier 1	25	9	16	20	26	13	5	13	17	26	1	7	5	27	17	6	2	7
	-3	6	7	16	-1	11	-5	16	14	9	13	11	9	17	14	14	7	0
	3	6	29	1	14	21	16	28	3	18	21	6	19	29	3	26	14	11
	-1	5	7	12	-5	16	10	13	14	8	9	12	9	9	12	11	2	1
	19	15	10	8	18	28	12	27	2	10	9	29	22	28	10	30	20	21
	0	7	8	11	13	14	12	14	16	10	10	12	12	15	8	10	9	7
	4	22	23	11	2	27	15	22	19	30	4	14	4	15	18	12	9	24
	3	12	10	12	13	13	13	15	15	13	13	17	17	16	14	13	10	10
	30	17	24	7	12	5	23	20	25	24	11	8	13	16	8	25	23	1
	5	13	12	15	16	15	17	17	16	17	19	24	24	25	20	15	12	13
Tier 2	8	14	19	13	29	2	19	22	7	20	11	6	6	29	18	3	20	15
	16	17	18	16	19	23	24	23	23	52	24	32	32	32	29	24	22	17
	5	6	11	17	28	22	14	1	15	5	23	3	24	21	19	28	16	7
	23	27	24	26	26	24	33	26	29	32	35	35	33	31	29	26	27	24
	18	7	21	26	25	20	26	29	10	30	28	4	25	17	1	13	27	12
	26	19	28	34	35	29	34	31	38	38	41	43	38	68	34	33	35	33
	1	24	12	10	27	16	25	2	15	24	9	13	14	26	9	11	23	5
	34	35	33	36	37	37	42	34	41	55	51	51	45	69	44	40	40	37
	4	15	3	23	9	30	18	21	12	8	17	27	10	2	8	22	4	30
	41	41	40	39	40	39	41	40	46	52	61	54	47	72	40	44	48	46
Tier 3	5	23	17	26	10	15	25	7	28	10	27	12	30	17	19	6	18	3
	17	46	16	53	44	46	43	44	24	62	61	59	51	48	44	45	54	54
	21	18	27	8	2	24	6	2	5	13	23	3	28	24	27	23	14	26
	-10	49	54	56	46	50	46	53	60	66	67	66	54	52	48	51	62	61
	25	3	7	11	20	9	20	9	24	15	21	19	9	20	2	29	5	4
	25	54	60	58	52	56	51	58	62	72	40	68	59	60	58	59	67	66
	14	6	1	30	4	12	14	8	11	18	22	17	13	22	10	8	11	12
	62	61	64	62	58	60	63	65	69	74	78	77	73	68	80	84	82	80
	13	22	28	29	16	19	1	16	30	29	4	25	25	1	16	7	15	21
	80	87	74	70	57	66	76	77	86	84	89	90	90	82	88	95	94	90

Figure 47. Elevation data of the marshland plots taken 17 December 1976. Ground elevations of each plot are given in centimetres below each plot number with respect to mean sea level

N

Tier	Block 1						Block 2						Block 3					
Tier 1	25	9	16	20	26	13	5	13	17	26	1	7	5	27	17	6	2	7
	-2	1	4	14	15	8	-8	13	9	4	11	8	5	15	11	11	2	3
	3	6	29	1	14	21	16	28	3	18	21	6	19	29	3	26	14	11
	3	2	1	11	14	16	10	8	12	5	7	10	5	5	12	9	-1	-2
	19	15	10	8	18	28	12	27	2	10	9	29	22	28	10	30	20	21
	0	5	4	10	11	11	9	10	13	7	7	11	9	15	8	6	6	5
	4	22	23	11	2	27	15	22	19	30	4	14	4	15	18	12	9	24
	5	6	6	10	11	11	11	11	13	9	10	16	14	13	10	11	6	8
	30	17	24	7	12	5	23	20	25	24	11	8	13	16	8	25	23	1
	9	11	8	12	14	15	12	15	13	16	14	21	20	26	18	12	9	9
Tier 2	8	14	19	13	29	2	19	22	7	20	11	6	6	29	18	3	20	15
	20	15	17	13	17	20	21	19	19	1	26	30	26	31	25	20	17	14
	5	6	11	17	28	22	14	1	16	5	23	3	24	21	19	28	16	7
	20	22	22	21	23	22	34	26	29	32	35	35	33	31	29	26	27	24
	18	7	21	26	25	20	26	29	10	30	28	4	25	17	1	13	27	12
	27	29	25	24	32	26	35	32	33	43	41	43	38	64	35	29	33	28
	1	24	12	10	27	16	25	2	15	24	9	13	14	26	9	11	23	5
	34	35	34	33	33	32	42	36	41	51	49	51	44	69	44	40	40	32
	4	15	3	23	9	30	18	21	12	8	17	27	10	2	8	22	4	30
	41	41	40	39	40	39	41	40	47	52	61	54	47	72	41	44	48	43
Tier 3	5	23	17	26	10	15	26	7	28	10	27	12	30	17	19	6	18	3
	17	45	17	53	44	46	43	44	24	62	61	59	51	47	44	45	54	51
	21	18	27	8	2	24	6	2	5	13	23	3	28	24	27	23	14	26
	-9	50	55	56	46	51	47	53	59	66	66	66	53	51	48	51	62	59
	25	3	7	11	20	9	20	9	24	15	21	19	9	20	2	29	5	4
	25	54	59	57	52	57	51	58	63	68	50	68	58	59	57	59	67	66
	14	6	1	30	4	12	14	8	11	18	22	17	13	22	10	8	11	12
	62	61	64	63	59	61	61	64	69	75	78	77	73	69	80	84	82	79
	13	22	28	29	16	19	1	16	30	29	4	25	25	1	16	7	15	21
	82	87	76	69	58	55	77	77	87	84	89	91	90	81	89	96	94	91

Figure 48. Elevation data of the marshland plots taken 20 January 1977. Ground elevations of each plot are given in centimetres below each plot number with respect to mean sea level

361. Sediment pH was quite constant regardless of core location. The pH values were all greater than 8.0. The pH values were as expected for sediments inundated with seawater and dominated by salts.

362. Redox potentials generally reflected the elevation of the plot from which the core was taken. Upland cores had Eh values of +356 to +786. The intermediate sites located in tier 3 of the marshland area gave values from +43 to +671. Those plots which were located at the lowest elevations, tiers 1 and 2, had Eh values of -114 to +186. Redox readings were somewhat erratic and difficult to duplicate in the field.

363. Organic matter was present in small quantities. Only one sample contained greater than 0.266 percent organic matter; the 0- to 15-cm section of upland core (T-23-FO) had 0.594 percent organic matter.

364. The research site was composed of predominantly sand-size particles. All samples were greater than 94.7 percent sand. Those samples containing greater than 1 percent clay generally had associated clay lens, clay stringers, or clay balls. Silt was present in amounts less than 2.0 percent in all samples.

365. Cation exchange capacity (CEC) of the sediments was low. The CEC was a function of the quantity of reactive materials in the sediment. In these materials the CEC was directly related to the clay and organic matter percentages in the sample. The highest CEC (6.69 meq/100 g) was measured in the surface 0 to 15 cm of core (T-23-FO). This sample contained 3.5 percent clay and 0.594 percent organic matter. The lowest CEC was for the 15- to 30-cm increment of the sediment core from plot (T3-B1-6). The CEC was 1.26 meq/100 g of sediment. The sample contained only 0.2 percent clay and 0.033 percent organic matter. Some exchange capacity could be associated with the silt-size particles, but this fraction was generally present in small amounts (<2 percent) in these sediments.

366. Exchangeable bases, Ca^{++}, Mg^{++}, K^{+}, and Na^{+}, were always higher than the CEC. This was expected because of the salt deposited by seawater. Salts were probably precipitated in the upland soils if

they were not leached with fresh rainwater. Two of the upland sites, plot (T-23-F1) and plot (G-45-F2), were apparently leached and contained smaller amounts of Na^{++} than the other upland sites and those plots located in the marshland. Potassium and Mg^{++} were less variable between locations than was Na^{+} but tended to be higher in the marshland area. Some of the higher Mg^{++} concentrations and the high Ca^{++} concentrations were related to the presence of shell fragments. Neutral normal ammonium acetate will attack and dissolve $CaCO_3$. Those samples containing visible shell fragments, plot (G-45-F2) and plot (T3-B2-11) also gave the higher values of exchangeable Ca^{++}.

367. The method of Toth and Ott (1970) for the determination of exchangeable cations assumes that the Ca^{++} and Mg^{++} carbonates dissolve at a constant rate throughout the collection of leachates 1 and 2. Due to the high amounts of exchangeable Ca^{++} found in the nine shallow cores and the fact that the Ca^{++} concentration of all cores was much greater than the cation exchange capacity values, the rate of carbonate dissolution was determined.

368. Two samples {(T3-B1-6 and T2-B1-17) 15 to 30 cm} were rerun according to the Toth and Ott (1970) procedure. Two 250-ml samples of the leachates (1 and 2) were collected in successive 50-ml aliquots. Each aliquot was then analyzed for Ca^{++}. The results are shown in Table 97 and Figure 49 .

369. The results show that Ca^{++} solubilized from $CaCO_3$ and/or $CaCO_3MgCO_3$ (shell fragments) does not dissolve at a constant rate in leachate 2 as proposed by Toth and Ott (1970). Instead, the Ca^{++} concentration in each successive aliquot of leachate 2 gradually declines. This would lead to high calculated exchangeable Ca^{++} values as is the case for all of the nine shallow cores analyzed..

370. Salinity was lower in the upland sediments where some leaching had occurred. This value was directly related to the exchangeable Na^{+}. The high exchangeable Na^{+} in core 2 (S-49-F1) was reflected in a much higher salinity reading. Conductivity of sediments from those cores located in the marshland ranged between 1.88 and 8.98 mmhos/cm. Again, these values tended to correlate with exchangeable Na^{+} levels.

371. Total Kjeldahl nitrogen (TKN) ranged from a low of 23.5 μg/g to a high of 129.9 μg/g. The top section of each core was higher in TKN than the lower 15 cm in all but one core G-45-F2. Inorganic forms of nitrogen (NH_4^+, NO_2^- and NO_3^-) were generally low and did not constitute a fraction of the total nitrogen.

372. Total phosphorus values were low. The highest concentration was 156.6 μg/g. Most of the samples contained less than 100 μg/g. The oxalate-extractable phosphorus made up a considerable fraction of the total phosphate. In general, however, about 10 to 40 percent of the total phosphorus was extracted by the oxalate solution. This extractant was thought to primarily remove iron phosphates.

373. Total sulfide concentration of sediments was highly variable. It was difficult to rationalize the two high values for sulfide found in samples with redox potentials greater than 300 mV {plot (T-23-F0) and plot (G-45-F2)}. Sulfide was measured in all of those samples with redox potentials less than +186 mV. These were the plots that were saturated most of the time. Concentrations of sulfide in the study area ranged from <0.05 μg/g to 15.07 μg/g.

374. Lime requirement in all the plots was zero because pH values were greater than 8.0.

Deep core analysis

375. Soil cores were taken for analysis from those marshland plots where the high fertilizer rates were to be applied to the sprigged *Spartina alterniflora* (plot 13 of each block in each tier). Sediment samples were taken to depths of 105 cm from the center of each plot.

376. Four sets of deep cores have been taken since the beginning of the project. Deep cores were taken on 18 August 1976, 20 November 1976, 27 June 1977 and 14 October 1977. Moisture content, pH, nitrogen forms, and oxalate extractable phosphorus in each 15-cm section of the four sets of nine cores are given in Table 98. CEC and organic matter were also determined for the fourth set of deep cores and are reported in Table 99. All values are reported as a mean value of three observations per tier.

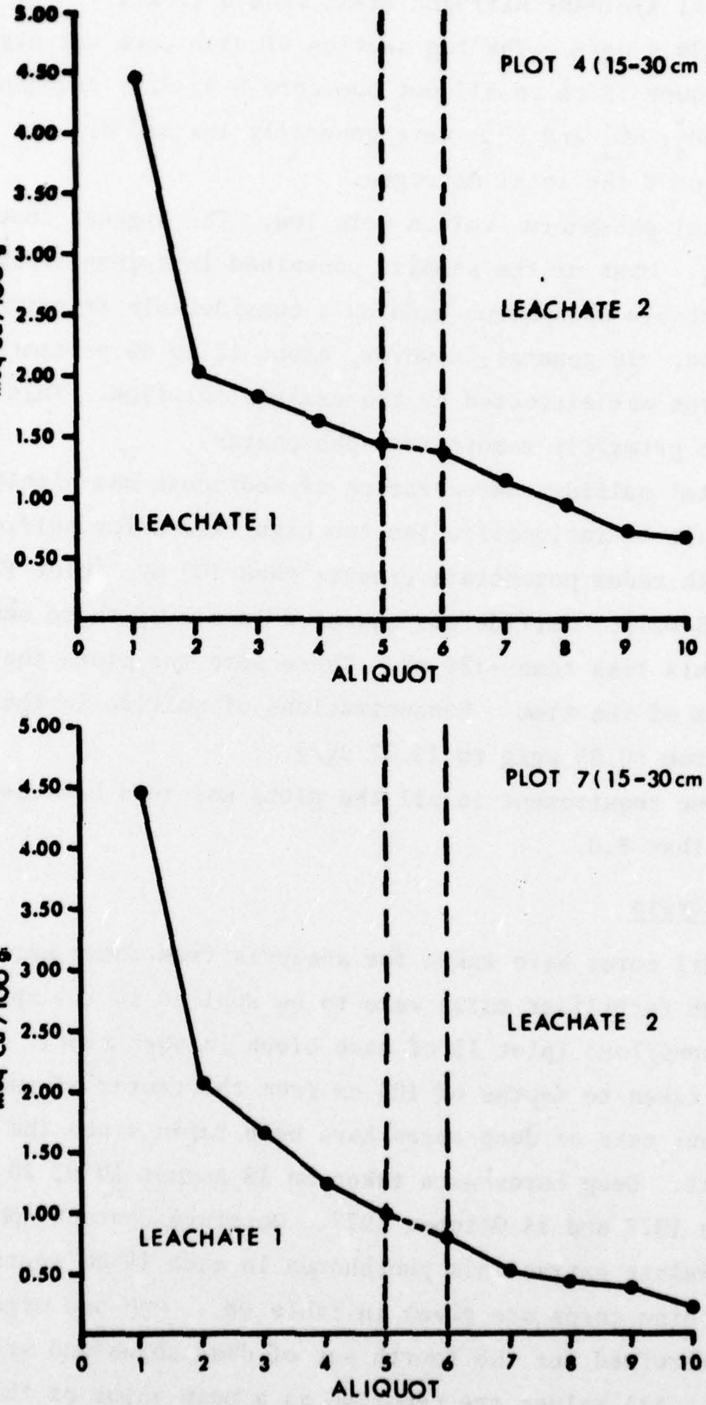

Figure 49. Calcium concentrations of successive 50-ml aliquot leachings to two sediment samples with 1*N* NH_4OAc

377. Moisture content with depth of the four sets of deep cores was always greater than 20 percent except for the 1 to 15-cm sections of the cores taken from tier 3 on 14 August 1976 and 27 June 1977. These sections (0 to 15 cm) were not completely flooded at the time of sampling and contained 17 to 20 percent moisture. Moisture content of the 0-to 15-cm sections of the fourth set of deep cores in tiers 1 and 2 was very high (65-79%). This was probably due to the buildup of finer grain soil particles on the surface which in turn could hold more water than the coarser grain fractions. Also, the entire research area was excessively wet during this sampling period.

378. Soil pH was consistent over the marshland area with depth and sampling date. Average pH values were generally between 7.8 and 8.4. A few values were outside this range. A low of 7.6 was recorded and a high of 8.9. These extremes are probably explained by the location of the plots within the marshland area. The mean high pH value of 8.9 was located in tier 3 and in the 0-to 15-cm core sections where a buildup of salts had taken place or deposits of calcareous material still existed. This along with the oxidizing condition found in tier three could account for the high pH values. The low pH extreme of 7.6 occurred in the 0 to 15-cm core section but taken from tier one. The reducing environment found in tier 1 as compared to tier 3 could account for the slightly less basic pH values.

379. TKN, NH_4^+-N, NO_2^--N, and NO_3^--N were determined on each core to a depth of 105 cm. Average TKN values in the first set of deep cores varied greatly with depth. There were areas within the cores where high local concentrations of TKN existed. These occurred randomly from tier to tier. Mixing of the wet sediment samples to produce a homogenous sample prior to analysis was a problem. The samples were visibly quite heterogenous so some variation in replicate analyses of the same sample was evident. Those samples containing high concentrations of TKN were especially variable as shown in Table 98 by large standard deviations around the mean. The TKN values of the second, third, and fourth sets of deep cores showed the same high variability as the first set. The highest concentrations of TKN were generally located in the upper section

of each core. This can be attributed to the buildup of plant and algal growth. Also, finer sediments and suspended organics were beginning to accumulate on the surface. The values reported (20 to 400 μg/g for TKN) were in the range which might be expected for these sandy type sediments.

380. TKN nitrogen values of the fourth set of deep cores were much less in the lower sections of the cores than the previous three sets. The first three sets of deep cores averaged around 80 μg/g. This reduction in TKN in the lower sections of the fourth set could be due to oxidation and utilization of nitrogen by plants or to the movement of inorganic nitrogen forms in the soil profile.

381. Ammonium nitrogen (NH_4^+-N) was also variable with depth, location, and sampling time. In general, the highest values were found at or near the surface for all four sets of deep cores. In all cases the surface values of NH_4^+-N in tiers 1 and 2 were higher than tier 3. This increase in NH_4^+-N in tiers 1 and 2 was probably due to a residual fertilizer effect and generally a more reducing condition in the two lower tiers as opposed to tier 3 which was farther upland and had a higher redox potential.

382. All plots received the same rate of fertilizer (224 kg N/ha as ammonium sulfate) on 22 July 1976, and the first set of deep cores was taken 14 August 1976. The high NH_4^+-N values in the surface layers of sediments taken from tiers 1 and 2 were likely due to the residual NH_4^+-N from the ammonium sulfate fertilizer applied 3 weeks earlier. These high surface values did not appear in tier 3. This was apparently due to the physical leaching of ammonium sulfate or to the oxidation of applied NH_4^+-N to NO_3^--N which in turn was easily leached out of the soil profile.

383. From the first set of deep cores to the fourth set, NH_4^+-N values generally decreased in all sections. Higher surface values of NH_4^+-N in sediments from tiers 1 and 2 of the third and fourth sets of deep cores compared to the second set of deep cores were measured. Mean ammonium (NH_4^+-N) values ranged from 2.6 to 51.5 μg/g in the first

set of cores, 2.4 to 16.2 μg/g in the second set, 1.6 to 23.0 μg/g in the third set, and 0.8 to 49.7 μg/g in the fourth set of deep cores.

384. Detectable amounts of NO_2^--N were present in all four sets of deep cores. Mean NO_2^--N values in Table 98 represent the maximum concentration a specific core section could have. This was due to the fact that many NO_2^--N values were below the detection limit, and to obtain a calculated mean value these low values were reported as the detection limit.

385. Higher values of NO_2^--N in the surface layers of tier 3 as compared to tiers 1 and 2 indicate that nitrification was occurring in the field. The small quantity of NO_2^--N in many samples may be an indication that a slight amount of NH_4^+-N had been oxidized. This oxidation may have occurred in the field or possibly after the collection of samples. The amounts were extremely small but may indicate that handling of samples in the thawed state may have to be improved. Maximum mean NO_2^--N values ranged from 0.03 to 0.19 μg/g in the first set of cores, 0.03 to 0.07 μg/g in the second set, 0.03 to 0.10 μg/g in the third set, and 0.03 to 0.11 μg/g in the fourth set of deep cores.

386. Detectable quantities (>0.6 μg/g) of NO_3^--N were not present in the first, second, and fourth sets of deep cores except for a few isolated core sections. As in the nitrite data, all nitrate (NO_3^--N) values represent maximum mean values with the actual nitrate means being much less than reported. Since the area was flooded much of the time and there was a source of organic matter for denitrification, nitrates would not be expected in sediments unless conditions were optimum for oxidation of NH_4^+-N and leaching was held to a minimum. The third set of deep cores showed more core sections with detectable NO_3^--N levels. This was most likely due to the sampling period when the tide was at its lowest level, thus exposing the entire marshland area to the atmosphere for brief periods of time. Under such conditions oxidation of NH_4^+-N could occur resulting in measurable quantities of nitrate. Maximum nitrate values for the third set of deep cores ranged from 0.60 to 2.38 μg/g.

387. Oxalate extractable phosphorus was highly variable with depth and with location on the research site. The highest values tended to be located in the upper section of each core. This may be reflecting a residue from a past fertilizer application of triple super phosphate. Also, additional phosphorus is being added to the surface as fine sediments and organics. Mean values ranged from a low of 16.0 μg/g to a high of 47.0 μg/g in the first set of deep cores. The second set of cores ranged from 20.7 to 112.9 μg/g, the third set from 14.9 to 93.2 μg/g, and the fourth set from 32.8 to 239.8 μg/g.

388. Extractable phosphorus in all sections of the fourth set of deep cores was higher than in any of the previous three sets of cores. The fourth set averaged around 60 μg/g in the lower sections as compared to about 30 μg/g in the first three sets of deep cores. It appears that there was a release of phosphorus from the surface layers of the cores and a reflecting increase of phosphorus in the lower sections of the deep cores.

389. CEC and organic matter were determined on the fourth set of deep cores. These data are presented in Table 99. Organic matter values ranged from 0.08 to 1.15% and CEC values varied between 1.3 and 3.2 meq/100g. CEC and organic matter appear to be somewhat higher in the lower two tiers (1 and 2 when compared to tier 3). A buildup of finer soil particles and organic matter in the lower tiers accounts for these differences. Higher values for organic matter were present in the upper sections of each core whereas CEC values varied with depth.

390. The results of the deep core analysis are plotted in Figures 50 to 54. TKN, NH_4^+-N, NO_3^--N, NO_2^--N, and extractable phosphorus are plotted against depth for each of the four sampling dates. Each point on the graph is a mean value of nine observations (three observations from each tier).

381. The graphs show the same results as did the analysis by tier (Table 98) discussed above. Generally the surface sections of the nine deep cores contained higher concentrations of TKN, NH_4^+-N, NO_3^--N, NO_2^--N and extractable phosphorus and these parameters decreased with depth. Higher surface values of TKN in the last 3 sets of cores as

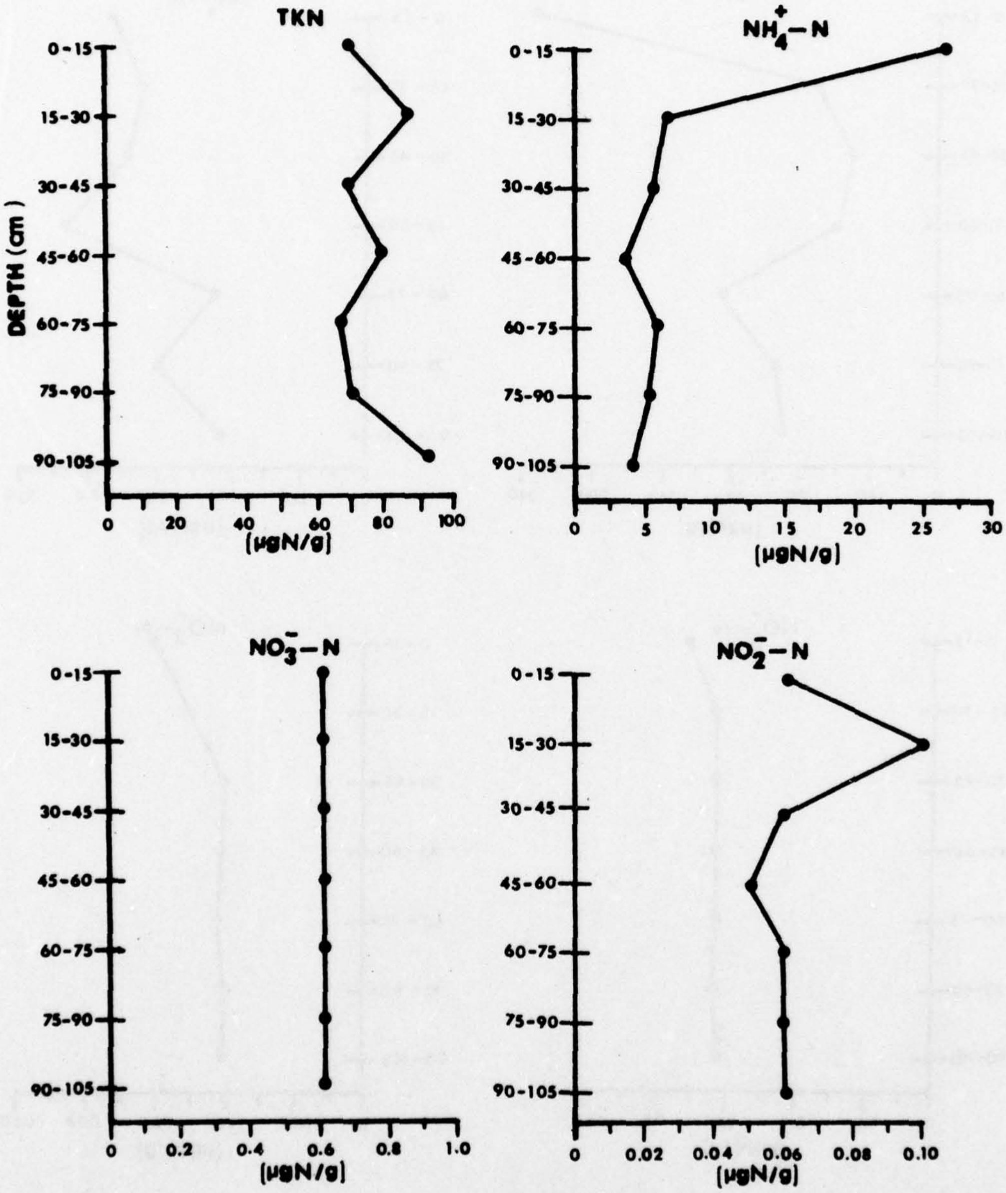

Figure 50. Mean concentrations with depth of TKN, NH_4^+-N, NO_3^--N, and NO_2^--N of deep cores sampled on 14 August 1976

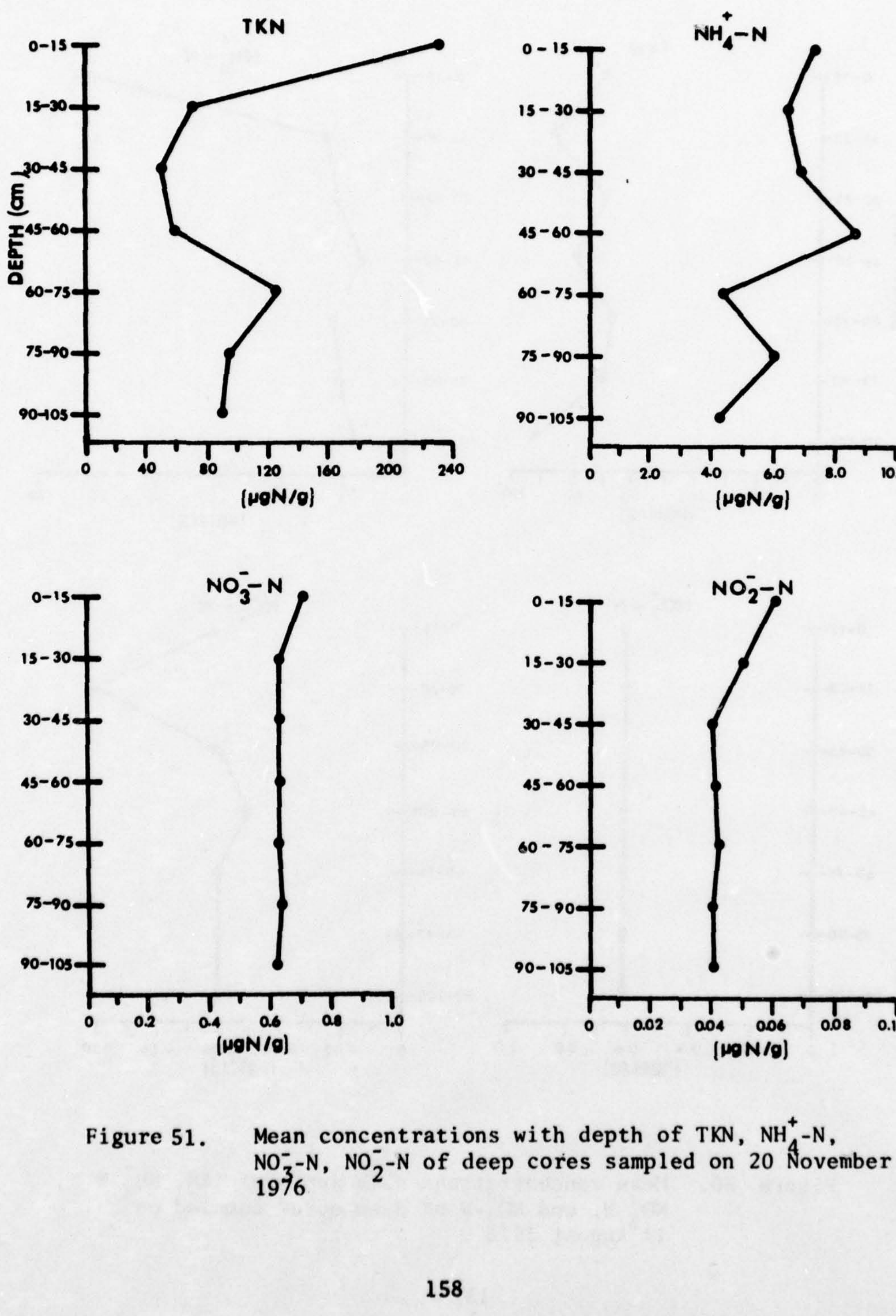

Figure 51. Mean concentrations with depth of TKN, NH_4^+-N, NO_3^--N, NO_2^--N of deep cores sampled on 20 November 1976

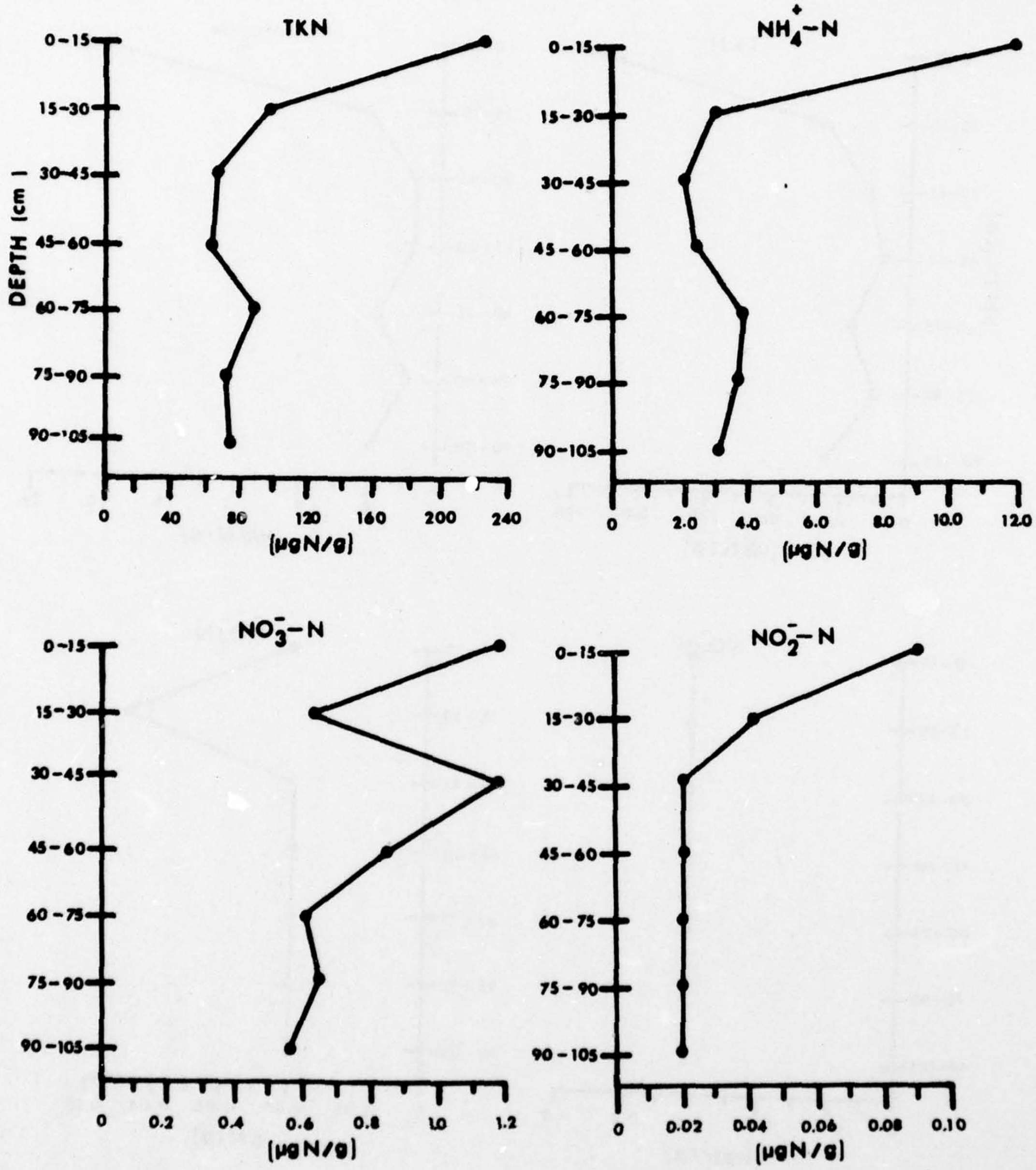

Figure 52. Mean concentrations with depth of TKN, NH_4^+-N, NO_3^--N, and NO_2^--N of deep cores sampled on 27 June 1977

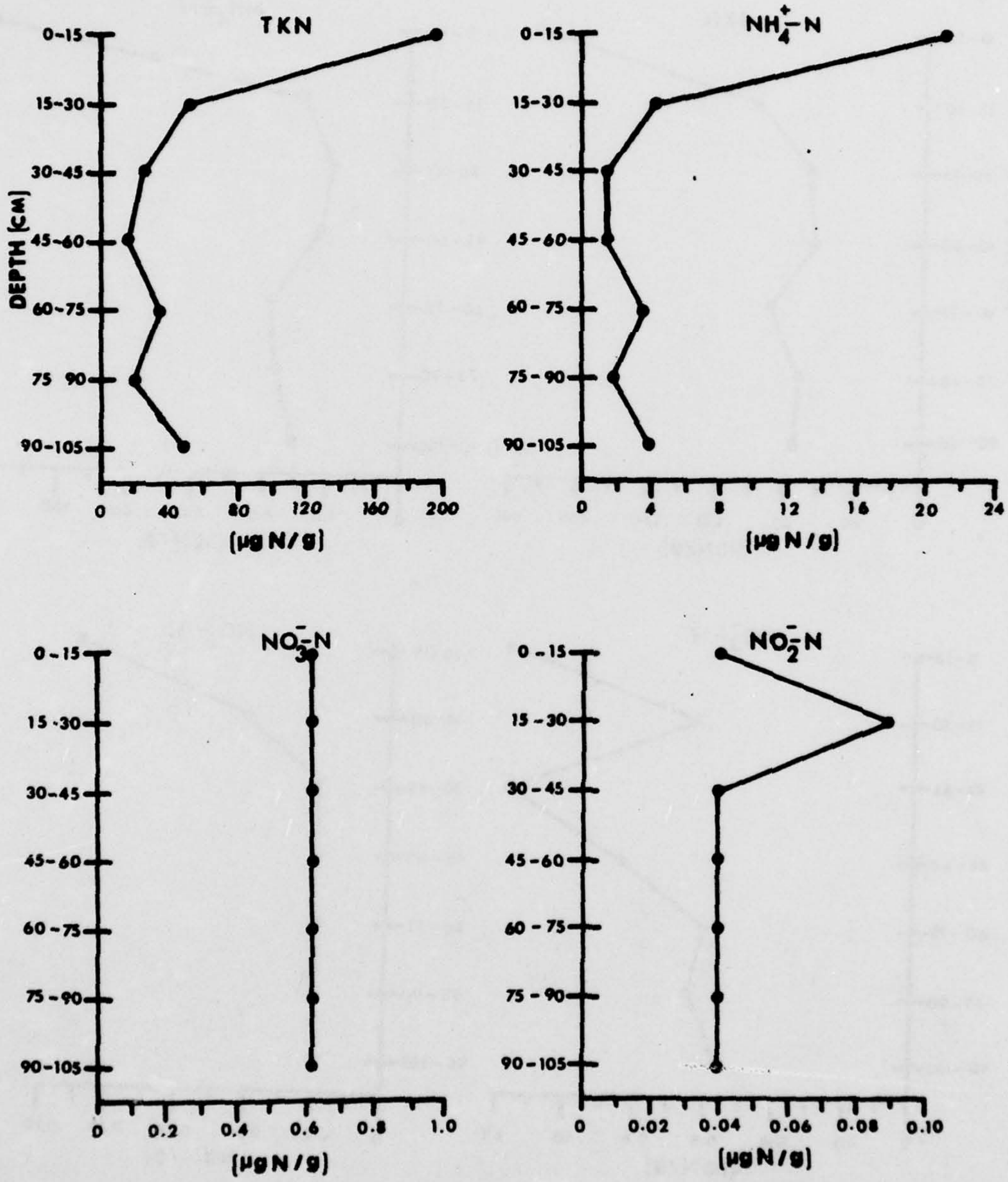

Figure 53. Mean concentrations with depth of TKN, NH_4^+-N, NO_3^--N, and NO_2^--N of deep cores sampled on 14 October 1977

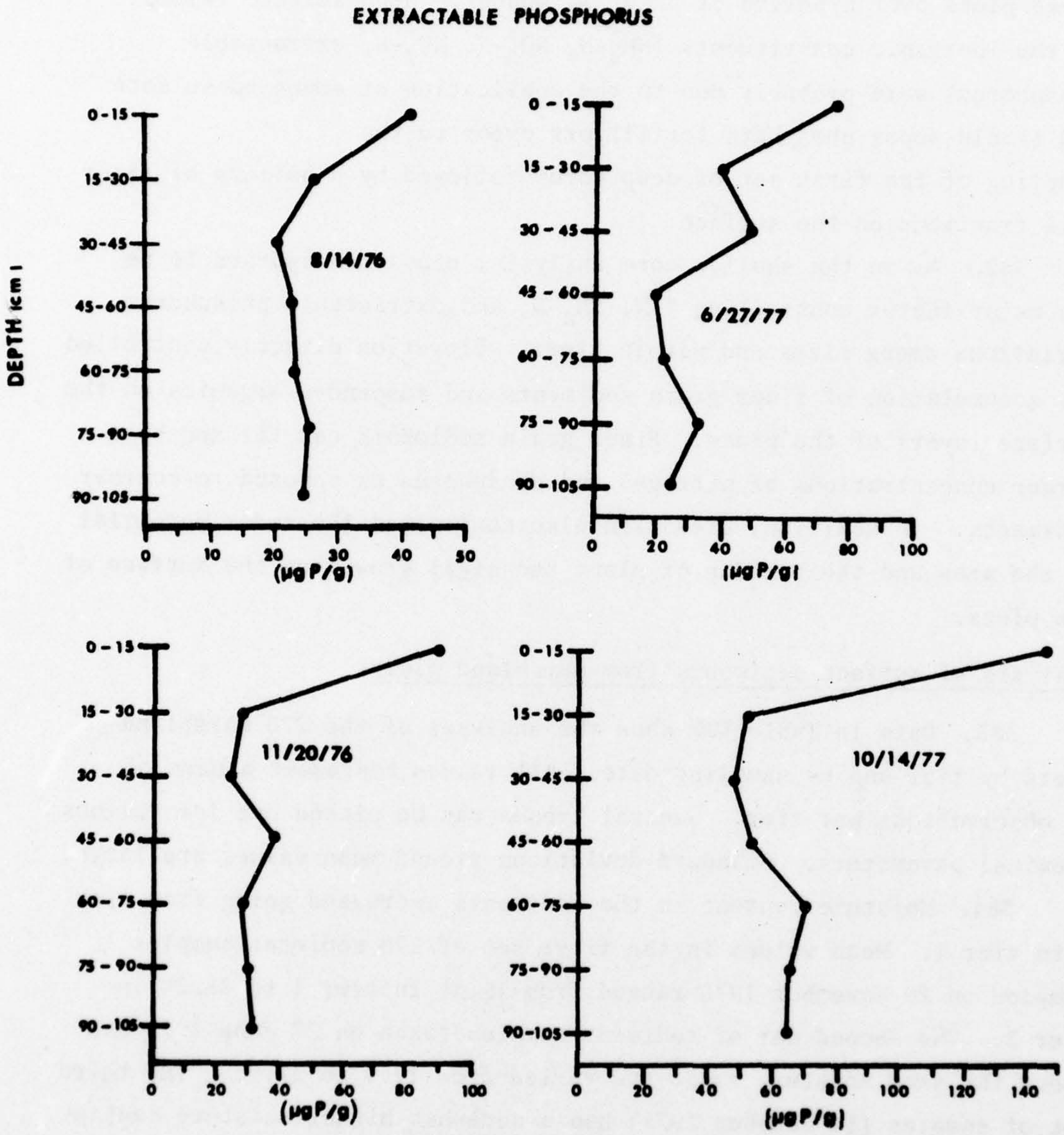

Figure 54. Mean concentrations with depth of extractable phosphorus of the four sets of cores taken on 14 August 1976, 20 November 1976, 27 June 1977 and 14 October 1977

opposed to the first set reflected the buildup of plant biomass for these plots over a period of about 14 months. High surface values of the inorganic constituents (NH_4^+-N, NO_3^--N, NO_2^--N, extractable phosphorus) were probably due to the application of ammonium sulfate and triple super phosphate fertilizers prior to the sampling of the first set of deep cores followed by a buildup of finer soil fractions on the surface.

382. As in the shallow core analysis, elevation appears to be the major factor controlling TKN, NH_4^+-N, and extractable phosphorus variations among tiers and within tiers. Elevation directly controlled the accumulation of finer grain sediments and suspended organics on the surface layers of the plots. Finer grain sediments can fix and hold larger concentrations of nitrogen and phosphorus as opposed to coarser sediments. In addition, elevation also controlled the redox potential of the area and the buildup of plant and algal growth on the surface of the plots.

Analysis of surface sediments from marshland plots

383. Data in Table 100 show the analyses of the 270 marshland plots by tier and by sampling date. All values represent a mean of 90 observations per tier. General trends can be picked out for various chemical parameters. Standard deviations around mean values are large.

384. Moisture content in the sediments increased going from tier 3 to tier 1. Mean values in the first set of 270 sediment samples sampled on 20 November 1976 ranged from 19.8% in tier 1 to 28.2% in tier 3. The second set of sediment samples taken on 27 June 1977 had about the same moisture range and varied from 17.4 to 31.4%. The third set of samples (14 October 1977) had a somewhat higher moisture content and ranged from 22.9 to 35.60%. Soil pH gradually increased from tier 1 to 3 at all sampling dates (20 November 1976, 27 June and 14 October 1977). Sediment pH varied from 8.0 to 8.7 in the first set of 270 samples, 7.5 to 8.7 in the second set and 7.9 to 8.6 in the final set.

385. Field measurements of Eh were made with a platinum and calomel electrode. Eh measurements were made by inserting the electrodes directly into the substrate to a depth of about 15 cm. Eh readings were

made in the field and coincided with the sampling dates of the 270 sediment samples.

386. Sediment Eh values became more positive from tier 1 to tier 3 for all sampling dates. Eh values ranged from -30 to +164 mV on the first sampling date, from +7 to +262 mV for the second sampling date and from -146 to +103 on the final date. Eh values for the third set were more negative than those measured earlier in the study. This was probably due to the fact that all of the 270 plots measured were extremely wet at the time the third set of samples was taken.

387. The standard deviation around the mean for Eh was very large. A portion of the variation was most likely due to the differences in elevation of the plots located within each tier. Also, it was difficult to consistently insert the platinum electrode into the sediment without introducing variable amounts of atmospheric oxygen around the platinum tip. Many factors can cause variations in Eh reading; thus, accurate measurements in the field are difficult to obtain.

388. Mean values for TKN, NH_4^+-N and extractable phosphorus were higher in the second and third sets of the 270 sediment samples compared to the first set of samples taken in 1976. Nitrate-N was slightly higher in the second set of samples compared to the first and third sets. Nitrite-N values have decreased from the first set to the third set of 270 cores.

389. TKN values decreased going from tier 1 to tier 3 for all three sets of surface samples.

390. For the 20 November 1976 sampling date, TKN ranged from 44 to 170 μg/g but increased from 51 to 302 μg/g for the 27 June 1977 set of samples. The 14 October 1977 set ranged between 66 and 288 μg/g.

391. Ammonium nitrogen (NH_4^+-N) concentration was 2.9 μg/g in tier 3 and increased to 4.83 μg/g in tier 1 on the first sampling date. The second sampling date showed a similar increase in NH_4^+-N going from tier 3 to tier 1 (7.5 - 16.4 μg/g), but concentrations were increased by a factor of 2.5 to 3.5. Ammonium-N values increased for the third sampling date from 3.7 in tier 3 to 9.9 μg/g in tier 1. Concentrations of NH_4^+-N

were higher than the first sampling date but somehwat lower than the second sampling date.

392. Ammonium-N values are highly variable and the mean values reported per individual tier have a large standard deviation associated with them. All trends and interpretations must be generalized because of such large experimental variation.

393. Nitrate-N values ranged from 0.7 to 1.2. μg/g for the first set of samples, and for the second set the range was from 0.9 to 1.7 μg/g. All of the NO_3^--N values for the third set were less than 0.6 μg/g. There was not a significant buildup of NO_3^--N in the surface horizons of these sediments due to the application of nitrogenous fertilizers.

394. Nitrite-N values ranged from 0.14 to 0.26 μg/g for the first sampling date, from 0.04 to 0.06 μg/g for the second sampling date, and 0.04 to 0.07 μg/g for the third sampling date. These concentrations are low.

395. Extractable phosphorus values ranged from 30 to 42 μg/g on the first set of 270 sediment samples compared to 38 to 62 μg/g on the second set and 27 to 96 μg/g for the final set of samples. Extractable phosphorus values increased from tier 3 to tier 1. Extractable phosphorus values showed the same trends as TKN and NH_4^+-N values.

396. CEC and organic matter values were also determined on the third set of 270 cores. These values are reported in Table 101 and are compared to the CEC and organic matter values of the soil samples taken 29 June 1976. A very generalized comparison must be made due to the fact that for the 29 June 1976 sample only six observations were made compared to a total of 270 observations for the 14 October 1977 sampling date.

397. In general, CEC and organic matter increased from 29 June 1976 to 14 October 1977. Both CEC and organic matter were higher in the lower tiers (1 and 2) for the 14 October 1977 sample when compared to the third tier, which was at the highest elevation.

398. Algal growth on the surface of the plots in tiers 1 and 2 was more intense than in the upper tier (3). This would also lead to a buildup of TKN and phosphorus in the lower tiers.

399. Most of the finer soil fractions in the third tier along with the applied inorganic fertilizers were probably being leached or transported out of the surface layer and were being deposited in the lower tiers. This was accomplished by wave action, precipitation, and energy-stilling action by the dike, as discussed below.

400. A combination of all the above factors probably accounts for the increase of nitrogen, phosphorus, CEC, and organic matter going from tier 3 to tier 1 in the marshland plots.

401. Elevation appears to be the controlling factor and also probably controls algal growth, sediment movement, fertilizer movement, and the relative redox potential in all tiers. Elevation is very critical for the establishment of good marshlands since it controls so many other vital factors.

402. Ammonium, NO_3^--N, and NO_2^--N have decreased in the third set of sediment samples when compared to the second set of 270 samples. Seasonal variations, plant growth and uptake, elevation changes or a combination of the factors probably accounts for the changes noted. Total Kjeldahl nitrogen values for tier 1 for the second and third sampling dates were similar, but there appeared to be an increasing buildup of TKN in tier 2. TKN increased from 141 μg/g to 214 μg/g in tier 2 from the second to third sampling dates. Extractable phosphorus values increased in tier 1 on each of the three sampling dates. Sedimentation processes were probably responsible for this gradual increase.

403. Data presented in Figures 55 to 60 illustrate how TKN, NH_4^+-N, NO_3^--N, extractable phosphorus, pH, and redox potential changed with time for the 270 marshland plots. All values represent a mean of 90 observations per tier except the initial sampling date (29 June 1976). For the initial date 2 observations were taken in tier 1, 1 observation in tier 2, and 3 observations in tier 3.

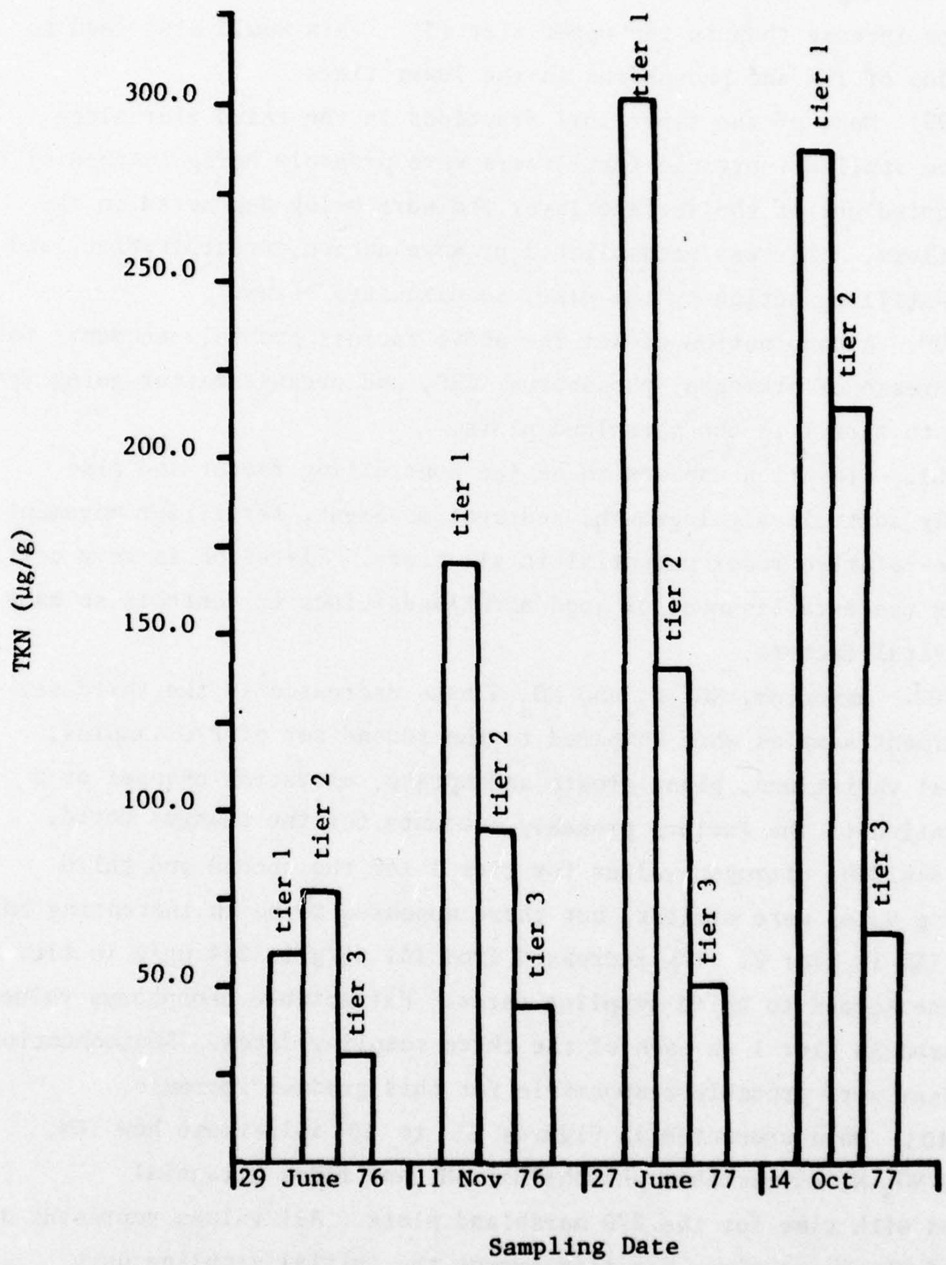

Figure 55. TKN concentration of sediment as influenced by tier and sampling date

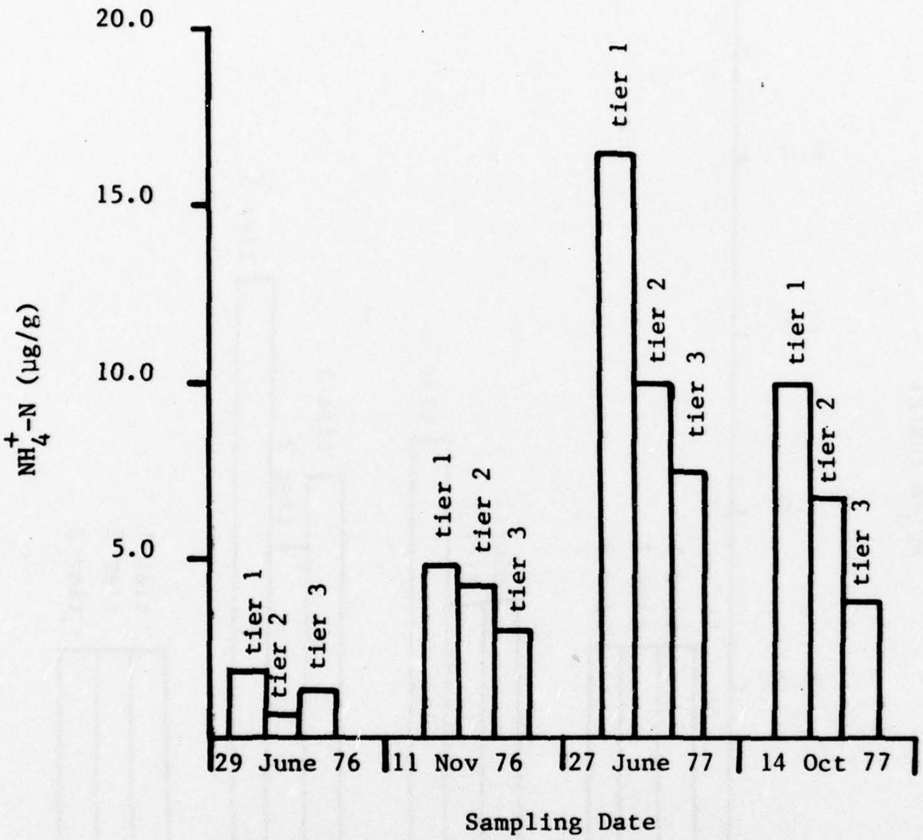

Figure 56. NH_4^+-N concentration of sediment as influenced by tier and sampling date

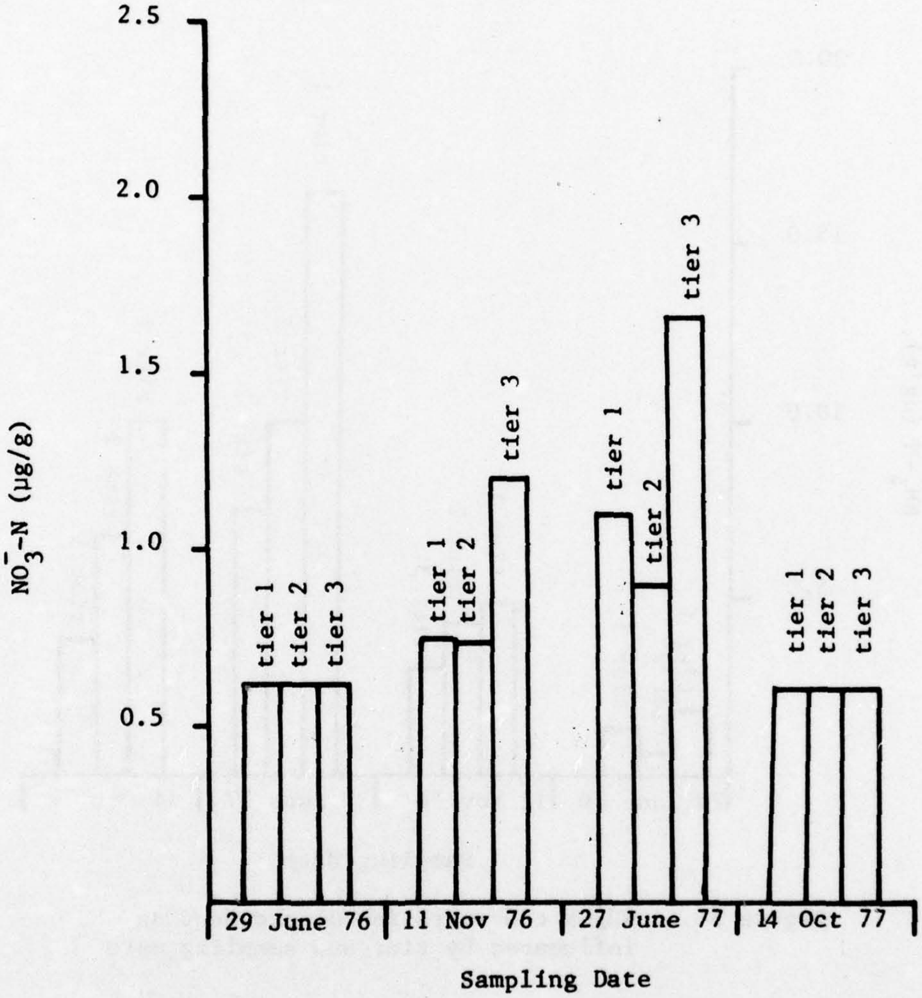

Figure 57. NO_3^--N concentration of sediment as influenced by tier and sampling date

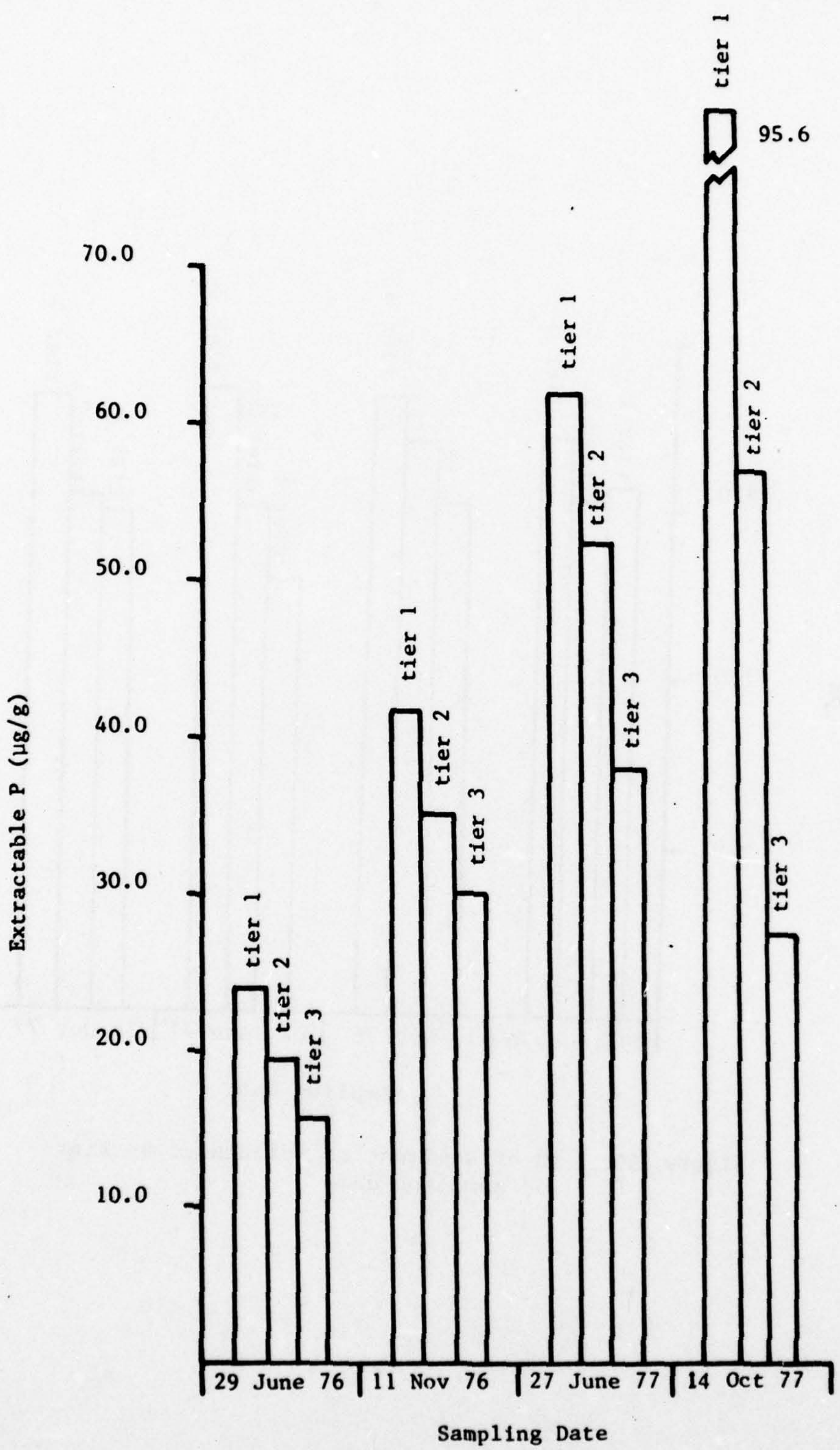

Figure 58. Oxalate extractable phosphorus concentration of sediment as influenced by tier and sampling date

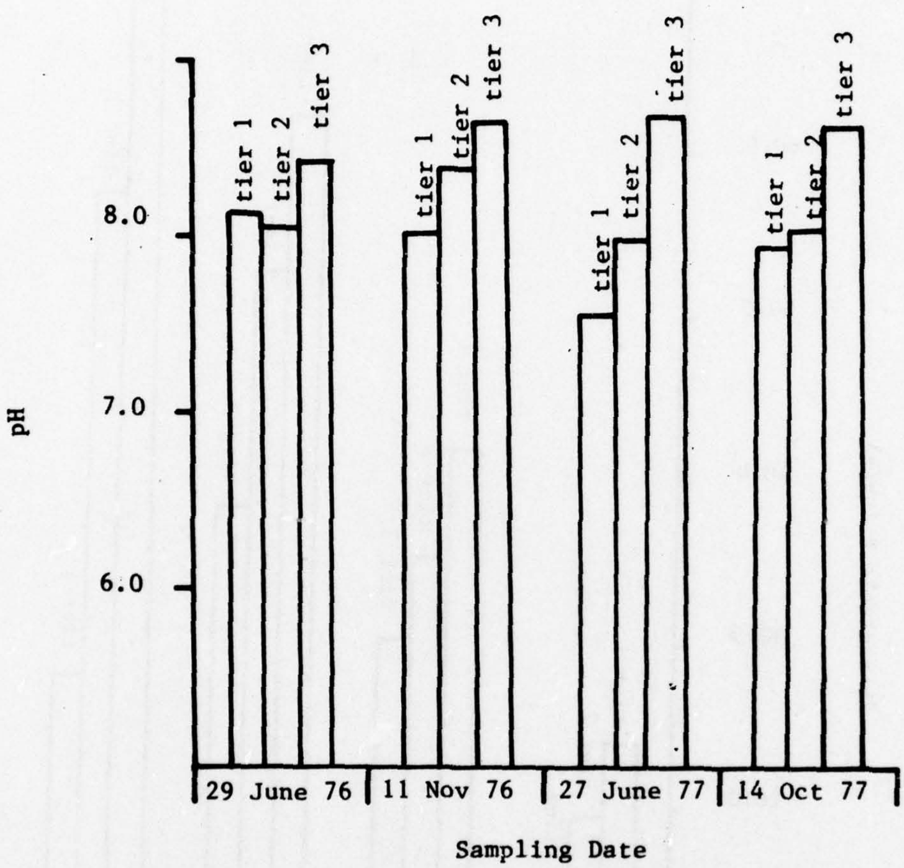

Figure 59. pH of sediment as influenced by tier and sampling date

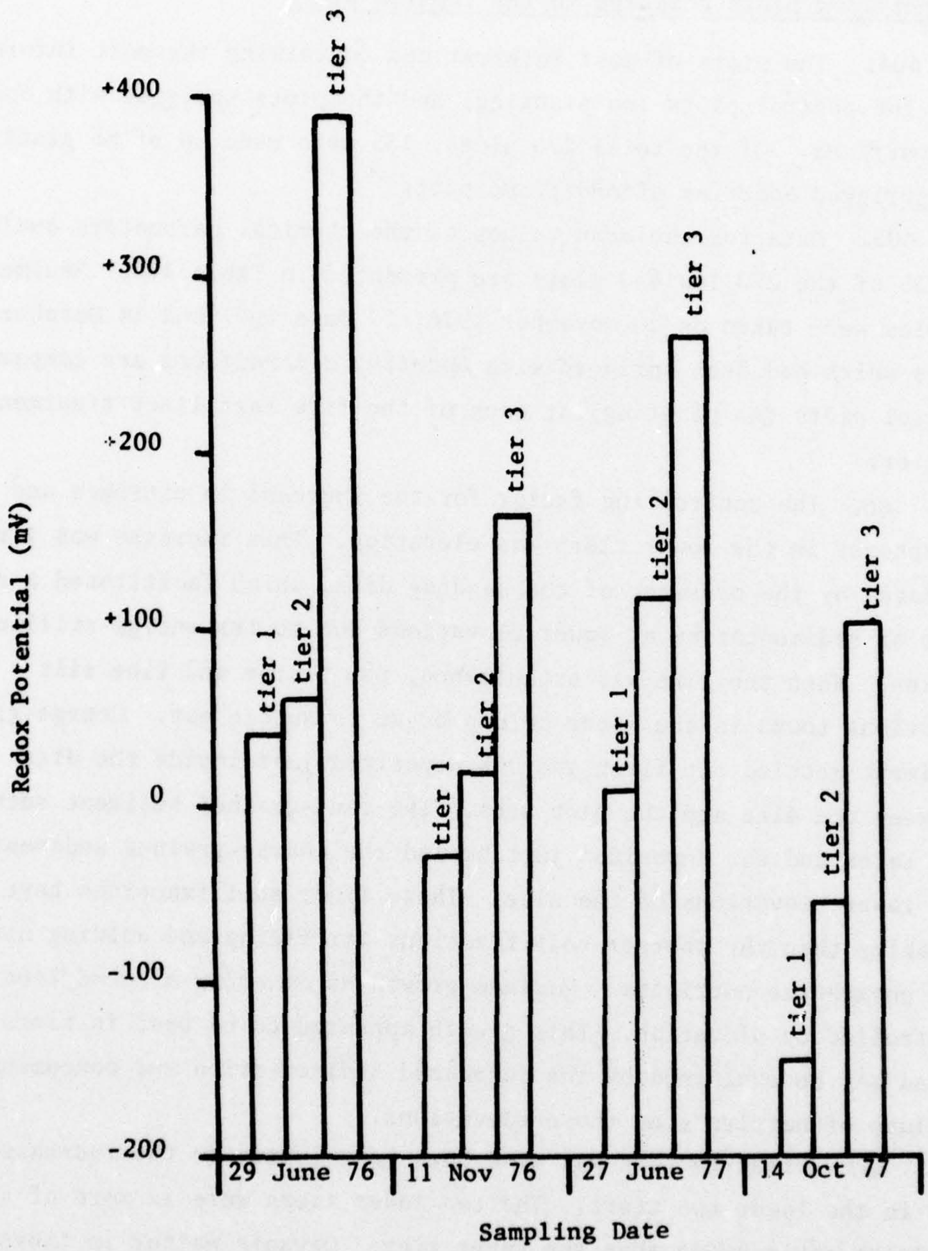

Figure 60. **Redox potential of sediment as influenced by tier and sampling date**

Sediment analysis of sprigged and seeded *Spartina alterniflora* plots compared to the control plots

404. The plots of most interest and containing the most information were the control plots (no planting) and the plots sprigged with *Spartina alterniflora*. Of the total 270 plots, 135 were made up of no planting and sprigged *Spartina alterniflora* plots.

405. Data for the mean values of the chemical parameters analyzed on 135 of the 270 lowland plots are presented in Table 102. Sediment samples were taken on 20 November 1976, 27 June 1977 and 14 October 1977. Plots which had been sprigged with *Spartina alterniflora* are compared to control plots (no planting) at each of the five fertilizer treatments by tier.

406. The controlling factor for the increase in nitrogen and phosphorus in the lower tiers was elevation. This increase was largely mediated by the presence of the sandbag dike, which facilitated a rapid rate of sedimentation at lower elevations due to its energy-stilling action. When the dike was established, the coarse and fine silt fractions found in the water column began to settle out. Coarse-grained sediment settled out first and was deposited just inside the dike between the dike and the plot area. The fine-grained sediment settled out later and was deposited just behind the coarse-grained sediment in the lower elevations of the site. These finer soil fractions have a higher capacity than the coarser soil fractions for fixing and holding nitrogen and phosphorus nutrients. Maximum growth of *Spartina alterniflora* was controlled by elevation. This growth appeared to be best in tiers 1 and 2 and may be explained by the increased sedimentation and concomitant buildup of nutrients at those elevations.

407. Other factors may also have contributed to the increase of TKN in the lower two tiers. The two lower tiers were in more of a reducing environment than the upper tier. Organic matter in tiers 1 and 2 would not be oxidized and decomposed as readily as in tier 3. Such reducing conditions would lead to a buildup of TKN and organic matter in tiers 1 and 2 as compared to tier 3.

409. Tier 1 sprigged with *Spartina alterniflora* plants and the control plots had the highest TKN values of the three tiers. Tier 2 plots had less TKN than tier 1 but more than tier 3. These differences are probably explained by the oxidizing/reducing condition of the marshland plots and increased sedimentation at the lower elevations. Tier 3 plots were in a more oxidizing environment relative to tier 2 and tier 1. As measured by redox potential (Eh), a more reducing environment was encountered going from tier 3 to tier 1. This was caused by sediments in tier 1 being submerged for longer intervals of time than tier 2. Tier 3 was very seldom under water. Organic matter produced in tier 3 plots would be subjected to oxidizing conditions. This would lead to the oxidation and decomposition of the organic matter. Lower TKN values were reflected in this tier. More reduced conditions (lower Eh value) existed in tiers 1 and 2. Under these conditions it would take much longer to decompose the organic matter produced. In addition, formation of a layer of algae in those areas that were under water a large proportion of time was apparent. These conditions combined to give higher TKN values than in tier 3.

410. TKN values of the plots sprigged with *Spartina alterniflora* ranged from 140 to 230 μg/g in tier 1 on the first sampling date. The range was from 190 to 400 μg/g on the second sampling date and from 180 to 390 μg/g on the third date. Mean TKN values for tier 2 varied between 80 μg/g and 160 μg/g for the first sampling date, 150 and 230 μg/g for the second date and 80 and 330 μg/g on the third date. Values for TKN were much lower for tier 3 (33 to 52 μg/g for the first sampling date as compared to 31 to 59 μg/g for the second date and 42 to 84 μg/g for the third date). TKN values in the control plots had the same general ranges by tiers as did the plots sprigged with *Spartina alterniflora* . This indicates a substantial elevation effect on TKN values largely influenced by tidal inundation.

411. Mean ammonium nitrogen (NH_4^+-N) values were also variable among tiers and among fertilizer treatments. There appears to be no clear relationship between the amount of NH_4^+-N fertilizer applied to the plots and the amounts of ammonium nitrogen found by sediment

analysis. Ammonium nitrogen values tended to decrease from tier 1 to tier 3 in both the plots sprigged with *Spartina alterniflora* and the control plots for both sampling dates. Ammonium values of sediments from the second sampling date (17 June 1977) tended to be higher than those values from the first sampling date (20 November 1976) and the third sampling date (14 October 1977). Most of the NH_4^+-N values fell within the 1- to 12-μg/g range. A few of the samples were higher than 12 μg/g.

412. Detectable levels of NO_2^--N were found in sediments from all the plots. Mean NO_2^--N values represent maximum concentrations a specific core section could have. This is due to the fact that many NO_2^--N values were below the detection limit and to obtain a calculated mean value these low values were reported as the detection limit. The actual NO_2^--N concentrations would be much less than the reported means. Nitrite values tended to be higher in the first sampling date as opposed to the second sampling period. These differences might be explained by better handling procedures of the second set of samples. Oxidation of NH_4^+-N to NO_2^--N was cut to a minimum. Mean nitrite values for sediments from the control plots and sprigged plots from the first sampling date were between 0.06 μg/g and 0.50 μg/g. A few values were higher than 0.50 μg/g. The highest value was 1.18 μg/g. Nitrite values from the second set of sediment samples were much lower and ranged from 0.03 μg/g to 0.12 μg/g. Nitrite-N ranged from 0.03 to 0.07 μg/g for the third set of sediment samples. Sediment temperatures were also higher in June, the second sample date, and October, the third sample date, which would encourage rapid transformation of NO_2^--N. This was probably a factor in the lower amounts of NO_2^--N detected during the summer and early fall months.

413. Nitrate nitrogen was generally not detected in the first and third sets of sediment samples. Most NO_3^--N concentrations were <0.6 μg/g. (Mean values of NO_3^--N again represent maximum values with the actual concentrations being much less.) Those nitrate values that were detected ranged from 0.6 to an extreme high of 4.8 μg/g. Nitrate

values in the second set of samples were higher than the first set and varied from 0.6 μg/g to 2.5 μg/g. All nitrate values for the third set were less than 0.6 μg/g.

414. Extractable phosphorus was highly variable among tiers and fertilizer treatments. No trend existed between the rate of fertilizer applied and that actually found in the soil. Extractable phosphorus in the second and third sets of samples tended to be higher when compared to the first set. This difference was more pronounced in the control plots than in the sprigged plots and was probably due to the addition of phosphorus fertilizer to the plots between the first and second sampling dates and to the uptake of phosphorus by the plants.

415. Extractable phosphorus ranged from 19 μg/g to 67 μg/g in the soil samples taken 20 November 1976 as compared to the second set taken 27 June 1977 which showed a range from 29 to 93 μg/g. Extractable phosphorus for the third set of samples ranged from 19 to 132 μg/g.

416. Phosphorus was higher in tiers 1 and 2 for the third set of samples when compared to the first and second sets of sediment samples. Sediments from tier 3 for the third sample appeared to be lower in P than the first two sets of samples. This may indicate some movement of phosphorus from the sandy sediments in the upper tier.

417. The increases of TKN, NH_4^+-N, and extractable phosphorus going from tier 3 to tier 1 were again controlled by elevation as in the previous analysis of the total 270 plots. Sedimentation processes and organic matter buildup could account for these increases by tier.

418. Seeded *Spartina alterniflora* plots were compared to control plots for the 14 October 1977 sampling date since the survival of the seeded plants was much better than when the second set of samples was taken (20 November 1976). The results can be seen in Table 102. There does not appear to be much difference in the chemical parameters between the seeded, sprigged, or control plots for the third set of sediment samples. This was to be expected since no large differences were noted between the sprigged and control plots at the three sampling dates.

419. CEC and organic matter were determined on the third set of sediment samples. These determinations were also made for sediments from seeded and sprigged plots of *Spartina alterniflora* and compared to the same control plots. These results are presented in Table 102 .

420. CEC values were not different among the sprigged, seeded and control plots but there was a tier effect. The highest CEC values were in tier 1 for the sprigged, seeded, and control plots. Values ranged from 5.1 to 12.1 meq/100g of sediment. Tier 3 CEC values were much less than tier 1 but only slightly greater than tier 2. Tier 3 CEC values ranged from a low of 3.0 meq/100g to a high of 5.3 meq/100g. Tier 2 values were from 2.4 to 3.6 meq/100g. Tier 1 CEC values were the highest due to the buildup of finer soil particles and organic matter compared to tiers 2 and 3. All CEC values were relatively low but were in the range expected for these sandy sediments.

421. Organic matter content of sediments from the seeded, sprigged, and control plots were about the same. Organic matter in the sprigged plots of *Spartina alterniflora* in tiers 1 and 2 appeared to be slightly higher than in the seeded and control plots. Organic matter increased from tier 3 to tier 1. Tier three organic matter values ranged from 0.08 to 0.24%. Tier 2 values were between 0.22 and 0.64% and tier 1 values were from 0.24 to 0.69%.

422. The results of the sprigged versus the control plots for TKN and extractable phosphorus of *Spartina alterniflora* over three sampling dates can be seen in Figures 61 and 62 . The figures again show how TKN and extractable phosphorus gradually increased with time in both the sprigged and control plots. A tier or elevation effect was also seen in these plots. The lower tiers (1 and 2) were higher in both nitrogen and phosphorus than the upper tier (3).

423. The data presented earlier showed how TKN, NH_4^+-N, and extractable phosphorus gradually increased with time, with the increase going from the upper tier (3) to the lower tier (1). Nitrate N, pH, and redox potential had changed very little over the four sampling dates. The variations in redox potential were due to the various stages of wetness of each sampling time. These data

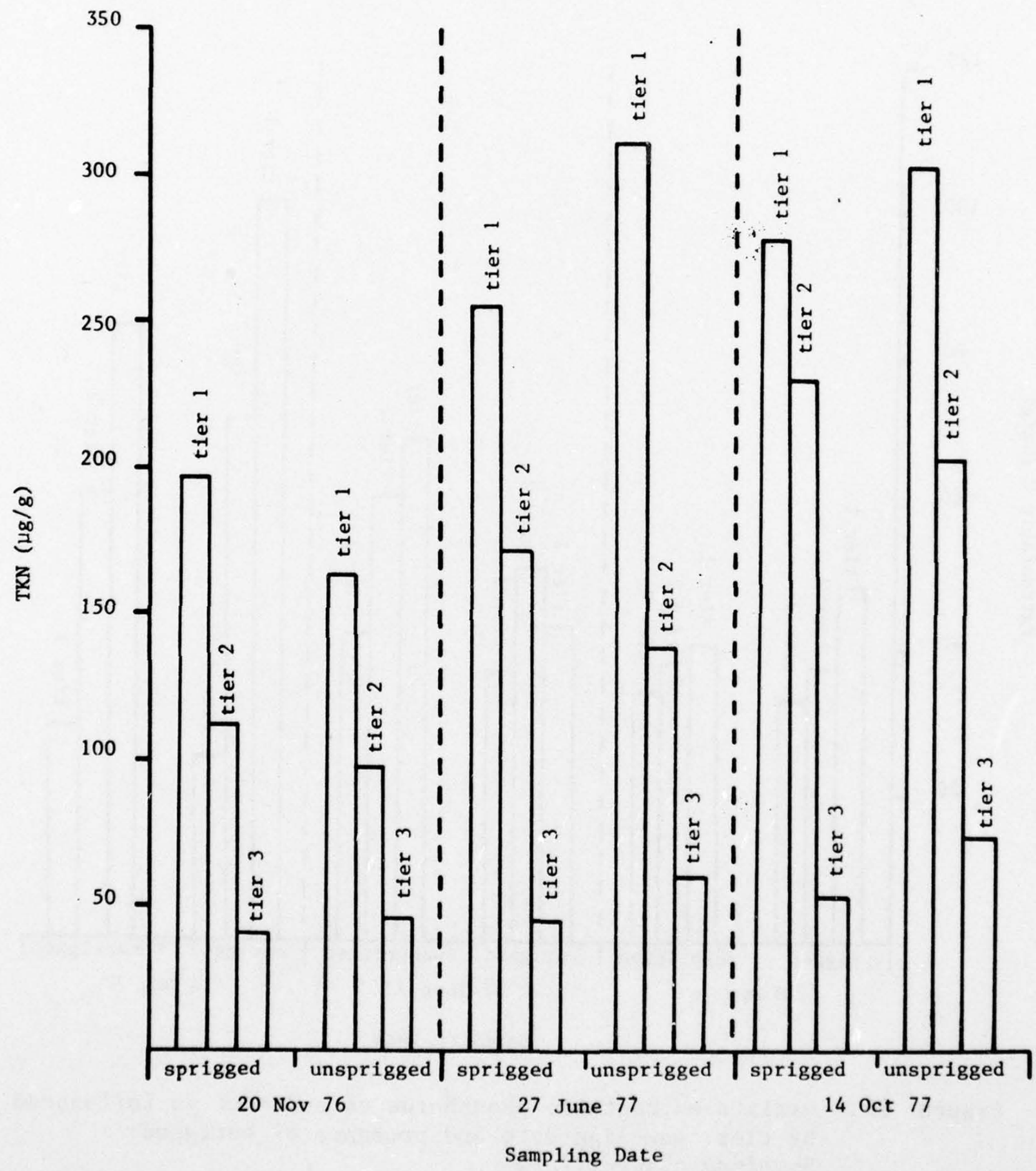

Figure 61. TKN of sediment as influenced by tier, sampling date and presence of sprigged *Spartina alterniflora*

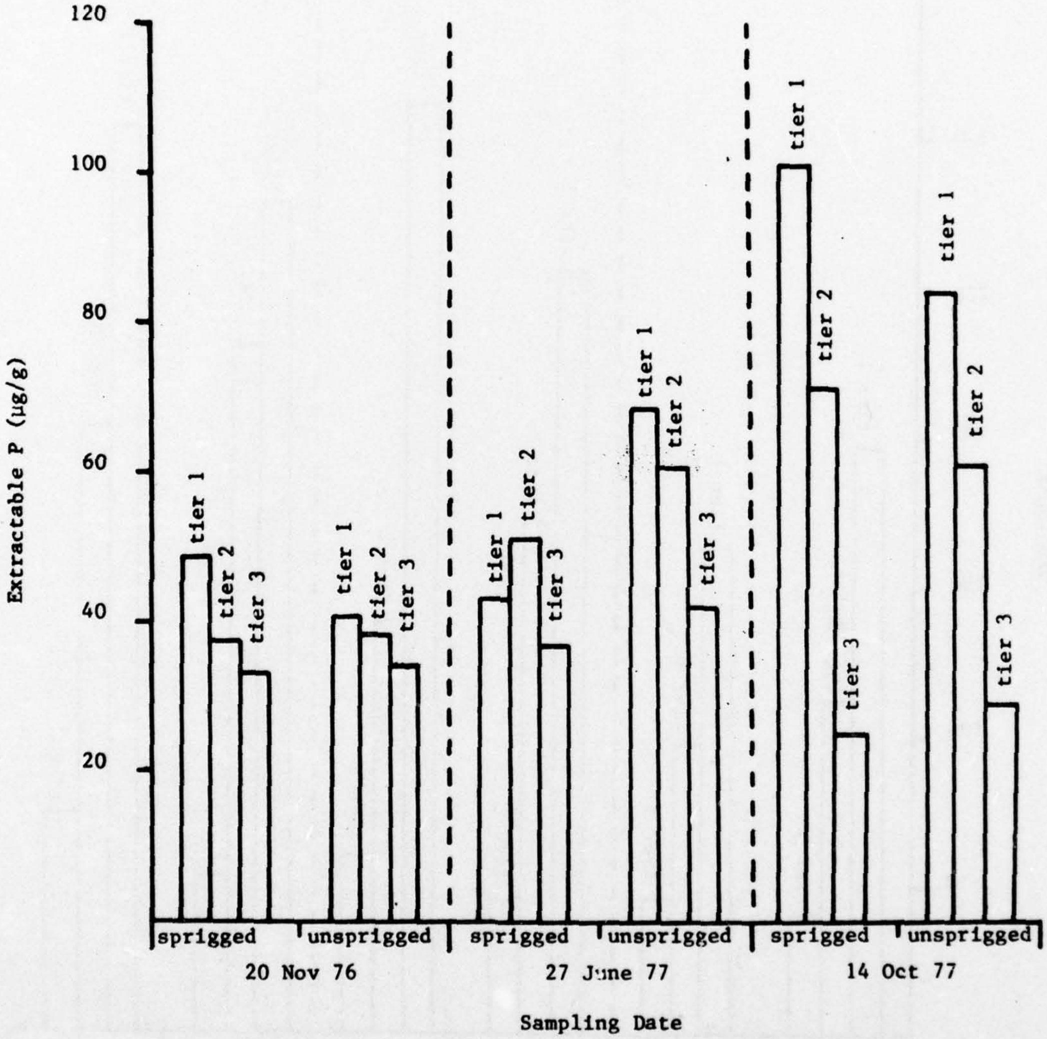

Figure 62. Oxalate extractable phosphorus of sediment as influenced by tier, sampling date and presence of sprigged *Spartina alterniflora*

emphasize that increases in nutrients in the sediment are independent of the presence or absence of plants in the early stages of marsh formation. Sediments from unsprigged control plots increased in organic matter, phosphorus and nitrogen at about the same rate as those where plants had been established.

Sediment analysis of sprigged and seeded *Spartina patens* plots compared to the control plots

424. There was lower survival of *Spartina patens* at the lower elevations of the experimental plot area. Plots that were seeded and sprigged with *Spartina patens* were compared to the control plots for the third sampling date. Survival of the plants in the *Spartina patens* plots at the end of 1977 was much better than at the end of the 1976 growing season (20 November 1976). Results of the sediment analysis of the sprigged and seeded *Spartina patens* plots are presented in Table 103 .

425. TKN, NH_4^+-N, extractable phosphorus, CEC and organic matter concentration of sediments from the *Spartina patens* plots show the same trends and about the same ranges as the seeded and sprigged plots of *Spartina alterniflora*. The *Spartina patens* plots exhibit the same wide variation in values and high standard deviations for most of the chemical parameters. TKN values for the seeded and sprigged *Spartina patens* plots ranged from a low of 39 μg/g to a high of 431 μg/g. Ammonium N values were from 2 to 19 μg/g. Extractable phosphorus varied widely and was between 18 and 147 μg/g. CEC values ranged from 2.0 to 10.0 meq/100g and organic matter values were from 0.08 to 0.84 %. TKN, NH_4^+-N, extractable phosphorus, CEC, and organic matter values generally increased in concentration going from tier 3 to tier 1. Nitrate N values were <0.62 μg/g throughout the plots.

426. The above data indicate that there were only minor differences in soil parameters of sediments taken from the seeded and sprigged *Spartina alterniflora*, the *Spartina patens* plots and the control plots on a given sample date. There always appeared to be a tier effect with concentrations of the various chemical components in tiers 1 and 2

being higher than tier 3. There also appeared to be a gradual buildup of chemical constituents over time in the plots.

Chemical analysis of the initial six marshland plots with time

427. Table 104 compares the nitrogen, phosphorus, CEC, and organic matter values of the initial six marshland plots prior to fertilization (29 June 1976) up throught the last sampling date of the 270 sediment samples (14 October 1977).

428. TKN values ranged from 20 to 85 μg/g for the 29 June 1976 sampling date and increased to 50 to 930 μg/g for the last sampling date (14 October 1977).

429. The NH_4^+-N values for the first sampling date (29 June 1976) varied between 0.60 to 2.51 μg/g and increased to 1.85 to 15.50 μg/g for the final sampling date.

430. Extractable phosphorus also increased over time. The 29 June 1976 phosphorus content ranged between 9.0 and 30.7 μg/g and increased to 21.3 to 150.0 μg/g for the last sampling date.

431. CEC and organic matter determinations were also made for the last set of sediment samples taken on 14 October 1977. These values can be compared to the CEC and organic matter values determined prior to fertilization (29 June 1977). CEC values increased over time (Table 104). CEC values for the 29 June 1977 sampling date ranged from 1.60 to 3.26 meq/100g and increased to 2.77 to 7.87 meq/100g for the last sampling date. Organic matter values show the same magnitude of increase in concentration with time. The 29 June 1977 values were between 0.08 and 0.23% and increased to values between 0.11 and 0.82% for the 14 October 1977 sampling date.

432. Those increases in the organic matter and CEC over time were probably due to elevation. The elevation of these plots controlled the sedimentation processes, plant growth, organic matter buildup, and redox potential. These factors in turn controlled the TKN, NH_4^+-N, NO_3^--N, extractable phosphorus, and CEC values in the six plots.

433. Applied nitrogen and phosphorus fertilizers after the initial sampling date (29 June 1976) also accounted for the buildup in nitrogen and phosphorus nutrients. A gradual building up of important chemical constituents for the establishment of a marshland was occurring over time.

434. Chemical analysis of the 36 sediment samples taken from the intertidal reference plots for three sampling dates are presented in Table 105. Sampling dates coincided with the sampling of the 270 marshland plots. Samples were separated on the basis of location in the area. Some sediments were taken from caged or noncaged vegetation quadrats. These locations were further divided as coming from inside or outside of the fenced area.

435. All chemical parameters were highly variable, and no distinct trends seemed to exist as to location of the samples, on whether the samples were taken from caged plots or vegetation quadrats.

436. Average TKN, NH_4^+-N, and extractable phosphorus did increase for the second and third sampling date as compared to the first sampling date.

437. Values for all chemical parameters for the intertidal reference plots are shown in Table 105. No distinct elevation effects appear to exist in relation to the levels of TKN, NH_4^+-N, and extractable phosphorus as was the case for the 270 marshland plots. The reasons, discussed below, may partly explain who no elevation effect was seen. The intertidal reference plots apparently did not have a differential buildup of fine sediment at lower elevations since there was no dike. Furthermore, fertilizer was not added to the plots in these areas.

Standing green biomass as influenced by elevation

438. Establishment and growth of *Spartina alterniflora* and *Spartina patens* were a function of elevation in the marshland area. Standing green biomass for these two grasses at different elevations for the sprigged plots is graphed in Figures 63 and 64. Figure 63 shows that maximum production of *S. alterniflora* was from plots between 0.0 and 0.2 ft msl. Maximum production of *S. patens* was not as clear as that for

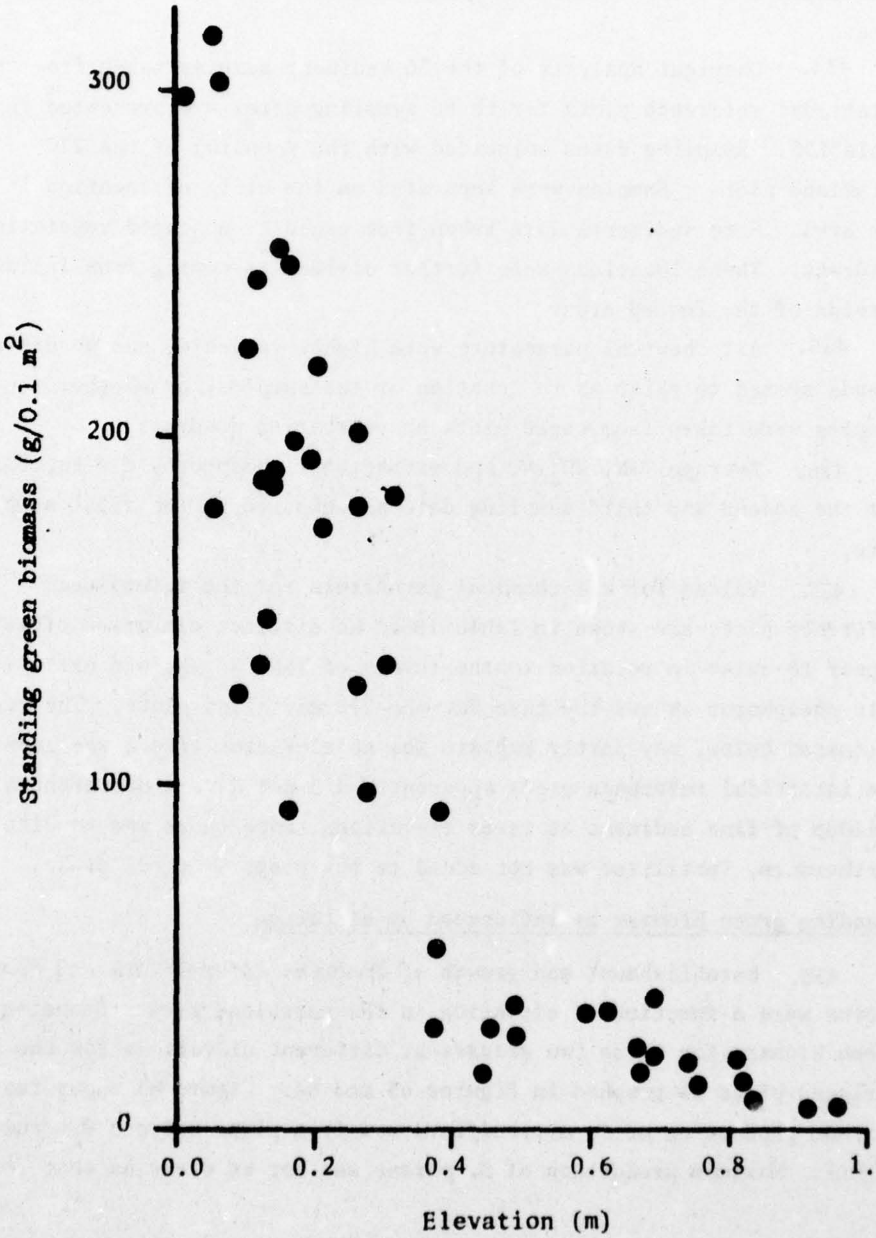

Figure 63. Standing green biomass in Oct 77 on plots sprigged to *Spartina alterniflora* as influenced by elevation from mean sea level

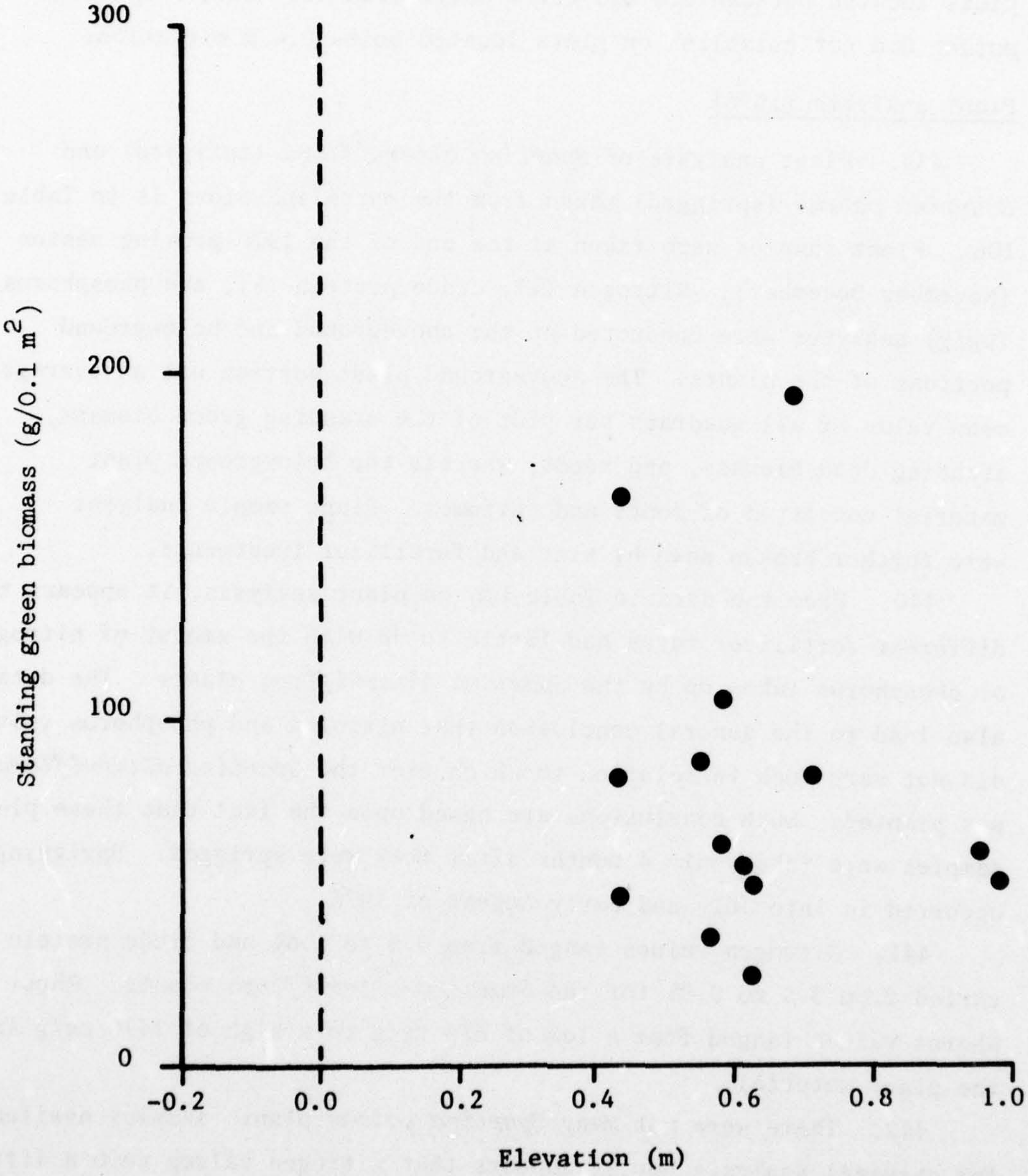

Figure 64. Standing green biomass in Oct 77 on plots sprigged to *Spartina patens* as influenced by elevations from mean sea level

S. alterniflora, but maximum production appeared to be from those plots located between 0.4 and 0.6 m above mean sea level. *Spartina patens* did not establish on plots located below 0.4 m elevation.

Plant analysis (1976)

439. Plant analysis of *Spartina alterniflora* (sprigged) and *Spartina patens* (sprigged) taken from the marshland plots is in Table 106. Plant samples were taken at the end of the 1976 growing season (November-December). Nitrogen (%), crude protein (%), and phosphorus (μg/g) analyses were conducted on the aboveground and belowground portions of the plants. The aboveground plant portion was an average mean value of all quadrats per plot of the standing green biomass, standing dead biomass, and seeds, whereas the belowground plant material consisted of roots and rhizomes. Plant sample analyses were further broken down by tier and fertilizer treatments.

440. From the data in Table 106 on plant analysis, it appears that different fertilizer rates had little to do with the amount of nitrogen or phosphorus taken up by the *Spartina alterniflora* plants. The data also lead to the general conclusion that nitrogen and phosphorus values did not vary much in relation to which tier the *Spartina alterniflora* was planted. Such conclusions are based upon the fact that these plant samples were taken only 4 months after they were sprigged. Sprigging occurred in late July and early August of 1976.

441. Nitrogen values ranged from 0.6 to 1.6% and crude protein varied from 3.5 to 9.9% for the *Spartina alterniflora* plants. Phosphorus values ranged from a low of 650 μg/g to a high of 1470 μg/g in the plant material.

442. There were not many *Spartina patens* plant samples available for chemical analysis but it appears that nitrogen values were a little higher than the *Spartina alterniflora* plant material. Total nitrogen in the *Spartina patens* plants ranged from 1.4 to 1.7%. This was based on a very small number of samples.

Plant analysis (1977)

443. Plant samples for the 14 October 1977 sampling date were analyzed for nitrogen (%), crude protein (%), and phosphorus (μg/g). The three analyses were conducted on the standing green only for the 1977 sampling date. All values reported were a mean value of all quadrats taken per plot. A maximum of three plots per tier per fertilizer treatment per propagation method was analyzed. Less than three observations (N) indicate no survival thus no analysis was conducted. Chemical analysis on the standing green for both sprigged and seeded *Spartina alterniflora* and *Spartina patens* plots were conducted and are shown in Tables 107 and 108. Standing green dry weights are also shown in Tables 107 and 108. Data for the standing green biomass were obtained from Dr. J. W. Webb (Range Science Department, Texas A&M University). Each value of standing green in the table represents a mean of all quadrats taken per plot that produced biomass. Quadrats that yielded no standing green were not included in the average.

444. Plant analysis for the sprigged *Spartina alterniflora* plots taken in 1977 shows the same relative trends as did the analysis performed on the 1976 plant samples. The initial fertilizer rate had little to do with the concentration of nitrogen or phosphorus found in the *Spartina alterniflora* plants. There also appeared to be little or no tier effect in regard to the nitrogen and phosphorus concentration in the plants. There did appear to be a tier effect in relation to the amount of standing green produced. An increase in standing green biomass was observed going from tier 3 to tier 1. Nitrogen content for the sprigged *Spartina alterniflora* plant samples ranged in value from 0.47 to 0.77%, crude protein varied between 2.69 and 4.79% and phosphorus ranged from 660 to 820 μg/g.

445. The plant samples collected from the seeded *Spartina alterniflora* plots had a nitrogen range of 0.40 to 1.05%, crude protein was 2.60 to 6.86%, and phosphorus ranged from 730 to 1250 μg/g. The phosphorus content of the seeded plant samples appeared to be higher than the samples taken from the sprigged plots. This observation is logical

because the plant material taken from the seeded plots is much younger than that sampled at the same time from the plants produced from sprigs.

446. Plant analysis of the seeded and sprigged *Spartina patens* plots can be seen in Table 108. Nitrogen values for the seeded and sprigged plots ranged from 0.35% to 1.20%, crude protein varied between 2.01 and 7.36%, and phosphorus content from 500 to 1080 μg/g. From the standing green data, *Spartina patens* yields were greater in the upper tiers (2 and 3) compared to tier 1.

447. In comparing the *Spartina alterniflora* and *Spartina patens* plant material taken in October 1977 there did not appear to be any large differences in nitrogen and phosphorus content. The only difference might be the plant material taken from the seeded *Spartina alterniflora* plots which did appear to be slightly higher in phosphorus content.

448. In comparing the plant samples taken in 1976 to the plant samples taken in 1977 it appears the the average nitrogen and phosphorus concentration of the sprigged *Spartina alterniflora* plant samples did decrease over time. This effect may be due to the increased maturity of the plants in 1977 compared to the 1976 sampling date. The average nitrogen and phosphorus concentration of the plants taken at the end of the 1976 and 1977 growing season can be seen in Figure 65.

The influence of elevation on changes in the chemical properties of sediment

449. During the course of this study it became increasingly evident that elevation within the marshland was exerting a predominant influence on the changes occurring in the sediment. Sedimentation was noticeable soon after the site was established. By the end of 1977, much of the lower elevation (tier 1 and part of tier 2), where inundation was common, was covered with varying amounts of new sediment. These sediments were brought in by water from the bay. Once behind the dike where some protection from wave action was afforded the fine sediments settled out on the surface. These sediments are of a finer texture and higher in clay and silt than the original substrate. Nutrient content associated with these sediments would be greater than

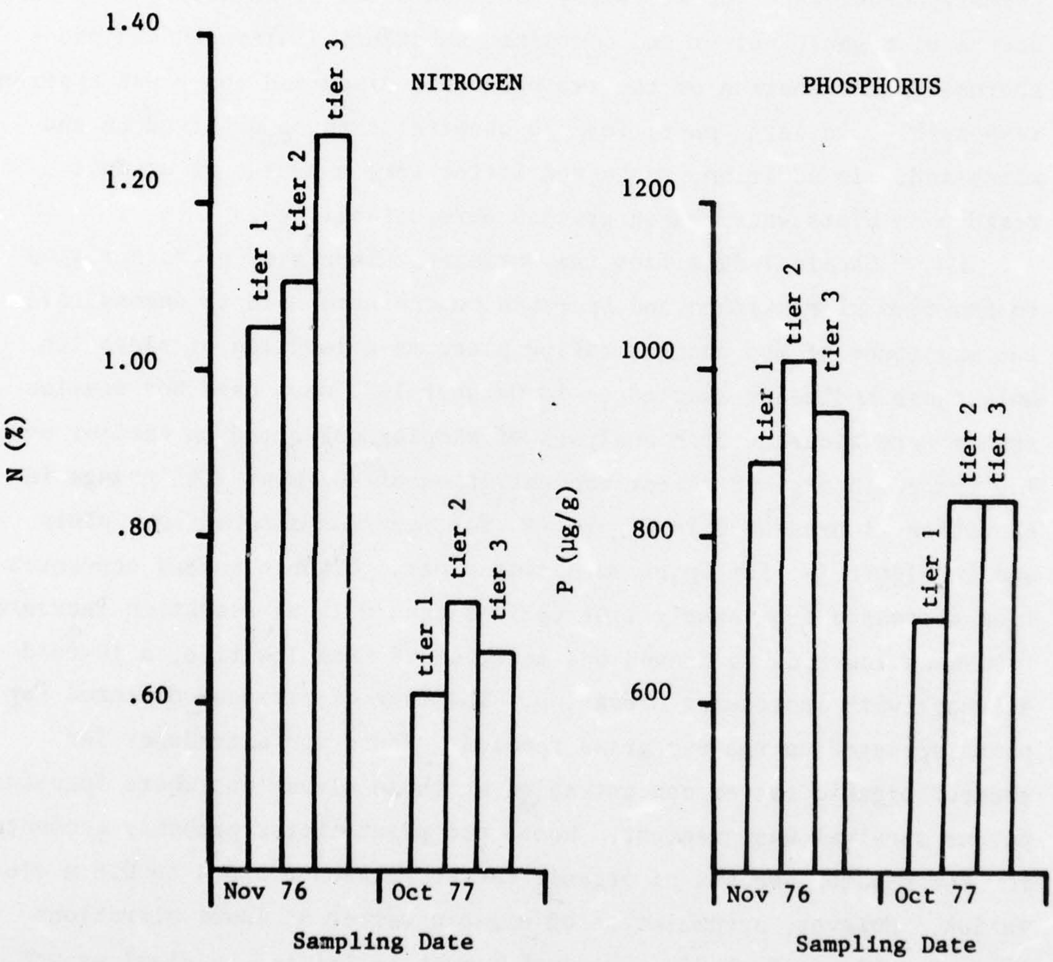

Figure 65. Average concentration of nitrogen and phosphorus in *Spartina alterniflora* as influenced by tier and sampling date

AD-A063 781 TEXAS AGRICULTURAL EXPERIMENT STATION COLLEGE STATION F/G 13/3
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
JUN 78 J W WEBB, J D DODD, B W CAIN DACW39-76-C-0109

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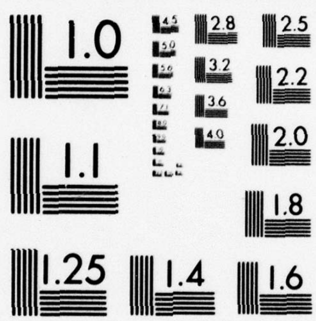

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for the original dredged material on the site. In addition to sedimentation processes from water suspended silt and clay, there was a considerable increase in algal growth in the lower tiers that were normally under water or extremely wet. This was apparently a very rich source of organic matter and contained substantial nitrogen and phosphorus. A combination of the two processes discussed above was apparently responsible, in large part, for the chemical changes observed in the marshland. In addition, roots and litter were a source of organic residue on plots where marsh grasses were established.

450. Chemical data from the surface sediments of plots sprigged to *Spartina alterniflora* and *Spartina patens* were used to demonstrate the magnitude of the changes taking place as a function of elevation. Only those sediments sampled on 14 October 1977 were used but similar trends were apparent from analyses of samples collected on earlier dates. The change in organic matter concentration of sediment with change in elevation is presented in Figure 66 for *Spartina alterniflora* plots and in Figure 67 for *Spartina patens* plots. Organic matter concentration decreased from nearly 1.0% to less than 0.1% as elevation increased from mean low tide to around one meter above mean low tide, a 10-fold decrease with increasing elevation. The rate of decrease differed for plots sprigged to the two grass species. There was a tendency for greater organic matter concentration at those elevations where *Spartina patens* survival was greatest. Roots and plant litter probably accounted for the greater amounts of organic matter between the 0.4 to 0.6 m elevation. However, accumulation of organic matter at lower elevations where *Spartina patens* did not survive must be related to algal growth and accumulation of organics in the sedimentation process.

451. TKN concentration changes with elevation were similar to those observed with organic matter. However, a 25-fold increase in TKN was observed in sediments at the lowest elevations compared to those located one meter above mean sea level. These data are presented in Figures 68 and 69 for the two marsh grasses. The range in TKN was from 25 to 635 μg/g over the one-meter change in elevation.

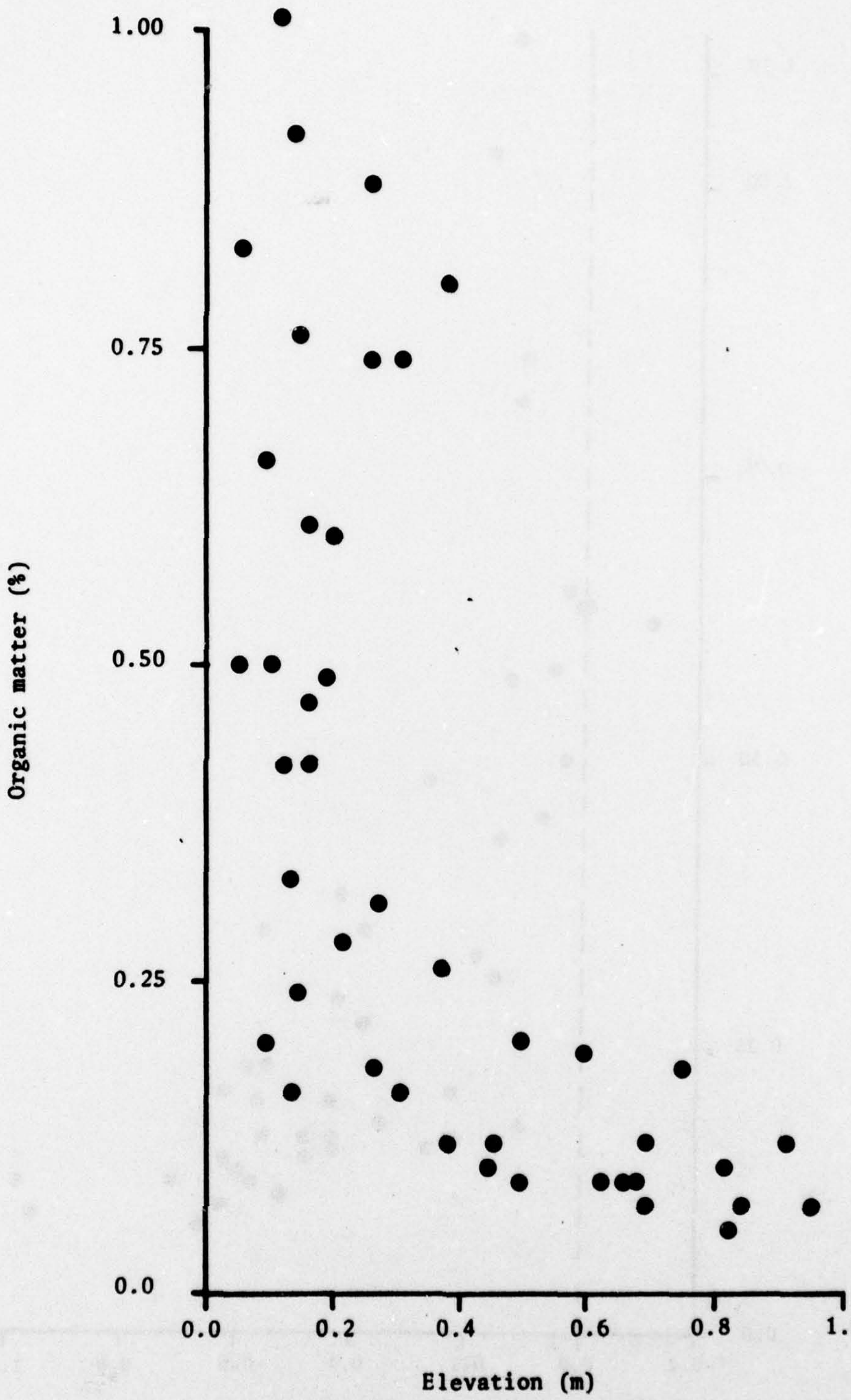

Figure 66. Organic matter concentration of sediment from sprigged *Spartina alterniflora* plots as influenced by elevation from mean sea level. Sediments were sampled 14 Oct 77

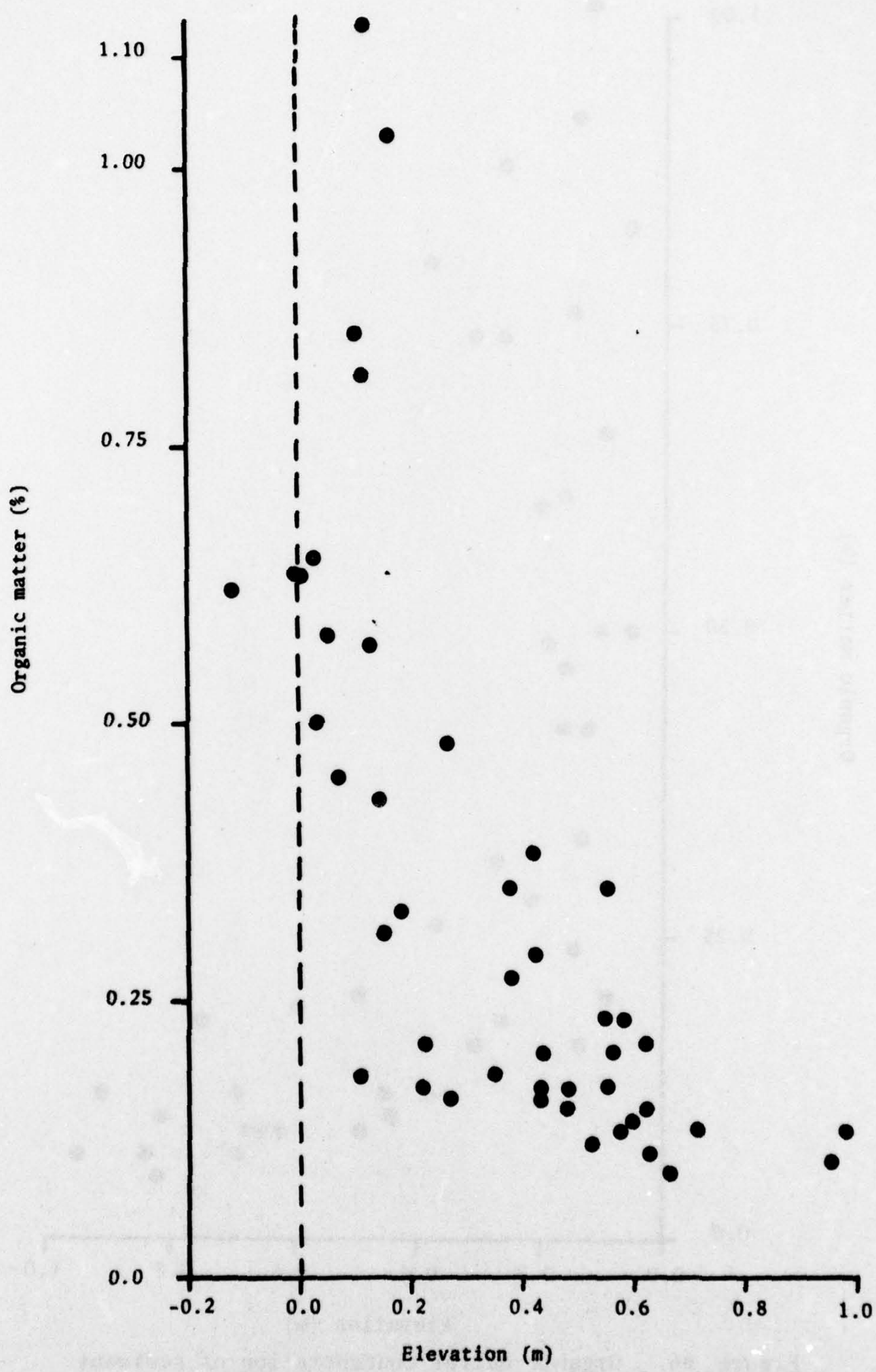

Figure 67. Organic matter concentration of sediment from sprigged *Spartina patens* plots as influenced by elevation from mean sea level. Sediments were sampled 14 Oct 77

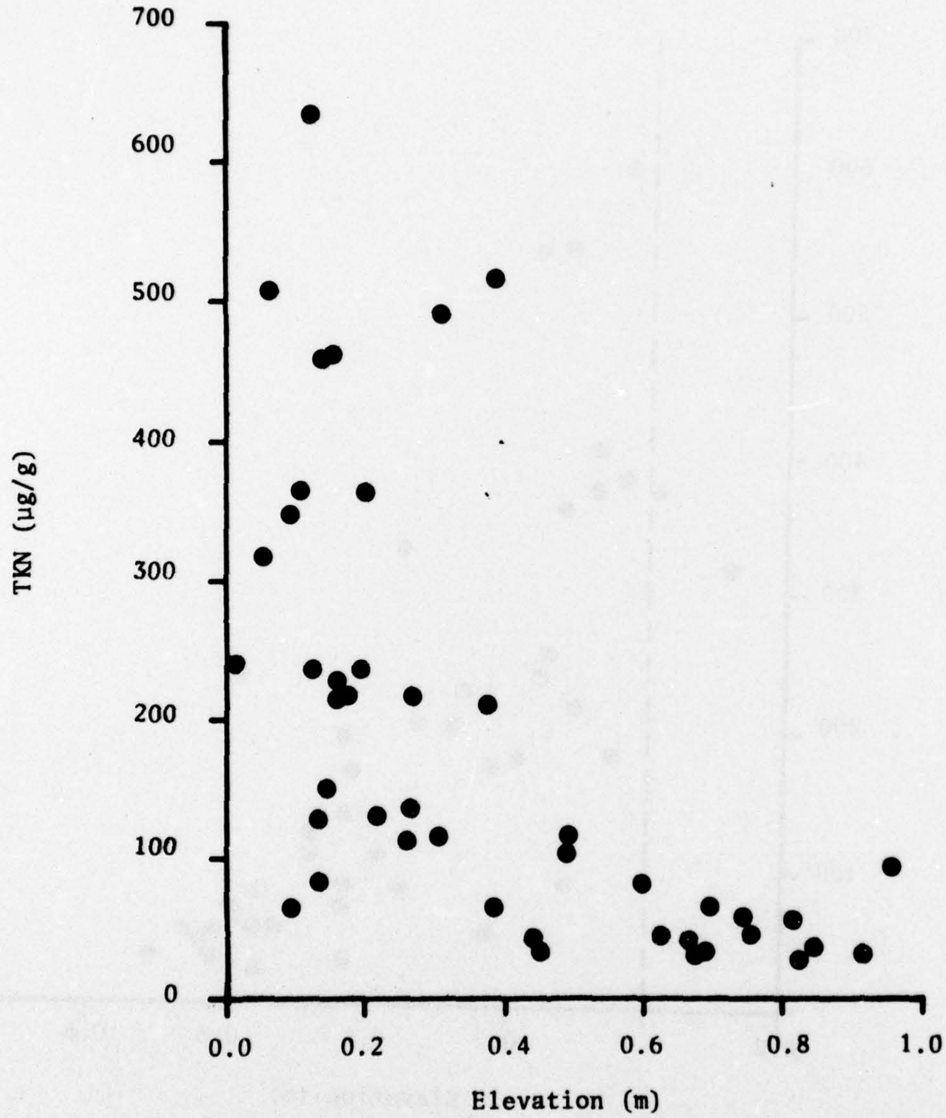

Figure 68. TKN concentration of sediment from sprigged *Spartina alterniflora* plots as influenced by elevation from mean sea level. Sediments were sampled 14 Oct 77

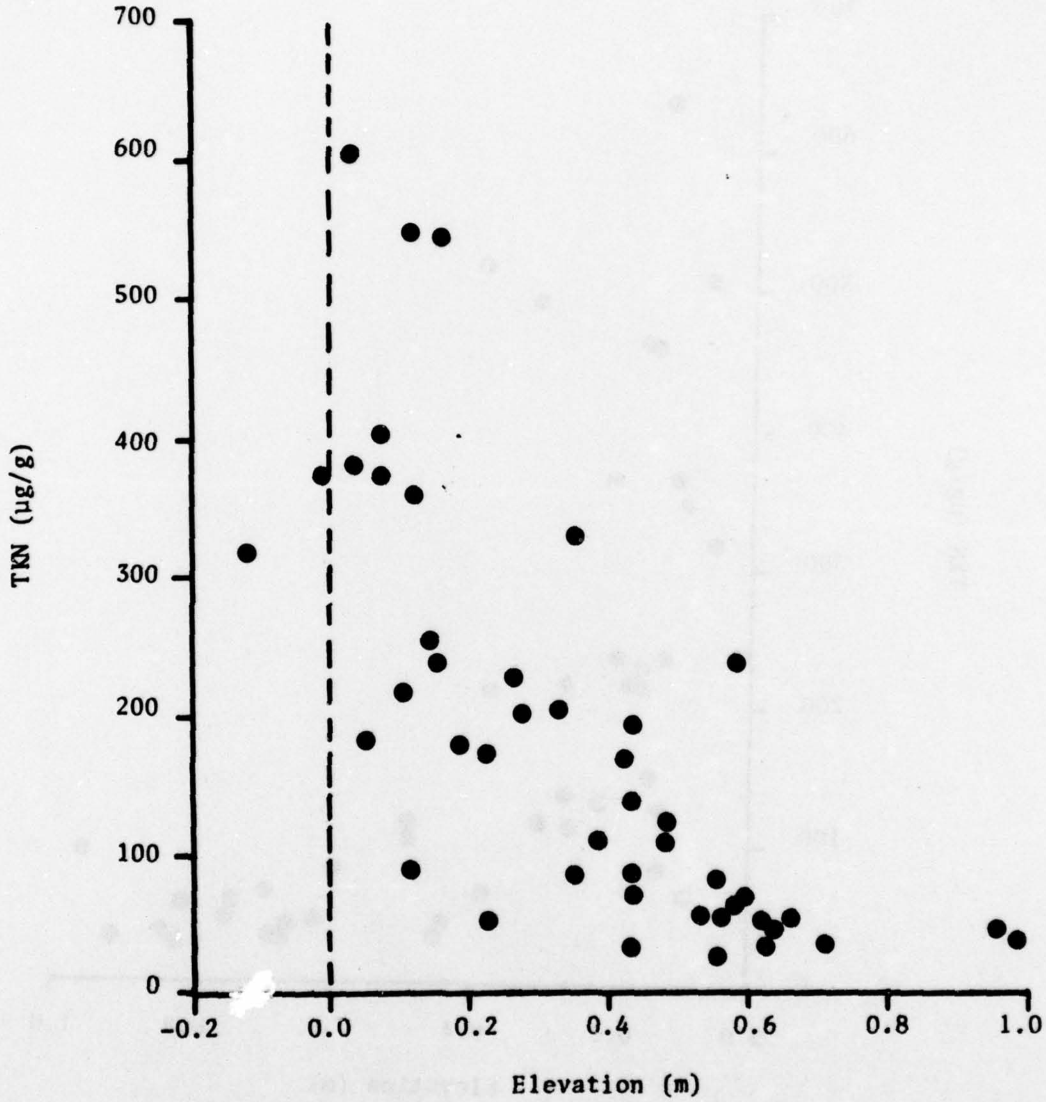

Figure 69. TKN concentration of sediment from sprigged *Spartina patens* plots as influenced by elevation from mean sea level. Sediments were sampled 14 Oct 77

452. Oxalate extractable phosphorus concentration gave similar trends as those reported for organic matter and TKN. Data for phosphorus buildup in plots sprigged to *Spartina alterniflora* and *Spartina patens* as influenced by elevation are presented in Figures 70 and 71, respectively. Oxalate extractable phosphorus increased from 6 μg/g at the highest elevation to greater than 160 μg/g for plots located near mean sea level. This represents a 27-fold increase in extractable phosphorus with elevation. The magnitude of change is similar to that reported for TKN.

Statistical analysis

453. Analysis of variance tables were constructed to show the influence of different soil parameters on plant performance (standing green biomass) for 1976 and 1977 plant sampling dates. All analysis were done by computer using the SAS (Statistical Analysis System) program. Computer programs were written according to the User's Guide to SAS - 76 (published by SAS Institute, P.O. Box 10522, Raleigh, North Carolina, 27605).

454. The basic model used for the analysis was as follows: Standing green (yield) = Block + Tier + Block X Tier + Propagation method + Fertilizer rates + Propagation X Fertilizer + Species + Species X Fertilizer rates + Species X Propagation + Species X Fertilizer X Propagation + Covariables {soil parameters (TKN, NH_4^+-N, NO_3^--N, NO_2^--N, extractable phosphorus, pH, Eh, elevation)} + Error.

455. The standing green biomass for *Spartina alterniflora* and *Spartina patens* was the dependent variable whereas all components on the right hand side of the equation were independent variables or covariables.

456. The analysis of variance table and statistics of fit for the dependent variable standing green (yield) for the 1976 plant samples are presented in Table 109. Looking at the mean square and the F-values it appears that none of the treatments (independent variables) or covariables had a significant effect on the yield of *Spartina alterniflora*.

457. Species or fertilizer rate applied had no effect on the yield of *Spartina alterniflora* and interactions were not significant.

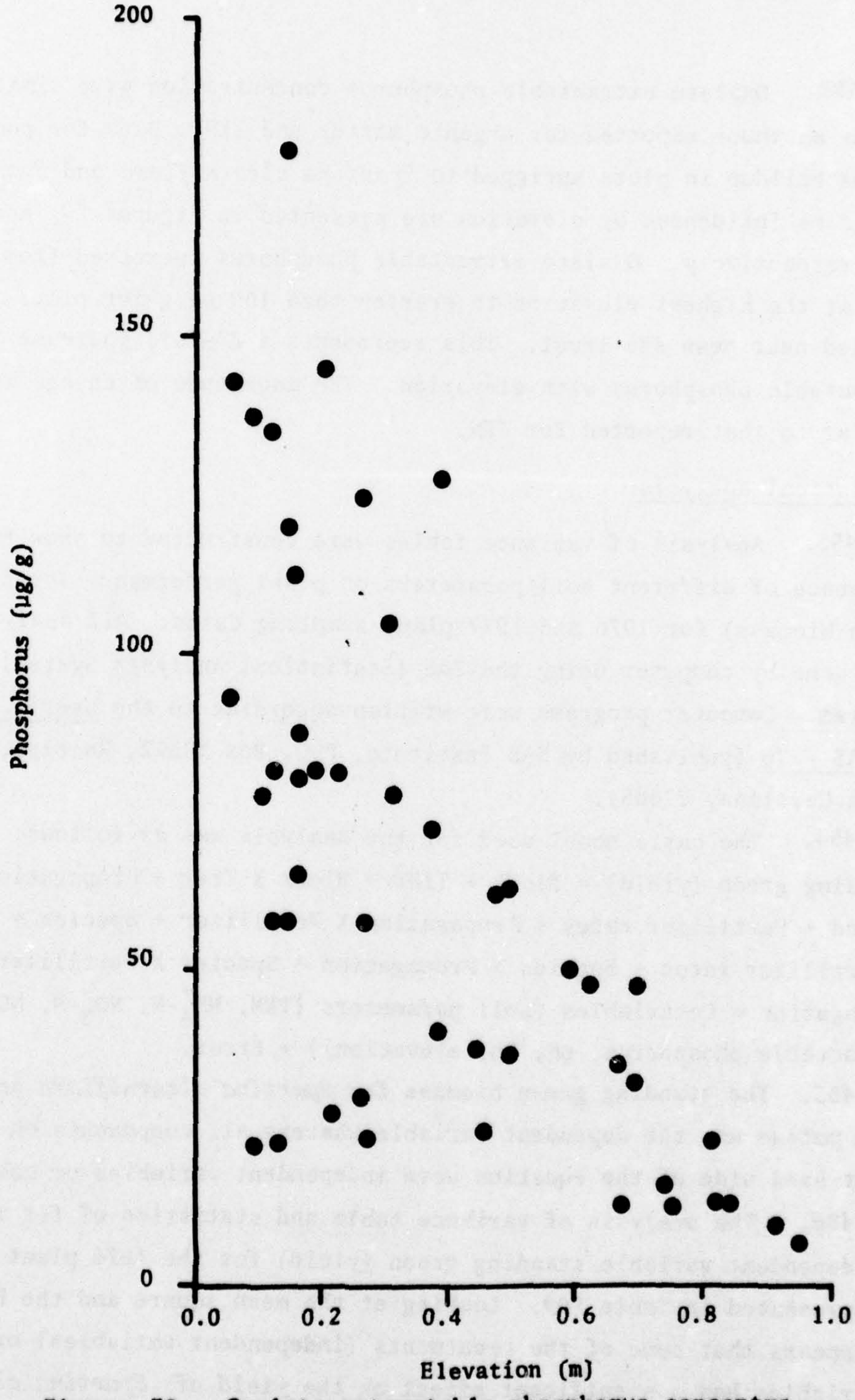

Figure 70. Oxalate extractable phosphorus concentration of sediment from sprigged *Spartina alterniflora* plots as influenced by elevation from mean sea level. Sediments were sampled 14 Oct 77

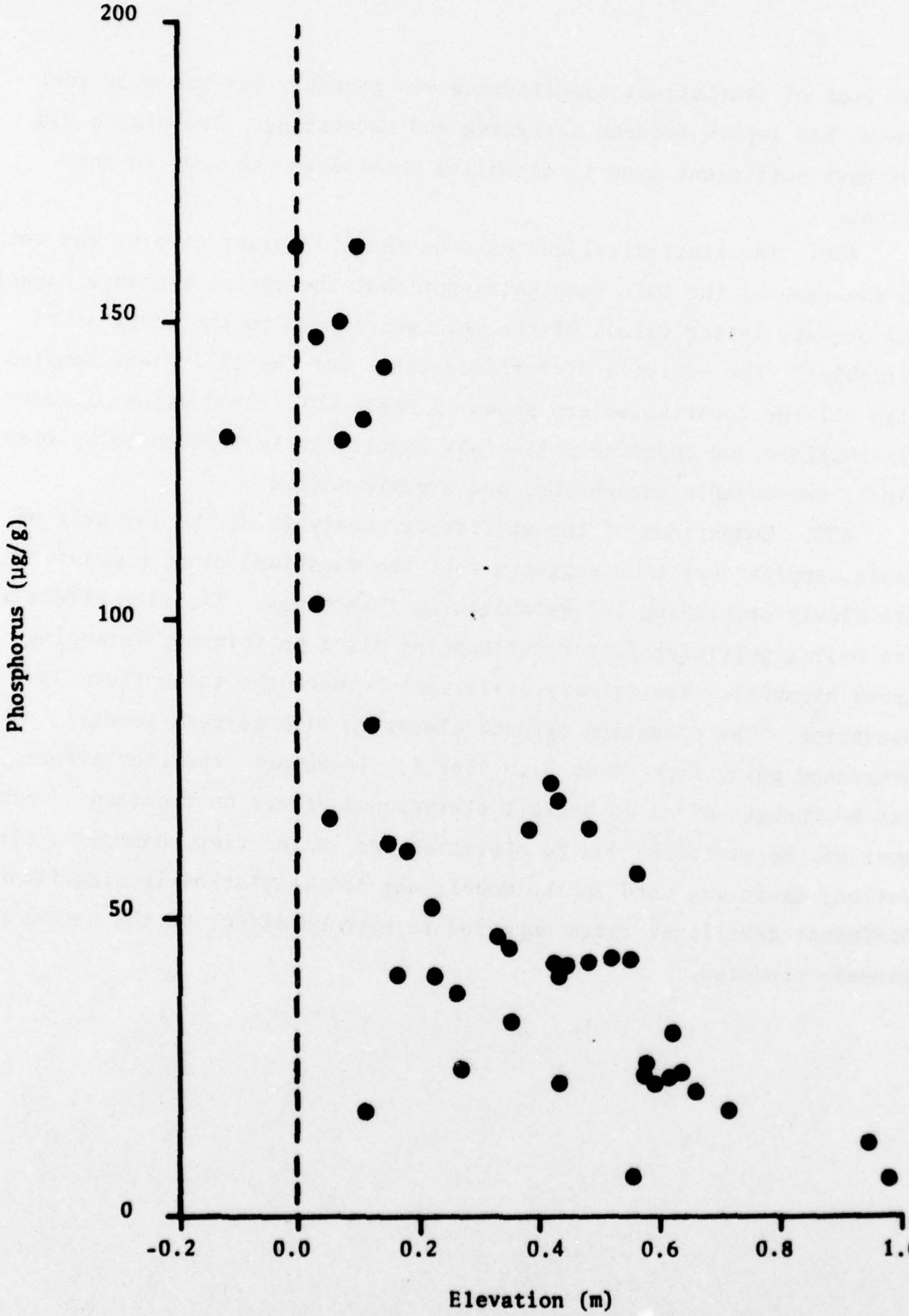

Figure 71. Oxalate extractable phosphorus concentrations of sediment from sprigged *Spartina patens* plots as influenced by elevation from mean sea level. Sediments were sampled 14 Oct 77

The lack of statistical significance was probably because only four months had lapsed between sprigging and harvesting. The plants did not have sufficient time to establish themselves and grow to any extent.

458. The statistical analysis on the 1977 plant samples was set up the same as the 1976 samples except that the cation exchange capacity and organic matter values of the soil were added to the model as co-variables. The analysis of variance table for the 1977 plant samples with all the covariables are shown in Table 110. Production of *Spartina alterniflora* and *Spartina patens* was significantly influenced by tier, block, extractable phosphorus, and organic matter.

459. Comparison of the statistical analysis on the two sets of plant samples over time suggests that the marshland plant populations are slowly developing and establishing themselves. The tier effect was the most significant factor influencing plant performance (standing green biomass). The primary difference between the three tiers was elevation. The elevation (ground elevation with respect to msl) decreased going from tier 3 to tier 1. Therefore, the tier effect can be thought of as an overall elevational effect on treatment. Since most of the variation due to elevation was in the tier component, elevation, as it was used in the model, was not statistically significant. Different fertilizer rates appeared to have no effect on the amount of biomass produced.

PART VII: AQUATIC BIOTA

Methods

460. Monthly aquatic biology samples were collected from July 1976 through June 1977 at the Bolivar Peninsula site. Twelve transects, perpendicular to the beach, were established. Transects were placed in six environmental types (Fig 72), with two transects in each type as follows:

- a. Transect Z - west reference area
- b. Transect A - west end bare and unprotected
- c. Transect B - west end unprotected, mixed plant species
- d. Transect X - west end bare and protected
- e. Transect C - west end protected, mixed plant species
- f. Transect D - protected marsh
- g. Transect F - protected marsh
- h. Transect G - east end protected, mixed plant species
- i. Transect Y - east end bare and protected
- j. Transect H - east end unprotected, mixed plant species
- k. Transect I - east end bare and unprotected
- l. Transect J - east reference area

An additional station (position E in Fig 72) was established for sampling of water quality and nekton only. Each of the 12 transects contained five sampling stations, numbered 1 through 5 consecutively, with station 1 being the most landward (Fig 72). Reference stations were established at either end of the site outside the fence (transects J and Z). Following the collection of samples in June 1976, it was determined that additional stations should be established to sample the bare protected areas (transects X and Y). Stations within transects are hereafter identified in terms of transect and level; for example, stations A1, A2, A3, A4, and A5.

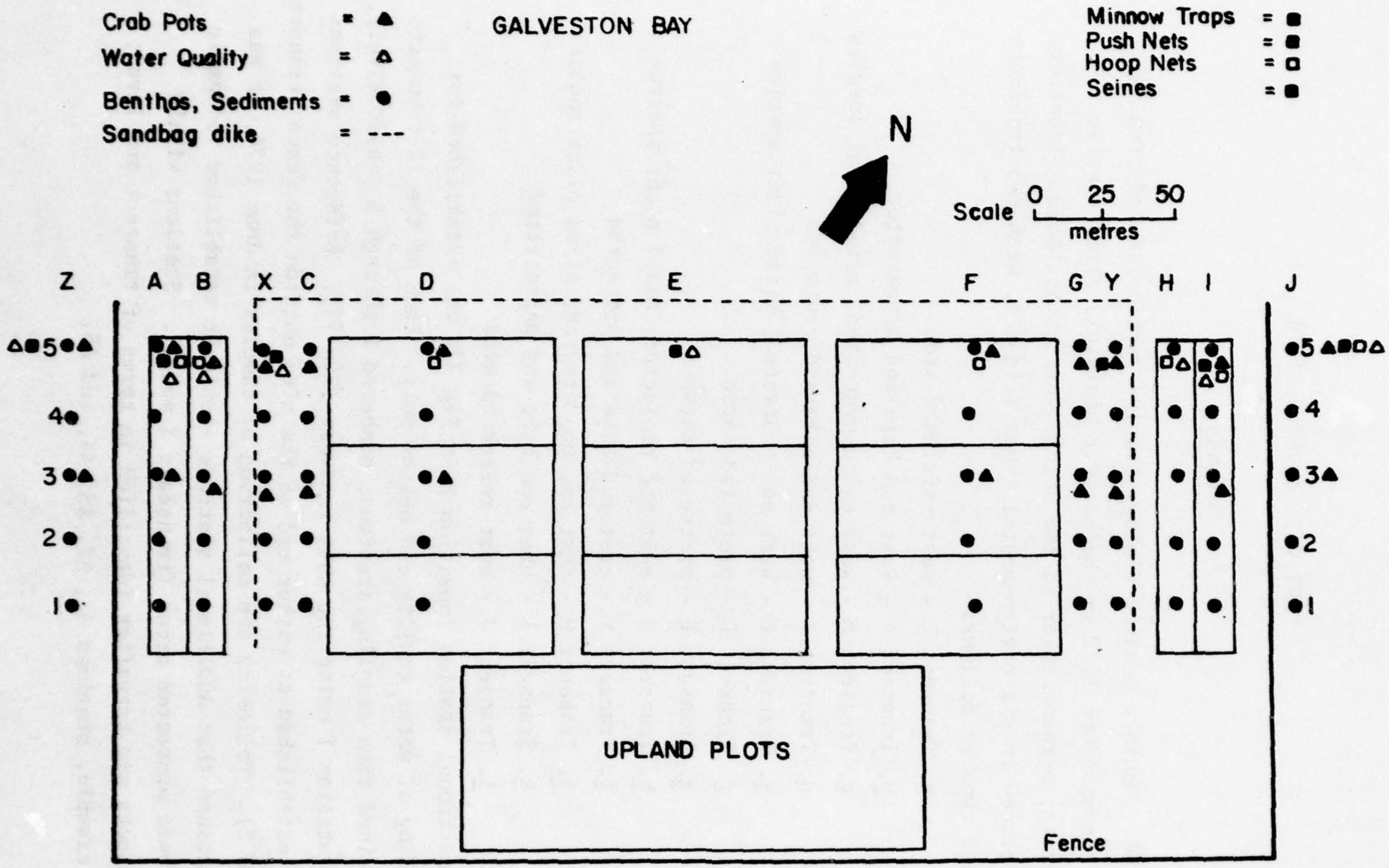

Figure 72. Location of aquatic sampling stations

461. Photographs were taken monthly at the five stations along each of the 12 transects and in 90 of the monotypic marsh plots within the protected area. Three tiers of 30 plots each were photographed in the blocks indicated by Roman numerals I, II, and III in Fig 73. The numerical designation for each plot is also presented. Photographs were identified by block and plot number; for example, I-1, I-2, I-3 ... I-30.

462. Beach seine samples were collected monthly, day and night at station E and along transects Z, A, X, Y, I, and J from July 1976 through June 1977. Push net samples were obtained from the same transects and stations through March 1977, after which that type of sampling gear was abandoned since push net samples did not provide information additional to that obtained from the beach seine. Insofar as possible, the same tide stage was sampled within each month both day and night, although in some instances this could not be done because the Gulf of Mexico frequently has diurnal tides. In all cases samples were obtained during the period of highest water at night or during the day, with seining and push netting operations being conducted between station 5 and the beach. Different extents of inundation were encountered during various months, but in general, the water was present at least to the level of station 3 along each transect, with the exception of position E, during each sampling period. The apparently higher elevation of position E as compared with the other areas in which seining was undertaken often left the sediments exposed to station 4 at position E while the water reached the level of station 3 along the other transects. Attempts were made to document the water inundation level during each month along each transect, but because of the fact that a wave of water preceded the seine during landing, the actual distance seined did not correspond with the observed extent of inundation. Waves generated by passing ships often caused changes in the extent of water coverage during seining operations. The data obtained were analyzed only in terms of species

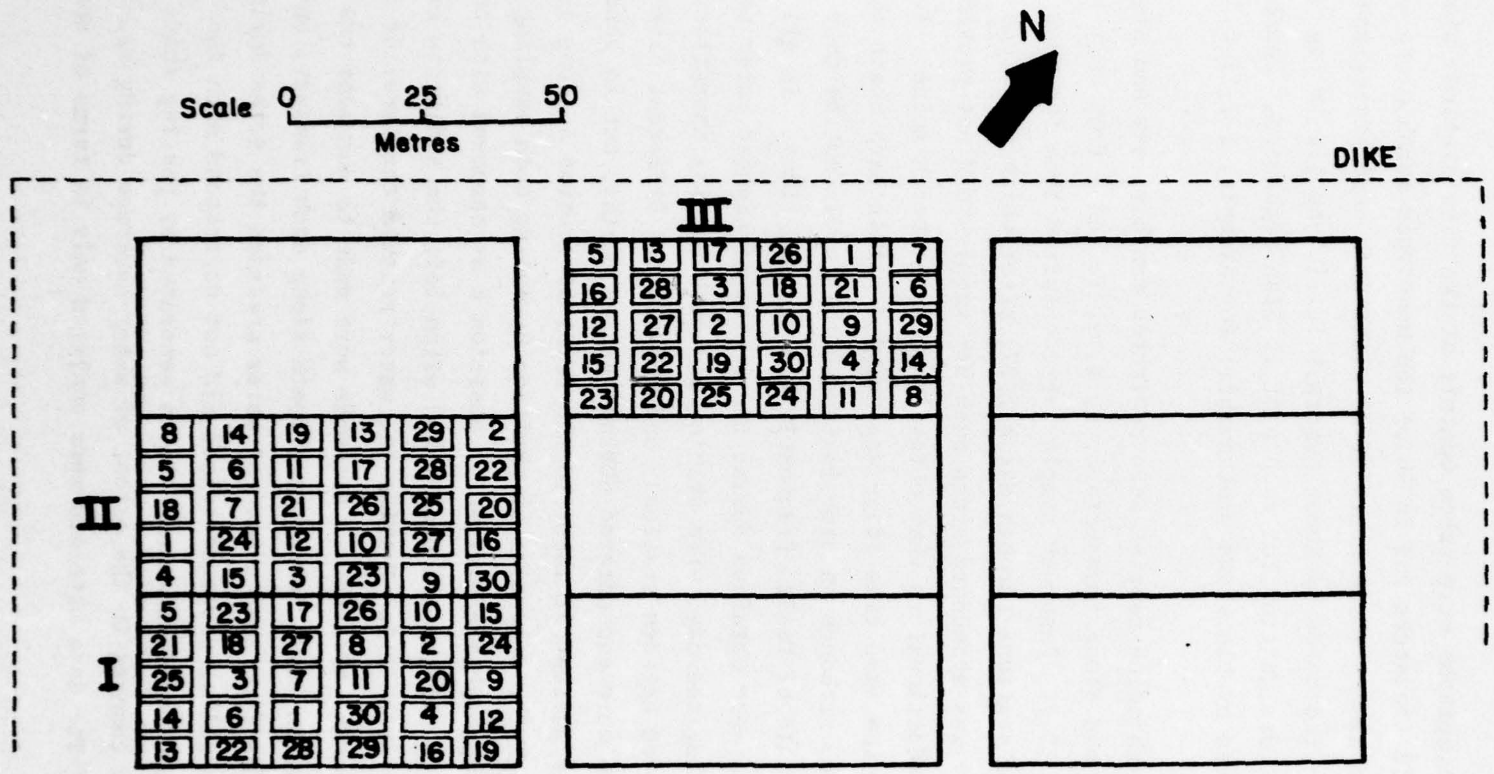

Figure 73. Photographic stations as indicated by number in marsh blocks I, II, and III

composition, abundance, and diversity.

463. Hoop nets were set monthly at stations A5, B5, D5, F5, H5, I5, and J5 through March 1977 after which this sampling technique was abandoned because of poor efficiency. The nets were set parallel to the shore with the mouths facing west. Each net was set approximately from 0700 to 1900 and 1900 to 0700 for a total of 24 hours monthly. At the end of each 12-hour set any animals collected were removed, weighed, measured, and released. No bait was utilized in the hoop nets.

464. Crab traps were initially to be set at station levels 1, 3, and 5 along each of 10 transects. Because the water rarely reached the level of station 1, no crab traps were set at that level. Instead, crab traps were set at stations 3 and 5 along 12 transects: Z, A, B, X, C, D, F, G, Y, H, I, and J. The monthly collections, day and night, corresponded with those described for the hoop nets, except the crab traps were set through June 1977 and were baited with fish. The traps were rebaited as necessary after each 12-hour set.

465. Minnow traps were set at the level of station 5 on each transect where beach seine samples were collected during May and June 1977. The duration of the minnow trap sets and times of checking them corresponded with those described above for hoop nets.

467. Portunids captured in the crab traps and hoop nets were measured in the field to the nearest millimetre carapace width, weighed to the nearest 0.5 g on a triple-beam balance, then released. Animals collected in the other types of nekton sampling gear were preserved in buffered 10 percent formalin (4 g/l Borax added) and returned to the laboratory. Standard lengths to the nearest millimetre were obtained from the fish, carapace widths from crabs, mantle lengths from squid, and the distance from the posterior edge of the carapace to the tip of the rostrum was measured on shrimp.

468. Weights of each individual were determined to the nearest 0.1 g utilizing a top-loading balance. A reference collection was made, after which duplicate vertebrates were discarded with the exception of those later utilized for food habit studies. Duplicate invertebrates were also discarded. All retained specimens were transferred after several days from formalin to 40 percent isopropyl alcohol.

469. Six species of fishes were selected from among those captured for food habit studies. The method of Borgeson (1963) was used in the evaluation of the fôod habits of *Leiostomus xanthurus*, *Micropogon undulatus*, *Paralichthys lethostigma*, *Menidia beryllina*, *Cyprinodon variegatus*, and *Fundulus similis*. All individuals of each species and from each station were pooled by month. If available, 25 individuals of each species were selected monthly in the following four size ranges: less than 20 mm, 20 to 50 mm, 51 to 100 mm, and greater than 100 mm. The fish were dissected and the stomach contents removed. If an empty fish was found, the fact was noted and an additional fish, if available, was added to the sample. The stomach contents of a maximum of 25 fish of each species were pooled and the volumetric displacement of the food material was determined in graduated centrifuge tubes each month. The material was then examined microscopically and all food items were classified to the lowest identifiable taxon and enumerated.

Benthos sampling

470. Benthos samples were collected monthly at each of five stations along transects Z, A, B, X, C, D, F, G, Y, H, I, and J from July 1976 through June 1977. From June 1976 through March 1977, 22.4-cm-square samples were hand dug in each location to a depth of 20 cm.

Photography stakes were used as reference points for the samples and attempts were made to sample in different areas within 1 metre of the stakes each month. From April through June 1977, paired samples were collected at each of the 60 stations with a pipe coring device (Fig 74). The 10.16-cm-diam pipe corer was driven into the sediments 20 cm and the duplicate samples were pooled. All sediment samples were placed in plastic buckets, thoroughly mixed, and preserved with 10 percent buffered formalin.

471. Following return to the laboratory, the samples were washed through a 0.5-mm standard sieve, and all material retained by the sieve was placed into bottles with 10 percent formalin containing 200 mg/l of Rose Bengal stain. The samples were allowed to stand in the stain for a minimum of 24 hours before being further processed.

472. Prior to microscopic examination, each sample was washed in an 0.5 mm sieve with tap water and placed in a white enamel pan. The benthic organisms contained in the samples were removed under a magnifying lens with forceps and placed in 40 percent isopropyl alcohol. Subsequently, all animals within each sample were separated to the lowest recognizable taxon, identified, enumerated, and dry weights were obtained. The specimens were placed in tared aluminum pans and dried to 105° C for 24 hours. Dry weights were obtained to the nearest 0.1 mg on an analytical balance. Data were reported by taxon, number per square metre, and biomass per square metre. A reference collection was maintained by preserving representative organisms in 40 percent isopropyl alcohol.

Sediment sampling

473. Adjacent to the collection point of each benthos sample, a sediment core 5.08 cm in diameter and 20 cm long was obtained with a plastic core barrel monthly. Each core barrel was capped and returned to the laboratory where it was placed in a freezer at -20° C to prevent oxidation of the organic matter. Volatile solids

Figure 74. Coring device with driver

percentages and grain-size analyses were determined from each core.

474. Following thawing, the sediments in each core barrel were extruded and then thoroughly mixed before subsampling. Approximately 7 to 9 g of material from each core were placed in tared aluminum weighing dishes and dried in an oven at 105° C for 24 hours. The dry weight of the sediments was determined to the nearest milligram after which the samples within the aluminum pans were placed in a muffle furnace for 1 hour at 550° C. It was previously determined that this temperature did not affect the tare weight of the aluminum pans. After being allowed to cool in a desiccator, each sample was re-weighed to the nearest milligram and the volatile solids percentage was determined from the weight loss on ignition.

478. An additional 45 to 65 g of sediment from each well-mixed sample was removed and placed in a tared 250-ml beaker. After drying for 24 hours at 105° C, the dry weight was determined to the nearest milligram. This procedure was required for later calculation of the percentage of the total sample contributed by particles of each grain size, including silt and clay. The weighed sediments were then placed in a 63-μm sieve and wet-sieved with dispersing agent (2.1 g of sodium hexametaphosphate dissolved in each litre of deionized water). The material which passed through the sieve was washed into a 1000-ml graduated cylinder for later pipet analysis following standard procedures (Holme and McIntyre 1971).

479. Coarse sediments were dry sieved in a mechanical sieve shaker. Initially, 13 sieves were used, but because the bulk of the sedimentary material was found in only a few particle size classes, the sieve stack was reduced to two sieves and a pan. The sieves utilized were 63 and 250 μm. Thus, the sediments were broken down into particles larger than 250 μm, those between 63 and 250 μm, and those smaller than 63 μm. The particles collected in the pan were used for pipet analysis. Material retained in the sieves was weighed to the nearest milligram, and the percentage contribution of each size

class was recorded.

Water quality samples

480. Water quality data were obtained, day and night, from mid-depth as close to the time of high tide as possible. The total water depth varied from month to month because of variations in normal tidal range and as a result of the wind control on the tides within Galveston Bay. Samples were obtained at stations Z5, A5, B5, X5, E5, H5, I5, and J5.

481. Temperature was determined to the nearest degree Celsius using a thermistor incorporated into the dissolved oxygen meter probe, or a mercury-in-glass thermometer. Salinity was determined to the nearest part per thousand with an American Optical Corp. refractometer (Model 516).

482. Dissolved oxygen readings were obtained with a YSI Model 518 oxygen meter (compensated for temperature, salinity, and altitude) or by Winkler titration (American Public Health Association 1975). Dissolved oxygen was determined to the nearest 0.1 part per million in each case. Total, bicarbonate, and carbonate alkalinities to the nearest 10 parts per million were obtained colorimetrically using a Hach DR-EL-2 water chemistry laboratory (Hach Chemical Company, Ames, Iowa).

483. Turbidity was determined in Formazin Turbidity Units (FTU) using the Hach colorimetric procedure. Suspended solids were determined to the nearest 5 parts per million colorimetrically using the Hach procedure. Total ammonia was determined utilizing either an ammonia electrode in combination with a digital pH meter or by direct nesslerization (American Public Health Association 1975). In the latter case, a 200-ml sample was distilled to eliminate competitive reactions prior to analysis for ammonia. Water sample pH was determined on an Orion digital pH meter (Model 701).

484. Dissolved oxygen, temperature, and salinity were measured

in the field immediately after the samples were collected. In some cases water samples for alkalinity, turbidity, and suspended solids were also placed on ice and returned to the laboratory for analysis. Of the parameters measured, only ammonia is subject to significant change within a short time period and this was retarded by acidifying subsamples to be used for ammonia analyses with sulfuric acid (Environmental Protection Agency 1974).

Photographic samples

485. Wooden stakes were driven at each of the 150 photographic stations (5 stations along transects Z, A, B, X, C, D, F, G, Y, H, I, and J and 90 stations in the three marsh blocks indicated by Roman numerals I, II, and III in Fig. 73). A plywood circle with an inside area of 1 m^2 was used to delimit the sample area for each photograph. The circle was placed around each stake with the same orientation each month so that approximately the same area would appear in successive photographs. Black and white 35-mm film was used and each negative was enlarged to facilitate visual examination. The photographs provided an indication of animal activity in the various sampling areas and also provided visual evidence of marsh grass growth. Because of the vagaries of the tides in Galveston Bay, during most months many of the stations were under water even at low tide and photographs at station level 5, and often level 4, could not be obtained. Block III was often inundated on all sides during the spring and summer. Further, as marsh grass colonization increased and the grass grew taller, it was not possible to visualize the substrate in many of the sampling sites.

486. Each photograph was examined and the incidence of bird, raccoon, and hermit crab tracks was noted. The number of holes present (attributable to pelecypod siphons, fiddler crabs, polychaetes, bird pecking, and other animal activity) was determined. The type of grass present in the photographs and evidence of the tubes of

Diopatra cuprea were also recorded.

Data analysis

487. The information collected during the period July 1976 through June 1977 has been summarized largely in terms of total annual means, often with standard deviations. Comparisons have also been made with respect to the colonization rates by benthos at different station levels, among habitats, and temporally. Benthos and sediment grain size data are compared to identify any correlations which might exist. Water quality data have been evaluated with respect to habitat and month. Diversity indices have been calculated on nekton and benthos data utilizing the formula:

$$H = -\Sigma \, pi \; ln \; pi$$

where pi is the proportion of species i in the sample. This diversity index (known variously as the Shannon-Wiener or Shannon-Weaver index) has been promoted by Margalef (1957) and is widely used in environmental studies.

Results and Discussion

Nekton

488. A total of 19,354 individual vertebrate and invertebrate nekton organisms representing 59 taxa and weighing 38.7 kg were collected in beach seines between July 1976 and June 1977 at the Bolivar Peninsula site (Table 111). Contributing to this total were 45 vertebrate and 14 invertebrate taxa. Push net samples contained 35 taxa (21 vertebrate and 14 invertebrate) weighing 1.5 kg and composed of 3,138 individual organisms. The total number of animals collected by these two methods was 22,492 with a total weight of over 40.2 kg. The average weight of animals taken in beach seines was 1.8 g, while that of animals collected in the push net samples was 0.5 g. A complete characterization of the nekton samples by species, month, time of day, and transect is presented in Appendix A', Table A15.

489. Prior to plant propagation, monthly sampling was conducted by the National Marine Fisheries Service [written communication, National Marine Fisheries Service (NMFS), Galveston, Texas, 1975] from March through October 1975 in an area adjacent to the present study site. A 3-m shrimp trawl with 25-mm bar mesh, a 15-m beach seine with 13-mm bar mesh, and a 1.5-m beam trawl with 0.47-mm mesh were utilized in the collection of those samples. Beam trawl samples by NMFS resulted in the collection of 33 species (28 vertebrate and 5 invertebrate), while 37 species of nekton organisms (31 vertebrate and 6 invertebrate) were taken with the NMFS beach seine. Comparison of the species lists from the two studies demonstrates that *Archosargus probatocephalus*, *Elops saurus*, *Cynoscion nebulosus*, *Myrophis punctatus*, *Bairdiella chrysura*, *Astroscopus y-gràecum*, and *Microgobius gulosus* were collected by NMFS in the beam trawl, but were not taken in the present study. The only invertebrate collected in the beam trawl by NMFS which did not appear in the 1976 and 1977 samples was the seabob shrimp, *Xiphopeneus kroyeri*. This species seems to prefer high-salinity waters (Gunter 1950) and is often only captured inshore during years when conditions are advantageous for its survival (Stickney and Miller 1973). Among the vertebrates collected in beach seines by NMFS, *Sardinella anchovia*, *Caranx hippos*, *Lucania parva*, *Peprilus alepidotus*, *Poecilia latipinna*, *Bairdiella chrysura*, *Astroscopus y-graecum*, and *Harengula pensacolae* were not observed in the present study. As in the case of the beam trawl samples, *Xiphopeneus kroyeri* was taken in beach seines by NMFS during the 1975 study.

490. NMFS shrimp trawl samples included the vertebrates *Caranx hippos*, *Peprilus alepidotus*, and *Trichiurus lepturus* which were not taken in the present study and the invertebrate *Loligo* sp. The squid was probably *Loliguncula brevis*, the common inshore squid of the Gulf of Mexico and east coast. This species was taken in the 1976 and 1977 samples.

491. Vertebrates which were collected during 1976 and 1977 but not during the 1975 study include *Cyprinodon variegatus*, *Harengula jaguana* (possibly the same animal as *H. pensacolae* in the 1975 study), *Fundulus grandis*, *Ophidion welshi*, *Menticirrhus littoralis*, *Anchoa hepsetus*, *Gerres cinereus*, *Hemicaranx amblyrhynchus*, *Gobionellus schufeldti*, *Eucinostomus lefroyi*, *Dorosoma cepedianum*, *Etropus crossotus*, and *Paralichthys albigutta*. Invertebrates taken in the present study but not reported by NMFS include *Callinectes similis*, *Loliguncula brevis*, *Neopanope texana texana*, and *Pagurus polycarpus*. The 1976 and 1977 study identified three species of *Palaemonetes (P. pugio, P. vulgaris* and *P. intermedius)*, while NMFS reported only *Palaemonetes* spp.

492. In general, the two studies compared favorably with respect to the total number of taxa collected and the relative contribution by taxa of vertebrates and invertebrates. Because of the mobility of these animals, it is not possible to determine how much influence the salt marsh had on their presence. In addition, during most of the study period, the plants were small and total area coverage was relatively insignificant, so the 1976-77 collections represent a baseline study more than they relate to utilization of an established marsh by nekton.

493. The most abundant fish species captured in the 1976-77 study was the bay anchovy, *Anchoa mitchilli*. This species is common along the Atlantic and Gulf of Mexico coasts of the United States from Massachusetts to Texas (Hildebrand and Schroeder 1927) and sometimes is found as far north as Maine (Bigelow and Schroeder 1953). Seldom reaching in excess of 85 mm (Bigelow and Schroeder 1953), and apparently consuming primarily mysids and copepods in Chesapeake Bay (Hildebrand and Schroeder 1927), *A. mitchilli* is a pelagic schooling fish which may gain some protection from salt marshes, but which is commonly found throughout estuarine and bay systems.

494. Second in abundance among the fishes collected in seines and push nets during 1976 and 1977 was the spot, *Leiostomus xanthurus*, a demersal species which is also found from Massachusetts to Texas (Hildebrand and Schroeder 1927). This sciaenid is abundant through much of its range and is present in the majority of commercial shrimp catches on the near shore shrimping grounds of Texas, contributing about 1 percent of the total catch (Chittenden and McEachran 1976). Bay shrimpers may take a much higher percentage of *L. xanthurus*. Gunter (1945) reported capturing individuals up to 282 mm along the Texas coast.

495. The Atlantic croaker, *Micropogon undulatus*, was found to be the most abundant fish on the white shrimp grounds off Texas by Chittenden and McEachran (1976), making up 41 percent of the total catch. Presently considered a trash species throughout much of its range, there does appear to be a commercial potential for this fish, which was fourth in abundance in the present study (Table 111). This demersal fish reaches a maximum size of about 370 mm along the Texas coast (Gunter 1945) and, like many other fishes found in Galveston Bay, is euryhaline. Both spot and Atlantic croaker are generally absent from Texas coastal waters in the winter (Gunter 1945) as confirmed by the present study (Appendix A', Table A15), but are abundant during the spring and summer. This species was the second most abundant demersal species of fish at the Bolivar site from July 1976 through June 1977.

496. The three most common species collected during 1975 by the NMFS were *Brevoortia patronus*, *Anachoa mitchilli*, and *Micropogon undulatus*, respectively, in beam trawls; *M. undulatus*, *Mugil curema*, and *Leiostomus xanthurus*, respectively, in beach seines; and *M. undulatus*, *L. xanthurus*, and *Arius felis*, respectively, in shrimp trawls. *B. patronus* was twelfth in abundance in the present study, while *A. felis* was fourteenth.

497. As indicated by the average weights of fishes collected both in the beach seine and the push net, most were juveniles. One exception was a single 1,230-g *Paralichthys albigutta* which was collected

in the beach seine during July 1976. Many adult specimens of fishes which do not attain large size were also taken, including *Anchoa mitchilli*, *Cyprinodon variegatus*, *Menidia beryllina*, *Membras martinica*, *Fundulus similis*, and *F. grandis*.

498. The striped mullet, *Mugil cephalus*, was third in overall abundance. A close relative, the white mullet, *M. curema*, ranked sixth in overall abundance from combined seine and push net samples. Some differences in order of abundance occurred between the two sampling devices, but they were generally similar in this respect (Table 111).

499. In terms of total weight, *M. cephalus* and *M. curema* ranked first and second. Total numbers of these species might have been considerably higher in the samples if the collecting gear had been more efficient. Mullet are strong and rapid swimmers and are often able to avoid capture by seines, push nets, and other active types of sampling gear. On one occasion several mullet jumped into the boat at night when a trawl sample was being taken.

500. Young *M. curema* first appeared in the present samples in May and June, indicating that they are spawned in the late winter and early spring as reported by Gunter (1945). Young *M. cephalus* were first collected in January 1977 in the present study, with small numbers occurring at that time. Large numbers were collected in February and March. The number of very young *M. curema* captured (as indicated by average weight) was small (Appendix A', Table A15).

501. The annual summary of nekton collected in hoop nets and minnow traps in the present study is presented in Table 112. Only four adult *Callinectes sapidus* were collected during that sampling period. Minnow traps collected a total of 15 vertebrates and 115 invertebrates, primarily *Palaemonetes pugio* and *P. vulgaris*. All of the species captured in the hoop nets and minnow traps were well represented in the beach seine and push net samples. Neither of these methods represents an improvement over the more active collection methods.

502. An annual summary of beach seine data in terms of

total number of organisms, average number per seine haul with standard deviation, total weight, and average weight per seine haul with standard deviation monthly, day and night, is presented in Table 113. Numerically, the largest collections, day and night, occurred during the spring and summer, as would be expected since many of the species collected migrate out of the bays and estuaries in the winter. The numbers of individuals collected during the daylight exceeded those of the night samples only during July and August 1976. The number of animals collected during day and night were similar in August, September, and October 1976 and dissimilar in the remaining samples, with the night samples containing many more individuals than day samples with the exception of July 1976.

503. The same breakdown of samples presented in Table 113 for beach seines is presented in Table 114 for push nets. More animals were taken during the day than at night in July, August, and September 1976 in push nets. Similar numbers were collected day and night in September 1976 and January 1977.

504. In both beach seine and push net samples the standard deviations of the average number of organisms captured at each station and the standard deviations of the average weight of individuals captured were high, indicating large variability among collections. In many cases the standard deviation values were equal to or higher than the mean numbers or weights for the time of day and month under consideration.

505. Total weights of organisms collected in beach seines, day and night, during each month of the study (Table 113) revealed the same pattern as total numbers. Spring and summer collections contained more biomass than did samples taken during other seasons. In beach seines, the total weight captured during the day exceeded that of the night samples only during July 1976. The day and night weights were similar in September 1976 and rather dissimilar during other months. Day total weights from the push net samples on the

other hand (Table 114) exceeded those of night samples during July, August, and September 1976 but not during any other month. The greatest day and night similarity in push net total weights occurred during October 1976, along with January and February 1977.

506. While total numbers of individuals captured during June 1977 after the marsh was fairly well established were somewhat greater than those of July 1976 when the marsh was being planted, the total biomass of organisms captured was not much different between the two most widely separated months. The nekton data, when viewed in the manner presented in Tables 113 and 114, demonstrate normal seasonal patterns of abundance and biomass but do not appear to support any statement that the marsh was obviously affecting these parameters through the period studied.

507. The diversity of organisms collected in beach seines, day and night, during each month of the study shows a great deal of variability (Table 113). Highest daytime beach seine diversity occurred during July 1976 and February 1977 with the highest nighttime diversity being in June 1977. The lowest diversity in day samples occurred during November 1976 at 0.04, with other diversities of less than 0.50 occurring only in the samples of November 1976, with the rest of the year being consistently between 0.60 and 1.73. A decrease in diversity during the fall was less apparent in the night seine samples than in those collected during the day. The observed trends may reflect normal seasonal patterns; however, the duration of sampling was insufficient to establish this point.

508. Push net diversity was greatest in day samples during July and August 1976 (Table 114), falling to below 0.75 thereafter. Diversity was very low in the night samples of July 1976, increased in August to nearly 1.30 and then fell gradually each month until November, when an increase began to occur which continued through the end of the period for which samples are available (Table 114). In the case of push nets, as was true in seine samples, diversity

between day and night was highly dissimilar during many months. In neither case did the patterns which were observed indicate that a distinct change was occurring with time which might be related to establishment of the marsh.

509. The annual summary of data collected day and night by transect is presented in Table 115 for beach seines and Table 116 for push nets. The total and average numbers of individuals captured in beach seines on the two reference transects (transects J and Z) during the day were slightly lower than at night (Table 115). The highest total number of individuals collected occurred at night in the bare unprotected areas (transects A and I), with markedly lower numbers occurring during the day. The numbers of individuals in the collections from the bare protected areas (transects X and Y) were similar to those from the reference area. The marsh area (position E) yielded less than 1,000 animals both day and night during the study. Elevational changes within the protected area, especially in the vicinity of the lower end of position E, appeared to account for the reduced numbers of organisms in that area. The water depth at high tide was rarely over 0.5 m as compared with at least 1 m in the reference areas, as well as at the most seaward point on transects A and I.

510. The patterns established from the beach seines with respect to numbers of individuals captured along the various transects were supported by the push net data (Table 116). More animals were captured along transect Y during the night than along any other transect at any other time of day. The fewest numbers were obtained from position E when day and night figures are combined, although there were more animals taken from position E during the day than at the same time along transect I.

511. Total annual seine haul weights exceeded 1 kg along all transects except transect I (day samples) and transect Y (day samples), which represented collections in the bare unprotected and bare protected areas, respectively (Table 115). Total catch

weights in push nets were less than 400 g in all cases with less than 100 g being taken both day and night along transect A and position E. Less than 100 g was also obtained from day samples from positions Z, E, and Y and from night samples along transect X (Table 116).

512. Because of variations in gear efficiency (rolling up of the nets in the mud and loss of animals under the nets in footprints and other variations in the bottom) and differences in water depth and extent of inundation from one station to another, it is not possible to evaluate differences in numbers or weights with any degree of reliability. Diversity, however, may provide a good indication of the differences along the various transects if it is assumed that escapement was similar from one species to another. Position E diversity was consistently lower both in beach seine and push net samples, day and night, than in samples taken at either time of day along the other transects (Tables 115 and 116), with the execption of day push net samples from transect Y, where the diversity compared favorably with that of Station E for day samples.

513. Overall diversities (day and night) were similar for beach seine samples collected along transects X and Y (bare protected areas), I (bare unprotected area) and Z (reference area).

514. This trend was also apparent in the push nets with the exception of the very low diversity that was obtained along transect Y during day sampling. Diversities in the reference and bare unprotected areas were similar, day and night, in both beach seine and push net samples. The establishment of the protected area appeared to enhance diversity near the ends of the diked region (transects X and Y), but detracted from diversity in the middle (position E). Part of this may have been due to the presence of large amounts of water during high tide in the bare protected areas with little water in the middle of the study area. Indications from these data are that at least a portion of the protected area attracted a wider variety of nekton organisms than did either the bare unprotected areas or the reference areas. Both the bare unprotected

and the bare protected areas were immediately adjacent to developing marsh grasses and as the marsh becomes more completely established its influence on diversity, if any, should become more readily apparent.

515. The collection of nekton in beach seines and push nets does not provide any firm indication that the newly created salt marsh was being utilized preferentially to existing bare areas, although because the marsh was in the early stages of development, such an indication of use should not have been expected. What the nekton sampling program did was provide a great deal of information with regard to the species of nekton organisms which can be found in the shoal areas of lower Galveston Bay during all seasons of the year. In addition, and possibly of much greater importance, animals collected by beach seines and push nets provided specimens for food habit studies. Such studies could provide a direct link between colonization of the study site by benthic invertebrates and the utilization of the benthos community by the nekton.

516. No detailed analysis of the data collected from hoop nets and minnow traps is provided because the numbers of animals collected were extremely low. However, data from the individual collections by these sampling devices are detailed in Appendix A' (Table A16).

517. Annual capture data on blue crabs, *Callinectes sapidus*, are presented in Tables 117 and 118. Table 117 includes data from the protected marshland, protected mixed planting areas, and protected bare transects. Table 118 includes data from the unprotected mixed planting areas, unprotected bare areas and reference areas. Data from transect stations 3 and 5 have been combined for presentation in these tables. In general, the collections at station 3 were insignificant because of shallow water at that elevation.

518. Blue crabs were not collected between November 1976 and February 1977. This is typical of Gulf of Mexico and North Atlantic estuaries where this species occurs since crab activity

is slowed considerably by the cold water. It is generally believed that these animals bury in the sediments and aestivate during the winter, and other studies along the Texas coast confirm that reduced numbers are taken during the winter (Gunter 1950).

519. A total of 13 blue crabs were collected along the marshland transects, 19 in the protected mixed planting zones, 35 in the protected bare areas, 73 in the unprotected mixed planting zones, 58 in the unprotected bare areas, and 52 in the reference areas. Thus, the sandbag dike which offered protection to the growing marshland seemed to restrict *C. sapidus*. The dike may have acted as a physical barrier to the lateral movement of blue crabs along the shore or to their movement in and offshore. Appendix A', Table A17 presents *C. sapidus* total numbers, mean carapace width, and mean weight by transect, monthly over the study period in crab traps.

520. The *C. sapidus* data collected in the various environments during May and June 1977 indicated that the protected areas (transects X, C, D, F, G, and Y) had an average of 2.7 crabs per transect in May and 1.5 in June. The unprotected areas (transects A, B, H, and I) had an average of 6.8 crabs in traps set in May and 5.0 in June, whereas the reference areas (transects J and Z) had an average of 4 crabs in May and 9 in June. Bare unprotected areas had an average of 7.5 crabs in May and 8 in June; planted unprotected areas had an average of 6 crabs in May and 12 in June; and planted protected areas had an average of 2.8 crabs in May and 0.5 in June. Thus, it is apparent that the presence or absence of plants within or outside of the dike had little effect on the number of blue crabs captured. It is possible that the dike impeded crab mobility and that the influence of the marsh plants on the movement of blue crabs may become increasingly important in the future as the marsh grass spreads throughout both the protected and unprotected planted portions of the study area.

521. The ratio of male *C. sapidus* to females captured in crab traps in the unprotected and reference areas was nearly 1:1 (Table 118),

while in all the protected areas more males were present than females. This phenomenon should be monitored in the future to determine whether some alteration in the environment is actually influencing this trend. Gunter (1950) observed that male *C. sapidus* were more abundant than females during certain portions of the year, but the adults captured in crab traps during this study did not demonstrate this trend. Further analysis of crab data obtained from beach seines will be required to address this point in more detail.

522. No gravid blue crabs were captured in crab traps set within the dike (Table 117), although a few were collected within each of the unprotected areas and the reference area (Table 118). This is another indication that the dike proved a deterrent to the movement of crabs. Gravid females may have somewhat more difficulty traversing obstacles and were thus eliminated from the protected area.

523. Such conclusions are tempered by the fact that relatively few crabs were collected in the crab traps during the course of the study. Further, evaluation of the beach seine and push net data is of little help in this regard since most of the crabs collected therein were immature (as indicated by the average weights in Table 111). Further, in no instance was a gravid female collected in the active types of sampling gear.

524. The majority of the crabs captured in the crab pots were hard (in excess of 80 percent at all stations). A few peelers were captured (Fig 75).

525. All crabs collected in crab pots averaged in excess of 110-mm carapace width and 85-g total weight. The average carapace width and weight in the unprotected and reference areas was somewhat greater than in the protected areas (Tables 117 and 118). Smaller crabs were able to escape through the walls of the crab traps.

526. Monthly changes in total abundance, sex, and condition of blue crabs are presented in Figure 75. With the exception of

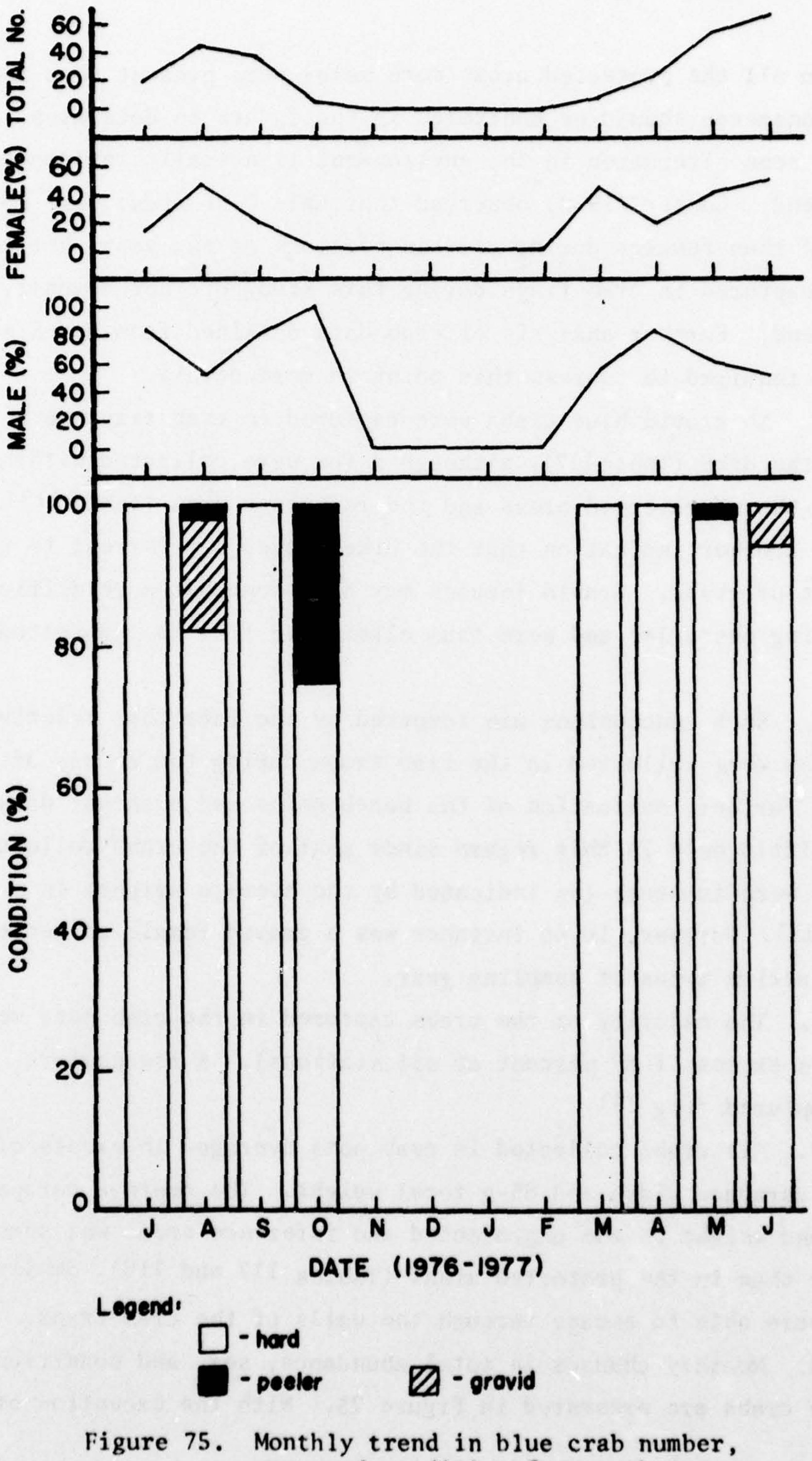

Figure 75. Monthly trend in blue crab number, sex, and condition from crab traps

the occurrence of gravid females (which were taken only during the spring and summer) and the fact that no *C. sapidus* were collected from November 1976 through February 1977, there were no trends visible in the data to indicate that patterns in sex were related to the time of year that the collections were made. No soft blue crabs were captured in crab traps during the study period, although crabs of this type were taken in beach seine samples.

Food habits

527. Large numbers of individuals of five of the six species examined for food habits were collected during the study period. The exception was the southern flounder, *Paralichthys lethostigma*. All six individuals were collected during March 1977. Five of them had food in their stomachs. Each of the flounders was in the 20- to 50-mm size range. A total of five unidentified fish were found in the stomachs of these animals. *P. lethostigma* from Texas have been reported to be largely piscivorous (Gunter 1945), but further collections should be obtained to document the possible utilization of benthic organisms within the study area by this fish.

528. Four size classes of *Micropogon undulatus* were examined for food habits (less than 20 mm, 21 to 50 mm, 51 to 100 mm, and greater than 100 mm in standard length) as indicated in Tables 119 through 122, respectively. Only 52 stomachs from fish less than 20 mm were available, 15 of which were empty. These small fish were collected from November 1976 through March 1977. Of the 535 individual food items identified in the samples, 84.6 percent consisted of copepods (36.1 percent harpacticoids and 48.0 percent calanoids). Barnacle larvae represented the next most important food component. Thus, from the limited amount of information available, it appears that small *M. undulatus* in Galveston bay feed largely on a combination of small zooplankton and benthic invertebrates.

529. The greatest number of stomachs examined were taken from *M. undulatus* in the size range 21 to 50 mm. Of 177 stomachs inspected, 161 contained recognizable food items. The majority of the food was zooplanktonic in origin, with 17.8 percent of the 2,045 food items consisting of the benthic harpacticoid copepods and 41.9 percent zooplanktonic calanoid copepods. Cyprid barnacle larvae contributed another 14.5 percent. A number of unidentified eggs (probably from a crustacean) were obtained, amounting to 12.1 percent of the total. Benthic organisms were more important in the food habits of *M. undulatus* of this size range than they were in smaller individuals. Polychaetes made up about 3.7 percent of the total number of food organisms identified, with penaeid mysids and the isopod *Xenanthura brevitelson* each accounting for 2.0 percent (Table 120). Fish eggs, oligochaetes, and various crustaceans made up the remainder.

530. Of 116 *M. undulatus* examined in the size range 51 to 100 mm, 105 contained food within their stomachs. Of the organisms identified, 15.5 percent were harpacticoid copepods, while 33.0 percent were calanoids. Cyprid larvae were relatively unimportant, while penaeid shrimp juveniles accounted for 6.8 percent and the isopod *X. brevitelson* 3.3 percent of the total food organisms identified. Polychaetes became more important, representing 12 percent of the total. Other organisms were present in lesser percentages (Table 121).

531. Only four fish greater than 100 mm standard length were collected. Three stomachs contained food. Of the nine food items identified from these stomachs, one was a smaller *M. undulatus*, three were polychaetes, and three decapod crustaceans. A single cyprid larva represented the only planktonic species present. One mollusk was also recovered (Table 122). Although the evidence from the largest size class is very speculative, the general indication from *M. undulatus* food habit studies supports the conclusion that this species feeds primarily on zooplankton and small benthic invertebrates at small sizes and increases its dependence upon the

benthos community, and possibly other fish, as it increases in size. Roelofs (1954) indicated that both *M. undulatus* and *Leiostomus xanthurus* at larger sizes often feed by taking bites out of the sediments and expectorating the inorganic component while swallowing the food items included in each bite. Various studies (Linton 1904, Welsh and Breder 1923, Gunter 1945, Roelofs 1954, Darnell 1958, Shickney et al. 1975) support the view that *M. undulatus* feeds on benthic invertebrates except during the first few months of life.

532. Three size classes of *Leiostomus xanthurus* were obtained during the June 1976 through June 1977 sampling period. Thirty-seven stomachs containing food were obtained from *L. xanthurus* of less than 20 mm (Table 123), and 96.1 percent of the 1,547 food items examined were harpacticoids. Second in abundance were polychaetes, with 2.1 percent of the total food being represented by *Eteone heteropoda*. All other food items were present at less than 1 percent of the total. Little change was observed in the food habits of *L. xanthurus* greater than 50 mm in standard length (Tables 124 and 125). Harpacticoid copepods dominated the food habits, representing 96.0 percent of the total. The polychaete *E. heteropoda* made up 2.4 percent.

533. Therefore, since harpacticoid copepods are predominantly benthic, *L. xanthurus* were almost exclusively benthic feeders in the size ranges collected at Bolivar Peninsula. This pattern of feeding was verified by numerous other studies throughout the range of this species and holds for fish of larger size classes than those available in the present study (Linton 1904, Welsh and Breder 1923, Hildebrand and Cable 1930, Reid 1954, Roelofs 1954, Darnell 1958, Stickney et al. 1975).

534. *Fundulus similis* collected at the Bolivar Peninsula stations occurred in two size classes: less than 20 mm, and between 2 and 50 mm standard length (Tables 126 to 128). Only three individuals of less than 20 mm were collected and each had a single harpacticoid copepod in its stomach. All three were collected in May. *F. similis* larger than 20-mm standard length were collected during every

month of the study with the exceptions of September and December 1976. A variety of organisms were found in the 252 food-containing stomachs examined (Tables 127 and 128). However, only out of 3801 food items identified, 2747 or 72.1 percent consisted of harpacticoid copepods. Harpacticoids dominated the food habits of this fish during many, but not all months of the year. Cyprid barnacle larvae were the most abundant organisms in the stomachs of *F. similis* during July and August, while polychaetes and the isopod *X. brevitelson* were consumed in relatively high percentages during February and March. Insects of various kinds contributed significantly to the food of *F. similis* in the summer (July and August), while crustaceans other than those mentioned, mollusks, and fish eggs were largely incidental.

535. *F. similis* appears to be opportunistic in its feeding behavior, selecting organisms which are abundant during any particular time of year, although appearing to prefer zooplankton to most benthic organisms. Polychaetes were virtually absent from *F. similis* stomachs during the early portion of the study (Table 127), but were important during the winter (Table 128). Neither the June 1976 nor the June 1977 stomachs contained evidence that *F. similis* consume many polychaetes in the summer. The increased consumption of polychaetes in the winter corresponds to a large extent with the increase in total polychaete density which occurred during that period.

536. The two size classes of *Cyprinodon variegatus* captured at the Bolivar Peninsula site corresponded with those of *F. similis*. *C. variegatus* spawn throughout the spring and summer (Hildebrand 1919) accounting for their relative abundance in the size class less than 20 mm in standard length throughout the fall and winter (Table 129). In November 1976 as well as January and March 1977, only detritus was recovered from the stomachs examined. Ostracods, harpacticoid copepods, and other crustaceans, along with

minute gastropods, made up the stomach contents during October 1976 and February 1977. With the exception of the gastropod mollusks, the food of the small *C. variegatus* consisted primarily of zooplankton forms. No benthic infaunal organisms were recovered.

537. *C. variegatus* between 20 and 50 mm standard length (Table 130) also often contained only unidentifiable organic matter, although a considerable number of stomachs were examined. Only in October 1976 and February 1977 were identifiable remains found. Harpacticoid copepods, cyprid larvae, fish eggs, and small gastropods were the only organisms identified. From the data available it appears as though *C. variegatus* feeds primarily on the benthic community.

538. *Menidia beryllina* of the size class 20 to 50 mm were taken 8 of the 12 months during which fish were collected for food habit analysis. Relatively scarce during the summer, *M. beryllina* were abundant during the winter and spring at the Bolivar Peninsula site (Table 131). Cyprid larvae dominated the food of this fish during January and February and were important during the period March through June. Calanoid copepods were the second most abundant food item in the diet of *M. beryllina*, being most important during April and June. Cyclopoid copepods were important food items in October.

539. Polychaetes did not appear to be important in the food of *M. beryllina*, although they were sometimes found. Harpacticoid copepods, so common in several other species, were nearly absent in *M. beryllina*. Insects and their larvae were common in August, with insect adults or larval stages appearing in low numbers during other months (Table 131). Amphipods, decapods, and mollusks were relatively unimportant during most of the study. Fish eggs seemed to be consumed with some regularity, but not in great numbers. The dominant food organisms in the diet of *M. beryllina* collected in this study were zooplanktonic.

540. In summary, only *Menidia beryllina* among the six species examined feeds to a significant extent on the zooplankton community. Most of the others feed on benthic organisms, or in the case of *Paralichthys lethostigma*, other fishes.

Benthos and sediments

541. Benthos samples were collected in conjunction with an earlier study conducted by NMFS (written communication, National Marine Fisheries Service, Galveston, Texas, 1975). Direct comparison of the NMFS data with those collected during the present study is not possible since the earlier study reported only total numbers of animals collected and numbers per litre of sediment. Since the depth of collections was not made available from the NMFS, it was not possible to determine how samples from the two studies compared on an areal basis.

542. A variety of organisms from the phyla Annelida, Arthropoda, Mollusca, and Rhynchocoela were collected during the present study (Table 132). Values representing benthos annual mean abundance ($number/m^2$) in decreasing order in terms of the 47 taxa identified are presented in Table 133 along with the mean weight (g/m^2) of each taxon. The most abundant organisms were polychaetes, with *Mediomastus californiensis* being present at three times the level of any other taxon on the average. The isopod *Xenanthura brevitelson* (also common in the food habits of the six species of fishes examined) was the third most abundant organism recovered from the sediments. On an areal basis, dry weight biomass of all species was about 0.1 g/m^2 or less with the exception of mollusks, the weights for which include the shells.

543. In addition to the organisms listed in Tables 132 and 133 a variety of other animals were collected in conjunction with sediment sampling which were felt to have been nonbenthic in nature. These included, supertidally, adult insects of taxa

other than those which are known to live within the sediments, penaeid shrimp postlarvae and juveniles, palaemonid shrimp, crab megalops and zoea, and fish. In most cases, such organisms were incidental to the collections.

544. Annual macrobenthos abundance (number/m^2) and diversity for each station, monthly are presented in Appendix A', Table A18. Mean monthly abundance (number/m^2) of macrobenthic invertebrates (Table 134) indicated increasing numbers from July 1976 through April 1977 with a decline thereafter. The difference between the mean abundance in July 1976 (745/m^2) and June 1977 (3162/m^2) may be representative of the fact that the sediments had been reworked by heavy equipment during site preparation a few weeks before the first samples were taken and the benthic invertebrates had probably not reached equilibrium with the environment by July 1976. It is not possible to determine from Table 106 whether the temporal changes which occurred were affected by the various treatments associated with the site.

545. Monthly diversity was remarkably consistent throughout the sampling period (Table 134). The lowest monthly mean diversity was recorded during August 1976, with the values at the beginning and end of the study being similar (0.79 in July 1976 and 0.91 in June 1977). Diversity was relatively low (rarely being in excess of 1.0 during the sampling period) and did not follow any noticeable pattern during the 12 month study.

546. The mean annual abundance and diversity of macrobenthos at each sampling station are presented in Table 135. These data are summarized by mean abundance (number/m^2) and diversity by sampling station elevation in Table 136. The mean abundance was highest at stations 4 and 5, respectively, and lowest at station 2. Station 1 was supertidal during most of the sampling period and was inhabited primarily by insect larvae and pupae. These organisms were also found in abundance at station 2 but were less common at

lower elevations. The intermittent inundation of station 2 by water during spring tides, especially during the summer, appears to have limited the abundance of benthic organisms present at that elevation. Similarly, because station 2 was not inundated with water on a consistent basis, aquatic benthic organisms (e. g., polychaetes, oligochaetes, and mollusks) were less abundant than at lower elevations. Some insect larvae and pupae were collected at station 3 during some months; however, most of the organisms collected at stations 3, 4, and 5 were marine forms.

547. Diversity was somewhat lower at stations 1 and 2 (dominated by insect pupae and larvae) than the other three stations (Table 136). This appears to reflect the relatively few species which inhabit the upper beach as compared with the abundance of species found inhabiting the intertidal sediments. Diversities at stations 3, 4, and 5 were similar even though the extent of inundation was quite different seasonally.

548. Transects established to sample duplicate environments were often quite different both in mean numbers/m^2 and diversity over the sampling period (Table 137). Thus, similar transects in different locations on the site appeared to represent different microhabitats. Benthic data collected to date indicate a high degree of variability in the benthic community but the observed differences do not seem to be dominated by the vegetation at present.

549. Six species (selected on the basis of abundance or as representatives of various phyla) were evaluated in terms of mean annual abundance and the habitats in which they were found (Table 138). The species selected were the polychaetes *Mediomastus californiensis*, *Parandalia fauveli*, *Aricidea* sp. 1 and *Eteone heteropoda*; the isopod *Xenanthura brevitelson*; and the mollusk *Macoma constricta*. No consistent trend was found relating the abundance of all six species with habitat type. Conversely, different patterns were associated

with the various species. The polychaetes *M. californiensis* and *P. fauveli* were most abundant within the protected area of the study site (bare protected, mixed protected, and marshland), while *Aricidea* sp. 1 was most abundant in the unprotected bare and mixed planting areas and in the reference areas. *E. heteropoda*, on the other hand, was most abundant in the mixed planting areas, both protected and unprotected, and was relatively evenly distributed in the other environments. The isopod *X. brevitelson* was least abundant within the protected area, with the highest numbers occurring in areas which were unplanted and unprotected (bare unprotected and reference areas). In contrast to the isopod data, the mollusk *M. constricta* was most abundant in the mixed protected area and was fairly evenly distributed in the bare protected, marshland, and reference areas (Table 138), being present at low levels in the bare and mixed unprotected areas.

550. Of the species examined, *Macoma constricta* is the most unusual since its abundances in the reference area and the unprotected bare area were considerably different while the reference area and protected bare areas were similar. From the data in Table 138, it appears as though the protected portion of the site attracted *M. constricta* to a greater extent than did the unprotected areas. In theory, the abundance of *M. constricta* should eventually be similar within the experimental and reference areas if the dike and plantings have no effect on the abundance of that organism. The failure of *M. constricta* to colonize the reworked sediments in the unprotected area to the extent that they recolonized the protected area demonstrates an effect of the sandbag dike rather than an effect of the marsh grass.

551. The monthly abundance (number/m^2) of each of the six macrobenthos species identified in Table 138 is presented in Figures 76 to 81. In most cases, the abundance of the organisms increased from June through the winter with the peak abundance occurring in February or thereafter in five of the six species. A decline in abundance during the latter sampling months was exhibited in all

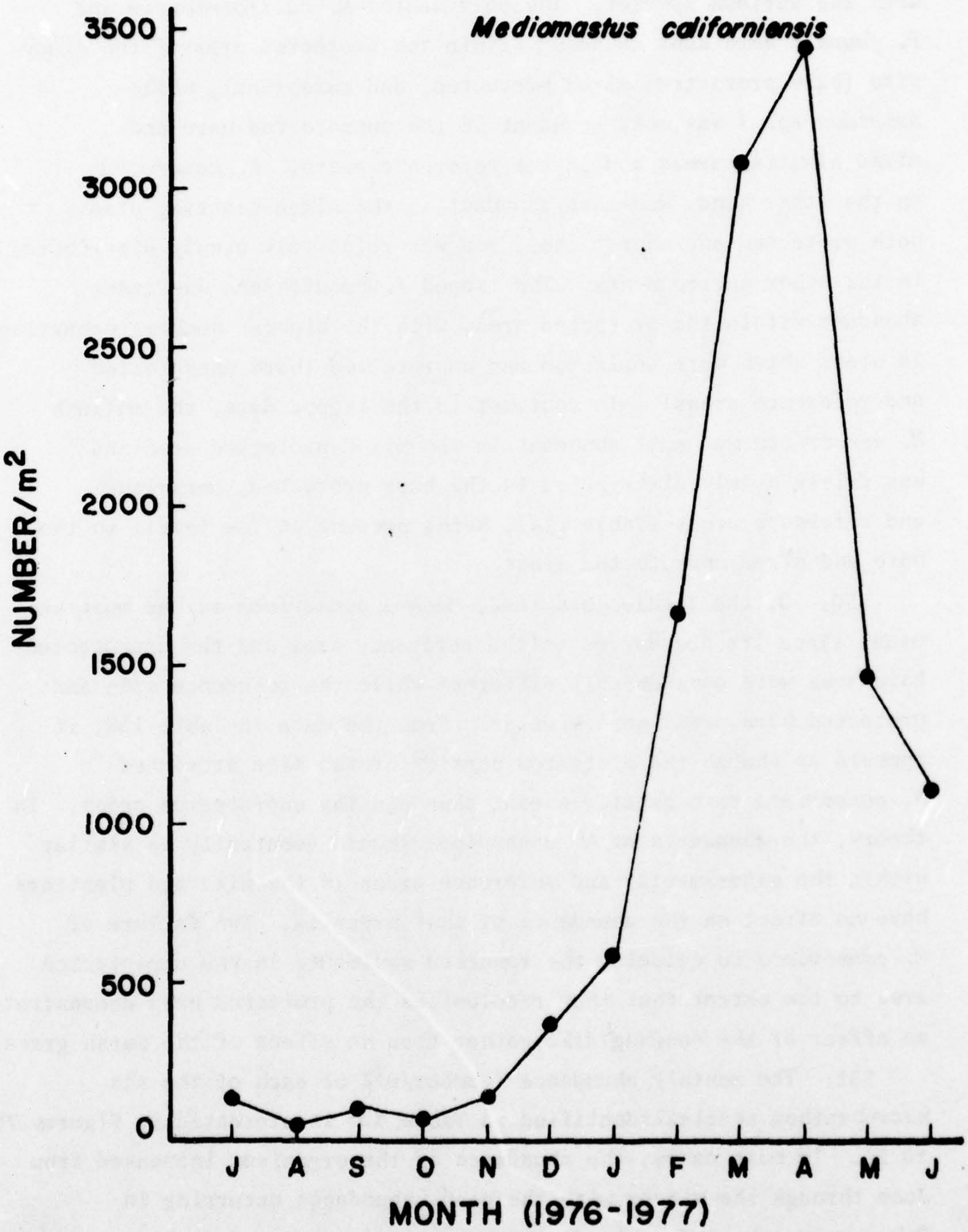

Figure 76. Mean monthly abundance of *Mediomastus californiensis* at the Bolivar Peninsula site

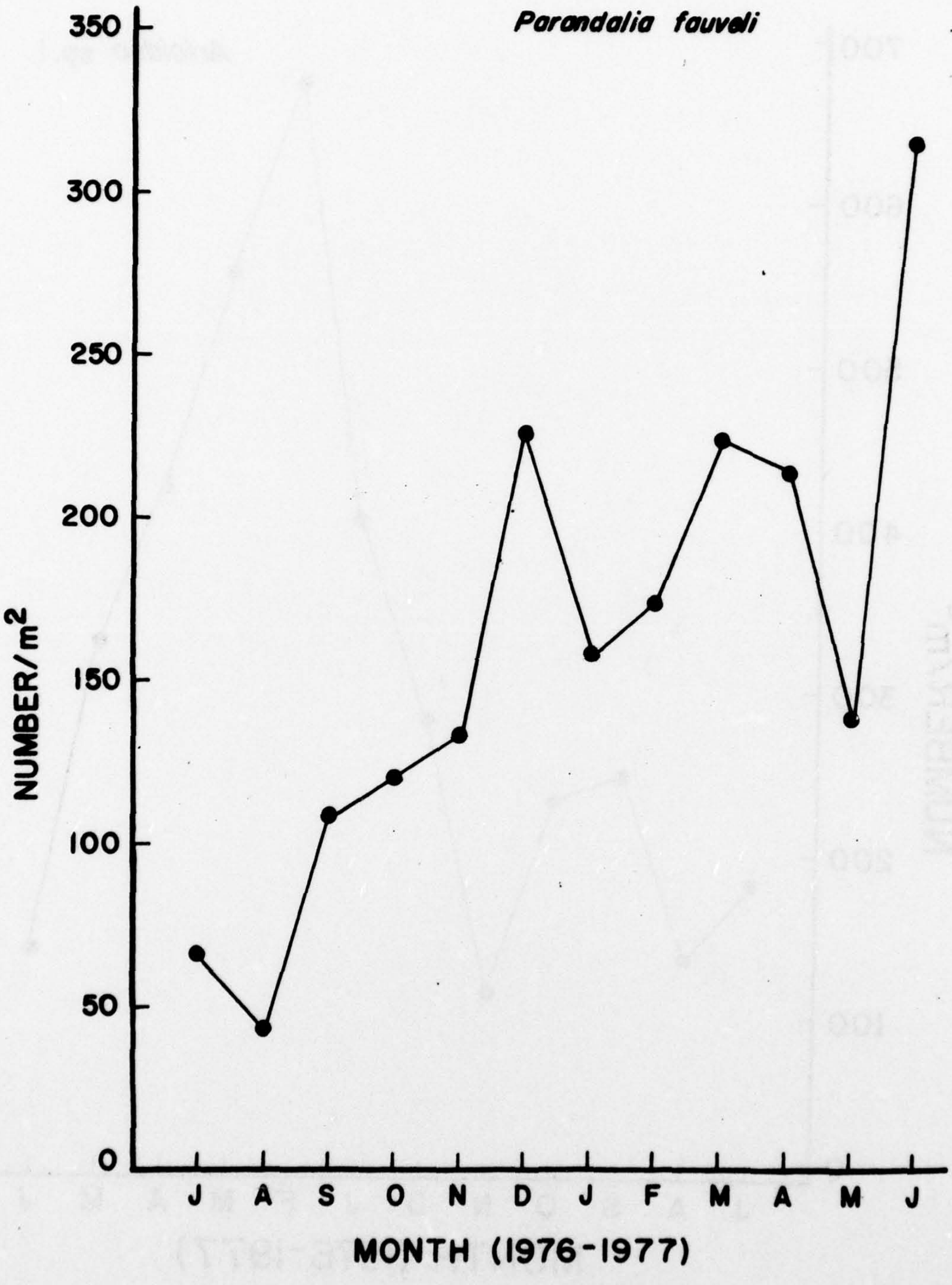

Figure 77. Mean monthly abundance of *Parandalia fauveli* at the Bolivar Peninsula site

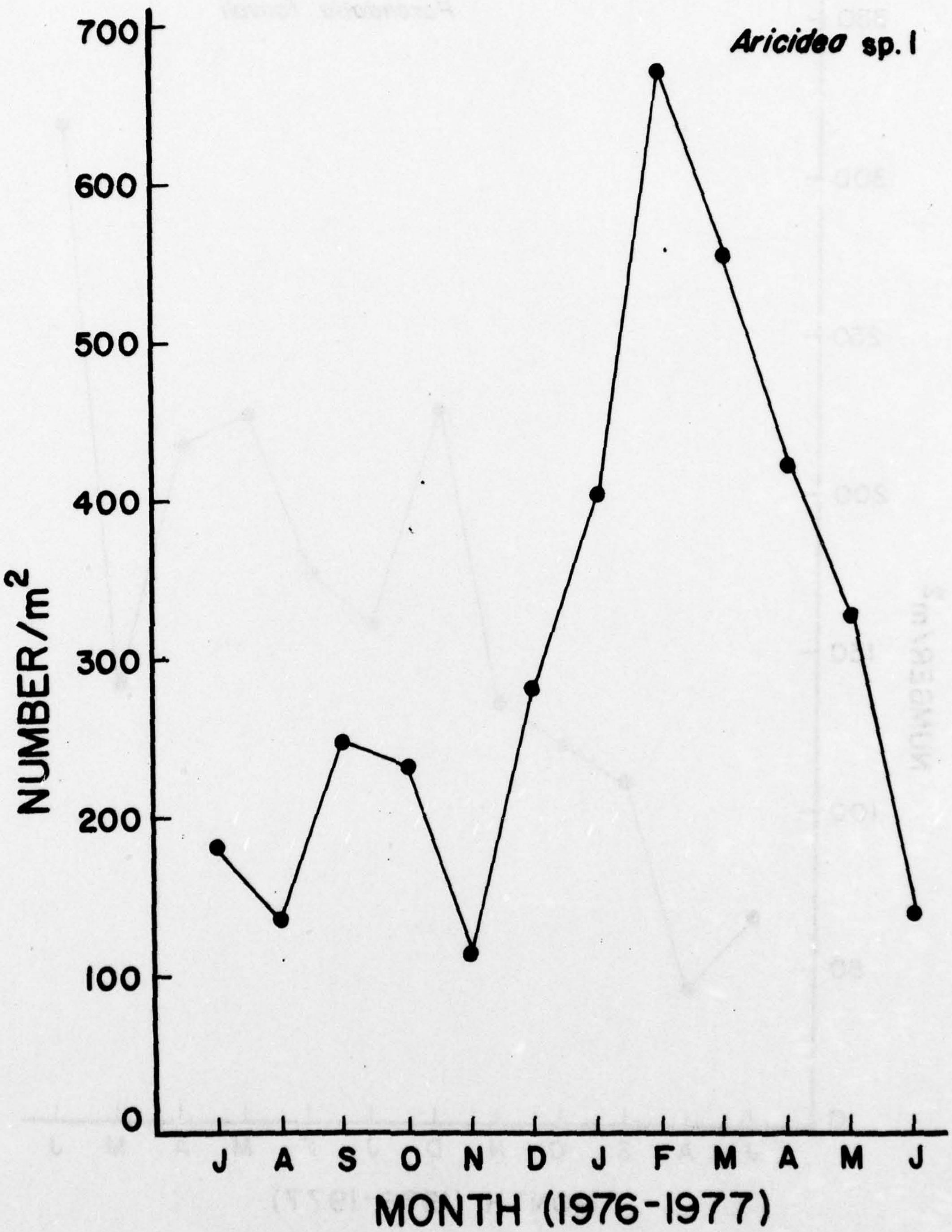

Figure 78. Mean monthly abundance of *Aricidea* sp. 1 at the Bolivar Peninsula site

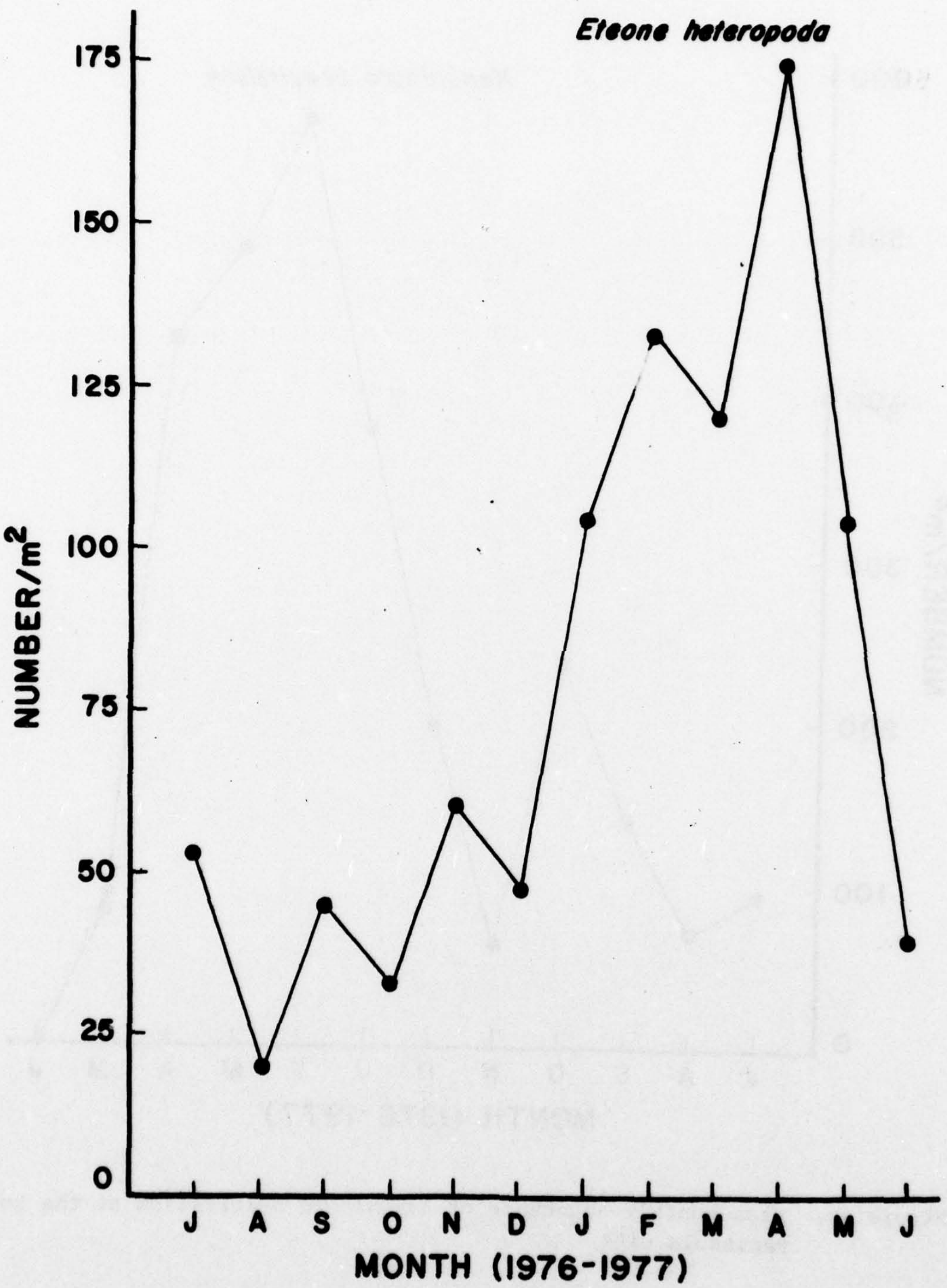

Figure 79. Mean monthly abundance of *Eteone heteropoda* at the Bolivar Peninsula site

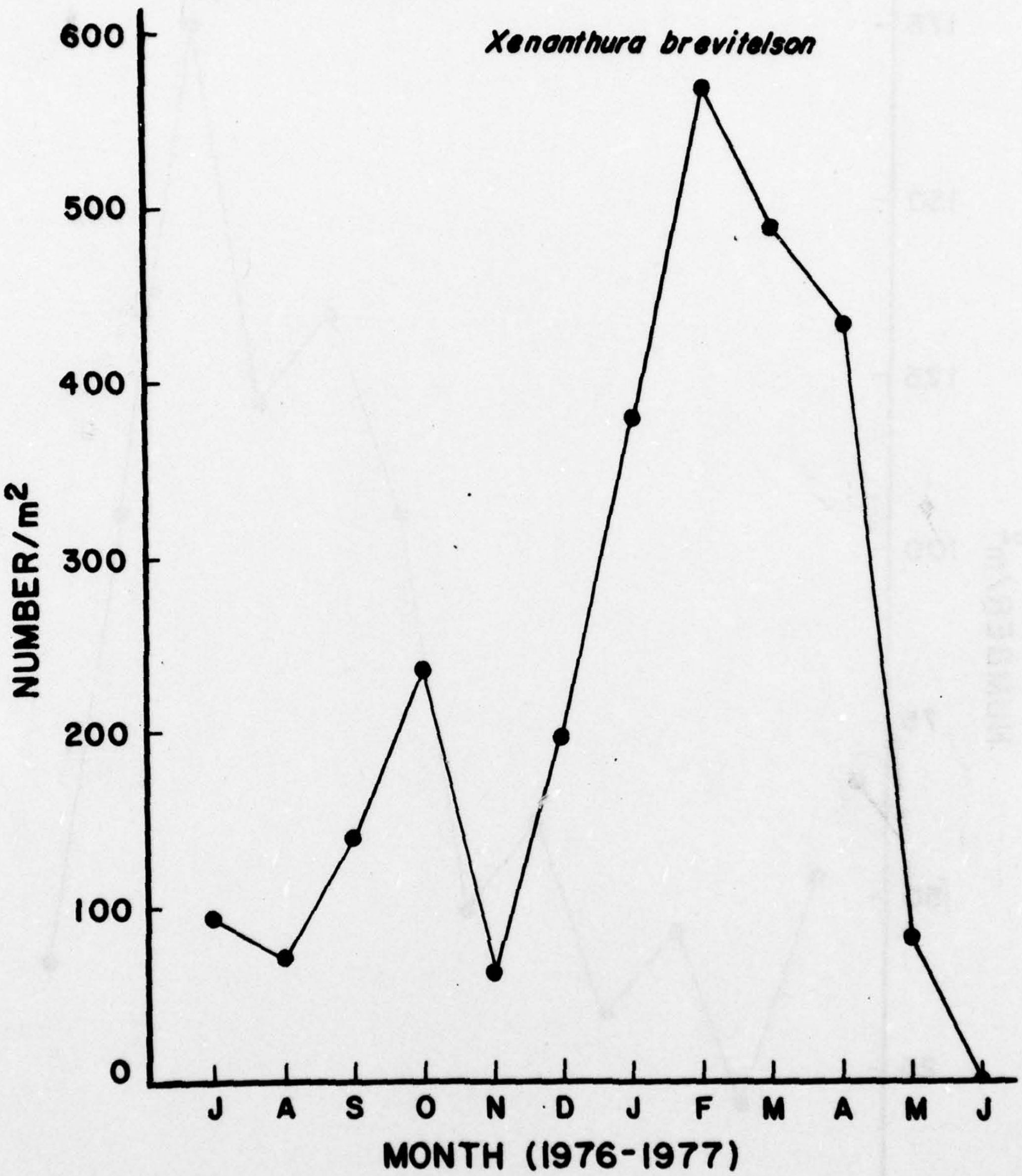

Figure 80. Mean monthly abundance of *Xenanthura brevitelson* at the Bolivar Peninsula site

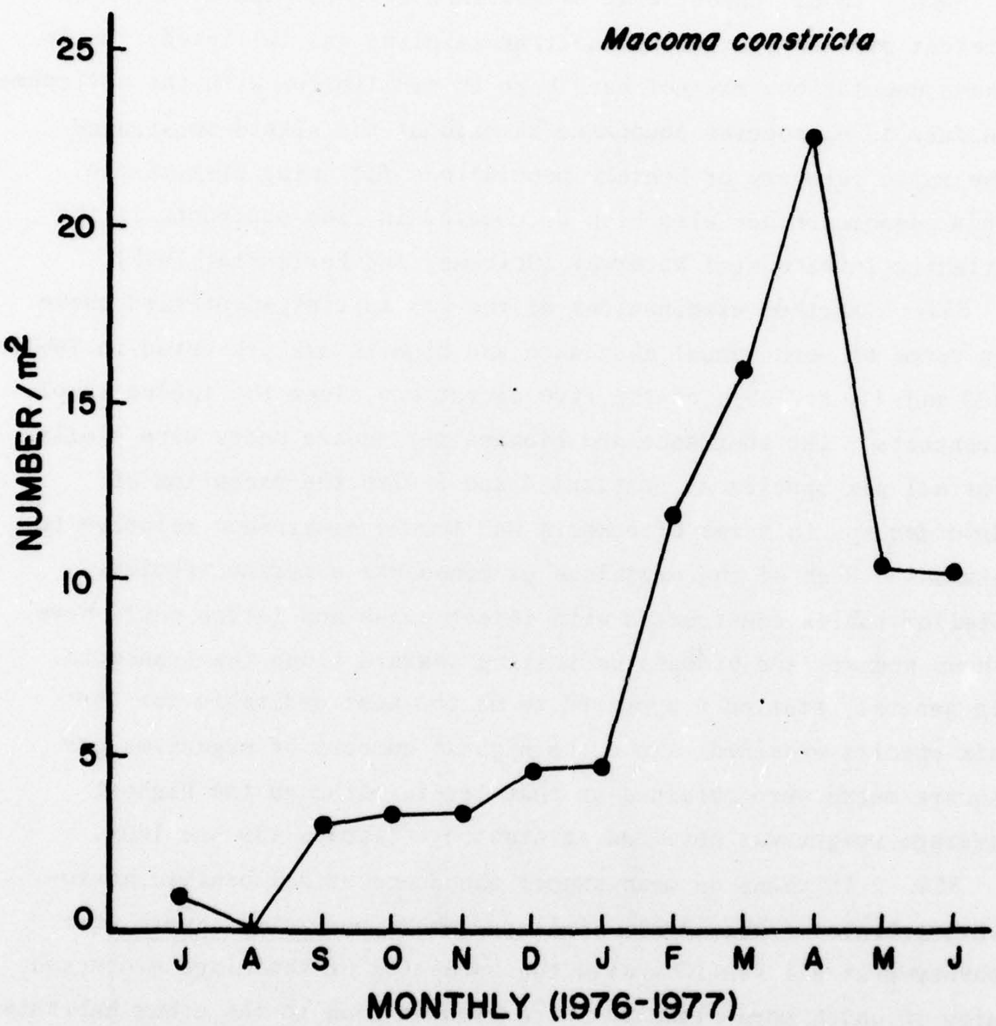

Figure 81. Mean monthly abundance of *Macoma constricta* at the Bolivar Peninsula site

species with the exception of *Parandalia fauveli* (Fig 77), which was most abundant during June 1977 after a fairly steady increase in abundance throughout the study period.

552. In all cases, well established benthic populations were present at each station by the time sampling was initiated. While these populations may not have been in equilibrium with the environment in July 1976, species abundance throughout the site demonstrated the rapid recovery of benthic populations following disturbance. This phenomenon has also been documented in fine sediments in the Atlantic Intracoastal Waterway (Stickney and Perlmutter 1975).

553. Further examinations of the six species identified above in terms of mean annual abundance and biomass are presented in Tables 139 and 140 for each of the five elevations along the twelve sample transects. The abundance and biomass per square metre were similar for all six species at stations 4 and 5 with the exception of *Aricidea* sp. in terms of numbers and *Macoma constricta* relative to biomass. Each of the organisms examined was a marine species. Similar tables constructed with insect pupae and larvae would have shown numbers and biomass decreasing seaward along the transects. In general, station 4 appeared to be the most desirable for the six species examined, since the highest numbers of organisms per square metre were obtained at that level, although the highest average weight was obtained at station 5 (Tables 139 and 140).

554. In terms of mean annual abundance of all benthic macroinvertebrates (Table 137), similar numbers per metre square were observed at all stations with the exception of the mixed protected area in which more organisms were present than in the other habitats. The significance of the higher numbers of animals per square metre in the mixed protected area will have to be evaluated further during future studies. From the standpoint of mean annual diversity, the reference area was the highest (Table 137), while the other habitats were similar to one another. The higher diversity in the reference area may reflect the fact that the sediments in the study

site were reworked and the benthos largely destroyed prior to sampling. The generally higher mean annual diversities along transects Z and J can be seen in Appendix A', Table A18.

555. Annual changes in volatile solids percentage in the sediments over the study period are presented in Figure 82. Volatile solids were highest during July 1976 and generally declined thereafter on the average until May 1977, after which the level increased to nearly that of the first sampling period. Even though a consistent temporal pattern was established, the variation between the maximum and minimum levels of volatile solids amounted to only 0.4 percent (Figure 82). There was no tendency toward increasing volatile solids with development of the marsh through June 1977 (although preliminary data obtained subsequently indicate that this may change in the future). The mean annual volatile solids levels at each sampling station are presented in Appendix A', Table A19.

556. Volatile solids levels associated with the various habitats at the Bolivar Peninsula site are presented in Tables 141 and 142. These data are also summarized in Table 138. While some variation was observed among sampling habitats, the range was only from 0.8 to 1.2 percent. The contribution of planted marsh grasses to the detritus within the sampling area during the winter of 1976-77 was extremely limited because of the limited extent of marsh development during the first growing season of the study. The winter of 1977-78 may reveal increases in volatile solids as the lush grass presently existing on the site enters the detritus food web.

557. Sediment grain-size data obtained along the various transects are presented in Tables 141 and 142 and are summarized in Table 138. Particles of sand larger than 250 μm exceeded 2 percent of the total only witin the mixed protected area on the average (Table 138). The lowest percentage of this size fraction was obtained within the reference area (0.97 percent). Sand of less than 250 μm exceeded 80 percent of the sediment material along all transects with the

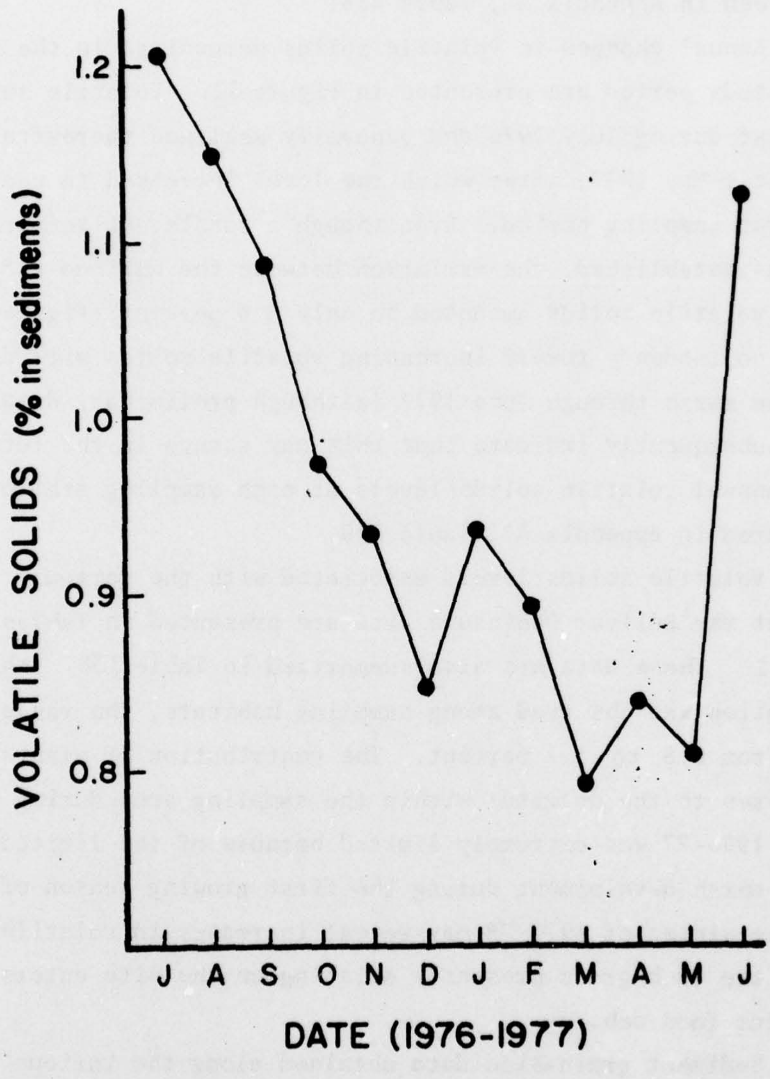

Figure 82. Mean monthly volatile solids percentage at the Bolivar Peninsula site

exception of the reference area transects where the level was slightly less than 80 percent. Particles of between 63 and 250 μm contributed more than 90 percent in both the bare and mixed unprotected areas (Table 138).

558. The percentages of silts and clays ranged from 2.77 to 9.70 percent among the sampling areas with the highest percentage of silt occurring in the reference area and the highest percentage of clay in the mixed protected area. Differences across the site were not great. Visually, increased levels of fine sediments appeared to be associated with transect Z (especially along the upper elevations) and along transects X, C, and D on the west end of the site within the protected zone. While some evidence of this was obtained from the sediment analyses from the upper stations, there was actually little overall change when the whole transects were considered. While a good deal of soft mud appeared to be present in the regions indicated, this appeared to be composed primarily of water; thus, when a 20-cm core was obtained and the material dried, the soft portion contributed only a minor amount to the total sample.

Water quality

559. Monthly mean water quality data are presented in Tables 143 to 145. During most months there was good agreement among the samples across the site during day and night. Good agreement between day and night sampling within months also occurred, with the major exception being diurnal temperature variations in October and November 1976 as well as April and June 1977 and diurnal dissolved oxygen variations during several months. These patterns are to be expected. Water temperature is dependent, in part, on air temperature, while dissolved oxygen concentration is related, in part, to photosynthetic and respiratory influences. Average values (pooled for day and night) for each water quality parameter with the exception of carbonate and bicarbonate alkalinities are presented

graphically in Fig 83.

560. Seasonal patterns in temperature and dissolved oxygen were typical for Gulf of Mexico estuaries, and both were related to climatic changes to a great extent. Cold water, present in the late fall and winter, can carry more dissolved oxygen than warm water (Weiss 1970) as is demonstrated in Table 143.

561. Salinity varied slightly in a diurnal manner during some months, but was, on the whole, relatively consistent in day and night samples within months across the site (Table 143). Salinities in excess of 20 parts per thousand were recorded during August and September 1976 and April and June 1977. Annual mean salinities cannot be presumed from these data since they were taken during only one 24-hour period each month and may not be representative.

562. Ammonia levels throughout the sampling period were consistently less than 1.0 part per million, although values in excess of 0.5 part per million may in some cases represent the inclusion of contaminated samples (Table 143). In most cases the standard deviations of the mean were high when the mean value was near or in excess of 0.5 part per million, although there was no apparent pattern in high ammonia values relative to specific sample locations. Ammonia pulses were noted during July 1976 and from December 1976 through February 1977 (Fig 83). Fertilizer applications were made in June and September 1976 and in January and April 1977. The high level of ammonia in July correlates with the June fertilization, but the pulse in ammonia began in the winter in advance of fertilization. The winter pulse may be related to the death and decay of vegetation within the study site or within the whole bay system during the winter or it may be an indication of increased benthic metabolism. No ammonia pulse was observed in conjunction with the fertilizer application of April 1977. Because of the relatively low application rates of fertilizer and the fact that the volume of water passing over the site was very large, it is relatively unlikely that increases in ammonia can be related to fertilizer

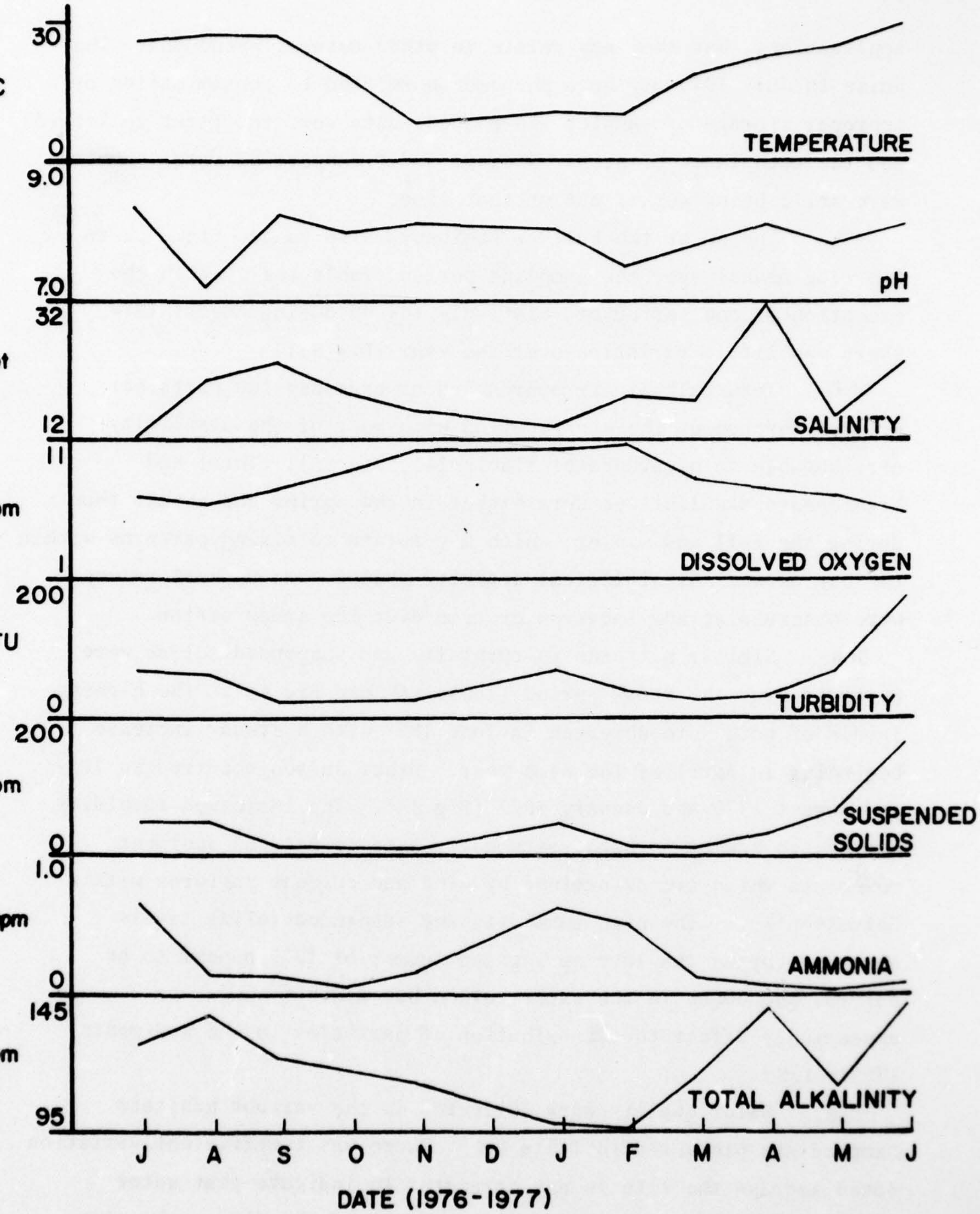

Figure 83. Monthly temperature, pH, salinity, dissolved oxygen, turbidity, suspended solids, ammonia and total alkalinity at the Bolivar Peninsula site

applications, but they may relate to other natural phenomena. The pulse in July 1976 may be a phenomenon related to contamination or improper storage of samples since these data were the first collected and the techniques of proper storage and transport of water samples were still being worked out at that time.

563. The pH at the Bolivar Peninsula site ranged from 7.2 to 8.5 (log means) over the sampling period (Table 144). With the exception of one period of relatively low pH during August 1976, there was little variation over the year (Fig 83).

564. Total alkalinity approached or exceeded 100 parts per million throughout the study period with most of the alkalinity attributable to bicarbonates (Table 144, Fig 83). Total and bicarbonate alkalinities were higher in the spring and summer than during the fall and winter, which may relate to mixing patterns within the bay as well as biological activity cycles. No unusual values were observed at any location or time over the study period.

565. Similar patterns in turbidity and suspended solids were observed over the study period (Table 145 and Fig 83). The highest levels of both were observed in June 1977 with a steady increase beginning in April of the same year. Other pulses occurred in July and August 1976 and January 1977 (Fig 83). The increased turbidity during the summer in both years may relate to natural sediment movements which are determined by wind and current patterns within Galveston Bay. The high turbidity and suspended solids levels observed during the late spring and summer of 1977 appear to be natural phenomena in the water column but did not appear to appreciably affect the distribution of particles in the sediments (Table 138).

566. Water quality data collected in the various habitats sampled are presented in Table 146. There was insufficient variation noted accross the site in any parameter to indicate that water quality was being affected by the presence of the dike or by plant

growth during the study period. The data in Table 146 represent pooled values in cases where two or more transects within the same type of habitat were sampled. Values for water quality obtained at station 5 on the individual transects are presented in Appendix A', Table A20.

Photographs

567. Many of the photographs taken during July 1977 showed that the sediments had been tilled for planting and fertilization (Fig 84); thus, animal activity could not be ascertained within the affected stations. By August 1976, all stations had been inundated and the sediments redistributed so that observations of animal activity could be made at all stations with the exception of any which may have been submerged at low tide. Tidal inundation throughout the daylight of several sampling trips hampered photography, especially at the levels of stations 4 and 5 along the various transects and within block III in the marsh area during the spring and summer. Photography was also hampered by the high level of plant coverage which occurred during the latter months of the study (Fig 85).

568. Both the east and west reference areas remained plant-free throughout the study period (Fig 86), while the unplanted plots within the fence were invaded during latter portions of the study with *Salicornia* sp. and *Scirpus americanus* (Fig 87). Examples of plots newly planted in *Spartina alterniflora* and photographed in July 1976 and after nine months growth (April 1977) are presented in Fig 88 and 89, respectively. Similarly, Fig 90 and 91 show *S. patens* shortly after planting in July 1976 and in April 1977, respectively.

569. With the exception of June 1977, 20 or more photographs were obtained monthly within block I (Table 147). Camera malfunction led to a loss of many of the photographs actually thought to be taken during June. Most of the stations in block II were exposed at low tide allowing the photographers to obtain in excess of 20 pictures during each month with the exception of May and June 1977.

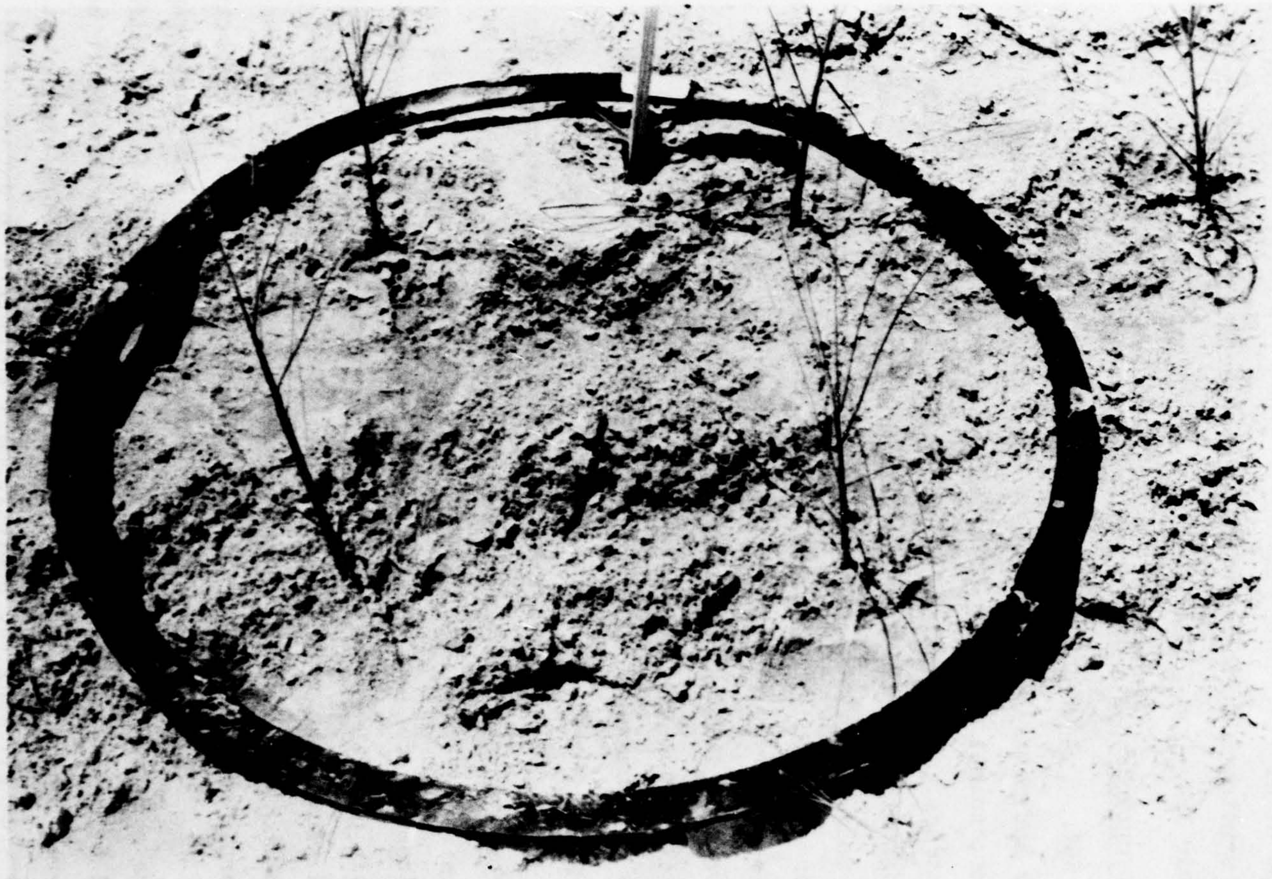

Figure 84. Block I-1, July 1976 showing tilled sediments

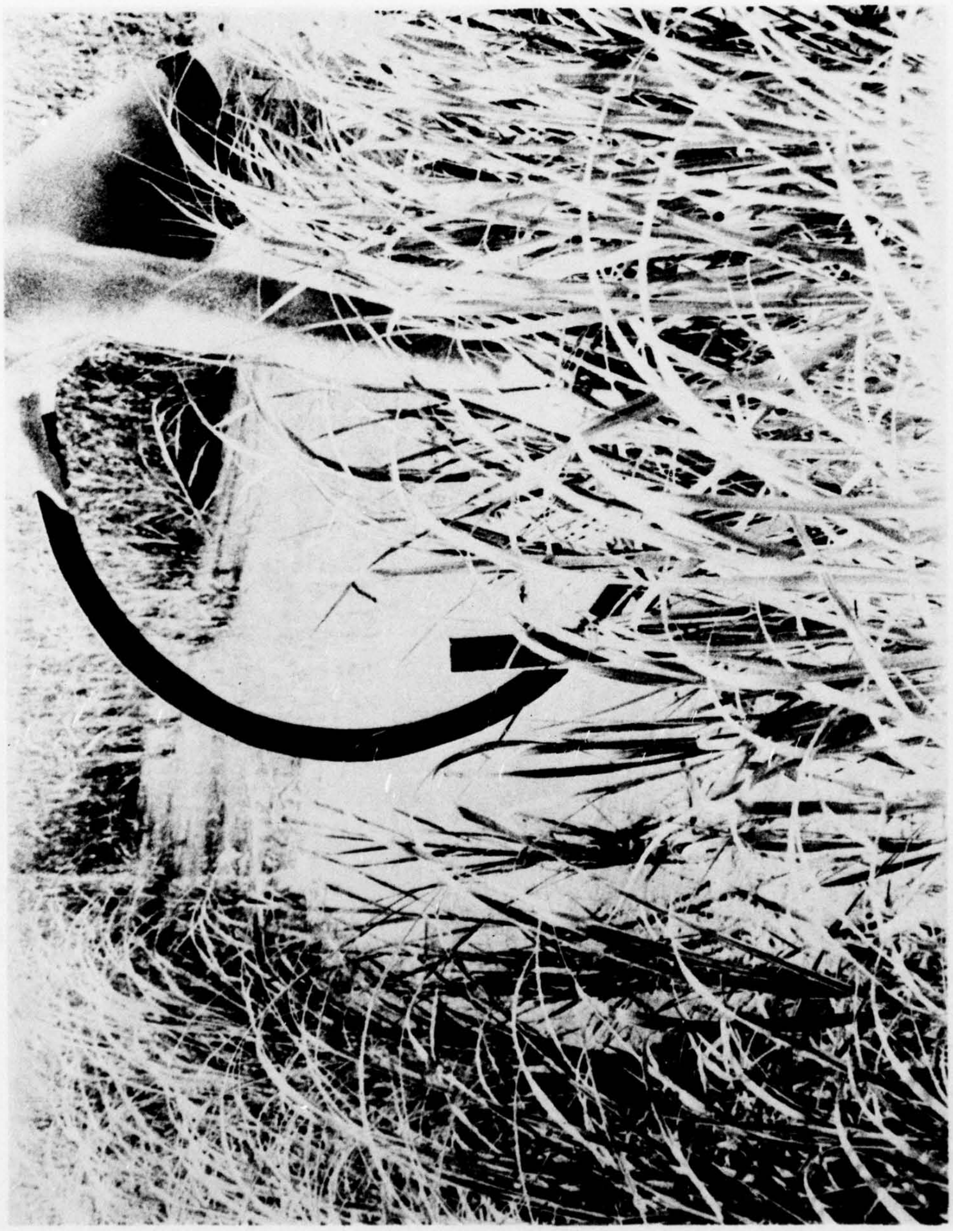

Figure 85. Station C3 in June 1977 demonstrating *Spartina alterniflora* growth

Figure 86. Station J3 in January 1977 demonstrating lack of vegetation in the reference areas

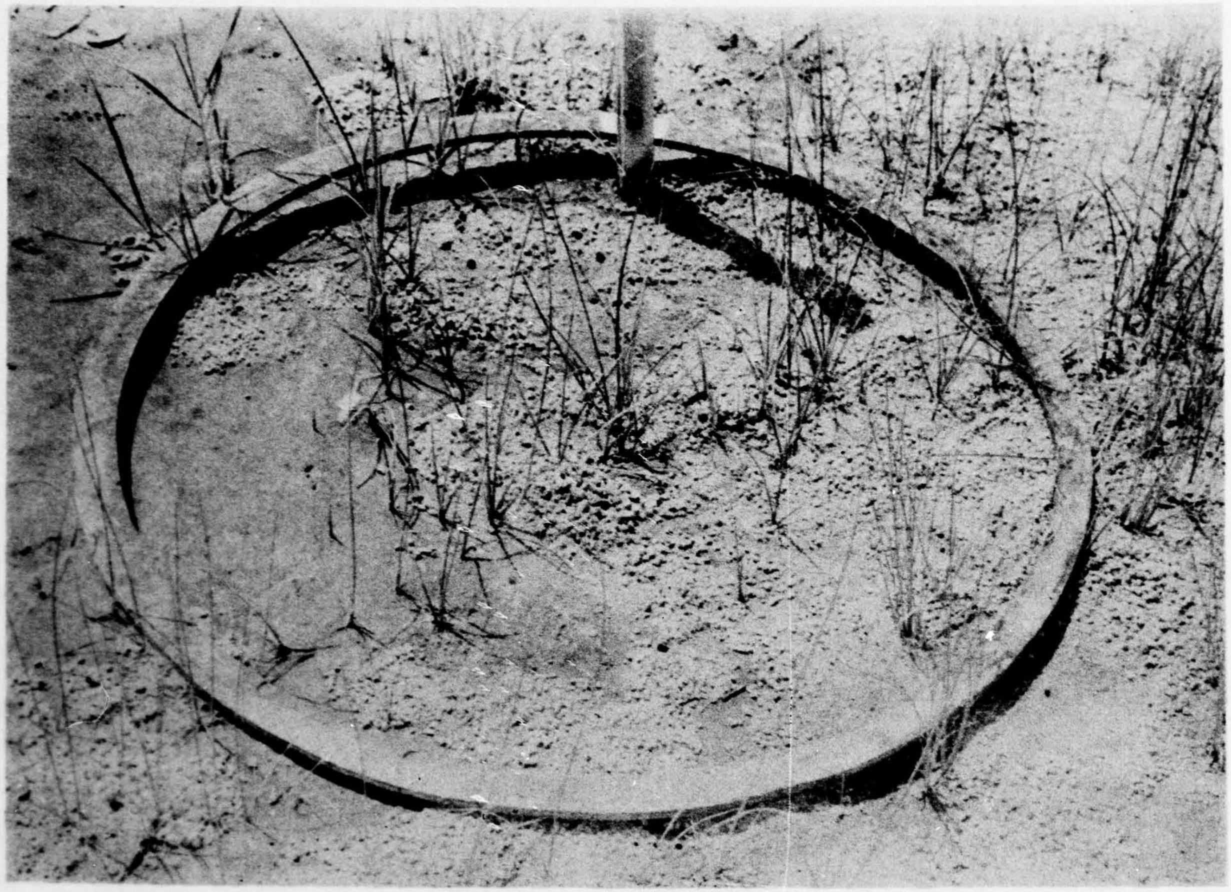

Figure 87. Station XI during May 1977 demonstrating growth of *Scirpus americanus*

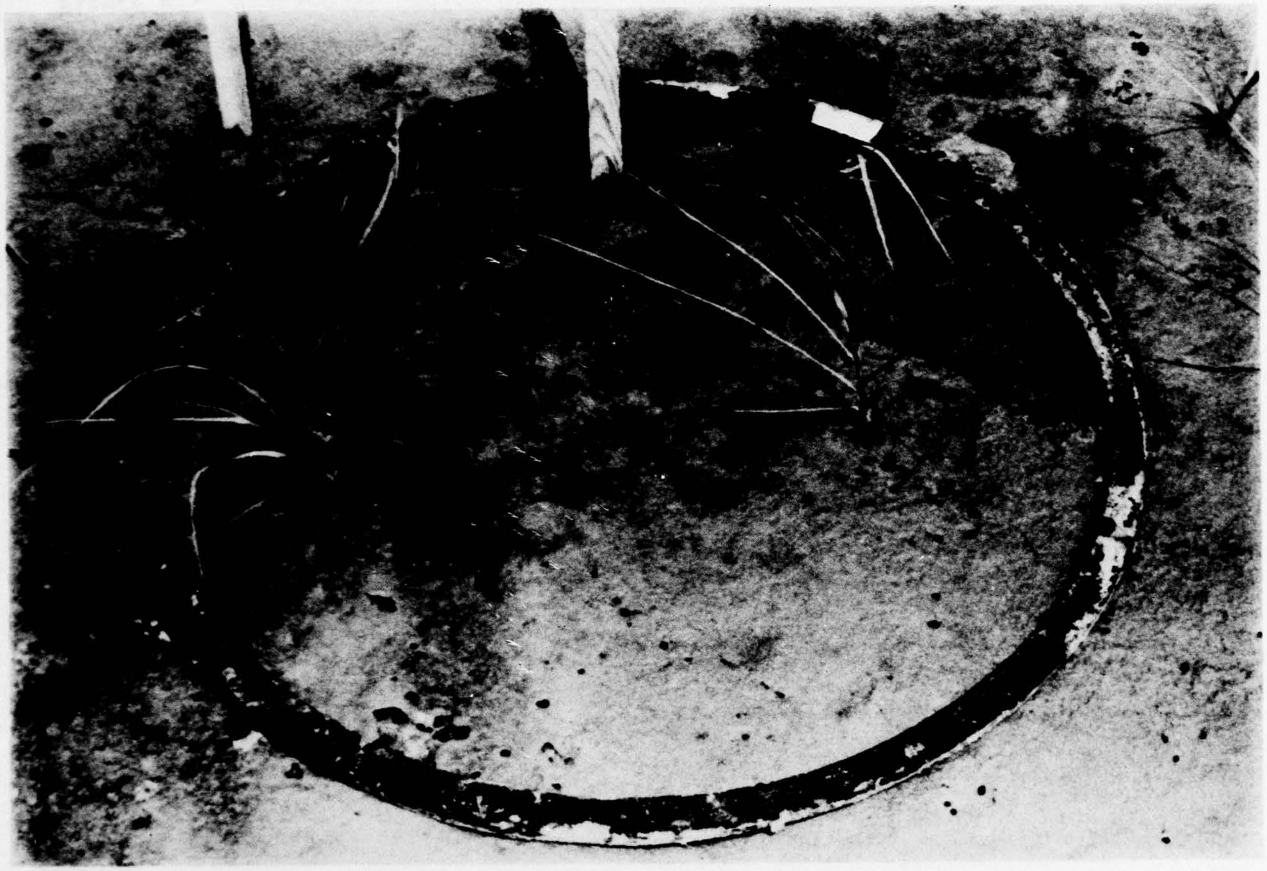

Figure 88. Station II-25 in August 1976 shortly after *Spartina alterniflora* planting

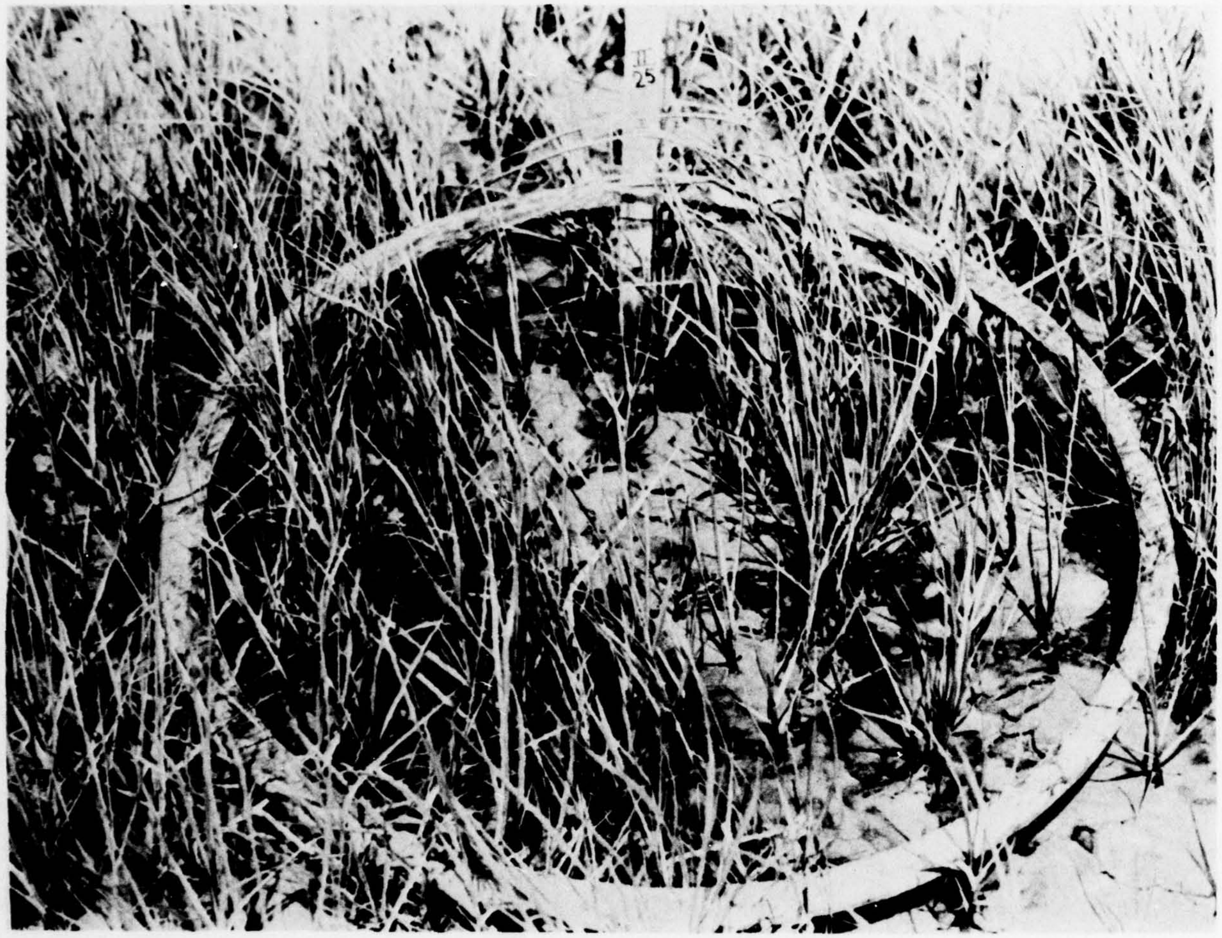

Figure 89. Station II-25 in April 1977 demonstrating growth of *Spartina alterniflora* during the study period

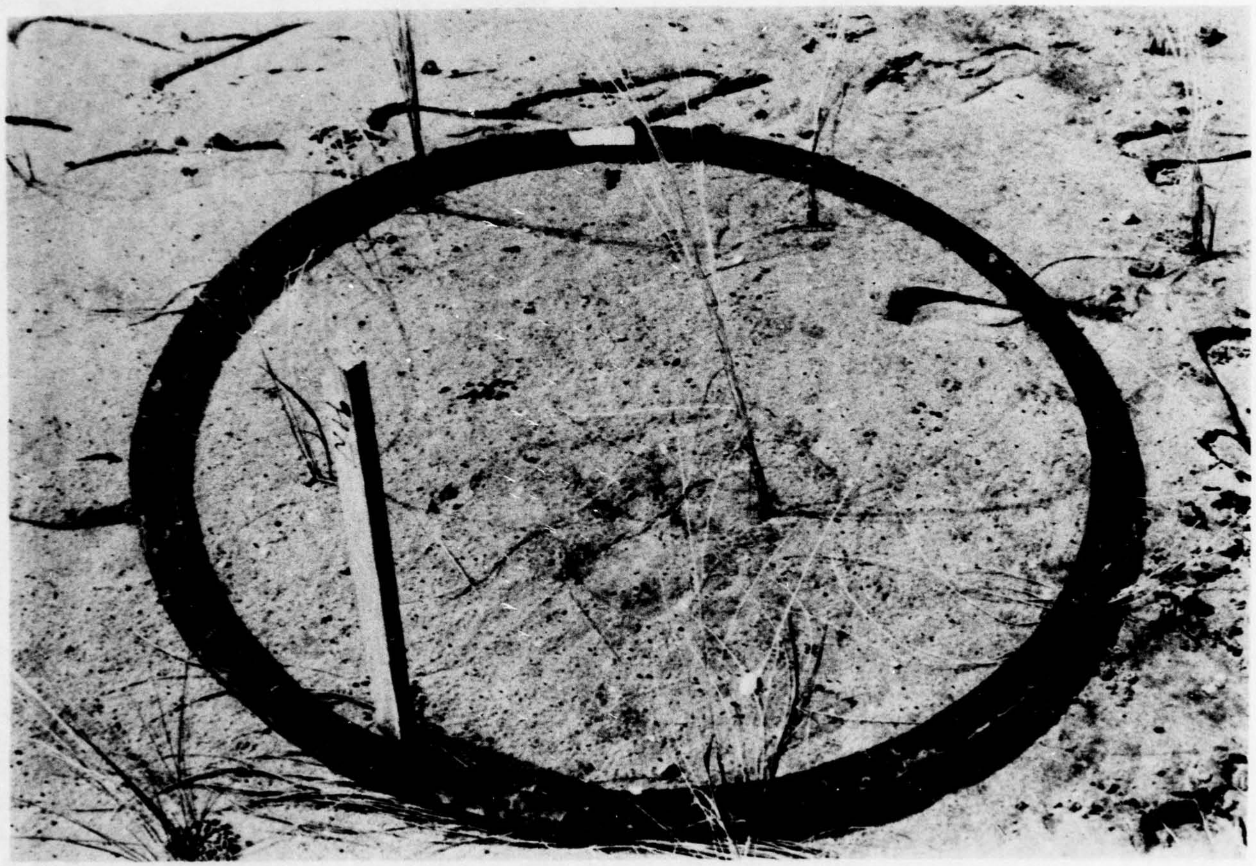

Figure 90. Station I-21 in September 1976 after *Spartina patens* plant

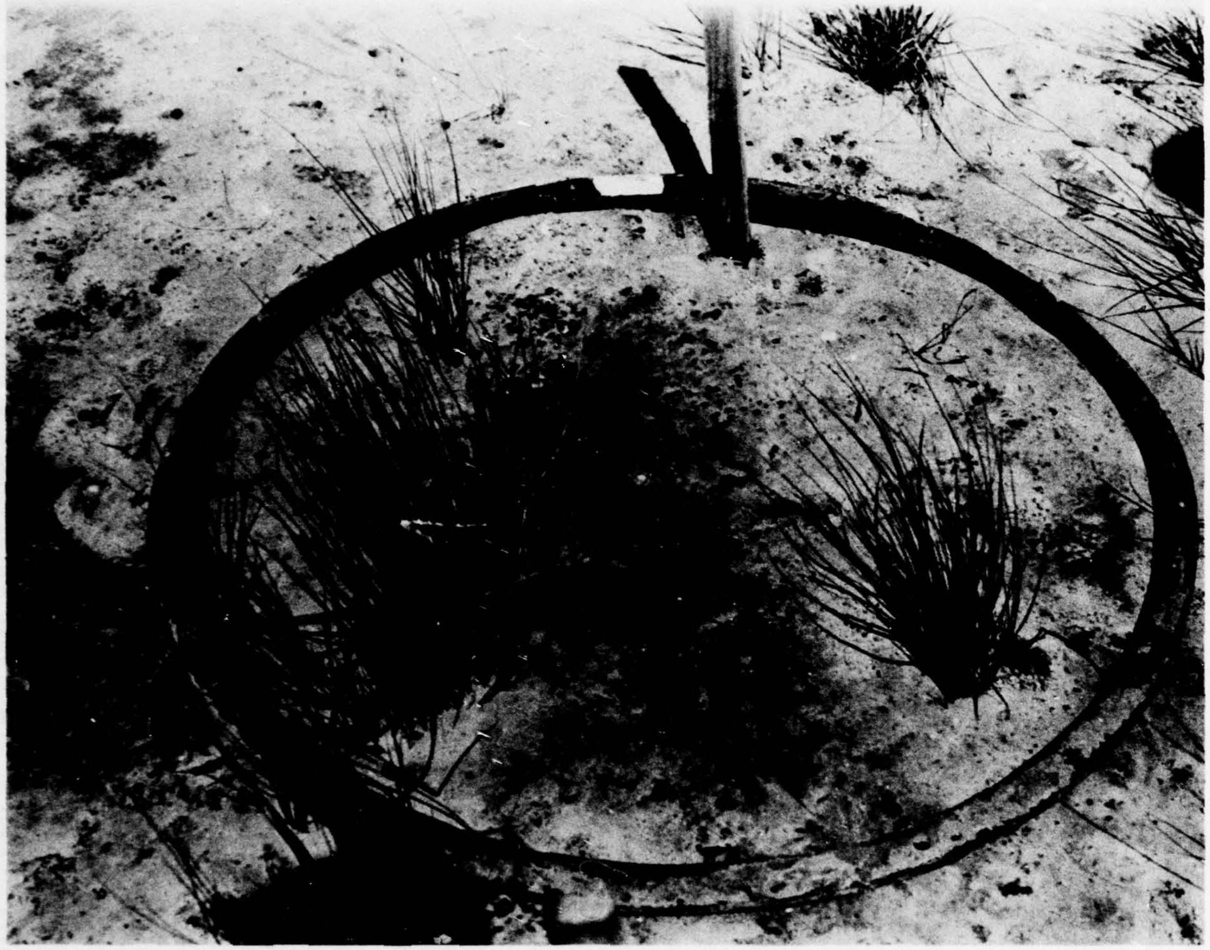

Figure 91. Station I-21 in April 1977 demonstrating growth of *Spartina patens* during the study

Block III was inundated with water during April through June 1977 at the time of sampling, so no photographs could be obtained. Nearly every station was photographed during the first 9 months of the study.

570. The average numbers of photographs obtained in blocks I, II, and III were 26.5, 23.9, and 21.8, respectively, over the sampling period. Based on 12 months of sampling, the average numbers of holes observed per square metre of bottom in the three blocks were 1.5 in block I, 3.1 in block II, and 1.7 in block III. Ignoring the three months in block III for which no photographs were taken because of water inundation, the mean number of holes per square metre was 2.3, intermediate between the number observed in blocks I and II. The activity of polychaetes, mollusks, fiddler crabs, and other organisms responsible for the observed holes seemed to be somewhat greater in the spring than in the fall and winter, but there was some activity during each month of the year. With the exception of the fact that no activity could be observed in block I during July becasuse the area was tilled, holes were present in all blocks each month, often at levels higher than 50 percent except during the winter.

571. Some raccoon tracks were observed in blocks I and II during several months, although no raccoon sign was observed in the photographs taken in block III. Bird activity was somewhat greater in block III, with less activity observed in block II and none in block I. Birds were observed pecking at the sediments, presumably to remove insects, crustaceans, and polychaetes which were present. This activity was concentrated in the lower two thirds of the intertidal zone indicating that the preferred foods were found in those areas. Insects were restricted largely to the upper intertidal zone; thus, the birds appear to have been seeking other types of food (Tables 147 to 149).

572. Fiddler crabs were active on the upper two thirds of the intertidal zone. Fiddler crab activity was assumed from the presence of piles of sand with or without apparent holes in association

with the sand piles. Fiddler crab activity may have been as great in block III but was masked because the sand piles formed during low tide would be eliminated when water covered the site at high tide. Block III was inundated nearly every day, while the upper two thirds of the intertidal zone might remain above the high water line for several consecutive days, especially during the winter. The fact that block II is intermediate in terms of inundation between blocks I and III was evident in terms of the extent of apparent fiddler crab activity. During some sampling trips the evidence of such activity may have been destroyed by tidal action within a few hours before the photographs were taken (Tables 147 to 149).

573. Hermit crabs (predominantly *Clibanarias vittata)* were often stranded in the intertidal zone at low tide and could often be seen by the hundreds during that portion of the tidal cycle several months of the year. Their presence in the photographs within the marsh area was documented only in the lower third of the intertidal zone (block III), where they were present during every month pictures were obtained except during the winter (November through February). Activity was noted by either the presence of the crab itself within a mollusk shell or by the presence of the distinctive tracks left by these animals.

574. The marine polychaete *Diopatra cuprea* was commonly observed during February 1977 in block III. This animal was generally restricted to the lower intertidal zone (see Tables 147 to 149) and was most evident during the winter. *D. cuprea* were easily recognized by their distinctive tube which protruded 1 cm or more from the surface of the sediments.

578. In summary, all three marsh blocks were extensively utilized by a variety of animals during low tide as evidenced by terrestrial animal tracks. The marine fauna varied to some extent from the upper to lower intertidal area with hermit crabs and *Diopatra cuprea* being restricted to the lower portions of the site and fiddler crabs being most obvious on the upper intertidal

reaches. Each block contained stations each month which showed no activity, although the percentage of stations showing no activity was somewhat lower on the average in block III than in the other two blocks.

579. The average number of holes present along the various transects varied to some extent (Tables 150 to 161). The reference areas average 11 holes monthly, the unprotected bare areas 3.5, the unprotected mixed areas 1.5, and protected bare areas 2.5, the protected mixed planting areas 4.5, and the marsh areas 2.8 holes monthly. Thus, the reference area had at least twice as many holes on the average each month as the plots within the fence. The difference between the reference transects and those within the plots does not seem to relate to the presence of either plants or the dike since all of the transects within the fence were similar in terms of average numbers of holes per transect monthly. It is possible that the presence of visible holes at the sediment surface, like the abundance of benthic infaunal organisms, is related to the disturbance which occurred when the site was graded and prepared for planting and that with time the marsh area will come into equilibrium with the reference area. Such an equilibrium situation may only be demonstrable when the reference and bare areas are compared since the increasing plant density makes observation for animal signs in the monospecific and mixed planting areas more and more difficult each month.

580. Raccoon activity was absent from the photographic stations within all 12 transects throughout the year (Tables 150 to 161) and bird sign was relatively rare except along transect G. Visual observation of bird use at the Bolivar Peninsula site indicated a preference for the eastern end, although this could have been associated with the relatively lower level of human activity within that area. If that were the case, bird utilization along transects F, H, I, and J should also have been somewhat higher than along the

western transects. Fiddler and hermit crab activity was fairly evenly spread throughout the study site, with the exception that there were no fiddler crab signs observed along transect J. Because of the greater extent of tidal inundation on transects Z and J as compared with the other transects, the mounds of sand created by digging fiddler crabs may have been obliterated leaving only the holes which could not be identified with any degree of precision.

581. *Diopatra cuprea* were most frequently observed along transects H, I, Y, Z, and J, and normally at the seaward end of those transects. The *D. cuprea* tubes appeared to be restricted to rather firm sandy areas and were largely present during the cold months, while absent in the summer.

582. A total absence of animal signs on the photographs within any given month was more common within the fence than in the reference areas. Only during December was inactivity found in any photograph from transect J, although some photographs which failed to demonstrate animal activity were taken during July, October, December, February, and March along transect Z. In the cases of the other 10 transects, the list of months during which inactivity occurred at one or more stations would be longer than that of the opposite condition. Thus, there are several indications that animal activity was greater in the reference areas than along transects within the fence. The reasons appear to be related to the disturbance of the sediments within the fence and not directly associated with the presence or absence of plants thus far, although this situation may change in the future. Also possibly tending to mask trends which might otherwise appear in the data is the fact that the most seaward stations were often under water during the time photographs were taken. This fact makes analysis by elevation difficult.

Conclusions

583. Utilization of the study site by nekton, including fishes and macroinvertebrates, was heavy throughout the study period in all areas sampled. Because of the relatively small size of the study area, it was not possible to demonstrate habitat preferences which may have existed. Sampling directly within the areas of developing marshland was prohibited because collecting gear designed for such areas is not presently available. Some type of passive sampling gear should be utilized throughout the site in any event since the presence of humans during active sampling with beach seines and push nets undoubtedly contributed to the relatively lower abundance of highly motile species as compared with the more sedentary organisms. Large animals were also able to escape the active sampling devices and failed to enter hoop nets, so little indication of their numbers or importance on the study site was obtained.

584. Food habit studies of six species of fishes indicated the need for study of the zooplankton and meiobenthos communities, since these were utilized to a great extent by all of the juvenile fishes studied with the exception of *Paralichthys lethostigma*. Benthic and meiobenthic organisms dominated the food habits of four of the six species examined, demonstrating the importance of these benthic communities in the maintenance of the fish populations inhabiting Galveston Bay.

585. The benthos community was well established throughout the study, with little variation across the study site within elevation. Because of the patterns observed, it seems unlikely that fish distribution would have been affected by the availability of food organisms larger than 0.5 μm, although the relationship between the availability of meiobenthic forms and fish distribution remains to be determined.

586. The distribution of benthic organisms varied considerably with elevation within transects. The observed patterns were in line with those which would be expected relative to diurnal and seasonal

tide fluctuations. The data collected cover only one year and may not be representative. The recovery of the benthic community following disturbance prior to initiation of the study was apparent when samples collected during July 1976 were compared with those obtained during June 1977. Because the marshland was not completely established prior to the conclusion of the study, future correlations between the presence of the grasses and alterations in the benthic community cannot be ruled out.

587. Volatile solids varied only to a limited extent throughout the study period, and no trends with respect to plant colonization or elevation were apparent. As indicated in Part III of this report, some variation in organic matter percentage occurred at the surface of the sediments. Well-mixed cores of 20 cm depth obtained for volatile solids obscured these changes.

588. Grain-size analyses revealed little change throughout the study period. Particles in the size range 63 to 250 μm dominated the sediments (often contributing 90 percent of the material collected). This is probably indicative of the origin of the sediments, i.e., dredged material. There was little change in the general pattern of grain-size distribution through June 1977. The general consistency of the benthic community within elevation across the site may have been attributable, in part, to the lack of variation in sedimentary structure.

589. Water quality fluctuated diurnally and seasonally within the limits which can be expected in northern Gulf of Mexico estuaries. The consistency within the data across the site at the same time of day on any given date was expected because of the limited area covered by the sampling program and because most of the parameters measured are conservative in nature. Some aberrant patterns in ammonia were uncovered, but these may have been artifacts associated with sampling and storage of the water prior to analysis. No differences in the general pattern of ammonia appeared to be associated with dates of fertilizer treatment.

590. Animal populations and sedimentary structure require time

to respond to environmental modification associated with the introduction of plants into a denuded area. The time frame of the present study was insufficient to allow these changes to be documented. Continued sampling of the study site from July through December 1977 has been undertaken, and while these samples have not been worked up in total, preliminary indications from volatile solids and sediment grain-size samples indicate that changes in the sediment structure were accelerated after the period considered in this report. In order to document these changes and assess their potential impact on commercial and sport fisheries, continued monitoring of the study site is strongly recommended.

PART VIII: SUMMARY

591. The feasibility of developing marshland and upland plant communities on dredged material was studied on Bolivar Peninsula, Galveston Bay, Texas. Selected plant species were planted, and their response to fertilizer rates evaluated with respect to growth, reproduction, and attraction to animals. Plants were placed in marshland, intertidal, and upland plots with respect to growth requirements. A total of 270 marshland and 108 upland experimental plots were developed in 1976. Four hundred and fifty smaller marshland plots were established in 1977. Marshland and intertidal plots were planted to *Spartina alterniflora* and *Spartina patens*. The upland was planted to trees, shrubs, and grasses. Trees planted were *Tamarix gallica*, *Pinus clausa*, and *Quercus virginiana*. Shrubs were *Prunus* sp., *Rhus copallina*, *Croton punctatus*, and *Myrica cerifera*. Grasses were *Andropogon perangustatus*, *Cynodon dactylon*, and *Panicum amarum*.

592. Seeds of *Spartina alterniflora* and *S. patens* were collected during the fall of 1976. The percent glumes filled of *S. patens* ranged from 3 to 36 percent and for *S. alterniflora* between 8 and 13 percent. Storage procedures (dry at ambient and dry at $4^{o}C$) did not affect percent germination of *S. patens* seeds (73 to 76.5 percent). However, indications were that with prolonged storage, cold storage was desirable. *S. alterniflora* seeds were stored wet in saline solution at $6^{o}C$. Germination varied from 60 to 70 percent in tests from mid-December to late February. Approximately 5 months after storage germination declined to less than 20 percent.

593. Sprigged plots of *Spartina alterniflora* and *S. patens* each received 5 fertilizer treatments, F_0 (no fertilizer), F_1 (low rate - single application of N, P, and K), F_2 (high rate - single application of N, P, and K), F_3 (split application of F_1), and F_4 (split application of F_2). Evaluations were made four times at 2-week intervals beginning 22 August 1976. Evaluation 5 was made at the end of the growing season

for the original 270 marshland plots. During 1977 evaluations of the original 270 marshland plots were made 24 February, 27 June and 11-14 October.

594. Survival was less than 15 percent for all *Spartina patens* treatments compared to over 37 percent for *S. alterniflora* by 9 November 1976. Percent survival had declined at each evaluation for each species, regardless of fertilizer treatment. Death of all *S. patens* plants had occurred in tier 1 by 30 November 1976. Survival also was low in tier 2. *S. alterniflora* survival was generally 50 percent or better in the lower 2 tiers, but varied from 20.4 percent to 44.4 percent by fertilizer treatment in tier 3. Initially *S. alterniflora* survival was better with no fertilizer or when the total fertilizer was by split application rather than a single application. In contrast, the lowest survival for *S. patens* plots occurred at the F_4 rate (split application). However, this may have been an elevation response rather than a fertilizer response.

595. New growth for *Spartina patens* after transplanting did not occur until September, a month after transplanting. Lower fertilizer rates appeared to enhance new growth. *S. patens* showed little increase in density until the November 1976 evaluation. *S. alterniflora* increased in density at each 2 week evaluation and in subsequent evaluations. In November 1976 stem density for *S. alterniflora* ranged from 11.7 to 16.0 stems per quadrat. For *S. patens* density was 1.4 to 23.9 stems per quadrat. In general, for *S. patens*, F_0, F_1, F_2, and F_3 treatments resulted in higher plant density than F_4. Except for lower numbers in the F_0 treatment, density for *S. alterniflora* was similar at all fertilizer treatments.

596. At the November 1976 evaluation, stems per surviving plant were generally similar for both species. Plant height, plants with tillers, and number of tillers were higher for *Spartina alterniflora* than *S. patens*. Foliage cover was less than 1 percent for both species at all evaluations. Animal damage was generally low. Aboveground biomass exceeded belowground biomass for both species. The

root:shoot ratio ranged from 0.4 to 0.7. Limited seed production occurred in *S. alterniflora* and none in *S. patens*. Invading plants occurred only at the highest elevations.

597. No seedling germination and survival was recorded below 1.2 ft in elevation. The lowest survival was approximately 1.4 ft above msl, where survival was recorded in six plots. By October 1977, density and biomass in some seeded plots were greater than that of any July sprigged plots at the November 1976 evaluation.

598. By October 1977, the density and height of *Spartina alterniflora* in July 1976 sprigged plots was much greater than *S. patens*. Density for all tiers combined varied from 411 to 576 stems per quadrat for *S. alterniflora* and from 4.1 to 178.5 stems per quadrat for *S. patens*. Over 500 stems per quadrat were recorded in all tier 1 and 2 fertilizer treatments for *S. alterniflora*, except the F_1 treatment in tier 2. Height varied from 108 to 130 cm in *S. alterniflora* and reached a maximum of 72.2 cm in *S. patens*. Tallest plants of *S. alterniflora* occurred in tier 1 and shortest in tier 3. Foliage cover range was from 10 to 25 percent in *S. alterniflora* and only 10 percent in *S. patens*. Root:shoot ratios were greater than 1 in both species. The only invading species recorded in the lower two tiers were *S. alterniflora* seedlings and tillers from already established plots. *S. alterniflora* also was the most numerous invading species in the upper tier.

599. In one-quarter-size plots planted in February and evaluated 2 months after planting, greatest survival occurred at the lowest and highest elevations. Survival declined in successive zones approaching the middle, 1.25-to 1.49-ft elevation zone. Density also was lowest in the middle elevational zones. Height was greatest in the lowest elevational zones. Fertilizer treatments did not produce differences in survival, density, or stems per plant.

600. In one-quarter-size plots planted from 11 May to 1 June 1977 and evaluated 2 months after planting, percent survival, density, stems per surviving plant, percent plants with tillers, tillers

per plant, and number of tillers were greatest in the 1.00 to 1.24 ft elevational zone. Height was greatest in the lowest elevational zone. Survival and density were slightly greater in F_4 plots. The lowest number of tillers occurred in F_0 plots.

601. Evaluations were made two months after each planting date and were compared. Survival, density, and height were all greater in the May planting. Inundation at the elevation of 1.21 ft was measured for a two-month period after each planting date. Percent inundation was 18.5 and 55.0 in the February and May plantings, respectively. Differences in survival at each elevation of the marshland were related to time of tidal inundation.

602. By 11-15 November 1977, density of February planted plots was over 1100 stems per plot in elevations below 1.24 ft. In May planted plots, density was greater than 1000 stems only in the 1.00- to 1.24-ft elevational zone. Height was greater in February planted plots in the lower four elevational zones but less than May-June plots in the upper two zones. Foliage cover was greater than 25 percent in the 0.50- to 0.99-ft elevational zone of February planted plots. Fertilizer treatments did not make any significant difference in density or height.

603. *Spartina alterniflora* and *S. patens* in rows 11 to 15 were similar in percent survival at the 27 April 1977 evaluation. Density, stems per surviving plant, and number of tillers were greater in *S. patens*. More plants were stressed in *S. patens* plots. Differences among fertilizer treatments were not found. Density and stems per plant increased in each row from row 11 to 15, except for *S. alterniflora* in row 15. Tillers per plant for *S. patens* were most numerous in rows 13 to 15. Height increased for *S. patens* with each successively higher row. Animal damage and number of invading species and invading plants were greatest in row 15.

604. In rows 11 to 15 evaluated 11-15 November 1977, survival and density of *Spartina patens* increased at each successively higher row. Survival was 11.3 percent in row 11 and 91.5 percent in row 15.

Density was significantly greater in *S. patens* plots than *S. alterniflora*. For *S. alterniflora*, density increased from 522 stems per plot in row 11 to 960 stems per plot in row 14. Density was only 397 in row 15. Height was greater in *S. alterniflora* than *S. patens* in all rows, but row 15.

605. February was the month of lowest tides and May was the month of highest tides. Average mhw for the Bolivar Peninsula site was 1.21 ft above msl during the study period.

606. Sprigs of *Spartina alterniflora* survived, grew, reproduced vegetatively, and produced seeds at both low and high marshland elevations. Seedling survival of both species was limited to a narrow zone above mhw in which wave action and inundation were absent but soil moisture was sufficient for establishment. Fertilizers did not make major differences in the survival, growth, and reproduction of plants. Protection from wave action appeared necessary for good survival and growth. Season of planting did not affect survival and subsequent growth of *S. alterniflora*. *S. patens* survival and growth was low in the July planting.

607. Three fertilizer rates were applied to upland plots: F_0, F_1, and F_2. Of the three grasses planted in the upland, *Andropogon perangustatus* had significantly less survival (9.3 percent) than the other two species on 2 September 1976. *Panicum amarum* (79.6 percent) and *Cynodon dactylon* (96.0 percent) were similar in survival. Survival was about the same for all three species in both September and December 1976.

608. *Panicum amarum* showed no significant differences in parameters measured due to fertilizer treatment in 1976. *Cynodon dactylon* showed a significantly higher mean shoot biomass at the higher fertilizer rate. No other differences were found in *C. dactylon* due to fertilizer treatment in 1976. No differences due to fertilizer were found in *Andropogon*.

609. At the May 1977 evaluation of *Panicum amarum* plots, differences in biomass production between plots fertilized only in 1976 and those refertilized in 1977 did not occur. For *Cynodon dactylon*, biomass in F_1 plots was twice and F_2 plots 3 times as great as plots fertilized only in 1976.

610. At the 26 September 1977 evaluation for *Panicum amarum*, those plots fertilized in both 1976 and 1977 were significantly higher ($P<0.05$) in density and height of plants from those fertilized only in 1976. Analysis of 1977 measurements revealed differences in F_0, F_1, and F_2 treatments for refertilized plots. F_2 plots were significantly ($P<0.10$) greater in density, height, root biomass, shoot biomass, and total biomass.

611. At the 26 September 1977 evaluation for *Cynodon* significant differences ($P<0.10$) in shoot biomass occurred between times of fertilization. Significant differences ($P<0.10$) between F_0, F_1, and F_2 treatments for biomass did not occur in plots fertilized only in 1977.

612. For *Andropogon perangustatus*, replanted in January 1977, survival was 6.5 percent in F_0 and F_1 plots and 0.9 percent in F_2 plots in September 1977. Lower elevation plots which remained wet most of the time had no survival.

613. For shrubs and trees there were significant differences in percent survival at the first evaluation. *Prunus* sp. had the lowest survival (0.7 percent) and *Croton punctatus* had the highest (54.9 percent) followed by *Rhus copallina* (11.8 percent). For each fertilizer treatment, survival appeared to vary with species.

614. *Tamarix gallica*, *Rhus copallina*, and *Pinus clausa* were replanted in January 1977. The lowest elevational block of *Croton punctatus* also was replanted. *Quercus virginiana* and *Myrica cerifera* were planted in place of *Pinus elliottii* and *Prunus* sp.

615. At the 26 September 1977 evaluation, highest survival was recorded in *Quercus virginiana* with 96.5 percent. *Rhus copallina* survival was 66 percent. *Pinus clausa* and *Tamarix gallica* had

approximately 30 percent survival. *Croton* failed to survive in the lowest elevational block.

616. Significant differences due to fertilizer treatments in shrub and tree species were found only in *Myrica cerifera* survival and *Pinus clausa* height.

617. The wildlife study examined avian and mammalian use of the experimental and reference marshlands, and in the experimental, reference, and control uplands. Reptiles and amphibians were recorded only as encountered. During the breeding season, nest searches were conducted in each of the five areas.

618. The avifauna were censused biweekly. Between August 1976 and November 1977, 135 species were seen directly utilizing or flying over the study site. Species numbers were lowest in the summer and winter seasons, with increases noted during fall and spring migrations.

619. Bird densities per hectare were recorded for each season and habitat type. Densities fluctuated sporadically due to the influence of flocks of gregarious species suddenly occurring on a census transect. Diversities gradually increased after August 1976 especially in the experimental marshland which attracted new species as the marsh developed.

620. Small mammal populations were captured, marked, and released in the experimental, reference, and control areas. Only four small mammal species were captured in those areas. *Sigmodon hispidus* was captured in areas of heavy vegetation, *Oryzomys palustris* was recorded in very moist habitats, and *Rattus norvegicus* and *Mus musculus* were caught in the sparser vegetation, near areas of human disturbance. During the last trapping period in August 1977, *S. hispidus* had colonized the *Cynodon dactylon* plots in the experimental upland, and *O. palustris* was captured in the *Spartina alterniflora* of the experimental marshland.

621. *Sylvilagus floridanus* were removed from the experimental area since they were feeding on the planted vegetation, especially *Spartina alterniflora*. However, no permanent damage was done to the plants. Other large mammals seen utilizing the experimental marshland were

Lutra canadensis, *Myocastor coypus*, and *Procyon lotor*.

622. Bird searches were conducted biweekly during the breeding season from March through June 1977. All nests found were identified, marked, and revisited at least twice. Of the six breeding species, five nested in the experimental marshland and upland. No nests were seen in the reference marshland, and no successful nests were found in the reference or control uplands. Ground nesting species were found only in the experimental area. *Sterna albifrons* bred extensively in the experimental upland. Two separate nestings occurred on the area, one in May and the second in June 1977. Combined nest success for *S. albifrons* on the experimental upland was 90 percent. Only *Charadrius vociferus* was more successful, hatching 100 percent of the eggs laid.

623. Dredged material at the Bolivar Peninsula site initially consisted of a coarse-textured sand with less than 5 percent clay. Organic matter and nutrient content of the sediment was low. Delivery of nitrogen and phosphorus to the site in rainfall did not contribute a significant input of these elements. During the two year period of this project there have been only minor elevation changes in the marshland. Sediment deposition has also occurred near the dike. There has been some erosion in both the upland and the marshland.

624. Monitoring of changes in sediment composition and nutrient status of the site has been accomplished by analysis of deep cores from selected plots as well as extensive sampling and analysis of surface sediments. Destructive sampling and analysis of established plants from all plots were conducted in the late fall months of 1976 and 1977.

625. The marshland site now consists of two distinct sediment zones separated by a zone of intermediate composition. The lower elevation marshland region (tier 1) is inundated much of the time. There has been a dramatic increase in clay content, organic matter, total Kjeldahl nitrogen and extractable phosphorus. These components are largely confined to the surface horizons and decrease rapidly with

depth. TKN in the surface horizon of the plots in tier 1 increased from an average of 50 μg/g in June 1976 to 290 μg/g on 14 October 1977. Similar increases were noted for organic matter and extractable phosphorus. The buildup of these components in the lower elevations of the marshland was associated with sedimentation from clay and silt laden waters, active algal growth, and dike influences. Due to the reduced chemical environment in this area a lower rate of oxidation of organic components would also be expected.

626. Changes in sediment composition at the higher elevations of the marshland (tier 3) have been quite different over the study period. Since it is located well above the mean low tide the area is rarely inundated. Sedimentation has not occurred. The chemical and physical composition of this area has remained essentially the same for the past two years with only moderate fluctuation in those parameters monitored. The region between these two extremes is intermediate in physical and chemical properties.

627. Changes in the properties of the sediments on the site have been largely controlled by elevation and mediated by presence of the dike. Establishment and biomass production of the two grasses planted in the marshland, *Spartina alterniflora* and *S. patens*, were also associated with elevation. There was no relationship between sedimentation or chemical composition of the sediment and the presence of plants in the marshland. Chemical changes occurred in the unsprigged control plots at the same rate as in vegetated plots. This was probably due to the influence of the dike which effectively controlled wave action and facilitated sedimentation within the marshland.

628. In excess of 22,000 individual organisms were captured in the various nekton nets and traps utilized. The species of vertebrates and macroinvertebrates collected during this study were compared with those of the National Marine Fisheries Service study at Bolivar Peninsula during 1975. The species collected and order of dominance in the samples were similar between the two studies.

629. Seasonal variations in the abundance and diversity of fishes

and macroinvertebrates were apparent: however, there seemed to be little relationship between habitat type and species composition or diversity. The bare protected transects did have somewhat higher diversity than did the other habitat types, although this should be further documented in the future. There were considerable differences in abundance of organisms captured night and day, although the patterns were not consistent throughout the study.

630. Six species of fish were retained and examined for food habits: *Paralichthys lethostigma*, *Micropogon undulatus*, *Leiostomus xanthurus*, *Menidia beryllina*, *Fundulus similis*, and *Cyprinodon variegatus*. *P. lethostigma* were present in low numbers, but all individuals examined fed on fish. Of the remaining species, all were primarily benthos feeders with the exception of *M. beryllina* which utilized the zooplankton community to a large extent. Many organisms present in the stomachs were not otherwise collected. It is recommended that zooplankton and meiobenthos sampling be initated to determine the relative abundance of the various species which were important as food for a variety of fishes, and that benthos sampling be continued. The six species examined to date should be further studied with respect to food habits to document any changes which may result as a function of alterations in the benthic and zooplankton communities in association with continued marsh growth.

631. A variety of benthic organisms were captured, representing the phyla Annelida, Ryncocoela, Crustacea, and Mollusca. The dominant organisms were several species of polychaetes and an isopod in the intertidal zone. Upper elevation stations revealed the presence of a variety of insects, primarily as pupae and larvae, although some adults were also collected.

632. The numbers of organisms in individual samples ranged from zero to over 40,000 per square metre within stations. The lowest numbers of animals were generally recovered from the elevation of station 3 which represents an ecotone between intertidal and supertidal regions. Above and below station 3 the numbers of organisms and

diversities generally increased.

633. In terms of benthos habitat preference, there was little difference across the site. All of the stations followed a seasonal pattern with the largest numbers of animals per square metre generally occurring during the winter. The disturbance of the site during the spring of 1976 may have been reflected in the relatively lower numbers of organisms present within most stations in July 1976 as compared with June 1977, but there was no apparent relationship between the presence of the developing marsh and benthos abundance. Colonization of the marsh has continued beyond the dates covered by this report and future changes in the benthic community may be more dramatic than those perceived to date.

634. Volatile solids levels were low throughout the sampling period, averaging about 1 percent throughout the study area, with little seasonal change. Sediment grain-size analyses demonstrated that the bulk of the material present at the Bolivar Peninsula site was in the fraction from 63 to 250 μm, with less than 10 percent being larger or smaller than that size range in most cases. There were no dramatic changes associated with time, habitat, or elevation in either the volatile solids or grain-size data.

635. Water quality varied to some extent seasonally. There was some variation in water samples taken during the day as opposed to night. However, the general characteristics of water quality (salinity, temperature, ammonia, alkalinity, pH, suspended solids, and turbidity) did not change in relation to habitat across the site within sampling periods.

636. Photographs demonstrated the presence of fiddler crabs in the upper three or four elevations throughout the study area. Worm holes were observed in many locations, especially at lower elevations. *Diopatra cuprea* tubes were observed primarily during the winter on hard sediments at the lower elevations. Hermit crabs were recognized by their tracks and the shells they inhabited, often being present from the middle elevations seaward. Bird and

raccoon tracks were common in many of the photographs indicating that these animals were utilizing the site, probably for feeding activity, on a routine basis.

637. In general, July 1976 through June 1977 represents a period of baseline data collection. Few responses of the biota, water chemistry, or sediments to the presence of the planted marshland were detected since it was only becoming well established at the conclusion of the study. Future sampling should include monitoring similar to that which has been done in the past. In addition, certain modifications appear to be desirable. For example, sediment grain analyses have been constant, thus, it might be better to obtain data at 2-to 3-month intervals instead of monthly. Similarly, the most important data obtained from nekton sampling appear to be associated with documentation of the presence of various species seasonally and the determination of the food habits of some of the important fishes. Monthly sampling should be continued to document population changes and to provide animals for food habit studies. The total numbers and weights of each species collected should be recorded, and if possible, individual measurements should be obtained.

638. Better ways of collecting nekton organisms within the marshland remain to be developed. One goal of future studies should be the development of such sampling techniques.

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Table 1

Mean Annual Meteorological Data by Month at Galveston, Texas

	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Daily solar energy													
mean % of possible sunshine (ave. of 86 years)	48	51	55	61	68	75	72	71	68	72	60	49	63
Maximum wind velocity, mph (fastest mile - 1872-1976)	53 S	60 N	50 SE	57 NW	66 W	62 SE	68 NW	91 E	100 NE	66 SE	54 N	50 NW	
Precipitation, cm													
mean (1871-1976)	8.46	7.06	6.73	7.67	8.79	9.78	10.08	11.25	14.45	9.85	9.17	10.13	113.44
low (1871-1976)	0.05	0.23	0.15	0.02	T	T	T	0.00	0.10	T	0.08	0.58	
high (1871-1976)	26.39	21.06	24.10	28.04	27.41	39.34	47.60	48.46	66.06	45.16	41.10	26.11	
Maximum 24-hour precipitation, cm (1871-1976)	13.66	16.64	20.57	23.44	19.58	31.90	36.45	22.99	29.59	35.81	22.88	13.79	
Temperature, °C													
mean 1874-1976	12.3	13.5	16.7	20.5	24.2	27.4	28.9	28.5	26.7	22.8	17.4	13.8	21.0
low (ave.) 1874-1976	9.2	10.5	13.9	18.0	17.8	25.0	25.0	25.9	24.0	20.0	14.4	10.8	18.3
high (ave.) 1874-1976	15.3	16.5	19.5	23.0	26.7	29.8	30.9	31.0	29.3	25.5	20.3	16.7	23.7
Relative humidity, %													
0000 hour (37 years)	84	82	84	85	82	80	80	78	78	76	81	82	81
0600 hour (89 years)	85	84	85	86	84	81	81	81	81	80	84	86	83
1200 hour (59 years)	77	74	74	75	73	70	70	69	68	65	72	77	72
1800 hour (89 years)	80	77	79	80	77	73	73	73	75	71	77	80	76

Table 2

Mean Monthly Meteorological Data at Galveston, Texas

June 1976 - October 1977

	Month						
	J 76	J 76	A 76	S 76	O 76	N 76	D 76
Solar energy (% sunshine)	77	63	74	64	56	40	40
Maximum wind velocity, mph (fastest mile)	24 NE	25 S	27 N	23 NE	29 SE	33 NE	30 N
Total precipitation in Galveston, cm	10.87	14.30	3.63	21.00	9.78	10.21	19.63
Total precipitation at Bolivar, cm	---	---	---	15.54	10.83	14.81	19.88
Maximum 24-hour precipitation, cm	5.00	8.88	1.83	8.13	5.41	5.87	5.33
Mean temperature, °C	26.7	27.5	28.1	26.5	18.5	12.6	11.6
Maximum temperature, °C (average)	28.9	29.8	31.0	29.2	21.5	15.4	14.4
Minimum temperature, °C (average)	24.5	25.2	25.2	23.9	15.4	9.7	8.7
Relative humidity, %							
0000 hour	77	82	78	75	73	81	83
0600 hour	80	85	83	80	81	84	86
1200 hour	67	74	66	68	66	70	78
1800 hour	69	78	71	69	67	76	83

(Continued)

Table 2

	Month						
	J 77	F 77	M 77	A 77	M 77	J 77	J 77
Solar energy (% sunshine)	43	69	33	58	64	76	68
Maximum wind velocity, mph (fastest mile)	30 NW	32 NW	33 NW	33 NW	30 S	30 S	18 SW
Total precipitation in Galveston, cm	8.66	2.72	3.53	17.12	1.71	7.19	1.73
Total precipitation at Bolivar, cm	8.08	4.75	4.75	17.13	0.0	9.95	6.18
Maximum 24-hour precipitation, cm	2.87	2.11	1.02	12.93	0.79	4.65	0.82
Mean temperature, °C	8.2	12.9	16.8	21.2	24.5	27.2	28.2
Maximum temperature, °C (average)	11.7	15.5	19.4	23.5	26.5	29.2	30.2
Minimum temperature, °C (average)	4.6	10.2	14.2	18.7	22.5	22.5	26.1

(Continued)

Table 2 (Concluded)

	Month			
	A 77	S 77	O 77	N 77
Solar energy (% sunshine)	48	64	50	44
Maximum wind velocity, mph (fastest mile)	23	28	27	34
Total precipitation in Galveston, cm	16.39	12.5	7.5	24.2
Total precipitation at Bolivar, cm	32.5	4.94	4.96	12.8
Maximum 24-hour precipitation, cm	6.15	4.0	3.0	11.4
Mean temperature, °C	28.1	27.5	22.7	18.4
Maximum temperature, °C (average)	30.3	29.8	25.4	21.4
Minimum temperature, °C (average)	25.9	25.1	19.9	15.4

Table 3

Fertilizer Treatments Applied to the Thirty Plots Within One Elevation Block of the Marshland Monotypic Plot Experiment

Plot No.	Fertilizer Treatment*	Species	Method**
1	F_0	*Spartina alterniflora*	sprig
2	F_0	*Spartina alterniflora*	seed
3	F_0	*Spartina patens*	sprig
4	F_0	*Spartina patens*	seed
5	F_0	No planting	none
6	F_0	No planting	none
7	F_1	*Spartina alterniflora*	sprig
8	F_1	*Spartina alterniflora*	seed
9	F_1	*Spartina patens*	sprig
10	F_1	*Spartina patens*	seed
11	F_1	No planting	none
12	F_1	No planting	none
13	F_2	*Spartina alterniflora*	sprig
14	F_2	*Spartina alterniflora*	seed
15	F_2	*Spartina patens*	sprig
16	F_2	*Spartina patens*	seed
17	F_2	No planting	none
18	F_2	No planting	none
19	F_3	*Spartina alterniflora*	sprig
20	F_3	*Spartina alterniflora*	seed

(Continued)

Table 3 (Concluded)

Plot No.	Fertilizer Treatment*	Species	Method**
21	F_3	*Spartina patens*	sprig
22	F_3	*Spartina patens*	seed
23	F_3	No planting	none
24	F_3	No planting	none
25	F_4	*Spartina alterniflora*	sprig
26	F_4	*Spartina alterniflora*	seed
27	F_4	*Spartina patens*	sprig
28	F_4	*Spartina patens*	seed
29	F_4	No planting	none
30	F_4	No planting	none

* The types of fertilizer treatment were:

- F_0: no fertilizer
- F_1: low rate, 122 kg N/ha, 122 kg P_2O_5/ha, and 122 kg K_2O/ha (122 g/m^2)
- F_2: high rate, 244 kg N/ha, 244 kg/P_2O_5/ha, and 244 kg K_2O/ha (244 g/m^2)
- F_3: split application, low rate
- F_4: split application, high rate

** Seeding was accomplished in winter 1976-1977 on 30-m^2 plots.

Table 4

Fertilizer Treatment Design for Upland Monotypic Plot Experiment

Plant Type and Tier	Row	Species	Random Fertilizer Treatment of Subplots* Replicate 1	Replicate 2	Replicate 3
Grasses, lower tier	1	*Panicum amarum*	F_0 F_1 F_2	F_1 F_2 F_0	F_2 F_0 F_1
	2	*Cynodon dactylon*	F_1 F_2 F_0	F_2 F_0 F_1	F_1 F_2 F_0
	3	*Andropogon perangustatus*	F_2 F_0 F_1	F_0 F_1 F_2	F_0 F_1 F_2
	4	No planting	F_1 F_2 F_0	F_0 F_2 F_1	F_2 F_0 F_1
Shrubs, middle tier	1	*Croton punctatus*	F_1 F_2 F_0	F_0 F_1 F_2	F_2 F_1 F_0
	2	*Prunus* sp.	F_0 F_1 F_2	F_2 F_1 F_0	F_2 F_0 F_1
	3	*Rhus copallina*	F_0 F_1 F_2	F_0 F_2 F_1	F_1 F_0 F_2
	4	No planting	F_2 F_0 F_1	F_1 F_0 F_2	F_0 F_2 F_1
Trees, upper tier	1	*Tamarix gallica*	F_2 F_1 F_0	F_1 F_0 F_2	F_1 F_2 F_0
	2	No planting	F_1 F_2 F_0	F_0 F_2 F_1	F_1 F_0 F_2
	3	*Pinus clausa*	F_0 F_1 F_2	F_1 F_2 F_0	F_0 F_1 F_2
	4	*Pinus elliottii***	F_0 F_2 F_1	F_2 F_1 F_0	F_2 F_0 F_1

* Treatments consist of: F_0 - no fertilizer applied; F_1 - low rate fertilizer application; F_2 - low rate fertilizer application.

** Was not planted.

Table 5

Species, Collection Location, and Date of Planting for the Upland Experimental Plots

Species	Collection Location	Planting Date (1976)	Planting Date (1977)
Pinus clausa	Macon, Georgia	8 July	1 January
Tamarix gallica	Local	1 July	24 February
Rhus copallina	Woodville, Texas	8 July	19 January
Prunus sp.	Woodville, Texas	8 July	19 January
Croton punctatus	Local	29 June	19 January
Andropogon perangustatus	Local	1 July	19 January
Cynodon dactylon	West Columbia, Texas	8 July	
Panicum amarulum	Local	7 July	
Myrica cerifera	Local		19 January
Quercus virginiana	Western Louisiana		9 February

Table 6

Initial Biomass of Marsh Transplants Utilized in Marshland Experimental Planting at the Bolivar Peninsula Habitat Development Site

		Shoot						Root							
		Height (cm)		Wet Weight (g)		Dry Weight (g)		Wet Weight (g)		Dry Weight (g)		$\bar{X}$ Total Biomass (g)		$\bar{X}$ Root:Shoot Ratio	
Species	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	Wet	Dry	Wet	Dry
*Spartina alterniflora**:															
High elevation	40	50.5	6.2	7.3	1.2	2.8	0.1	5.8	1.7	3.7	0.1	13.1	6.5	0.80	1.29
Intermediate elevation	40	62.4	12.5	10.7	4.4	3.8	0.3	8.5	6.2	2.4	0.2	19.2	6.2	0.80	0.62
Low elevation	40	77.9	24.5	13.0	6.4	4.6	0.4	6.2	3.1	2.3	0.2	19.2	6.9	0.48	0.51
*Spartina patens***	--	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Spartina alterniflora+	40	47.8	1.9	6.1	0.5	1.6	0.1	2.0	0.2	0.5	0.1	8.1	2.1	0.32	0.31
Spartina patens+	40	75.3	2.5	6.5	0.6	4.0	0.4	3.2	0.3	1.6	0.2	9.7	4.6	0.49	0.40
Spartina alterniflora++	40	59.1	2.3	11.9	0.8	3.9	0.3	8.8	0.5	2.7	0.2	20.7	6.6	0.73	0.69

* Transplanted July 1976.

** *Spartina patens* data were not collected in 1976.

+ Transplanted into 1/4-size plots 3 February 1977.

++ Transplanted into 1/4-size plots 30 May-1 June 1977.

AD-A063 781 TEXAS AGRICULTURAL EXPERIMENT STATION COLLEGE STATION F/G 13/3
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
JUN 78 J W WEBB, J D DODD, B W CAIN DACW39-76-C-0109
UNCLASSIFIED WES-TR-D-78-15-APP-D NL

4 OF 6
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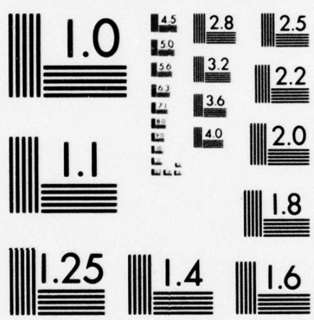

MICROCOPY RESOLUTION TEST CHART
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Table 7

Initial Biomass of Upland Transplants Utilized in Upland Experimental Planting at the Bolivar Peninsula Habitat Development Site

Species	N	Shoot: Height (cm) $\bar{X}$	Height SD	Shoot: Wet Weight (g) $\bar{X}$	Wet Weight SD	Shoot: Dry Weight (g) $\bar{X}$	Dry Weight SD	Root: Wet Weight (g) $\bar{X}$	Wet Weight SD	Root: Dry Weight (g) $\bar{X}$	Dry Weight SD	$\bar{X}$ Total Biomass (g) Wet	Total Biomass Dry	$\bar{X}$ Root:Shoot Ratio Wet	Root:Shoot Ratio Dry
1976															
*Pinus elloittii**															
Pinus clausa	20	26.8	15.1	10.8	5.8	3.0	2.7	2.5	0.8	0.7	0.3	13.3	3.7	0.23	0.23
*Tamarix gallica***	20	87.8	10.8	65.0	25.3	16.5	12.8	---	---	---	---	65.0	16.5	---	---
Rhus copallina	20	58.5	10.1	32.0	15.3	16.4	9.0	30.6	23.1	15.6	13.7	62.6	32.0	0.96	0.95
Prunus sp.: Tall	6	50.1	14.0	9.5	5.3	5.5	1.9	7.7	4.8	3.6	1.9	17.2	9.1	0.81	0.66
Short	10	17.6	5.8	9.6	9.4	4.3	4.1	16.1	54.7	6.1	8.0	25.7	10.4	1.70	1.40
Croton punctatus	20	28.8	6.2	6.0	2.0	0.8	0.5	0.6	0.3	0.1	0.1	6.5	0.9	0.10	0.14
Andropogon perangustatus	40	67.8	8.3	1.7	0.8	0.8	0.4	0.3	0.1	0.2	0.2	2.0	1.0	0.18	0.24
Cynodon dactylon+	40	---	---	9.0	5.2	3.6	2.2	8.1	4.6	4.9	3.0	17.1	8.5	0.90	1.36
Panicum amarulum	40	54.3	15.0	20.5	15.4	4.9	3.4	11.3	17.8	2.8	2.1	31.8	7.7	0.55	0.57
1977															
Quercus virginiana	20	72.1	4.6	44.9	3.2	25.6	1.9	49.8	2.9	26.0	1.9	94.7	51.6	1.10	1.01
Pinus clausa	20	41.0	1.0	8.4	0.9	2.6	0.3	1.4	0.1	0.5	0.1	9.8	3.1	0.17	0.19
Tamarix gallica	20	77.4	2.5	27.4	1.8	13.9	1.0	---	---	---	---	27.4	13.9	---	---
Rhus sp.	21	28.7	1.2	11.8	2.1	9.8	0.1	50.1	10.0	23.5	4.1	61.9	33.3	4.25	2.39
Myrica cerifera	21	59.5	4.3	10.7	1.6	5.9	1.0	12.6	4.4	5.3	1.9	23.3	11.2	1.18	0.90
Andropogon perangustatus	40	77.4	4.1	5.3	0.7	3.9	0.5	1.9	0.2	0.8	0.1	7.2	4.7	0.36	0.21

* Data not available, plants died prior to planting.

** Cuttings were used, and roots were not present.

\+ Sprigs were used, and they were not considered to have height.

Table 8

Germination Percentages for *Spartina patens* and *S. alterniflora* Under Different Seed Storage Conditions. *S. patens* Seeds Were Stored in Mid-October at Ambient Temperature and 4°C. *S. alterniflora* Seeds Were Stored in Mid-December in a Saline Solution at 6°C

Test Initiation	Test Number	Storage Conditions and Germination (%): Dry Ambient Temperature	Dry, 4°C
Spartina patens			
10/25	1	71.5	82.0
11/12	2	71.5	72.0
12/14	3	76.0	75.0
1/15	4	79.5	73.5
1/29	5	77.5	68.5
2/12	6	67.0	64.0
2/26	7	73.5	71.5
3/12	8	47.0	36.0
3/26	9	72.0	69.5
4/15	10	61.0	58.0
4/23	11	48.5	42.5
5/11	12	36.0	32.5
*Spartina alterniflora** (saline solution at 6°C)			
1/14	1	61.0	
1/29	2	59.5	
2/12	3	68.5	
2/26	4	74.0	
3/12	5	16.0	
3/26	6	27.0	
4/15	7	25.0	
4/23	8a	9.5	
4/23	8b	25.5	

* *Spartina alterniflora* seeds utilized in tests 1-4 and 8a were collected at the South Jetty while those in tests 6,7, and 8b were collected at the North Jetty.

Table 9

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 23-25 August 1976 (Evaluation 1)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1 F_0	7 F_1	13 F_2	19 F_3	25 F_4	3 F_0	9 F_1	15 F_2	21 F_3	27 F_4
Survival, %*,**	68.8 ab	63.6 ab	49.1 acd	67.9 ab	58.3 abc	39.5 acde	30.6 acdefg	40.7 acd	44.1 acd	32.1 acdef
Height, cm*	47.2 abcdefg	54.2 abcdefg	50.7 abcdefg	52.3 abcdefg	48.5 abcdefg	57.3 abcdefg	45.3 abcdefg	59.3 abcdfg	64.4 acg	66.4 ac
Plants with new growth/quadrat+	3.8 adfhj	2.3 adfghi jkl	2.5 adfhij kl	3.5 adfhjl	3.4 adfhjkl	2.1 adefgh ijkl	2.2 adefghi jkl	1.9 acdefg hijkl	1.9 acdefg hijkl	0.5 bcegikl
Plants with new growth, %**	42.6	28.0	33.4	40.2	48.2	41.1	45.4	40.4	45.7	20.0
Density/m^2 +,++	4.4 a	3.7 a	3.2 a	4.2 a	3.6 a	1.7 a	1.6 a	1.8 a	2.1 a	1.9 a
Stems/surviving plant	6.4	1.4	1.4	1.5	1.4	0.9	0.7	1.0	1.0	1.4
Plants with animal damage*,**,‡	1.2	0.1 ade	0.7 be	0.6 bde	0.7 be	0.0 acde	0.0 acde	0.1 ade	0.0 acde	0.0 acde
Foliage cover, %	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

* Analysis of variance F-test for differences among treatments was significant (P < 0.05).

** Means followed by different letters were significantly different as tested by Student-Newman-Keuls' multiple-range test (P < 0.05).

\+ Analysis of variance F-test for interaction among tiers and treatments was significant (P < 0.05).

\++ Analysis of variance F-test for treatments was significant (P < 0.10).

‡ Analysis of variance F-test for interaction among tier and treatment was significant (P < 0.20).

Table 10

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots

On 6-8 September 1976 (Evaluation 2)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1	7	13	19	25	3	9	15	21	27
	F_0	F_1	F_2	F_3	F_4	F_0	F_1	F_2	F_3	F_4
Survival, %*,**	61.7 bg	58.0 bfg	40.8 defg	63.3 b	54.0 befg	19.7 acdefg	12.6 acdefg	22.2 acdefg	24.4 acdefg	12.3 acdefg
Height, cm*,**,+	47.9 abcde	56.2 abe	50.8 abcde	47.8 abcde	43.3 acdf	57.4 abe	43.0 acdfg	59.8 ab	55.9 abe	42.3 acdfgh
Plants with new growth/quadrat*	5.9 adho	4.9 adghmno	3.9 adfgjlm no	6.6 adh	5.3 adghno	2.1 acdefij klmno	2.7 adfijkl	2.3 adefijk lmno	3.6 adfgjkl mno	0.6 bcdeikl mno
Plants with new growth, %++	77.0	65.9	57.6	82.9	77.4	51.5	66.7	52.9	73.2	36.4
Density/m^2*,**	4.7 de	4.9 e	4.2 bcde	5.3 f	4.3 cde	1.2 abcde	1.0 abcde	1.4 abcde	1.5 abcde	0.9 abcde
Stems/surviving plant	1.5	2.0	1.6	1.8	1.3	0.9	0.8	1.0	1.0	0.7
Plants with animal damage‡	0.4	0.4	0.3	0.2	0.5	0.0	0.0	0.0	0.0	0.0
Foliage cover, %	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

* Analysis of variance F-test for differences among treatments was significant ($P < 0.05$).

** Means followed by different letters were significantly different as tested by Student-Newman-Keuls' multiple-range test ($P < 0.05$).

\+ Analysis of variance F-test for interaction among tiers and treatments was significant ($P < 0.05$).

++ Analysis of variance F-test for differences among treatments was significant ($P < 0.10$).

‡ Analysis of variance F-test for interaction among tiers and treatments was significant ($P < 0.20$).

Table 11

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 21-22 September 1976 (Evaluation 3)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1 F_0	7 F_1	13 F_2	19 F_3	25 F_4	3 F_0	9 F_1	15 F_2	21 F_3	27 F_4
Survival, %*,++	60.5 f	54.0 de	41.0 bcde	60.2 e	51.9 cde	13.9 abcde	9.3 abcde	14.8 abcde	19.8 abcde	9.9 abcde
Height, cm+	50.1	56.0	53.3	54.8	49.7	53.1	46.5	48.5	52.5	51.4
Plants with new growth/quadrat*,++	6.6 behn	6.0 behlmn	4.6 bklmn	7.0 beh	6.1 behmn	2.7 bdgij klmn	3.6 bdgjkl mn	2.3 bcfgij kmn	2.6 bdfgij kl	0.4 acfijk lmn
Plants with new growth, %*,++	88.9 bcef	84.9 bce	87.7 bce	93.0 bcdef	87.7 bce	100.0 bdf	100.0 bdf	100.0 bdf	100.0 bdf	0.0 a
Density/m^2*,++	6.4 a	6.8 a	5.6 a	1.9 a	1.5 a	1.4 a	1.7 a	1.8 a	5.8 a	1.8 a
Plants with tillers/quadrat*,++	6.4 bdfh	5.2 bdfgh	5.1 bdefgh	6.5 bdf	5.6 bdfh	1.5 acegh	4.4 bcdefgh	1.5 acegh	1.3 acegh	0.0 acegh
Plants with tillers, %**,+	85.5	75.3	84.2	87.6	81.6	64.3	77.1	68.4	60.5	0.0
No. of tillers/quadrat*,+,++	14.5 bf	14.5 bf	14.2 bef	16.3 b	13.0 bdef	1.6 acdef	4.4 acdef	3.9 acdef	2.3 acdef	0.0 acdef
Stems/surviving plant**,+	3.5	2.8	2.6	2.6	2.4	1.0	1.0	2.0	1.5	1.0
Tillers/plant with tillers	2.1	2.6	2.3	2.2	2.2	1.1	1.0	2.3	1.5	---
Plants with animal damage	0.5	0.6	0.9	0.0	0.3	0.0	0.0	1.2	0.4	0.0
Foliage cover, %	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

* Analysis of variance F-test for difference among treatments significant ($P < 0.05$).

** Analysis of variance F-test for difference among treatments significant ($P < 0.10$).

\+ Analysis of variance F-test for difference between *interaction among tiers and treatment significant* ($P < 0.20$).

++ Means followed by different letters were significantly different as tested by Student-Newman-Keuls' multiple-range test ($P < 0.05$).

Table 12

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 4-5 October 1976 (Evaluation 4)

	Spartina alterniflora Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1	7	13	19	25	3	9	15	21	27
Parameter	F_0	F_1	F_2	F_3	F_4	F_0	F_1	F_2	F_3	F_4
Survival, %*,**,‡	57.4 bd	52.5 bdhi	37.3 bfghi	58.3 bd	48.1 bdghi	9.3 acefghi	7.1 acefghi	11.4 acefghi	14.5 acefghi	5.9 acefghi
Height+	55.3	63.0	57.9	57.2	48.5	55.1	35.9	39.1	41.5	43.7
Plants with new growth/quadrat*,**,‡	6.2 bdfim	6.0 bdfilm	4.7 bdfhiklm	6.8 bdfi	6.3 bdfim	2.5 bcdefghjklm	4.6 bdfhijklm	3.8 bdfghjklm	2.8 bdefghjklm	0.4 acegjklm
Plants with new growth, %	86.6	87.5	97.4	92.8	96.1	64.6	93.3	85.7	80.0	100.0
Density/m^2*,++,‡	6.6 a	8.0 a	6.3 a	9.0 a	6.6 a	2.6 a	4.7 a	2.3 a	2.5 a	1.3 a
Plants with tillers/quadrat*,**,‡	6.1 acfhl	6.0 acfhkl	4.5 acefhjkl	6.8 acfh	6.1 acfhl	1.7 abcdgijkl	4.4 acefgijkl	3.0 acegijkl	2.6 acdegijkl	0.3 abdgijkl
Plants with tillers, %	87.6	87.8	92.7	92.4	94.2	65.3	95.8	75.3	85.5	100.0
No. of tillers/quadrat*,++,‡	16.4 acegjk	19.5 acegk	16.2 acegijk	21.6 aceg	15.9 acdefghijk	5.1 abdefhijk	10.6 abcdefghijk	3.8 abdefhijk	3.4 abdfhijk	0.2 abdhijk
Stems/surviving plant	2.6	3.5	3.7	3.2	2.9	2.4	2.3	1.8	2.4	1.0
Tillers/plant with tillers	2.5	3.3	3.4	2.7	2.5	3.7	2.1	1.4	1.9	1.0
Plants with animal damage+,++	0.9	0.8	0.7	0.1	1.6	0.0	0.0	2.4	1.7	0.0
Foliage cover, %	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

* Analysis of variance F-test for differences in treatments was significant ($P < 0.05$).

** Analysis of variance F-test for interaction among tiers and treatments was significant ($P < 0.05$).

\+ Analysis of variance F-test for interaction among tiers and treatments was significant ($P < 0.20$).

\++ Analysis of variance F-test for differences among treatments was significant ($P < 0.10$).

‡ Means followed by different letters were significantly different as tested by Student-Newman-Keuls' multiple-range test ($P < 0.05$).

Table 13

Means for Parameters in Sprigged Plots of *Spartina alterniflora* and *Spartina patens*

On 9 November 1976 (Evaluation 5)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1 F_0	7 F_1	13 F_2	19 F_3	25 F_4	3 F_0	9 F_1	15 F_2	21 F_3	27 F_4
Survival, %*,**,‡	54.6 bcd	49.7 bcd	37.3 bd	56.2 bc	46.3 bcd	8.3 a	8.3 a	12.7 a	14.2 a	3.4 a
Height, cm*	51.9 abce	65.3 ace	59.5 ace	58.5 ace	54.0 abce	51.9 ace	36.6 abd	36.4 abd	35.4 abd	46.5 abce
Plants with new growth/quadrat⁺	6.6	6.0	5.0	6.7	5.8	5.0	5.0	3.9	3.7	1.0
Plants with new growth, %	98.8	89.6	92.9	97.9	86.5	91.7	94.2	98.4	94.9	50.0
Density/m^{2+}	11.7	16.0	14.8	15.4	14.8	11.7	23.9	10.6	11.4	1.4
Plants with tillers/quadrat⁺,⁺⁺,‡	6.6 adfhi	6.0 acdef ghi	5.3 acdef ghi	7.1 ad	6.1 acdef ghi	3.6 acefghi	4.8 acdef ghi	3.5 aceghi	3.4 acgi	0.7 b
Plants with tillers, %	100.0	93.6	97.6	100.0	95.9	91.7	91.7	84.7	84.4	100.0
No. of tillers/quadrat⁺	32.6	43.3	42.0	42.2	41.5	30.6	68.4	29.4	34.6	0.7
Stems/surviving plant	4.8	6.8	7.3	5.5	6.1	8.7	9.6	5.4	6.0	2.0
Tillers/plant with tillers	4.5	6.8	7.1	5.0	6.0	8.7	10.4	5.2	6.1	1.0
Plants with animal damage	1.1	1.0	0.6	0.3	1.0	0.0	0.0	1.1	0.1	0.0

(Continued)

Table 13 (Concluded)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1 F_0	7 F_1	13 F_2	19 F_3	25 F_4	3 F_0	9 F_1	15 F_2	21 F_3	27 F_4
Foliage cover, %	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Below ground biomass, g/0.1 m^2	3.9	5.5	4.8	4.3	5.1	6.3	4.4	3.2	4.5	---
Above ground biomass, g/0.1 m^2	7.8	13.0	8.7	8.4	8.4	8.6	6.5	6.4	6.7	---
Total biomass	11.7	18.4	13.5	12.7	13.6	14.9	10.9	9.6	11.3	---
Root/shoot ratio	0.5	0.4	0.6	0.6	0.6	0.7	0.7	0.6	0.7	---
Grams of seed, g/0.1 m^2	0.2 a	0.4 a	0.1 a	0.2 a	0.1 a	0.0 b	0.0 b	0.0 b	0.0 b	---
No. of invading species/quadrat	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0
No. of invading plants/quadrat	0.0	0.4	0.0	0.0	0.5	0.5	0.0	40.4	2.8	0.0

* Analysis of variance F-test for difference among treatments was significant ($P < 0.01$).

** Analysis of variance F-test for interaction of treatment and tier was significant ($P < 0.01$).

+ Analysis of variance F-test for interaction of treatment and tier was significant ($P < 0.20$).

++ Analysis of variance F-test for treatments was significant ($P < 0.05$).

♦ Means followed by different letters were significantly different as tested by Student-Newman-Keuls' multiple-range test.

Table 14

Percent Survival of Transplants in Marsh Plot Experiments During 1976 Growing Season

Species	Elev-ation	Fertilizer Application: F_0 1*	F_0 2	F_0 3	F_0 4	F_0 5	F_1 1	F_1 2	F_1 3	F_1 4	F_1 5	F_2 1	F_2 2	F_2 3	F_2 4	F_2 5	F_3 1	F_3 2	F_3 3	F_3 4	F_3 5	F_4 1	F_4 2	F_4 3	F_4 4	F_4 5
Spartina alterniflora (Transplant)	Low	65.7** (6.6)+	63.0 (5.7)	58.3 (5.4)	53.7 (4.4)	52.8 (6.1)	81.5 (4.3)	74.1 (4.3)	63.0 (5.4)	59.3 (5.5)	54.6 (4.2)	56.5 (4.8)	42.8 (7.0)	42.6 (5.6)	39.8 (6.0)	43.5 (5.7)	82.4 (4.5)	75.0 (5.2)	68.5 (5.2)	65.7 (6.3)	61.1 (6.2)	82.4 (4.9)	72.2 (6.2)	69.4 (6 4)	63.9 (5.6)	61.1 (6.7)
	Mid	85.2 (4.3)	82.4 (4.5)	79.6 (4.8)	78.7 (5.2)	78.7 (5.2)	78.7 (5.2)	71.3 (6.4)	70.4 (6.8)	70.4 (6.8)	68.5 (7.3)	57.4 (12.5)	53.7 (13.3)	52.8 (12.8)	49.1 (12.5)	48.1 (12.2)	86.1 (4.4)	82.4 (4.7)	81.5 (5.0)	81.5 (5.0)	80.6 (5.2)	36.1 (10.2)	36.1 (10.5)	35.2 (9.8)	32.4 (9.6)	33.3 (9.5)
	High	55.6 (5.0)	39.8 (5.3)	43.5 (7.3)	39.8 (7.6)	32.4 (0.0)	30.6 (7.9)	28.7 (7.6)	28.7 (7.6)	27.8 (7.6)	25.9 (6.9)	33.3 (7.7)	25.9 (8.3)	27.8 (7.9)	23.2 (8.3)	20.4 (8.5)	35.2 (5.5)	32.4 (7.7)	30.6 (7.9)	27.8 (7.1)	26.9 (0.0)	56.5 (8.1)	53.7 (7.7)	50.9 (7.9)	48.1 (7.7)	44.4 (8.8)
	Mean	68.8 (3.8)	61.7 (4.5)	60.5 (4.4)	57.4 (4.5)	54.6 (8.6)	63.6 (5.7)	58.0 (5.3)	54.0 (5.1)	52.5 (5.1)	49.7 (0.0)	49.1 (5.4)	40.8 (5.9)	41.0 (5.5)	37.3 (5.6)	37.3 (0.0)	67.9 (5.3)	63.3 (5.5)	60.2 (5.4)	58.3 (5.6)	56.2 (7.6)	58.3 (5.8)	54.0 (5.5)	51.9 (5.3)	48.1 (5.0)	46.3 (0.0)
Spartina patens (Transplant)	Low	63.9 (9.1)	21.3 (7.7)	3.7 (2.0)	0.0 (0.0)	0.0 (0.0)	65.7 (7.8)	14.8 (5.5)	2.8 (2.0)	0.0 (0.0)	0.0 (0.0)	57.5 (7.4)	18.5 (6.2)	4.6 (2.0)	0.9 (0.9)	0.0 (0.0)	74.1 (6.3)	13.9 (6.4)	2.8 (1.4)	1.9 (1.9)	0.0 (0.0)	60.2 (9.9)	5.6 (2.0)	1.9 (1.9)	0.9 (0.9)	0.0 (0.0)
	Mid	37.1 (12.1)	19.4 (8.4)	19.4 (6.8)	10.2 (3.9)	6.5 (4.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	37.0 (11.1)	25.0 (7.3)	13.9 (5.7)	6.7 (3.5)	8.3 (4.6)	31.5 (9.7)	29.6 (9.7)	23.2 (8.1)	9.3 (5.1)	7.4 (3,8)	28.7 (14.5)	27.8 (13.7)	25.0 (12.6)	15.7 (9.5)	8.3 (5.6)
	High	17.6 (8.3)	18.5 (9.3)	18.5 (9.5)	17.6 (9.0)	18.5 (9.5)	25.9 (10.7)	23.1 (10.3)	25.0 (11.1)	21.3 (8.5)	25.0 (10.3)	27.8 (11.4)	23.1 (9.6)	25.9 (9.2)	29.2 (11.5)	29.6 (10.1)	26.9 (6.2)	29.6 (10.6)	33.3 (10.8)	32.4 (11.3)	35.2 (10.6)	7.4 (5.5)	3.7 (2.8)	2.8 2.0)	0.9 (0.9)	1.9 (1.9)
	Mean	39.5 (6.7)	19.7 (4.7)	13.4 (4.1)	9.3 (3.5)	8.3 (0.0)	30.6 (6.8)	12.7 (4.2)	9.3 (4.2)	7.1 (3.3)	8.3 (0.0)	40.7 (6.1)	22.2 (4.4)	14.8 (3.9)	11.4 (4.2)	12.7 (0.0)	44.1 (5.9)	24.4 (5.3)	19.8 (5.0)	14.5 (4.8)	14.2 (0.0)	32.1 (7.3)	12.3 (5.0)	9.9 (4.6)	5.9 (3.4)	3.4 (0.0)

* Evaluation dates: 1 - 22-25 August; 2 - 6-8 September; 3 - 21-22 September; 4 - 4-5 October; 5 - 9 November 1976.

** Mean.

+ Standard deviation of mean.

Table 15

Plant Height in Marsh Plot Experiments During 1976 Growing Season

Species	Elevation	Fertilizer Application++ F0 1*	F0 2	F0 3	F0 4	F0 5	F1 1	F1 2	F1 3	F1 4	F1 5	F2 1	F2 2	F2 3	F2 4	F2 5	F3 1	F3 2	F3 3	F3 4	F3 5	F4 1	F4 2	F4 3	F4 4	F4 5
Spartina alterniflora (Transplant)	Low	61.7** (4.4)+	65.4 (4.1)	67.2 (4.3)	78.8 (2.7)	76.3 (3.5)	61.9 (2.6)	67.0 (3.4)	72.4 (3.8)	78.9 (3.5)	73.3 (6.5)	57.3 (3.4)	57.0 (4.3)	62.7 (4.4)	69.9 (4.3)	67.4 (6.3)	62.0 (3.6)	62.9 (2.6)	73.4 (3.8)	76.4 (2.8)	72.7 (3.7)	61.8 (5.6)	70.4 (4.8)	75.8 (5.1)	75.8 (4.5)	75.3 (4.0)
	Mid	42.8 (6.7)	47.6 (7.0)	54.4 (8.4)	59.0 (7.9)	55.6 (7.0)	57.4 (4.2)	59.9 (3.6)	65.0 (7.3)	75.6 (7.1)	84.3 (7.4)	57.1 (5.7)	54.1 (7.3)	62.9 (8.3)	80.1 (6.6)	74.5 (9.0)	63.2 (4.8)	60.4 (6.8)	65.0 (5.1)	71.6 (3.1)	73.9 (3.7)	29.7 (3.8)	26.1 (9.0)	36.5 (8.4)	46.8 (11.5)	60.0 (14.7)
	High	36.9 (4.8)	28.7 (4.0)	28.8 (3.6)	28.0 (4.1)	23.7 (2.5)	40.0 (4.1)	34.4 (4.4)	25.7 (4.8)	26.4 (2.9)	30.6 (3.2)	38.4 (5.9)	39.0 (4.7)	33.1 (6.3)	27.7 (5.3)	30.1 (5.5)	31.7 (4.1)	23.0 (6.2)	24.9 (3.9)	19.5 (3.7)	25.0 (3.5)	49.7 (11.2)	28.8 (3.8)	32.3 (3.6)	22.3 (2.8)	28.7 (4.1)
	Mean	47.2	47.9	50.1	55.3	51.9	54.2	56.2	56.0	63.0	65.3	50.7	50.8	53.3	57.9	59.5	52.3	47.8	54.8	57.2	58.5	48.5	43.3	49.7	48.5	54.0
Spartina patens (Transplant)	Low	78.1 (4.2)	66.7 (3.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	71.9 (2.2)	72.9 (5.0)	46.3 (---)	0.0 (0.0)	0.0 (0.0)	72.9 (4.2)	73.6 (2.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	70.3 (1.6)	70.1 (3.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	68.5 (3.4)	52.5 (11.9)	0.0 (0.0)	66.4 (---)	0.0 (0.0)
	Mid	65.2 (3.7)	51.4 (11.1)	61.6 (---)	80.6 (---)	0.0 (0.0)	2.0 (2.0)	0.0 (0.0)	46.6 (10.6)	0.0 (0.0)	0.0 (0.0)	52.1 (2.2)	58.0 (5.5)	44.5 (---)	51.7 (7.8)	26.5 (7.3)	61.7 (3.1)	59.2 (2.4)	0.0 (0.0)	0.0 (0.0)	36.8 (1.9)	53.2 (2.3)	35.9 (11.7)	51.4 (0.8)	0.0 (0.0)	0.0 (0.0)
	High	23.8 (10.4)	47.7 (5.2)	50.2 (4.3)	46.6 (8.1)	51.0 (11.0)	32.3 (10.3)	39.0 (10.2)	0.0 (0.0)	35.9 (10.1)	36.6 (8.3)	46.1 (9.4)	42.8 (5.4)	49.5 (6.1)	34.1 (5.6)	41.3 (3.8)	60.0 (2.3)	45.2 (6.7)	52.5 (6.0)	41.5 (6.7)	34.8 (4.7)	73.4 (3.7)	31.0 (20.5)	52.4 (1.8)	20.9 (---)	46.5 (---)
	Mean	57.3	57.4	53.1	55.1	51.9	45.3	43.0	46.5	35.9	36.6	59.3	59.8	48.5	39.1	36.4	64.4	55.9	52.5	41.5	35.4	66.4	42.3	51.4	43.7	46.5

* Evaluation dates: 1 - 22-25 August; 2 - 6-8 September; 3 - 21-22 September; 4 - 4-5 October; 5 - 9 November 1976.

** Mean.

\+ Standard deviation of mean.

++ Second application of fertilizer made on 28 September 1976. Before this time $F_1 = F_4$ and $F_3 = 1/2\ F_1$.

Table 16

Stem Density (Per Quadrat) in Marsh Plot Experiments During 1976 Growing Season

Species	Elevation	Fertilizer Application F0 1*	F0 2	F0 3	F0 4	F0 5	F1 1	F1 2	F1 3	F1 4	F1 5	F2 1	F2 2	F2 3	F2 4	F2 5	F3 1	F3 2	F3 3	F3 4	F3 5	F4 1	F4 2	F4 3	F4 4	F4 5
Spartina alterniflora (Transplant)	Low	9.1** (1.3)+	12.4 (1.8)	20.4 (3.1)	18.4 (2.3)	45.7 (6.7)	11.2 (0.6)	14.8 (2.2)	18.0 (3.3)	21.1 (3.3)	45.6 (6.9)	9.7 (1.7)	12.1 (2.7)	15.7 (3.4)	17.3 (5.2)	51.9 (16.4)	12.6 (1.2)	17.1 (2.5)	20.4 (2.8)	25.6 (5.2)	46.6 (7.5)	13.4 (1.7)	16.0 (2.8)	22.2 (3.5)	25.7 (4.1)	63.3 (13.1)
	Mid	19.8 (1.8)	22.3 (1.9)	29.0 (3.6)	32.3 (4.0)	50.3 (6.7)	15.1 (2.0)	20.0 (2.5)	32.9 (4.2)	40.1 (5.5)	79.6 (12.2)	13.6 (3.0)	17.6 (4.7)	25.5 (6.7)	30.0 (7.8)	57.5 (16.1)	20.4 (2.8)	23.3 (2.8)	36.3 (3.9)	47.0 (5.7)	80.0 (11.2)	9.3 (2.6)	13.8 (3.8)	20.2 (5.1)	22.5 (6.7)	56.0 (20.9)
	High	10.3 (1.6)	7.1 (1.6)	8.7 (1.8)	8.7 (2.2)	9.2 (2.8)	6.3 (1.3)	7.7 (1.5)	7.9 (1.2)	7.9 (2.0)	10.7 (2.4)	6.0 (1.9)	7.4 (2.4)	9.8 (3.5)	9.9 (3.8)	15.7 (5.5)	5.2 (1.1)	6.3 (1.6)	6.5 (1.6)	6.4 (1.6)	7.9 (2.3)	9.2 (1.3)	10.0 (1.7)	10.9 (2.0)	12.2 (2.7)	17.4 (6.0)
	Mean	13.1	14.0	19.4	19.8	35.0	11.2	14.7	20.5	24.2	48.0	9.6	12.6	16.9	19.0	44.4	12.7	15.9	21.7	27.1	46.2	10.8	13.0	17.5	19.8	44.3
Spartina patens (Transplant)	Low	7.7 (1.1)	3.8 (1.0)	1.3 (0.3)	0.0 (0.0)	0.0 (0.0)	7.9 (0.9)	2.7 (0.3)	1.5 (0.5)	0.0 (0.0)	0.0 (0.0)	6.9 (0.9)	2.9 (0.8)	1.3 (0.3)	1.0 (0.0)	0.0 (0.0)	8.9 (0.8)	3.8 (0.9)	1.0 (0.0)	2.0 (0.0)	0.0 (0.0)	7.2 (1.2)	0.8 (0.2)	2.0 (0.0)	1.0 (0.0)	0.0 (0.0)
	Mid	5.7 (1.6)	2.2 (0.7)	4.2 (0.7)	2.2 (0.5)	3.5 (1.5)	3.0 (0.0)	3.0 (0.0)	--- (---)	--- (---)	0.0 (0.0)	6.7 (1.1)	5.2 (1.3)	3.0 (0.8)	5.0 (2.5)	4.5 (2.6)	5.7 (1.1)	5.3 (1.2)	4.2 (1.0)	3.3 (0.9)	3.0 (0.7)	10.3 (0.9)	5.0 (2.2)	6.8 (2.3)	5.7 (2.2)	4.5 (0.5)
	High	2.1 (1.0)	6.7 (0.3)	6.7 (0.9)	17.3 (1.2)	56.3 (5.0)	3.5 (1.4)	5.0 (1.6)	6.8 (1.5)	14.0 (5.8)	71.6 (32.3)	3.3 (1.4)	5.0 (1.4)	10.5 (4.0)	9.2 (3.1)	50.2 (20.6)	3.6 (0.7)	4.6 (1.5)	8.9 (3.1)	9.9 (2.3)	50.0 (20.0)	1.3 (1.0)	2.0 (1.0)	1.5 (0.5)	1.0 (0.0)	4.0 (0.0)
	Mean	5.1	3.7	4.1	7.9	35.2	5.0	2.9	5.0	14.0	71.6	5.5	4.2	5.5	6.9	31.9	6.2	4.6	5.6	7.4	34.3	5.8	2.8	4.6	3.8	4.3

* Evaluation dates: 1 - 22-25 August; 2 - 6-8 September; 3 - 21-22 September; 4 - 4-5 October; 5 - 9 November 1976.

** Mean.

+ Standard deviation of mean.

Table 17

Number of Stems Per Plant in Marsh Plot Experiments During 1976 Growing Season

		Fertilizer Application																								
		F_0					F_1					F_2					F_3					F_4				
Species	Elevation	1*	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Spartina alterniflora (Transplant)	Low	1.1** (0.1)+	1.2 (4.1)	2.9 (0.2)	2.8 (0.2)	7.3 (0.6)	1.2 (0.1)	--- (---)	2.5 (0.4)	3.0 (0.2)	7.1 (0.9)	1.4 (0.1)	1.6 (0.2)	2.7 (0.4)	4.1 (0.7)	9.0 (2.1)	1.3 (0.1)	1.9 (0.3)	2.6 (0.2)	2.9 (0.3)	6.1 (0.6)	1.3 (0.1)	1.3 (0.3)	2.7 (0.4)	3.3 (0.5)	8.4 (1.4)
	Mid	1.9 (0.1)	2.2 (0.2)	3.0 (0.3)	3.4 (0.3)	5.3 (0.6)	1.6 (0.1)	2.4 (0.3)	3.9 (0.2)	4.7 (0.4)	9.4 (0.8)	1.6 (0.2)	1.6 (0.3)	3.0 (0.5)	4.6 (0.2)	7.8 (1.3)	1.9 (0.2)	3.5 (---)	3.7 (0.2)	4.7 (0.4)	8.1 (0.8)	1.5 (0.2)	1.4 (0.1)	3.0 (0.5)	3.5 (0.7)	8.0 (2.2)
	High	16.1 (14.6)	1.2 (0.2)	4.8 (3.2)	1.7 (0.2)	2.0 (0.2)	1.3 (0.1)	1.7 (0.2)	1.8 (0.2)	2.6 (0.7)	3.1 (1.1)	1.4 (0.2)	1.7 (0.4)	2.1 (0.4)	2.7 (0.4)	2.2 (1.1)	1.2 (0.1)	1.5 (0.2)	1.5 (0.1)	1.7 (0.1)	2.0 (0.3)	1.4 (0.2)	1.0 (---)	1.8 (0.1)	2.0 (0.2)	2.6 (0.5)
	Mean	6.4 (4.9)	1.5 (0.2)	3.5 ( )	2.6 (0.2)	4.8 (0.5)	1.4 (0.1)	2.0 (0.2)	2.8 ( )	3.5 (0.3)	6.8 (0.7)	1.4 (0.1)	1.6 (0.2)	2.6 ( )	3.7 (0.3)	7.3 (1.0)	1.5 (0.1)	1.8 (0.3)	2.6 ( )	3.2 (0.3)	5.5 (0.6)	1.4 (0.1)	1.3 (0.2)	2.4 ( )	2.9 (0.3)	6.1 (0.9)
Spartina patens (Transplant)	Low	1.0 (0.0)	1.0 (0.0)	--- (---)	--- (---)	--- (---)	1.0 (0.0)	1.0 (0.0)	1.0 (---)	--- (---)	--- (---)	1.0 (0.0)	1.0 (0.0)	--- (---)	--- (---)	--- (---)	1.0 (0.0)	1.0 (---)	--- (---)	--- (---)	--- (---)	1.8 (0.8)	1.0 (0.0)	--- ---	1.0 (---)	--- (---)
	Mid	1.0 (0.0)	1.0 (0.0)	1.0 (---)	1.0 (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	1.0 (0.0)	1.0 (0.0)	1.0 (---)	2.2 (1.2)	1.8 (0.4)	1.0 (0.0)	1.0 (0.0)	--- (---)	--- (---)	2.1 (0.5)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	--- (---)	--- (---)
	High	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.9 (0.5)	8.7 (1.1)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.3 (0.6)	9.6 (3.8)	1.0 (0.0)	1.0 (0.0)	2.3 (0.3)	1.6 (0.2)	7.2 (2.0)	1.0 (0.0)	1.0 (0.0	1.5 (0.2)	2.4 (0.6)	7.5 (1.9)	1.0 (0.0)	1.0 (0.0)	--- (---)	1.0 (---)	2.0 (---)
	Mean	1.0 (0.0)	1.0 (0.0)	1.0 ( )	2.4 (0.6)	8.7 (1.1)	1.0 (0.0)	1.0 (0.0)	1.0 ( )	2.3 (0.6)	9.6 (3.8)	1.0 (0.0)	1.0 (0.0)	2.0 ( )	1.8 (0.3)	5.4 (1.6)	1.0 (0.0)	1.0 (0.0)	1.5 ( )	2.4 (0.6)	6.0 (1.6)	1.4 (0.4)	1.0 (0.0)	1.0 ( )	1.0 (0.0)	2.0 (---)

* Evaluation dates: 1 - 22-25 August; 2 - 6-8 September; 4 - 4-5 October; 5 - 9 November 1976.

** Mean.

\+ Standard deviation of mean.

Table 18

Number of Invading Plant Species per Quadrat in Marsh Plot Experiment

		Fertilizer Application																								
		F_0					F_1					F_2					F_3					F_4				
Species	Elevation	1*	5	6	8	9	1	5	6	8	9	1	5	6	8	9	1	5	6	8	9	1	5	6	8	9
Spartina alterniflora (Transplant)	Low	0.0** (0.0)+	0.0 (0.0)	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.9 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.9 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	7.8 (0.7)	0.0 (0.0)	0.0 (0.0)
	Mid	0.0 (0.0)	0.0 (0.0)	0.9 (0.3)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.2 (0.1)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)	0.0 (0.0)	0.0 (0.0)
	High	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.9 (0.4)	1.0 (0.4)	0.1 (0.1)	0.1 (0.1)	0.3 (0.2)	0.6 (0.3)	0.9 (0.4)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.3 (0.2)	1.0 (0.4)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.8 (0.2)	0.6 (0.2)	0.0 (0.0)	0.1 (0.1)	0.4 (0.2)	1.3 (0.3)	1.1 (0.4)
	Mean	0.0 (0.0)	0.0 (0.0)	0.7 (0.1)	0.4 (0.1)	0.3 (0.2)	0.04 (0.04)	0.04 (0.04)	0.8 (0.1)	0.2 (0.1)	0.3 (0.1)	0.0 (0.0)	0.0 (0.0)	0.4 (0.1)	0.1 (0.1)	0.3 (0.2)	0.0 (0.0)	0.0 (0.0)	0.7 (0.1)	0.3 (0.1)	0.2 (0.1)	0.0 (0.0)	0.04 (0.04)	0.7 (0.1)	0.4 (0.2)	0.4 (0.2)
Spartina patens (Transplant)	Low	0.0 (0.0)	0.0 (0.0)	0.5 (0.2)	0.0 (0.0)	0.1++ (0.1)	0.0 (0.0)	0.0 (0.0)	0.4 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.1 (0.1)	0.0 (0.0)
	Mid	0.0 (0.0)	0.0 (0.0)	0.5 (0.3)	0.3 (0.2)	0.4 (0.2)	0.0 (0.0)	0.0 (0.0)	0.4 (0.2)	0.4 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.2)	0.4 (0.2)	0.3 (0.2)	0.0 (0.0)	0.0 (0.0)	0.7 (0.2)	0.2 (0.1)	0.4 (0.2)	0.0 (0.0)	0.0 (0.0)	0.6 (0.2)	0.3 (0.2)	0.4 (0.2)
	High	0.0 (0.0)	0.1 (0.1)	0.4 (0.2)	0.9 (0.3)	0.7 (0.2)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.6 (0.2)	0.3 (0.2)	0.1 (0.1)	0.5 (0.3)	0.4 (0.2)	0.7 (0.2)	0.7 (0.2)	0.1 (0.1)	0.4 (0.3)	0.4 (0.3)	0.8 (0.3)	0.8 (0.2)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.8 (0.3)	0.7 (0.3)
	Mean	0.0 (0.0)	0.04 (0.04)	0.5 (0.1)	0.4 (0.1)	0.4 (0.1)	0.0 (0.0)	0.0 (0.0)	0.3 (0.1)	0.3 (0.1)	0.2 (0.1)	0.04 (0.04)	0.2 (0.1)	0.5 (0.1)	0.4 (0.1)	0.3 (0.1)	0.04 (0.04)	0.1 (0.1)	0.4 (0.1)	0.3 (0.1)	0.4 (0.1)	0.0 (0.0)	0.0 (0.0)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)

* Evaluation dates: 1 - 22-25 August 1976; 5 - 9 November 1976; 6 - 24 February 1977; 8 - 27 June 1977; 9 - 11-14 October 1977.

** Mean.

\+ Standard deviation of mean.

Table 19

Number of Invading Plants (Individuals) per Quadrat in Marsh Plot Experiments

Species	Elevation	Fertilizer Application: F_0 1*	F_0 5	F_0 6	F_0 8	F_0 9	F_1 1	F_1 5	F_1 6	F_1 8	F_1 9	F_2 1	F_2 5	F_2 6	F_2 8	F_2 9	F_3 1	F_3 5	F_3 6	F_3 8	F_3 9	F_4 1	F_4 5	F_4 6	F_4 8	F_4 9
Spartina alterniflora (Transplant)	Low	0.0** (0.0)+	0.0 (0.0)	12.2 (3.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	15.7 (6.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2.6 (1.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	10.3 (3.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	17.3 (3.1)	0.0 (0.0)	0.0 (0.0)
	Mid	0.0 (0.0)	0.0 (0.0)	7.4 (3.3)	1.0 (0.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	9.0 (2.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	7.6 (3.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	11.7 (2.9)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.8 (0.9)	0.0 (0.0)	0.0 (0.0)
	High	0.0 (0.0)	0.0 (0.0)	0.6 (0.4)	6.2 (4.9)	2.3 (1.1)	0.1 (0.1)	1.2 (1.2)	0.6 (0.4)	2.7 (1.6)	4.6 (2.2)	0.0 (0.0)	0.0 (0.0)	4.2 (4.2)	0.3 (0.2)	3.3 (1.8)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	1.3 (0.4)	0.9 (0.4)	0.0 (0.0)	1.4 (1.4)	1.1 (0.7)	2.6 (0.9)	8.6 (6.5)
	Mean	0.0 (0.0)	0.0 (0.0)	6.7 (1.8)	2.4 (1.7)	0.8 (0.4)	0.04 (0.04)	0.4 (0.4)	8.4 (2.6)	0.9 (0.6)	1.5 (0.8)	0.0 (0.0)	0.0 (0.0)	4.8 (2.0)	0.1 (0.1)	1.1 (0.7)	0.0 (0.0)	0.0 (0.0)	7.4 (1.8)	0.6 (0.2)	0.3 (0.2)	0.0 (0.0)	0.5 (0.5)	6.7 (1.8)	0.9 (0.4)	2.9 (2.2)
Spartina patens (Transplant)	Low	0.0 (0.0)	0.0 (0.0)	1.7 (0.8)	0.0 (0.0)	10.8++ (10.8)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.1 (0.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.6 (0.4)	1.1 (1.1)	0.0 (0.0)
	Mid	0.0 (0.0)	0.0 (0.0)	2.6 (1.5)	9.1 (8.3)	34.3 (26.5)	0.0 (0.0)	0.0 (0.0)	0.9 (0.5)	2.8 (1.6)	24.3 (18.9)	0.0 (0.0)	0.0 (0.0)	2.9 (1.3)	3.6 (2.3)	30.6 (16.4)	0.0 (0.0)	0.0 (0.0)	1.4 (0.7)	18.0 (17.8)	35.0 (27.5)	0.0 (0.0)	0.0 (0.0)	0.9 (0.4)	1.6 (1.3)	33.0 (18.4)
	High	0.0 (0.0)	1.4 (1.4)	0.4 (0.2)	3.3 (2.1)	7.3 (3.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	4.6 (3.1)	16.0 (8.5)	0.2 (0.2)	121.2 (83.8)	1.3 (0.7)	7.8 (3.4)	11.2 (4.9)	0.1 (0.1)	8.4 (7.0)	0.5 (0.4)	10.7 (8.7)	13.0 (10.2)	0.0 (0.0)	0.0 (0.0)	1.0 (0.7)	6.1 (3.5)	18.9 (10.9)
	Mean	0.0 (0.0)	0.5 (0.5)	1.5 (0.5)	4.1 (2.8)	17.5 (9.5)	0.0 (0.0)	0.0 (0.0)	0.6 (0.2)	2.5 (1.2)	13.4 (6.9)	0.08 (0.08)	40.4 (29.1)	1.8 (0.5)	3.8 (1.5)	13.9 (6.0)	0.04 (0.04)	2.8 (2.4)	0.7 (0.3)	9.6 (6.5)	16.0 (9.8)	0.0 (0.0)	0.0 (0.0)	0.9 (0.3)	2.9 (1.3)	17.3 (7.3)

* Evaluation dates: 1 - 22-25 August 1976; 5 - 9 November 1976; 6 - 24 February 1977; 8 - 27 June 1977; 9 - 11-14 October 1977.

** Mean.

\+ Standard deviation of mean.

Table 20

List of All Invading Plant Species in Marshland Plots at the End of the 1976 Growing Season in Order of Relative Abundance

Species	Total Number Recorded in All Quadrats*
Cyperus esculentus	108
Scirpus americanus	9
Cynodon dactylon	8
Sporobolus virginicus	8
Fimbristylis castaneum	1
Spartina alterniflora	1
Unknowns	6

* All invading species recorded were in tier 3.

Table 21

Miscellaneous Enviromental Effects in Marshland Plots at Bolivar Peninsula on 9 November 1976

Species	Fertilizer	Replication 1			Replication 2			Replication 3		
		Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
Spartina alterniflora sprig	(Lowest tier)									
	F_0	0	waves	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	0	0	0
	F_2	waves	0	waves	waves	waves	waves	0	0	0
	F_3	0	0	0	0	0	0	0	0	0
	F_4	0	0	0	0	0	0	0	0	0
	(Middle tier)									
	F_0	0	0	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	0	0	0
	F_2	0	0	0	waves	waves	waves	erosion	0	0
	F_3	0	0	0	0	0	0	0	0	0
	F_4	0	0	0	0	0	0	erosion	0	0
	(Highest tier)									
	F_0	0	0	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	waves	waves	0
	F_2	0	0	0	waves	waves	0	0	0	0
	F_3	0	0	0	waves	waves	0	waves	waves	waves
	F_4	0	0	0	0	0	0	0	0	0

(Continued)

Table 21 (Concluded)

Species	Fertilizer	Replication 1			Replication 2			Replication 3		
		Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
Spartina patens sprig	(Lowest tier)									
	F_0	0	0	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	0	0	0
	F_2	0	0	0	0	0	0	0	0	0
	F_3	waves	waves	waves	0	0	0	0	0	0
	F_4	0	0	0	0	0	0	0	0	0
	(Middle tier)									
	F_0	0	0	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	0	0	0
	F_2	erosion	0	0	0	0	0	0	0	0
	F_3	0	0	0	0	0	0	0	0	0
	F_4	0	0	0	0	0	0	0	0	0
	(Highest tier)									
	F_0	0	0	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	0	0	0
	F_2	erosion	erosion	erosion	0	0	0	0	0	0
	F_3	0	0	0	0	0	0	0	0	0
	F_4	0	0	0	0	0	0	0	0	0

Table 22

Percent Survival of Transplants in Marsh Plot Experiments

During 1977 Growing Season

		Fertilizer Application									
		F_0		F_1		F_2		F_3		F_4	
Species	Elevation	6*	8	6	8	6	8	6	8	6	8
Spartina alterniflora (Transplant)	Low	55.6** (5.7)+	---++ (---)	57.3 (4.6)	--- (---)	46.3 (5.9)	--- (---)	60.2 (7.3)	--- (---)	64.8 (6.2)	--- (---)
	Mid	80.6 (5.6)	--- (---)	70.4 (6.5)	--- (---)	50.0 (13.0)	--- (---)	81.5 (5.2)	--- (---)	37.0 (10.6)	--- (---)
	High	31.5 (8.0)	--- (---)	23.1 (6.9)	--- (---)	23.1 (8.5)	--- (---)	26.9 (7.5)	--- (---)	41.7 (9.4)	--- (---)
	Mean	55.9 (5.3)	--- (---)	50.0 (5.3)	--- (---)	39.8 (5.8)	--- (---)	56.2 (5.8)	--- (---)	47.8 (5.5)	--- (---)
Spartina patens (Transplant)	Low	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Mid	11.5 (5.4)	11.1 (5.7)	0.0 (0.0)	0.0 (0.0)	2.8 (2.0)	3.7 (2.0)	6.5 (3.9)	6.0 (3.0)	8.3 (4.4)	1.4 (1.4)
	High	15.0 (7.7)	15.7 (7.9)	27.8 (10.2)	26.9 (10.6)	34.3 (10.7)	35.2 (11.1)	41.7 (10.4)	40.0 (10.3)	2.8 (2.8)	2.8 (2.8)
	Mean	8.6 (3.3)	9.0 (3.4)	9.3 (4.2)	10.1 (4.7)	12.3 (4.6)	13.0 (4.8)	15.1 (4.9)	17.0 (5.4)	3.7 (1.8)	1.4 (1.1)

* Evaluation dates: 6 - 24 February; 8 - 27 June 1977.

** Mean.

+ Standard deviation of mean.

++ Survival was not measured because of density of plants.

Table 23

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 24 February - 2 March 1977 (Evaluation 6)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1 F_0	7 F_1	13 F_2	19 F_3	25 F_4	3 F_0	9 F_1	15 F_2	21 F_3	27 F_4
Survival, %	55.9	50.0	39.8	56.2	47.8	8.6	9.3	12.3	15.1	3.7
Height, cm	33.1	45.8	42.5	38.7	37.4	25.0	25.2	24.9	26.0	29.9
Density/m^2	19.9	28.5	31.8	27.0	23.9	14.5	36.4	27.1	24.6	5.3
Plants with tillers, %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No. of tillers/quadrat	59.7	85.5	96.9	77.2	71.7	43.6	109.3	81.4	73.6	15.8
Stems/surviving plant	8.2	12.4	13.6	9.5	9.1	8.1	14.8	14.7	10.1	5.1
Tillers/plant with tillers	8.2	12.4	13.8	8.8	9.1	8.1	14.8	14.7	10.1	5.1
Plants with animal damage/quadrat	4.0	3.9	3.9	4.1	3.6	1.6	2.3	2.8	2.8	0.3
Foliage cover, %	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Plants in flower, %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plants with seed, %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No. invading plants/quadrat	6.7	9.1	5.9	7.7	7.6	2.7	0.2	2.1	1.1	1.3
No. invading species/quadrat	0.7	0.8	0.5	0.8	0.8	0.6	0.2	0.8	0.5	1.0

Table 24

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots

On 27 June 1977 (Evaluation 8)

	Spartina alterniflora Plot Number and Fertilizer Treatment					*Spartina patens* Plot Number and Fertilizer Treatment				
	1	7	13	19	25	1	9	15	21	25
Parameter	F_0	F_1	F_2	F_3	F_4	F_0	F_1	F_2	F_3	F_4
Survival, %	---	---	---	---	---	9.0	10.1	13.0	17.0	1.4
Height, cm	87.9	96.6	80.2	90.2	77.4	73.3	86.2	80.6	78.1	31.7
Density/m^2	113.5	136.5	107.5	107.2	90.1	87.1	124.4	85.0	102.6	7.9
Stems/surviving plant	---	---	---	---	---	51.6	84.2	62.6	48.1	31.5
Plants with animal damage	0.5	0.4	0.6	0.7	1.1	0.0	0.0	0.0	0.0	0.0
Foliage cover, %	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Plants in flower, %	0.0	0.0	0.0	0.0	0.0	95.8	83.3	54.3	36.8	66.7
Plants with seed, %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.8	18.2	0.0
No. invading species/quadrat	0.4	0.2	0.1	0.3	0.4	0.4	0.3	0.4	0.3	0.4
No. invading plants/quadrat	2.4	0.9	0.1	0.6	0.9	4.1	2.5	3.8	9.6	2.9

Table 25

Stem Density (Per Quadrat) in Marsh Plot Experiments During 1977 Growing Season

Species	Elevation	Fertilizer Application F0 6*	F0 8	F0 9	F1 6	F1 8	F1 9	F2 6	F2 8	F2 9	F3 6	F3 8	F3 9	F4 6	F4 8	F4 9
Spartina alterniflora (Transplant)	Low	82.1** (9.3)+	454.2 (39.3)	714.7 (31.8)	93.8 (17.8)	486.0 (59.5)	778.3 (100.5)	100.7. (28.9)	441.0 (108.8)	562.0 (72.8)	86.2 (14.4)	386.0 (40.5)	587.0 (43.7)	96.0 (19.4)	394.4 (25.1)	680.0 (75.1)
	Mid	84.9 (10.8)	509.3 (65.3)	812.0 (57.8)	132.8 (16.0)	579.7 (71.8)	134.6 (4.3)	152.4 (38.3)	414.9 (124.7)	567.0 (141.6)	138.2 (15.6)	509.0 (47.6)	814.7 (58.8)	103.3 (38.1)	321.0 (123.2)	524.4 (157.2)
	High	12.1 (3.8)	58.3 (25.4)	98.0 (40.8)	15.4 (4.6)	92.9 (41.6)	96.3 (38.6)	21.5 (7.7)	64.7 (26.7)	104.7 (33.1)	10.6 (3.8)	39.0 (16.2)	126.8 (55.4)	26.3 (10.1)	101.8 (36.3)	219.2 (95.4)
	Mean	59.7 (8.1)	340.6 (47.1)	541.6 (66.8)	85.5 (12.9)	409.6 (53.4)	575.9 (77.7)	95.5 (19.7)	322.5 (66.1)	411.2 (67.2)	81.0 (12.6)	321.8 (44.5)	509.5 (63.4)	71.7 (14.0)	270.5 (46.5)	474.6 (73.9)
Spartina patens (Transplant)	Low	---++ (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)
	Mid	18.5 (14.2)	166.0 (44.5)	128.0 (92.0)	0.0 (---)	0.0 (0.0)	0.0 (---)	12.0 (7.0)	45.0 (36.0)	18.4 (13.9)	6.0 (2.1)	11.3 (2.2)	1.1 (0.8)	5.7 (2.7)	0.0 (0.0)	4.3 (3.4)
	High	77.0 (18.5)	357.0 (105.5)	131.6 (68.8)	109.3 (46.6)	559.9 (235.6)	463.0 (211.8)	104.5 (27.6)	360.2 (26.1)	379.9 (110.8)	99.0 (38.4)	432.8 (90.8)	534.3 (113.2)	46.0 (---)	95.0 (---)	7.9 (7.9)
	Mean	43.6 (15.7)	261.5 (66.7)	86.5 (38.7)	109.3 (46.6)	373.3 (178.4)	154.3 (80.2)	81.4 (25.3)	255.1 (56.1)	132.8 (49.5)	73.6 (30.3)	317.8 (87.8)	178.5 (61.2)	15.8 (10.3)	23.8 (23.8)	4.1 (2.8)

* Evaluation dates: 6 - 24 February; 8 - 27 June; 9 - 11-14 October

** Mean.

\+ Standard deviation of mean.

++ No survival.

Table 26

Plant Height in Marsh Plot Experiments During 1977 Growing Season

Species	Elevation	Fertilizer Application														
		F_0			F_1			F_2			F_3			F_4		
		6*	8	9	6	8	9	6	8	9	6	8	9	6	8	9
Spartina alterniflora (Transplant)	Low	53.7**	127.5	153.8	58.1	123.2	157.7	55.1	103.7	146.1	52.2	113.1	145.3	54.2	106.8	139.7
		(5.5)+	(5.1)	(4.4)	(6.2)	(2.2)	(4.4)	(4.6)	(4.1)	(4.3)	(4.4)	(2.4)	(43.7)	(4.9)	(5.5)	(75.1)
	Mid	32.8	89.9	120.4	57.8	112.2	134.6	48.1	86.3	110.1	45.8	107.2	142.7	41.2	69.6	101.7
		(4.0)	(8.0)	(5.7)	(7.3)	(6.3)	(4.3)	(8.5)	(15.0)	(17.6)	(2.8)	(3.6)	(3.1)	(11.7)	(14.1)	(17.1)
	High	13.0	46.7	67.8	16.6	42.2	82.4	17.1	43.0	75.5	15.5	45.4	78.9	18.1	55.0	83.4
		(1.1)	(5.6)	(11.9)	(1.4)	(5.4)	(11.1)	(1.4)	(6.5)	(8.3)	(2.1)	(4.7)	(5.5)	(2.4)	(5.2)	(4.1)
	Mean	33.1	88.0	115.8	45.8	96.6	130.2	42.5	80.2	110.6	38.7	90.2	119.8	37.4	77.4	108.3
		(3.9)	(7.6)	(8.2)	(5.1)	(7.5)	(7.0)	(4.7)	(7.4)	(8.5)	(3.6)	(6.3)	(7.1)	(4.7)	(6.6)	(7.4)
Spartina patens (Transplant)	Low	---++	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)	(---)
	Mid	25.5	80.3	80.6	---	---	---	22.3	60.9	75.5	37.2	58.2	65.9	30.1	9.0	49.5
		(8.3)	(4.4)	(7.9)	(---)	(---)	(---)	(8.0)	(13.1)	(17.7)	(11.5)	(6.0)	(11.9)	(4.5)	(---)	(13.7)
	High	24.3	66.3	63.8	25.2	86.2	67.4	25.8	90.4	69.7	21.8	85.5	71.4	29.2	54.4	47.5
		(2.5)	(3.8)	(0.3)	(4.8)	(7.9)	(12.1)	(3.5)	(1.8)	(2.4)	(2.7)	(4.7)	(2.7)	(---)	(---)	(---)
	Mean	25.0	73.3	72.2	25.2	86.2	67.4	24.9	80.6	71.1	26.0	78.1	70.3	29.9	31.7	48.8
		(4.5)	(4.1)	(5.2)	(4.8)	(7.9)	(12.1)	(3.0)	(6.3)	(3.9)	(4.0)	(5.3)	(2.8)	(3.2)	(22.7)	(7.9)

* Evaluation dates: 6 - 24 February; 8 - 27 June; 9 - 11-14 October

** Mean in cm.

+ Standard deviation of mean.

++ No survival.

Table 27

Number of Stems Per Plant in Marsh Plot Experiments

During 1977 Growing Season

Species	Elevation	Fertilizer Application									
		F_0		F_1		F_2		F_3		F_4	
		6*	8	6	8	6	8	6	8	6	8
Spartina alterniflora (Transplant)	Low	12.7** (1.0)+	77.4 (0.0)	13.2 (3.6)	72.6 (0.0)	16.9 (3.6)	74.2 (0.0)	11.5 (1.5)	58.4 (0.0)	11.5 (1.7)	56.8 (0.0)
	Mid	8.8 (0.9)	55.0 (0.0)	15.7 (1.2)	77.3 (0.0)	17.2 (3.2)	40.3 (0.0)	13.9 (1.0)	52.1 (0.0)	13.1 (3.6)	38.2 (0.0)
	High	3.2 (0.6)	19.8 (0.0)	7.2 (4.3)	22.5 (0.0)	4.6 (0.8)	11.6 (0.0)	2.3 (0.4)	9.1 (0.0)	4.0 (1.0)	15.5 (0.0)
	Mean	8.2 (0.9)	50.8 (0.0)	12.4 (1.6)	57.5 (0.0)	13.6 (2.1)	42.1 (0.0)	9.5 (1.1)	39.9 (0.0)	9.1 (1.4)	36.9 (0.0)
Spartina patens (Transplant)	Low	---++ (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)
	Mid	4.6 (2.5)	40.6 (5.9)	--- (---)	--- (---)	10.8 (8.3)	6.0 (---)	2.6 (0.5)	6.7 (1.7)	1.7 (0.5)	--- (---)
	High	12.7 (2.8)	62.5 (16.6)	14.8 (5.1)	84.2 (31.6)	16.0 (1.8)	72.1 (17.1)	12.9 (3.1)	74.0 (14.1)	15.3 (---)	31.5 (---)
	Mean	8.1 (2.4)	51.6 (9.3)	14.8 (5.1)	84.2 (31.6)	14.6 (2.2)	62.6 (17.3)	10.1 (2.7)	48.1 (12.7)	5.1 (3.4)	31.5 (---)

* Evaluation dates: 6 - 24 February; 8 - 27 June.

** Mean.

+ Standard deviation of mean.

Table 28

Seedling Emergence (per m^2) in Marshland. Plots Were Seeded 21-23 March 1977 At 100 Seeds per m^2

Species	Elevation	F0 1*	F0 2	F0 3	F1 1	F1 2	F1 3	F2 1	F2 2	F2 3	F3 1	F3 2	F3 3	F4 1	F4 2	F4 3	Mean 1	Mean 2	Mean 3
Spartina alterniflora	Low	0.0** (0.0)+	0.0 (0.0)	---++ (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)
	Mid	7.7 (3.9)	1.0 (0.7)	--- (---)	4.0 (2.0)	0.0 (0.0)	--- (---)	8.8 (4.4)	3.6 (2.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	5.1 (3.7)	0.0 (0.0)	--- (---)	5.5 (1.5)	0.9 (0.4)	--- (---)
	High	16.0 (5.1)	12.3 (5.3)	14.1 (7.3)	27.0 (9.8)	21.8 (10.1)	28.5 (15.0)	18.5 (6.5)	17.0 (5.4)	16.3 (6.9)	43.1 (11.3)	39.0 (11.5)	45.9 (14.2)	13.8 (4.9)	0.0 (0.0)	0.4 (0.4)	23.8 (3.8)	19.4 (4.2)	21.1 (4.9)
	Mean	7.9 (2.4)	4. (2.0)	14.1 (7.3)	10.3 (4.0)	6.7 (3.6)	28.5 (15.0)	8.7 (2.8)	5.6 (2.0)	16.3 (6.9)	16.2 (6.0)	13.0 (5.2)	45.9 (14.2)	6.3 (2.3)	0.0 (0.0)	0.4 (0.4)	9.8 (1.6)	6.1 (1.5)	21.1 (4.9)
Spartina patens	Low	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)
	Mid	0.0 (0.0)	0.0 (0.0)	--- (---)	0.3 (0.3)	0.3 (0.3)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.0 (0.0)	0.0 (0.0)	--- (---)	0.1 (0.1)	0.1 (0.1)	--- (---)
	High	4.7 (2.0)	4.0 (1.8)	10.8 (3.5)	0.3 (0.3)	0.8 (0.5)	1.5 (1.1)	1.0 (0.5)	1.1 (0.8)	4.4 (2.6)	0.0 (0.0)	0.0 (0.0)	5.2 (1.4)	0.0 (0.0)	0.5 (0.5)	8.5 (4.9)	1.2 (0.5)	1.5 (0.5)	6.1 (1.4)
	Mean	1.8 (0.9)	1.4 (0.7)	10.8 (3.5)	0.2 (0.2)	0.3 (0.2)	1.5 (1.1)	0.4 (0.2)	0.3 (0.2)	4.4 (2.6)	0.0 (0.0)	0.0 (0.0)	5.2 (1.4)	0.0 (0.0)	0.0. (0.1)	8.5 (4.9)	2.0 (0.2)	0.4 (0.2)	6.1 (1.4)

* Evaluation dates: 1 - 13-14 April; 2 - 27 April; 3 - 2 June 1977.

** Mean.

+ Standard error of mean.

++ Tiers 1 and 2 not evaluated because of high water.

Table 29

Means for Parameters Measured in Seeded Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 27 June 1977 (Evaluation 8)

Parameter	*Spartina alterniflora*	*Spartina patens*
Density/m^2	22.9	11.5
Height, cm	22.8 (1.6)⁺	23.3 (1.6)
No. Plants with Animal Damage/m^2	18.4 (4.0)	1.3 (0.6)
Foliage cover, %	1.1 (0.1)	1.0 (0.1)
No. plants in flower, %	0	0
No. plants with seed heads, %	0	0

⁺ Standard deviation of mean.

Table 30

Means for Parameters Measured in Seeded Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 27 June 1977 (Evaluation 8)

Parameter	*Spartina alterniflora* Tier Number 1	2	3	*Spartina patens* Tier Number 1	2	3
Density/m^2	0	4.2	53.4	0	1.6	33.2
Height, cm	0	22.4 (3.6)⁺	23.8 (1.5)	0	28.0 (1.2)	22.6 (1.8)
No. plants with animal damage/m^2	0	4.2 (2.6)	42.4 (8.1)	0	1.9 (1.1)	1.2 (0.6)
Foliage cover, %	0	< 1	< 1	0	< 1	< 1
No. plants in flower %	0	0	0	0	0	0
No. plants with seed heads, %	0	0	0	0	0	0

⁺ Standard deviation of mean.

Table 31

Means for Parameters Measured in Seeded Plots of *Spartina alterniflora* and *Spartina patens* in Marshland Plots on 27 June 1977 (Evaluation 8)

	Spartina alterniflora Fertilizer Treatment					*Spartina patens* Fertilizer Treatment				
Parameter	F_0	F_1	F_2	F_3	F_4	F_0	F_1	F_2	F_3	F_4
Density/m^2	18	21.2	25.5	40.1	4.1	6.0	5.2	6.3	19.1	20.5
Height, cm	23.0 (4.7)+	23.1 (3.8)	22.7 (2.7)	22.8 (2.2)	22.1 (3.3)	19.0 (3.5)	28.0 (1.2)	19.2 (4.3)	25.8 (1.8)	30.4 (0.9)
No. plants with animal damage	10.0 (5.7)	23.4 (10.8)	23.1 (9.0)	26.8 (9.2)	2.4 (1.1)	0.1 (0.1)	6.3 (3.6)	0.5 (0.3)	0.4 (0.4)	1.0 (1.0)
Foliage cover, %	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
No. plants in flower, %	0	0	0	0	0	0	0	0	0	0
No. plants with seed heads, %	0	0	0	0	0	0	0	0	0	0
No. of plants stressed/quadrat	0	0.3 (0.2)	1.0 (0.7)	0	0	0	0	0	0	0

+ Standard deviation of the mean.

Table 32

Means for Parameters Measured in Sprigged Plots of *Spartina alterniflora* and *Spartina patens*

In Marshland plots 11-14 October 1977 (Evaluation 9)

Parameter	*Spartina alterniflora* Plot Number and Fertilizer Treatment						*Spartina patens* Plot Number and Fertilizer Treatment					
	1 F_0	7 F_1	13 F_2	19 F_3	25 F_4	Mean	3 F_0	9 F_1	15 F_2	21 F_3	27 F_4	Mean
Density, quadrat	541.6 (66.8)*	575.9 (77.7)	411.2 (67.2)	509.5 (63.4)	474.6 (73.9)	502.5 (31.2)	86.5 (38.7)	154.3 (80.2)	132.8 (49.5)	178.5 (61.2)	4.1 (2.8)	111.2 (24.0)
Height, cm	115.8 (8.2)	130.2 (7.0)	110.6 (8.5)	119.8 (7.1)	108.3 (7.4)	116.5 (3.5)	72.2 (5.2)	67.4 (12.1)	71.1 (3.9)	70.3 (2.8)	48.8 (7.9)	68.4 (2.7)
No. of plants with animal damage/quadrat	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Foliage cover, %	10-25	25-50	10-25	10-25	10-25	10-25	< 1	< 10	< 10	< 10	< 1	< 10
Root biomass, g/0.1 m^2	107.7 (16.7)	146.4 (24.1)	165.4 (34.3)	128.4 (19.7)	128.8 (27.3)	135.1 (11.1)	72.6 (13.7)	295.0 (104.8)	170.3 (50.6)	99.3 (21.8)	58.3 (20.7)	128.0 (21.6)
Shoot biomass, g/0.1 m^2	122.1 (23.9)	141.9 (20.8)	119.5 (20.5)	103.7 (19.1)	103.7 (23.3)	124.1 (9.6)	56.6 (9.1)	144.7 (43.0)	106.2 (28.1)	89.0 (14.5)	44.7 (10.0)	85.3 (10.4)
Root:shoot ratio	1.2 (0.1)	1.5 (0.1)	1.5 (0.2)	1.7 (0.1)	1.7 (0.2)	1.3 (0.1)	1.4 (0.2)	1.9 (0.2)	1.5 (0.1)	1.3 (0.3)	1.3 (0.4)	1.4 (0.1)
Seed production, g/quadrat	36.2 (5.7)	36.7 (5.9)	36.0 (7.8)	39.8 (6.0)	21.9 (4.5)	--- (---)	13.9 (6.8)	36.7 (16.7)	28.0 (7.7)	33.1 (10.2)	1.4 (1.4)	--- (---)
Seed production, g/0.1 m^2	7.1 (2.0)	8.2 (44.0)	8.2 (1.8)	7.2 (1.2)	5.4 (1.7)	7.0 (0.7)	---** (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)
Total biomass, g/0.1 m^2	236.9 (40.2)	293.2 (1.3)	293.2 (53.3)	238.0 (37.5)	238.0 (50.3)	268.0 (20.1)	58.0 (---)	449.7 (---)	276.5 (---)	188.3 (---)	103.0 (---)	213.3 (---)

* Standard deviation of mean.

** Not measured on plants taken in 0.1 m^2 areas of *S. patens.*

Table 33

Means for Parameters Measured in Seeded Plots of *Spartina alterniflora* and *Spartina patens* In Marshland Plots on 14 October 1977 (Evaluation 9)

Parameter	*Spartina alterniflora* Fertilizer Treatment F_0	F_1	F_2	F_3	F_4	Mean	*Spartina patens* Fertilizer Treatment F_0	F_1	F_2	F_3	F_4	Mean
Density, 3 m^2	77.6 (33.1)*	143.2 (51.0)	135.3 (40.3)	205.8 (75.7)	8.0 (4.2)	113.3 (21.3)	119.6 (43.9)	8.8 (8.7)	83.6 (30.5)	147.4 (57.5)	91.6 (50.8)	90.2 (18.9)
Height, cm	54.4 (9.5)	69.6 (8.1)	80.4 (4.3)	74.5 (9.1)	30.7 (5.4)	62.1 (4.2)	52.0 (6.2)	30.8 (23.7)	56.4 (2.8)	68.2 (3.4)	75.6 (2.5)	58.0 (3.4)
No. plants with animal damage, 3 m^2	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Foliage cover, %**	< 10	< 10	< 10	< 10	< 1	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Root biomass, g/0.1 m^2	21.2 (7.4)	44.3 (13.0)	31.7 (5.3)	55.2 (13.1)	7.2 (1.6)	32.5 (4.9)	21.7 (4.3)	43.2 (7.7)	47.8 (5.3)	52.7 (8.5)	92.4 (21.1)	45.7 (4.9)
Shoot biomass, g/0.1 m^2	11.2 (2.6)	20.6 (5.4)	27.5 (4.9)	31.4 (6.0)	7.4 (1.8)	19.1 (2.3)	20.5 (5.1)	41.7 (2.7)	47.7 (7.7)	49.7 (9.4)	82.5 (18.4)	43.5 (5.0)
Root:shoot ratio	1.6 (0.2)	2.2 (0.3)	1.3 (0.2)	1.8 (0.2)	1.1 (0.2)	1.7 (0.1)	1.3 (0.3)	1.1 (0.3)	1.2 (0.2)	1.2 (0.1)	1.1 (0.0)	1.2 (0.1)
Total biomass, g/0.1 m^2	33.0 (9.9)	66.1 (17.8)	62.0 (10.5)	88.0 (19.1)	14.8 (3.0)	52.8 (7.1)	42.2 (---)	84.9 (---)	17.4 (---)	65.9 (15.0)	--- (---)	89.3 (19.2)
Seeds produced, g/3 m^2	1.9 (0.7)	7.6 (2.6)	6.3 (1.8)	9.5 (2.2)	0.5 (0.4)	--- (---)	0.8 (0.8)	--- (---)	1.4 (0.7)	7.9 (1.9)	9.9 (---)	--- (---)
Grams of seed, g/0.1 m^2+	0.6 (0.2)	1.3 (0.4)	2.7 (1.0)	1.4 (0.4)	0.2 (0.1)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)	0.2 (0.1)

* Standard error of mean.

** Analysis of variance F-test for differences in fertilizer treatments significant at P < 0.10.

\+ Analysis of variance F-test for differences in fertilizer treatments significant at P < 0.05.

Table 34

Number of Invading Plants in Marshland Plots by Tier

11-14 October 1977 (Evaluation 9)

Tier	Species	Number Invading
Low	*Spartina alterniflora*	156
Middle	*Spartina alterniflora*	3582
High	*Spartina alterniflora*	5920
	Sporobolus virginicus	892
	Spartina patens	127
	Scirpus americanus	112
	Fimbristylis castaneum	69
	Cyperus esculentus	33
	Salicornia spp.	19
	Cynodon dactylon	6
	Unknown forb	4
	Sesuviun spp.	3
	Panicum amarum	2

Table 35

Means for Parameters Measured on *Spartina alterniflora* in One-Fourth Size Plots
Planted 1-4 February 1977 and Evaluated by Elevation Zones.
Evaluation Was Conducted 27-28 April, 1977

	Elevation in Feet									
Parameter	< 0.50	0.50-0.74	0.75-0.99	1.00-1.24	1.25-1.49	1.50-1.74	1.75-1.99	2.00-2.24	2.25-2.49	> 2.5
Survival, %	77.9 (2.1)+	76.8 (1.9)	66.7 (4.7)	34.0 (6.0)	19.8 (4.4)	22.9 (5.4)	56.0 (6.1)	40.3 (8.5)	83.3 (2.2)	84.5 (2.0)
Density/plot	64.3 (3.6)	78.0 (4.3)	74.1 (9.3)	29.3 (5.3)	21.0 (5.7)	17.6 (5.1)	43.8 (5.5)	25.5 (6.6)	57.9 (6.3)	41.5 (3.0)
Height, cm	62.9 (1.3)	59.3 (2.1)	51.5 (2.7)	37.4 (2.6)	29.1 (4.6)	25.1 (3.9)	40.0 (2.3)	39.0 (3.2)	40.3 (2.3)	42.0 (3.4)
Stems/surviving plant	2.6 (0.1)	3.3 (0.1)	3.1 (0.2)	2.2 (0.2)	1.8 (0.3)	1.3 (0.2)	2.3 (0.1)	2.0 (0.2)	2.3 (0.2)	1.6 (0.1)
Plants w/new growth, %	97.0 (0.7)	98.5 (0.5)	98.0 (1.1)	87.1 (6.7)	86.4 (8.0)	80.2(11.8)	101.0 (1.1)	84.8 (9.8)	99.2 (0.6)	97.1 (1.9)
Plants w/tillers, %	72.7 (3.0)	83.5 (2.6)	81.0 (5.2)	76.2 (3.5)	78.9 (5.4)	72.6 (5.1)	75.0 (3.6)	68.0 (4.4)	64.4 (7.7)	37.4 (4.6)
Tillers/plant	2.3 (0.1)	2.8 (0.1)	11.0 (8.3)	2.0 (0.2)	2.1 (0.3)	1.5 (0.2)	2.4 (0.2)	2.0 (0.1)	2.2 (0.2)	1.8 (0.1)
Animal plant damage	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.8 (0.5)	3.0 (1.1)	6.2 (1.8)	7.9 (1.4)
Foliage cover, %	1.0 (0.0)	1.1 (0.1)	1.3 (0.1)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
No. species invading	0.0 (0.0)	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)	0.1 (0.1)	0.4 (0.1)	0.6 (0.1)	0.5 (0.2)	0.7 (0.3)	0.4 (0.3)
No. invading plants	0.0 (0.0)	0.5 (0.4)	4.5 (4.3)	3.4 (2.3)	0.2 (0.2)	1.2 (0.7)	3.0 (1.1)	1.0 (0.5)	1.6 (0.9)	0.6 (0.5)
No. tillers	40.7 (3.1)	55.4 (3.8)	55.3 (8.2)	19.8 (3.8)	16.7 (5.1)	12.3 (3.6)	31.0 (3.9)	17.1 (4.5)	36.9 (6.0)	18.0 (2.9)

+ Standard deviation of mean.

Table 36

Means for Parameters Measured by Fertilizer Treatment on *Spartina alterniflora*

In One-Fourth-Size Plots Planted 1-4 February in Tiers One through Fifteen

Evaluation Was Made 28-29 April, 1977

Parameter	Fertilizer Treatment				
	F_0	F_1	F_2	F_3	F_4
Survival, %	61.8 (4.4) +	53.2 (4.9)	60.4 (4.2)	57.7 (4.9)	59.2 (4.6)
Density/plot	53.1 (5.5)	50.0 (5.0)	54.5 (5.3)	50.8 (5.0)	51.2 (4.9)
Height, cm	48.8 (2.4)	45.6 (3.3)	48.3 (2.6)	46.7 (2.7)	47.3 (2.6)
Stems/ surviving plant	2.4 (0.1)	2.2 (0.2)	2.6 (0.2)	2.4 (0.1)	2.4 (0.1)
Plants with new growth, %	91.0 (4.1)	97.5 (1.3)	96.3 (1.4)	91.8 (3.7)	95.6 (3.5)
Plants with tillers, %	71.9 (3.3)	72.2 (3.0)	74.1 (3.3)	76.7 (3.5)	75.0 (3.0)
Tillers/plant	5.9 (3.7)	2.3 (0.1)	2.5 (0.1)	2.2 (0.1)	2.2 (0.1)
Animal plant damage	1.1 (0.4)	0.6 (0.2)	0.9 (0.4)	1.0 (0.5)	1.2 (0.5)
Foliage cover, %	1.0 (0.0)	1.1 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
No. species invading	0.5 (0.1)	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)
No. invading plants	2.4 (1.1)	2.9 (1.9)	0.3 (1.1)	0.6 (0.3)	1.0 (0.5)
No. tillers	36.2 (4.5)	34.1 (4.0)	37.4 (4.2)	33.6 (3.7)	34.3 (3.7)

+ Standard deviation of mean.

Table 37

Means for Parameters Measured on *Spartina alterniflora* in One-Fourth-Size Plots

Planted May-June 1977 and Evaluated by Elevation Zones.

Evaluation Was Conducted 21-27 July, 1977

Parameter	Elevation in Feet					
	< 0.50	0.50-0.74	0.75-1.99	1.00-1.24	1.25-1.49	1.50-1.75
Survival, %	59.3 (3.3)+	80.2 (2.0)	83.5 (4.4)	90.9 (2.0)	81.8 (2.9)	63.8(11.9)
Density/plot	58.0 (5.2)	125.0 (9.3)	165.2(13.3)	209.7(10.8)	158.2(15.5)	87.7(33.2)
Height, cm	81.9 (1.6)	84.0 (3.2)	80.4 (3.3)	76.9 (1.8)	62.8 (4.5)	57.7 (2.7)
Stems/surviving plant	3.1 (0.2)	5.1 (0.3)	6.2 (0.4)	7.4 (0.4)	11.2 (5.2)	4.0 (1.0)
Plantswith new growth, %	97.3 (0.7)	98.8 (0.4)	99.8 (0.2)	99.3 (0.3)	98.7 (0.7)	98.7 (0.8)
Plants with tillers, %	97.3 (0.7)	99.0 (0.3)	99.8 (0.2)	99.5 (0.3)	98.7 (0.7)	98.7 (0.8)
Tillers/plant	3.2 (0.2)	5.2 (0.3)	6.2 (0.4)	7.9 (0.5)	6.4 (0.5)	4.0 (1.0)
Animal plant damage	0.0 (0.0)	0.0 (0.0)	0.4 (0.2)	6.5 (1.7)	3.1 (0.9)	2.3 (1.5)
Foliage cover, %	0.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
No. species invading	0.0 (0.0)	0.1 (0.0)	0.2 (0.1)	0.1 (0.1)	0.3 (0.2)	0.1 (0.1)
No. invading plants	0.6 (0.6)	0.9 (0.5)	1.5 (1.0)	0.1 (0.1)	0.5 (0.3)	0.1 (0.1)
No. tillers	58.0 (5.2)	125.3 (9.3)	165.2(13.3)	209.7(10.8)	158.2(15.5)	87.7(33.2)

+ Standard deviation of mean.

Table 38

Means for Parameters Measured by Fertilizer Treatments on *Spartina alterniflora*

In One-Fourth-Size Plots Planted May-June, 1977 in Tiers One Through Ten.

Evaluation Was Made 21-27 July, 1977

Parameter	Fertilizer Treatment				
	F_0	F_1	F_2	F_3	F_4
Survival, %	76.2 (4.2)[+]	72.1 (4.8)	73.4 (1.1)	77.7 (3.2)	79.8 (3.0)
Density/plot	109.9 (11.3)	132.9 (17.1)	130.4 (15.0)	127.6 (13.5)	133.0 (11.8)
Height, cm	75.8 (2.2)	78.6 (2.1)	78.9 (3.5)	80.1 (1.7)	78.1 (4.7)
Stems/surviving plant	4.5 (0.3)	5.4 (0.5)	7.9 (2.8)	5.1 (0.4)	5.4 (0.4)
Plants w/new growth, %	99.3 (0.3)	98.4 (0.7)	99.0 (0.6)	97.3 (0.8)	98.9 (0.3)
Plants w/tillers, %	99.3 (0.3)	98.4 (0.7)	99.0 (0.6)	97.8 (0.7)	98.9 (0.2)
Tillers/plant	4.5 (0.3)	5.5 (0.5)	5.6 (0.6)	5.2 (0.4)	5.4 (0.4)
Animal plant damage	1.0 (0.5)	0.8 (0.4)	1.7 (0.8)	1.8 (0.9)	1.9 (0.9)
Foliage cover, %	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
No. species invading	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
No. invading plants	1.1 (0.8)	1.0 (0.7)	0.5 (0.3)	0.1 (0.1)	1.0 (0.9)
No. tillers	109.9 (11.3)	132.9 (17.1)	130.4 (14.9)	127.6 (13.5)	133.0 (11.8)

[+] Standard deviation of mean.

Table 39

Means for Parameters Measured in Six Elevational Zones for *Spartina alterniflora* Sprigged at Two Dates, 1-4 February and 27 May-2 June 1977. Evaluations were Conducted Approximately Two Months After Each Planting

Parameter	Date	Elevation in Feet						
		<0.50	0.50-0.74	0.75-0.99	1.00-1.24	1.25-1.49	1.50-1.74	Mean
Survival, %*	1	77.9	76.8	66.7	34.0	20.2	9.4	60.6**
	2	59.3	80.2	83.5	90.9	81.9	63.8	75.8
Density/plot*	1	64.3	77.9	74.1	29.3	23.0	5.4	58.6**
	2	58.0	125.3	165.2	209.7	158.2	87.7	126.7
Height, cm*	1	62.9	59.3	51.5	37.4	28.1	17.8	52.1**
	2	81.9	83.9	80.4	76.9	62.8	57.7	78.3
Stems/surviving plant*	1	2.6	3.3	3.1	2.3	1.8	1.2	2.6**
	2	3.1	5.1	6.2	7.4	11.4	4.0	5.7
No. stressed/plot*	1	1.4	1.5	1.4	9.1	2.8	2.6	1.7**
	2	1.6	1.2	0.9	0.7	1.2	1.9	1.2
No. stable/plot*	1	22.2	21.8	18.7	87.1	5.8	1.0	17.9**
	2	16.7	22.9	25.3	26.5	23.4	17.3	21.8
Plants with new growth, %	1	97.0	98.5	98.0	76.2	84.2	80.0	94.5**
	2	97.3	98.8	99.8	99.3	98.7	98.7	98.6
Plants with tillers, %+	1	72.7	83.5	81.0	2.0	78.7	80.7	77.5**
	2	97.3	99.0	99.8	99.5	98.7	98.7	98.7

(Continued)

Table 39 (Concluded)

Parameter	Date	<0.50	0.50-0174	0.75-0.99	1.00-1.24	1.25-1.49	1.50-1.74	Mean
Tillers/plant	1	2.3	2.8	11.0	0.0	2.2	1.2	3.5
	2	3.2	5.2	6.2	7.9	6.4	4.0	5.3
Animal plant damage*	1	0.0	0.1	0.0	0.0	0.0	0.0	0.1**
	2	0.0	0.1	0.4	6.5	3.1	2.3	1.4
Percent foliage cover	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	2	< 1	< 1	< 1	< 1	< 1	< 1	< 1
No. invading species/plot	1	0.0	0.2	0.2	0.3	0.1	0.2	0.1
	2	0.1	0.1	0.2	0.1	0.3	0.1	0.1
No. invading plants/plot	1	0.0	0.5	4.5	3.4	0.2	0.2	1.2
	2	0.6	0.9	1.5	0.1	0.5	0.1	0.7
No. tillers/plot*	1	40.7	55.4	55.3	19.8	18.5	3.6	40.2**
	2	58.0	25.3	165.2	209.7	158.2	87.7	126.7

* Significant differences in interaction between dates and zone ($P < 0.10$).

** Significant differences by date ($P < 0.05$).

\+ Significant differences in interaction between dates and zones ($P < 0.20$).

Table 40

Means for Parameter Measured at Five Fertilizer Rates for *Spartina alterniflora* Sprigged 1-4 February and Sprigged 27 May-2 June 1977 in Six Elevational Zones

Parameter	Date	F_0	F_1	F_2	F_3	F_4
Survival, %	1	64.0	54.1	63.2	63.0	58.7
	2	76.2	72.1	73.4	77.7	79.8
	Mean	70.1	63.1	68.3	70.3	69.2
Density/plot	1	61.9	54.2	62.3	59.5	54.9
	2	109.9	132.9	130.4	127.6	133.0**
	Mean	86.3	95.7	96.9	94.7	94.6**
Height, cm	1	53.7	50.9	54.6	50.6	50.7
	2	75.8	78.6	78.9	80.1	78.1
	Mean	64.9	65.0	66.9	65.6	64.4
Stems/surviving plant	1	2.7	2.4	2.9	2.6	2.6
	2	4.5	5.4	7.9	5.1	5.4
	Mean	3.6	3.9	5.4	3.9	4.0
No. stressed/plot	1	1.2	1.9	1.8	2.0	1.5
	2	0.9	1.3	1.5	1.4	1.0
	Mean	1.1	1.6	1.6	1.7	1.3*
No. stable/plot	1	18.7	16.8	17.9	18.3	17.4
	2	22.0	21.2	21.2	21.9	23.0
	Mean	20.4	19.1	19.6	20.2	20.3
Plants with new growth, %	1	94.5	95.8	96.2	92.2	93.7
	2	99.3	98.4	99.0	97.3	98.9**
	Mean	96.9	97.2	97.6	94.9	96.4*
Plants with tillers, %	1	76.9	73.3	78.3	80.4	78.4**
	2	99.3	98.4	99.0	97.8	98.9
	Mean	88.3	86.5	88.8	89.5	89.0

(Continued)

Table 40 (Concluded)

Parameter	Date	F_0	F_1	F_2	F_3	F_4
Tillers/ plant	1	7.9	2.4	2.5	2.3	2.3
	2	4.5	5.4	5.6	5.2	5.4
	Mean	6.1	4.0	4.1	3.9	3.9
Animal plant damage/plot	1	0.0	0.0	0.0	0.0	0.1
	2	1.0	0.8	1.7	1.8	1.9
	Mean	0.5	0.4	0.9	0.9	1.0
Foliage cover, %	1	< 1	< 1	< 1	< 1	< 1
	2	< 1	< 1	< 1	< 1	< 1
	Mean	< 1	< 1	< 1	< 1	< 1
No. species invading/plot	1	0.2	0.1	0.1	0.1	0.1
	2	0.1	0.1	0.1	0.1	0.1
	Mean	0.2	0.1	0.1	0.1	0.1
No. invading plants/plot	1	1.9	3.2	0.2	0.1	0.5
	2	1.1	1.0	0.5	0.1	1.0
	Mean	1.5	2.1	0.3	0.1	0.7
No. plants with tillers/plot	1	14.9	14.0	15.5	16.5	14.6
	2	22.7	22.0	21.8	22.8	23.7
	Mean	18.9	18.3	18.7	19.8	19.3
No. of tillers/plot	1	42.9	37.0	43.0	40.3	37.2**
	2	109.9	132.9	130.4	127.6	133.0
	Mean	77.0	87.6	87.4	85.4	85.9*

* Differences significant by date ($P < 0.05$).

** Differences significant by date x fertilizer interaction ($P < 0.10$).

Table 41

Means for Parameters Measured in Six Elevational Zones for *Spartina alterniflora* Sprigged at Two Dates, 1-4 February and 11 May - 2 June 1977 and Evaluated 11-15 November 1977

		Elevation in Feet					
Parameter	Date	< 0.50	0.50-0.74	0.75-0.99	1.00-1.24	1.25-1.49	1.50-1.74
Density, plot	1	1143.6 (66.1)*	1511.6 (69.6)	1727.5 (102.0)	1140.1 (139.2)	627.4 (147.8)	160.5 (156.8)
	2	388.9 (42.8)	663.4 (51.0)	953.8 (67.8)	1047.3 (72.0)	872.2 (92.9)	425.5 (161.4)
Height, cm	1	156.9 (8.2)	151.7 (1.9)	150.2 (2.4)	121.2 (6.6)	93.6 (5.9)	54.0 (25.5)
	2	127.9 (2.6)	131.2 (2.2)	137.3 (2.3)	118.3 (3.1)	95.6 (4.7)	69.3 (12.2)
Plants with animal damage, plot	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	2	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Foliage cover, %**	1	10-25 (---)	25-50 (---)	25-50 (---)	< 10 (---)	< 10 (---)	< 10 (---)
	2	< 10 (0.0)	< 10 (0.0)	< 10 (0.0)	< 10 (0.0)	< 10 (0.0)	< 10 (0.0)

(Continued)

Table 41 (Concluded)

Parameter	Date	Elevation in Feet < 0.50	0.50-0.74	0.75-0.99	1.00-1.24	1.25-1.49	1.50-1.74
No. species invading, plot**	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)
	2	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)
No. invading plants, plot	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.1 (0.1)	0.0 (0.0)
	2	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.0 (0.0)

* Standard error of the mean.

** Analysis of variance F-test significant at $P < 0.05$.

Table 42

Means for Parameters Measured by Fertilizer Treatments on *Spartina alterniflora* in One-Fourth Sized Plots Planted 1-4 February and 27 May - 2 June 1977 in Tiers One Through Ten. Evaluation was Made 11-15 November 1977

Parameter	Date	Fertilizer Treatment				
		F_0	F_1	F_2	F_3	F_4
Density	1	973.1 (99.6)*	883.3 (91.8)	1062.4 (95.3)	954.8 (88.4)	1161.3 (95.6)
	2	637.1 (66.7)	694.4 (84.4)	725.2 (81.2)	681.2 (69.0)	786.6 (70.1)
Height	1	121.5 (5.0)	123.4 (5.1)	133.3 (10.9)	131.0 (4.3)	128.7 (5.2)
	2	118.5 (5.3)	119.1 (4.2)	128.0 (3.7)	122.5 (4.3)	124.3 (3.7)
Plants with animal damage	1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.4)	0.0 (0.0)
	2	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Foliage cover, %	1	< 10 (---)	< 10 (---)	< 10 (---)	< 10 (---)	10-25 (---)
	2	< 10 (---)	< 10 (---)	< 10 (---)	< 10 (---)	< 10 (---)
No. species invading	1	0.4 (0.1)	0.3 (0.1)	0.3 (0.1)	0.4 (0.1)	0.3 (0.1)
	2	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)
No. invading plants	1	3.6 (1.7)	1.5 (1.2)	1.4 (0.8)	0.6 (0.3)	5.6 (4.3)
	2	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)

* Standard error of mean.

Table 43

Means for Parameters Measured in Rows 11-15 for *Spartina alterniflora* and *Spartina patens* in One-Fourth-Size Plots Planted 28-29 April 1977

Evaluation was Made 11-15 November 1977

Parameter	Species	Row 11	Row 12	Row 13	Row 14	Row 15	Combined Rows
Survival, %	*Spartina alterniflora*	31.3	36.0	44.0	80.8	80.2	54.1 (3.7)+
	Spartina patens	11.3	30.4	45.1	78.4	90.0	51.1 (4.2)
Density/plot*	*Spartina alterniflora*	18.8	31.0	34.0	64.1	39.9	38.3 (3.1)
	Spartina patens	16.7	36.6	56.7	85.8	120.8	70.6 (7.1)
Height, cm	*Spartina alterniflora*	36.4	29.8	36.3	43.9	42.4	37.7 (1.5)
	Spartina patens	28.1	29.0	35.0	49.8	52.3	39.5 (2.0)
Stems/plant*	*Spartina alterniflora*	1.6	1.8	2.0	2.6	1.6	1.9 (0.1)
	Spartina patens	1.1	1.9	3.4	3.6	4.4	3.0 (0.2)
No. stressed/ plot*	*Spartina alterniflora*	5.2	4.7	4.4	3.2	7.3	5.0 (0.5)
	Spartina patens	7.3	10.5	13.3	16.1	19.8	14.3 (1.0)
No. stable/ plot*	*Spartina alterniflora*	5.3	7.8	9.7	21.3	16.8	12.4 (1.2)
	Spartina patens	0.0	0.9	1.2	7.4	7.2	3.9 (0.7)
Plants with new growth, %	*Spartina alterniflora*	91.3	84.3	97.5	100.4	96.9	94.3 (2.9)
	Spartina patens	71.4	91.9	97.6	100.0	99.7	94.7 (2.5)
Plants with tillers, %	*Spartina alterniflora*	66.4	80.3	92.5	74.3	41.3	66.9 (2.5)
	Spartina patens	28.4	54.0	51.8	68.9	85.5	61.8 (3.6)

(Continued)

Table 43 (Concluded)

Parameter	Species	Row 11	12	13	14	15	Combined Rows
Tillers/plant	*Spartina alterniflora*	2.0	2.1	2.0	2.4	1.9	2.1 (0.1)
	Spartina patens	1.6	2.0	2.6	2.4	2.6	2.4 (0.2)
Plants with animal damage*	*Spartina alterniflora*	0.3	0.5	0.9	4.1	9.0	2.9 (0.5)
	Spartina patens	0.0	0.0	0.0	0.0	0.0	0.0 (0.0)
Foliage cover, %	*Spartina alterniflora*	< 1	< 1	< 1	< 1	< 1	< 1
	Spartina patens	< 1	< 1	< 1	< 1	< 1	< 1
No. invading species/plot	*Spartina alterniflora*	0.4	0.5	0.3	0.7	0.9	0.5 (0.1)
	Spartina patens	0.3	0.6	0.6	0.3	0.8	0.5 (0.1)
No. invading plants/plot	*Spartina alterniflora*	0.5	2.4	2.9	1.9	2.1	2.0 (0.5)
	Spartina patens	1.1	1.9	1.1	0.4	7.1	2.3 (0.8)
Plants with tillers/plot	*Spartina alterniflora*	6.8	9.5	10.5	18.4	9.8	--- (---)
	Spartina patens	2.7	6.3	8.6	16.8	23.1	--- (---)
No. tillers/ plot*	*Spartina alterniflora*	12.5	21.8	23.9	44.7	19.4	24.9 (2.3)
	Spartina patens	5.0	20.3	32.0	43.9	62.4	36.8 (4.8)

* Significant differences between species ($P < 0.05$).

+ Standard deviation of mean.

Table 44

Means for Parameters Measured in Tiers 11-15 for *Spartina alterniflora* and *Spartina patens* in One-Fourth-Size Plots Planted 1-4 February 1977. Evaluation was Made 11-15 November 1977

Parameter	Species	Row 11	12	13	14	15	Combined Rows
Surivial, %*	*Spartina alterniflora*	---	---	---	---	---	---
	Spartina patens	11.3	32.0	51.1	81.8	91.5	53.6
Density, plot	*Spartina alterniflora*	522.0	608.0	653.4	960.5	397.0	631.3**
	Spartina patens	203.5	642.6	1440.1	2035.4	2185.8	1301.5
Height	*Spartina alterniflora*	95.6	105.1	105.0	114.1	86.9	101.4**
	Spartina patens	54.6	66.9	70.7	89.1	87.0	76.0
Plants with animal damage	*Spartina alterniflora*	0.0	0.0	1.3	0.0	0.0	0.3
	Spartina patens	0.0	0.0	0.0	0.0	0.0	0.0
Foliage cover, %	*Spartina alterniflora*	< 10	< 10	< 10	< 10	< 10	< 10
	Spartina patens	< 1	< 10	< 10	< 10	< 10	1.7
No. invading species	*Spartina alterniflora*	0.0	0.2	0.3	1.5	2.9	1.0
	Spartina patens	0.7	0.8	0.7	1.5	1.9	1.1
No. invading plants	*Spartina alterniflora*	0.0	4.3	1.3	6.1	27.1	7.5**
	Spartina patens	50.3	70.6	51.6	22.0	18.8	42.7

* Survival could not be determined because original transplants could not be located.

** Highly significant differences ($P < 0.01$) between species.

Table 45

Means for Various Parameters Measured on 2 September 1976 (Evaluation 1) on Three Grasses Transplanted into Upland Plots

(Grasses were planted 1-8 July 1976)

Parameter	Species		
	Panicum amarum	*Cynodon dactylon*	*Andropogon perangustatus*
Survival, %*	79.6a**	96.0a	9.3b
Plants with new growth*	8.6b	11.5b	1.0a
Plants with new growth, %	88.3	100.0	86.1
Density* (no. per quadrat)	22.2c	11.5c	1.5c
No. of invading species**	1.1	0.6	1.6
No. of invading plants	3.3	1.5	7.4

* Analysis of variance F-test for differences between species was highly significant ($P < 0.01$). Means with different letters across parameters were significantly different as tested by Student-Newman-Keuls' multiple-range test ($P < 0.05$).

** Differences between species were significant ($P < 0.10$).

Table 46

Means for Various Parameters Measured On 13 December 1976 (Evaluation 2) on Three Grasses of the Upland

(Grasses were planted 1-8 July 1976)

	Species		
Parameter	*Panicum amarum*	*Cynodon dactylon*	*Andropogon perangustatus*
Survival, %*,**	77.5ac	98.1a	6.8bc
Plants with new growth/ quadrat *,**	8.7ac	11.6a	1.7bc
Plants with new growth, %	91.3	98.1	100.0
No. of invading species/ quadrat *,**	0.9a	0.5a	1.7a
No. of invading plants/ quadrat *,**	2.7a	1.4a	16.7a
Plants with tillers, %**,+	89.8a	99.7a	0.0b
Tillers per plant with tillers	2.4	---	---
Root biomass, g/0.1 m^2	4.5	23.7	1.7
Shoot biomass, g/0.1 m^2	10.8	12.1	3.3
Total biomass, g/0.1 m^2	15.3	35.9	5.1
Root:shoot ratio*	0.5a	1.9a	0.7a
Grass seed	0.0	0.0	0.0

* Analysis of variance F-test for differences between species was highly significant ($P < 0.05$).

** Means with different letters across parameters were significantly different as tested by Student-Newman-Keuls' multiple-range test ($P < 0.05$).

\+ Analysis of variance F-test for differences between species was highly significant ($P < 0.01$).

Table 47

Means for Various Parameters Measured on 2 September 1976 (Evaluation 1) on Upland Grasses At Three Rates of Fertilizer

(Fertilizer applied 30 June; grasses planted 1-8 July 1976)

Parameter	Fertilizer Treatments		
	F_0	F_1	F_2
Survival, %	63.9	58.3	62.6
Plants with new growth/quadrat	7.7	6.5	7.0
Density (stems per quadrat)	11.7	9.6	13.5

Table 48

Means for Various Parameters Measured on
13 December 1976 (Evaluation 2) on Upland Grasses
At Three Rates of Fertilizer
(Fertilizer applied 30 June; grasses planted 1-8 July 1976)

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	64.8	55.9	61.7
Plants with new growth/quadrat*	10.0	7.8	7.9
Plants with new growth, %	95.7	94.5	96.9
No. of invading species/quadrat	0.8	1.1	1.2
No. of invading plants/quadrat	6.5	4.1	10.2
Plants with tillers,%**	83.2a	80.1ac	70.0bc
Tillers per plant with tillers	2.3	1.6	3.1
Root biomass, g/0.1 m^2	8.4	13.1	15.6
Shoot biomass, g/0.1 m^2	6.9	9.2	14.9
Total biomass, g/0.1 m^2	15.3	22.3	30.4
Root:shoot ratio	1.2	1.1	1.1

* Analysis of variance F-test for differences between means was significant ($P < 0.10$).

** Analysis of variance F-test for differences between means was highly significant ($P < 0.05$). Means with different letters across parameters were significantly different as tested by Student-Newman-Keuls' multiple-range test ($P < 0.05$).

Table 49

Differences in *Panicum amarum* on 2 September 1976 (Evaluation 1) Due to Fertilizer Treatment

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	92.6	68.5	77.8
Plants with new growth/quadrat	10.8	6.7	8.4
Plants with new growth, %*	96.9	78.7	89.4
Density (stems per quadrat)	22.9	16.4	26.8

* This parameter was not tested by analysis of variance F-test for differences.

Table 50

Differences in *Cynodon dactylon* on 2 September 1976 (Evaluation 1) Due to Fertilizer Treatment

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	97.2	99.1	91.7
Plants with new growth/quadrat	11.7	11.9	11.0
Plants with new growth, %	100.0	100.0	100.0
Density (stems per quadrat)	11.7	11.9	11.0

Table 51

Differences in *Andropogon perangustatus* on 2 September 1976 (Evaluation 1) due to Fertilizer Treatment

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	1.9	7.4	18.5
Plants with new growth/ quadrat	0.5	0.9	1.5
Plants with new growth, %	100.0	100.0	76.2
Density (stems per quadrat)	0.5	1.2	2.9

Table 52

Parameter Means for *Panicum amarum* by Fertilizer Treatment on 13 December 1976 (Evaluation 2)

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	92.6	62.0	77.8
Plants with new growth/quadrat	10.4	6.5	9.1
Density (stems per quadrat)	25.3	14.7	40.7
No. invading species/quadrat	0.9	1.1	0.7
No. invading plants/quadrat	5.1	1.9	1.1
Root biomass, $g/0.1\ m^2$	4.0	2.8	6.7
Shoot biomass, $g/0.1\ m^2$	7.3	7.6	17.6
Total biomass, $g/0.1\ m^2$	11.3	10.4	24.3
Root:shoot ratio	0.5	0.4	0.6

Table 53

Parameter Means for *Cynodon dactylon* by Fertilizer Treatment on 13 December 1976 (Evaluation 2)

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	98.1	99.1	97.2
Plants with new growth /quadrat	11.3	11.8	11.5
No. invading species /quadrat	0.3	0.5	0.7
No. invading plants /quadrat	0.4	1.1	2.5
Root biomass, $g/0.1\ m^2$	15.0	26.9	29.2
Shoot biomass, $g/0.1\ m^{2}$*	7.2ab	13.2ab	16.0a
Total biomass, $g/0.1\ m^2$	22.2	40.2	45.2
Root:shoot ratio	2.2	1.9	1.7

* Analysis of variance F-test for differences among fertilizer treatments was significant ($P < 0.05$). Means followed by different letters were significantly different as tested by Student-Newman-Keuls' multiple-range test.

Table 54

Parameter Means for *Andropogon perangustatus* by Fertilizer Treatment on 13 December 1976 (Evaluation 2)

Parameter	Fertilizer Treatment F_0	F_1	F_2
Survival, %	3.7	6.5	10.2
Plants with new growth/quadrat	2.0	1.7	1.6
Density (plants per quadrat)	2.0	1.7	1.6

Table 55

Means for Parameters Measured on *Panicum amarum*, *Cynodon dactylon*, and *Andropogon perangustatus* on 22 June 1977

Parameter	*Panicum amarum*	*Cynodon dactylon*	*Andropogon perangustatus*
Survival, %*	84.7** (2.7)+	81.3 (3.7)	5.4 (2.5)
Plants with new growth	100.0 (0.0)	99.7 (0.3)	87.8 (12.2)
Plants with tillers, %	100.0 (0.0)	----	----
Tillers/plant	6.7 (0.5)	----	----

* Differences between species were significant ($P < 0.05$).

** Mean.

+ Standard deviation of mean.

Table 56

Percent Survival for *Panicum amarum*, *Cynodon dactylon*, and *Andropogon perangustatus* by Fertilizer Treatment on 22 June 1977

Species	Fertilizer Application*		
	F_0	F_1	F_2
Panicum amarum	93.1** (1.4)+	80.1 (5.0)	81.0 (5.9)
Cynodon dactylon	81.9 (5.3)	87.9 (4.5)	74.1 (8.5)
Andropogon perangustatus	3.7 (2.0)	10.2 (6.6)	2.1 (2.1)

* Differences between fertilizer treatments were not significant.

** Mean.

\+ Standard deviation of mean.

Table 57

Biomass Production (g/m^2) of *Cynodon dactylon* (Alecia variety), *Panicum amarum*, And Invading Plants in Response to Number of Fertilizer Applications

Species	Fertilizer Treatment							
	F_0		F_1		F_2		Mean	
	1976	1976-1977	1976	1976-1977	1976	1976-1977	1976	1976-1977
Cynodon dactylon	27.0 (14.2)	35.2 (19.0)	42.6 (21.7)	145.9 (67.2)	57.7 (16.9)	118.5 (104.2)	42.4 (10.0)	99.9 (39.9)
Invading plants in *Cynodon*	0.1 (0.1)	0.5 (0.4)	11.7 (10.7)	4.3 (1.0)	0.4 (0.3)	14.7 (12.0)	4.1 (3.6)	6.5 (4.1)
Panicum amarum	26.5 (7.2)	20.7 (5.2)	11.6 (4.1)	42.3 (18.7)	78.5 (37.4)	87.2 (30.9)	38.9 (15.0)	50.1 (14.4)
Invading plants in *Panicum*	3.6 (3.6)	9.4 (1.1)	0.7 (0.5)	8.1 (5.8)	5.9 (3.1)	13.0 (3.5)	3.4 (1.6)	10.2 (2.1)

Table 58

Any Biomass Production (g/m^2) of *Cynodon dactylon* (Alecia variety), *Panicum amarum*, and Invading Plants in Response to Fertilizer Treatment, Years Combined

Species	Fertilizer Treatment F_0	F_1	F_2
Cynodon dactylon	31.1 (10.8)*	94.3 (39.2)	88.1 (49.1)
Invading plants in *Cynodon dactylon*	0.3 (0.2)	8.0 (5.1)	7.6 (6.3)
Panicum amarum	23.6 (4.2)	26.9 (11.0)	82.9 (21.8)
Invading plants in *Panicum*	6.5 (2.1)	4.4 (3.1)	9.5 (2.6)

* Standard deviation of mean.

Table 59

Parameter Means for Repeated Versus One Application of Fertilizer On *Panicum amarum*, 26 September 1977

Parameter	Times of Fertilization	
	1976	1976 & 1977
Density/quadrat*	63.9 (6.1)**	88.9 (8.7)
Height, cm*	68.0 (3.6)	79.6 (3.8)
Root biomass	35.6 (7.2)	41.0 (7.2)
Shoot biomass	48.6 (13.1)	49.9 (9.2)
Total biomass	84.2 (20.0)	90.9 (15.8)
Root:shoot ratio	1.0 (0.1)	0.9 (0.1)
Biomass seed	0.3 (0.1)	0.5 (0.1)

* Significant differences ($P < 0.05$) between amounts of fertilizer applied.

** Standard deviation of mean.

Table 60

Parameter Means for *Panicum amarum* by Fertilizer Treatment For Applications in 1977 Only

Parameter	Fertilizer Treatment F_0	F_1	F_2
Density /quadrat*	53.9	96.9	116.0
Height, cm**	63.6	77.3	98.0
Root biomass, g/0.1 m^2**	15.2	32.3	71.6
Shoot biomass, g/0.1 m^2*	18.4	48.7	78.9
Root:shoot ratio	0.9	0.9	0.9
Total biomass, g/0.1 m^2*	33.6	81.1	150.5
Seed production, g/0.1 m^2	0.3	0.5	0.9

* Analysis of variance F-test significant at $P < 0.10$.

** Analysis of variance F-test significant at $P < 0.05$.

Table 61

Parameter Means for Repeated Versus Only One Application of Fertilizer on *Cynodon dactylon*, 26 September 1977

Parameter	Times of Fertilization: 1976	Times of Fertilization: 1976 & 1977
Root biomass, $g/0.1\ m^2$	70.7 (7.3)**	96.7 (18.2)
Shoot biomass, $g/0.1\ m^2$*	29.0 (2.4)	40.5 (4.3)
Total biomass, $g/0.1\ m^2$	99.7 (7.8)	137.2 (20.8)
Root:shoot ratio	2.7 (0.3)	2.3 (0.3)

* Significant differences ($P < 0.10$) between times of fertilization by analysis of variance F-test.

** Standard deviation of mean.

Table 62

Parameter Means for *Cynodon dactylon* by Fertilizer Treatment For Applications in 1977 Only at September 1977 Evaluation

Parameter	Fertilizer Treatment*		
	F_0	F_1	F_2
Root biomass, g/0.1 m^2	55.6 (7.9)**	133.6 (43.4)	100.9 (29.8)
Shoot biomass, g/0.1 m^2	31.3 (4.1)	41.3 (5.7)	48.8 (10.6)
Root:shoot ratio	1.9 (0.3)	3.0 (0.5)	2.1 (0.6)
Total biomass, g/0.1 m^2	86.9 (10.9)	174.9 (47.7)	149.7 (36.5)

* Differences were not significantly different ($P < 0.10$).

** Standard deviation of mean.

Table 63

Means for Parameters Measured on *Panicum amarum*, *Cynodon dactylon*, And *Andropogon perangustatus* on 26 September 1977

Parameter	*Panicum amarum*	*Cynodon dactylon*	*Andropogon perangustatus*
Density, per quadrat	63.9 (6.1)**	--- (---)	22.1 (9.8)
Height, cm	68.0 (3.6)	--- (---)	65.7 (3.2)
Root biomass, g* (per 0.1 m^2)	35.6 (7.2)	70.7 (7.3)	10.6 (2.6)
Shoot biomass, g (per 0.1 m^2)	48.6 (13.1)	29.0 (2.4)	26.7 (6.1)
Total biomass, g (per 0.1 m^2)	84.2 (20.0)	99.7 (7.8)	37.2 (---)

* Highly significant differences ($P < 0.05$) occurred between species.

** Standard deviation of mean.

Table 64

Differences in *Andropogon perangustatus* on 26 September 1977 (Evaluation 4) Due to Fertilizer Treatment

	Fertilizer Treatment		
	F_0	F_1	F_2
Survival, %*	6.5 (4.6)**	6.5 (2.3)	0.9 (0.9)
Density (plants per quadrat)	31.3 (27.3)	20.0 (9.8)	5.0 (---)
Stems per plant	8.4 (4.4)	13.0 (4.6)	5.0 (---)
Root biomass	9.0 (2.6)	6.3 (2.8)	25.0 (3.4)
Shoot biomass	37.1 (15.7)	25.4 (8.7)	20.2 (9.9)
Total biomass	46.0 (---)	31.7 (---)	45.2 (12.2)
Grams of seed	--- (---)	--- (---)	--- (---)
Root:shoot ratio	0.3 (0.0)	0.2 (0.0)	2.7 (1.6)

* Analysis of variance could be run only on survival because of the low survival. Differences due to fertilizer were not significant.

** Standard deviation of mean.

Table 65

Survival Means (percent) for Shrubs and Trees by Species and Fertilizer Treatment on 2 September 1976 (Evaluation 1)

Species	Survival, %*	F_0	F_1	F_2
Pinus clausa	4.2	2.1	0.0	10.4
Tamarix gallica	2.8	6.3	2.1	0.0
Prunus sp.	0.7	2.1	0.0	0.0
Rhus copallina	11.8	10.4	14.6	10.4
Croton punctatus	54.9	62.5	52.1	50.0
Combined species	---	16.7	13.8	14.2

* Analysis of variance F-test for difference in survival by species was significant ($P < 0.10$).

Table 66

Survival Means (percent) Shrubs and Trees by Species And Fertilizer Treatment on 10 November 1976 (Evaluation 2)

Species	Survival, %*	F_0	F_1	F_2
Pinus clausa	4.2	7.8	0.0	3.1
Tamarix gallica	2.8	4.2	2.1	2.1
Prunus sp.	0.7	0.0	0.0	2.1
Rhus copallina	9.0	4.2	10.4	12.5
Croton punctatus	54.2	62.5	43.8	53.1
Combined species		15.2**	8.9	17.9

* Analysis of variance F-test for differences in survival by species was highly significant ($P < 0.05$).

** Analysis of variance F-test for differences in survival because of fertilizer treatments was highly significant ($P < 0.001$).

Table 67

Survival and Height in Upland Trees and Shrubs at 22 June 1977 Evaluation

Species	Survival,%*	Height, cm*
Pinus clausa	33.8 (5.3)**	25.1 (0.8)
Tamarix gallica	34.7 (8.5)	90.2 (4.5)
Quercus virginiana	94.4 (3.5)	81.0 (1.5)
Rhus copallina	72.9 (5.2)	41.3 (2.4)
Croton punctatus	20.8 (7.4)	34.9 (2.4)
Myrica cerifera	63.2 (7.9)	38.3 (2.3)

* Differences between species were significant ($P < 0.05$).

** Standard deviation of mean.

Table 68

Parameters Measured in Upland Trees and Shrubs on 26 September 1977

Species	Survival, %	Height, cm	Root Biomass, g	Shoot Biomass, g	Total Biomass, g	Root:shoot Ratio
Pinus clausa	28.4 (5.4)*	25.2 (1.8)	2.4 (0.3)	4.2 (0.4)	6.7 (0.5)	0.6 (0.1)
Tamarix gallica	31.9 (7.8)	106.9 (11.1)	25.0 (7.7)	80.1 (39.7)	105.1 (47.3)	0.4 (0.0)
Quercus virginiana	96.5 (2.1)	78.9 (1.8)	69.8 (8.9)	48.6 (4.9)	118.4 (13.7)	1.4 (0.1)
Rhus copallina	66.0 (7.7)	39.3 (1.7)	42.9 (8.5)	20.7 (4.1)	63.7 (11.3)	2.5 (0.5)
Croton punctatus	22.2 (6.7)	41.7 (3.2)	24.9 (11.7)	393.0 (232.8)	417.9 (244.3)	0.1 (0.0)
Myrica cerifera	62.9 (8.9)	36.8 (2.8)	37.5 (7.8)	39.2 (7.9)	76.8 (15.6)	1.0 (0.1)

* Standard deviation of mean.

Table 69

Percent Survival of Shrubs and Trees on 26 September 1977

By Fertilizer Treatment

Species	Fertilizer Treatment		
	F_0	F_1	F_2
*Pinus clausa**	29.2 (7.5)**	31.3 (10.8)	25.0 (13.0)
Tamarix gallica	29.2 (11.0)	33.3 (14.5)	33.3 (19.9)
Quercus virginiana	100.0 (0.0)	95.8 (2.1)	93.7 (6.3)
Rhus copallina	83.3 (9.1)	62.5 (9.5)	52.1 (17.1)
Croton punctatus	16.7 (11.0)	29.2 (14.6)	20.8 (12.7)
*Myrica cerifera**	87.5 (6.3)	62.5 (6.3)	38.8 (16.5)
Combined species	57.6 (8.6)	52.4 (6.9)	44.0 (7.8)

* Significant difference ($P < 0.05$) occurred among fertilizer treatments.

** Standard deviation of mean.

Table 70

Height of Shrubs and Trees on 26 September 1977 by Fertilizer Treatment

Species	Fertilizer Treatment F_0	F_1	F_2
*Pinus clausa**	22.8 (2.3)**	22.8 (2.4)	29.9 (3.1)
Tamarix gallica	102.2 (7.9)	96.9 (10.4)	129.2 (47.7)
Quercus virginiana	76.4 (1.5)	82.5 (2.9)	77.9 (4.3)
Rhus copallina	40.6 (2.4)	39.3 (2.7)	37.9 (4.5)
Croton punctatus	36.0 (2.1)	41.2 (1.5)	48.0 (8.7)
Myrica cerifera	37.7 (3.2)	40.9 (2.7)	31.9 (7.7)

* Significant differences ($P < 0.05$) occurred among fertilizer treatments.

** Standard deviation of mean.

Table 71

Root Biomass in Shrubs and Trees on 26 September 1977

By Fertilizer Treatment

Species	Fertilizer Treatment*		
	F_0	F_1	F_2
Pinus clausa	2.6 (0.5)**	2.1 (0.6)	2.6 (0.1)
Tamarix gallica	17.0 (4.4)	17.0 (7.8)	49.0 (25.8)
Quercus virginiana	80.9 (11.4)	56.4 (15.3)	72.2 (20.7)
Rhus copallina	34.1 (9.3)	50.0 (19.8)	44.7 (18.0)
Croton punctatus	9.8 (3.2)	15.7 (10.3)	49.1 (32.7)
Myrica cerifera	40.6 (6.0)	30.7 (8.2)	41.3 (24.3)

* No significant differences among fertilizer treatments ($P < 0.10$).

** Standard deviation of mean.

Table 72

Shoot Biomass for Shrubs and Trees on 26 September 1977 By Fertilizer Treatment

Species	Fertilizer Treatment*		
	F_0	F_1	F_2
Pinus clausa	3.9 (0.5)**	3.7 (0.8)	5.2 (0.3)
Tamarix gallica	39.3 (12.5)	38.3 (12.6)	20.4 (150.9)
Quercus virginiana	54.0 (5.8)	43.2 (8.7)	48.6 (12.2)
Rhus copallina	17.3 (6.7)	23.3 (8.5)	21.6 (8.6)
Croton punctatus	131.2 (66.1)	135.9 (67.8)	912.0 (632.3)
Myrica cerifera	40.3 (7.2)	36.7 (8.6)	40.8 (24.9)

* No significant differences among fertilizer treatments occurred ($P < 0.10$).

** Standard deviation of mean.

Table 73

Root:Shoot Ratio for Shrubs and Trees on 26 September 1977 By Fertilizer Treatment

Species	Fertilizer Treatment* F_0	F_1	F_2
Pinus clausa	0.7 (0.1)**	0.6 (0.1)	0.5 (0.1)
Tamarix gallica	0.5 (0.1)	0.4 (0.1)	0.3 (0.1)
Quercus virginiana	1.5 (0.1)	1.3 (0.1)	1.4 (0.1)
Rhus copallina	2.6 (1.4)	2.4 (0.6)	2.5 (0.8)
Croton punctatus	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)
Myrica cerifera	1.0 (0.1)	0.8 (0.0)	1.2 (0.2)

* No significant differences among fertilizer treatments (P < 0.10).

** Standard deviation of mean.

Table 74

Total Biomass of Shrubs and Trees on 26 September 1977 By Fertilizer Treatment

Species	Fertilizer Treatment		
	F_0	F_1	F_2
*Pinus clausa***	6.5 (1.0)*	5.8 (1.2)	7.8 (0.2)
Tamarix gallica	56.3 (16.8)	55.3 (20.4)	253.1 (176.8)
Quercus virginiana	134.8 (16.9)	99.6 (24.0)	120.8 (32.9)
Rhus copallina	51.4 (12.4)	73.3 (27.4)	66.3 (22.2)
Croton punctatus	141.0 (69.3)	151.5 (78.0)	961.1 (665.0)
Myrica cerifera	80.9 (12.6)	67.4 (16.8)	82.1 (49.1)

* Standard deviation of mean.

** Significant differences among fertilizer treatments ($P < 0.10$).

Table 75

Mean Number of Invading Plant Species in Upland Plot Experiments

Plant	Fertilizer Application					
	F_0		F_1		F_2	
	2 Sep.	9 Nov.	2 Sep.	9 Nov.	2 Sep.	9 Nov.
Panicum amarum	1.3* (0.4)**	0.8 (0.4)	1.3 (0.4)	1.1 (0.4)	0.7 (0.5)	0.7 (0.2)
Cynodon dactylon	0.4 (0.3)	0.3 (0.2)	0.4 (0.2)	0.6 (0.2)	0.7 (0.2)	0.7 (0.2)
Andropogon perangustatus	1.3 (0.3)	1.1 (0.3)	1.4 (0.3)	1.7 (0.3)	2.1 (0.5)	2.4 (0.4)

* Mean.

** Standard deviation of mean.

Table 76

Mean Number of Invading Plants in Upland Plot Experiments

Plant	Fertilizer Application					
	F_0		F_1		F_2	
	2 Sep.	9 Nov.	2 Sep.	9 Nov.	2 Sep.	9 Nov.
Panicum amarum	6.0* (3.5)**	5.1 (3.8)	3.0 (1.2)	1.9 (0.8)	0.8 (0.5)	1.1 (0.5)
Cynodon dactylon	1.2 (0.8)	0.4 (0.3)	0.4 (0.2)	1.1 (0.7)	2.9 (1.1)	2.6 (1.4)
Andropogon perangustatus	6.9 (2.6)	13.9 (6.1)	3.6 (1.1)	9.2 (3.5)	11.7 (5.7)	27.0 (8.7)

* Mean.

** Standard deviation of mean.

Table 77

List of All Invading Plant Species in Each Tier of Upland Plot Experiment at the End of the 1976 Growing Season

Species	Tier							
	Grass		Shrub		Tree		Combined	
	Total*	Freq.**	Total	Freq.	Total	Freq.	Total	Freq.
Cyperus esculentus	192	(13)	308	(14)	463	(20)	963	(47)
Scirpus americanus	501	(14)	224	(13)	164	(12)	889	(39)
Ambrosia psilostachya	0	(0)	151	(10)	153	(8)	304	(18)
Unknown forbs	0	(0)	104	(10)	50	(11)	154	(21)
Sporobolus virginicus	4	(3)	34	(3)	21	(5)	59	(8)
Solanaceaae family	0	(0)	0	(0)	37	(12)	37	(12)
Spartina patens	11	(4)	5	(5)	13	(2)	29	(11)
Paspalum setaceum var. *ciliatifolium*	6	(3)	10	(4)	1	(1)	17	(8)
Fimbristylis castaneum	15	(12)	0	(0)	0	(0)	15	(12)
Sesbania drummondii	0	(0)	12	(4)	2	(2)	14	(6)
Cynodon dactylon (common)	0	(0)	10	(3)	0	(0)	10	(3)
Dicanthelium sp.	0	(0)	4	(3)	5	(2)	9	(5)
Tridens sp.	0	(0)	6	(3)	0	(0)	6	(3)
Aristida longespica	0	(0)	2	(2)	1	(1)	3	(3)
Digitaria sanguinalis	0	(0)	0	(0)	2	(1)	2	(1)
Cenchrus incertus	0	(0)	0	(0)	1	(1)	1	(1)
Chenopodium ambrosioides	1	(1)	0	(0)	0	(0)	1	(1)
Lantana horrida	0	(0)	0	(0)	1	(1)	1	(1)

* Total plants recorded in 27 quadrats (1 by 3 m) in each tier.

** Number of occurrences of each species in 27 quadrats in each tier.

Table 78

Miscellaneous Environmental Effects in Grass Plots in Upland Area at Bolivar Peninsula on 9 November 1976*

Species	Fertilizer	Replication 1 Q_1	Replication 1 Q_2	Replication 1 Q_3	Replication 2 Q_1	Replication 2 Q_2	Replication 2 Q_3	Replication 3 Q_1	Replication 3 Q_2	Replication 3 Q_3
Panicum amarum	F_0	erosion	0	0	0	0	0	0	0	0
	F_1	erosion	0	0	0	0	0	0	0	0
	F_2	0	0	0	0	0	0	0	0	0
Cynodon dactylon	F_0	erosion	erosion	erosion	0	0	0	sand burial	sand burial	sand burial
	F_1	0	erosion	0	0	0	0	sand burial	sand burial	sand burial
	F_2	erosion	drowning erosion	0	drowning erosion	0	0	sand burial	0	0
Andropogon perangustatus	F_0	erosion	erosion	drowning	0	0	0	0	0	erosion
	F_1	drowning	erosion	erosion	0	0	0	0	0	0
	F_2	drowning	drowning	drowning	0	0	0	0	0	0
No Planting	F_0	0	0	0	0	0	0	0	0	0
	F_1	0	0	0	0	0	0	0	0	0
	F_2	0	0	0	0	0	0	0	0	0

* No damage recorded in trees or shrubs.

Table 79

Calculated Area (Hectares) of Avian Transect

Habitat Types By Season*

Month	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Fall				
August 1976	3.46	1.05	2.39	0.43
September 1976	2.92	0.89	2.39	0.43
October 1976	3.73	1.13	2.39	0.43
November 1976	3.73	1.13	2.39	0.43
Winter				
December 1976	3.77	1.14	1.04	0.43
January 1977	3.89	1.18	1.04	1.76
February 1977	4.58	1.26	1.04	1.76
Spring				
March 1977	3.12	0.47	1.04	1.76
April 1977	4.10	0.88	1.04	1.76
May 1977	2.58	0.26	1.04	1.76

(Continued)

* Lengths of the marsh transects varied as tidal changes occurred, thus changing the observed area each month. The areas were averaged for each season to determine density of bird species in later tables.

Table 79 (Concluded)

Month	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Summer				
June 1977	1.95	0.42	1.04	1.76
July 1977	2.09	0.40	1.04	1.76
Fall				
August 1977	1.15	0.21	1.04	1.76
September 1977	1.67	0.18	1.04	1.76

Table 80

Mammals Seen or Captured on Bolivar Peninsula

Species*	Abundance**
Didelphis virginiana	c
Dasypus novemcinctus	c
Sylvilagus floridanus	vc
Sylvilagus aquaticus	r
Oryzomys palustris	r
Sigmodon hispidus	vc
Rattus norvegicus	r
Mus musculus	c
Myocastor coypus	r
Vulpes vulpes	r
Procyon lotor	c
Lutra canadesis	r

* Nomenclature follows Jones et al. (1975).

** r = rare, seen once or twice; c = common, seen occasionally; vc = very common, seen or captured on every visit.

Table 81

Small Mammal Trapping Results

Habitat	Size of Habitat	Trap Nights	Species	Total Number Trapped	Number Recaptured
			September 1976		
Experimental marsh	1.14 ha	80		0	0
Experimental upland	1.04 ha	120	*Mus musculus*	5	2
			Rattus norvegicus	1	0
Reference	0.81 ha	200	*Sigmodon hispidus*	2	0
Control	0.95 ha	196	*Sigmodon hispidus*	10	2
			Mus musculus	9	3
			Rattus norvegicus	1	0
			November 1976		
Experimental marsh	1.14 ha	80		0	0
Experimental upland	1.04 ha	120	*Mus musculus*	1	0
Reference	0.81 ha	196	*Sigmodon hispidus*	35	13
			Mus musculus	3	1

(Continued)

Table 81

Habitat	Size of Habitat	Trap Nights	Species	Total Number Trapped	Number Recaptured
Control	0.95 ha	200	*Sigmodon hispidus*	9	0
			Mus musculus	3	1
			February 1977		
Experimental marsh	1.14 ha	80		0	0
Experimental upland	1.04 ha	120		0	0
Reference	0.81 ha	200	*Oryzomys palustris*	8	1
			Sigmodon hispidus	24	12
			Mus musculus	3	0
Control	0.95 ha	200	*Oryzomys palustris*	2	1
			Sigmodon hispidus	2	2
			Mus musculus	10	1
			May 1977		
Experimental marsh	1.14 ha	80		0	0
Experimental upland	1.04 ha	120		0	0

(Continued)

Table 81 (Concluded)

Habitat	Size of Habitat	Trap Nights	Species	Total Number Trapped	Number Recaptured
Reference	0.81 ha	200	*Sigmodon hispidus*	20	12
Control	0.95 ha	200	*Oryzomys palustris*	1	1
			Sigmodon hispidus	6	3
			Mus musculus	1	0
			August 1977		
Experimental marsh	1.14 ha	80	*Oryzomys palustris*	1	0
			Mus musculus	1	0
Experimental upland	1.04 ha	120	*Sigmodon hispidus*	4	0
			Mus musculus	2	1
Reference	0.81 ha	200	*Oryzomys palustris*	4	1
			Sigmodon hispidus	36	12
Control	0.95 ha	200	*Sigmodon hispidus*	16	6
			Mus musculus	1	0

Table 82

Mammal, Reptile, and Amphibian Species
Noted on Bolivar Peninsula

Date	Species*	Number Noted	Form of Observation
		MARSH	
7 July 1976	*Lutra canadensis*	1	visual
30 November 1976	*Lutra canadensis*	1	visual
6 February 1977	*Myocastor coypus*	1	visual
8 February 1977	*Lutra canadensis*	1	visual
24 February 1977	*Sylvilagus floridanus*	4 young	in nest, removed
19 March 1977	*Dasypus novemcinctus*	1	tracks
		UPLAND	
6 July 1976	*Capra hircus*	30	visual
8 July 1976	*Capra hircus*	40	visual

(Continued)

* Amphibian nomenclature follows Conant (1975). Mammalian nomenclature follows Jones et al. (1975).

Table 82

Date	Species	Number Noted	Form of Observation
17 July 1976	*Sylvilagus floridanus*	3 young	in nest, removed
19 July 1976	*Sylvilagus floridanus*	1	collected
24 July 1976	*Sylvilagus floridanus*	1	collected
26 July 1976	*Sylvilagus floridanus*	1	collected
4 August 1976	*Capra hircus*	1	visual
10 September 1976	*Procyon lotor*	1	visual
24 September 1976	*Lampropeltis getulus*	1	visual
28 September 1976	*Lampropeltis getulus*	1	visual
30 September 1976	*Heterodon platyrhinos*	1	visual
16 November 1976	*Procyon lotor*	1	trapped
18 November 1976	*Procyon lotor*	2	trapped
19 November 1976	*Procyon lotor*	2	trapped
23 November 1976	*Procyon lotor*	1	trapped
30 November 1976	*Lutra canadensis*	1	visual

(Continued)

Table 82

Date	Species	Number Noted	Form of Observation
30 November 1976	*Phrynosoma cornutum*	1	visual
9 December 1976	*Didelphis virginiana*	1	sign
27 January 1977	*Sylvilagus floridanus*	1	visual
6 February 1977	*Sylvilagus floridanus*	1	collected
7 February 1977	*Sylvilagus floridanus*	3	collected
7 February 1977	*Sylvilagus aguaticus*	2	collected
13 February 1977	*Myocastor coypus*	1	carcass
22 February 1977	*Sylvilagus floridanus*	1	collected
22 February 1977	*Sylvilagus aquaticus*	1	collected
1 March 1977	*Sylvilagus floridanus*	1	collected
7 March	*Sylvilagus floridanus*	1	sign
19 March 1977	*Sylvilagus floridanus*	1	sign
19 March 1977	*Terrapene ornata*	3	visual
19 March 1977	*Phrynosoma cornutum*	1	visual

(Continued)

Table 82 (Concluded)

Date	Species	Number Noted	Form of Observation
1 May 1977	*Sylvilagus floridanus*	1	trapped
2 May 1977	*Sylvilagus floridanus*	1	visual
10 May 1977	*Sylvilagus floridanus*	1	collected
17 May 1977	*Sylvilagus floridanus*	1	visual
20 May 1977	*Sylvilagus floridanus*	4 young	in nest, removed
23 May 1977	*Sylvilagus floridanus*	2	visual
29 May 1977	*Sylvilagus floridanus*	1	visual
10 June 1977	*Sylvilagus floridanus*	1	collected
16 June 1977	*Sylvilagus floridanus*	1	carcass
16 June 1977	*Sylvilagus floridanus*	5	collected
20 June 1977	*Sylvilagus floridanus*	1	visual
22 June 1977	*Sylvilagus floridanus*	1	collected
16 August 1977	*Sylvilagus floridanus*	3	collected

Table 83

Bird Species Recorded on the Bolivar Peninsula Study Site*

Species	1976: 7	8	9	10	11	12	1977: 1	2	3	4	5	6	7	8	9	10	11
Podiceps nigricollis									+		+						
Pelecanus erythrorhynchos	+			+	+				+								
Phalacrocorax auritus				+												+	+
Phalacrocorax olivaceus												+		+			
Fregata magnificens		+	+	+								+	+				
Ardea herodias		+	+	+	+	+	+	+			+			+	+	+	+
Casmerodius albus	+	+	+	+	+	+				+	+	+	+	+	+	+	+
Egretta thula	+	+	+	+		+	+	+	+			+	+	+			+
Dichromanassa rufescens	+	+	+			+			+	+	+			+			
Hydranassa tricolor	+	+	+	+	+						+	+				+	
Bubulcus ibis										+							
Butorides striatus									+	+	+						
Nycticorax nycticorax	+																
Plegadis chihi			+	+	+					+				+		+	
Eudocimus albus			+	+	+				+	+		+				+	
Ajaia ajaja	+			+	+	+			+		+	+	+	+			+
Chen caerulescens				+													
Anas fulvigula														+			
Anas discors			+	+			+		+	+	+						
Anas clypeata									+								
Aythya valisineria								+									
Mergus serrator								+									
Elanus leucurus					+	+											
Buteo jamaicensis					+												
Circus cyaneus	+		+	+	+	+	+	+				+				+	
Pandion haliaetus				+		+											
Falco sparverius				+													+

(Continued)

* Nomenclature follows American Ornithologists' Union (1975), as amended by supplements 32 and 33.

Table 83

Species																	
	Months of the Study																
	1976						1977										
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Rallus longirostris	+	+	+		+					+				+		+	
Fulica americana				+													
Haematopus palliatus			+				+										
Charadrius semipalmatus	+	+	+	+	+	+	+	+	+	+	+	+		+	+		
Charadrius melodus	+	+	+	+	+	+	+	+	+	+	+			+		+	+
Charadrius wilsonia	+	+	+						+	+	+	+	+	+			
Charadrius vociferus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pluvialis squatarola	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Arenaria interpres	+	+	+		+	+	+	+	+	+	+	+	+	+		+	+
Numenius americanus	+		+	+	+	+	+	+	+					+	+		+
Numenius phaeopus										+	+						
Actitis macularia	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
Tringa solitaria										+							
Tringa melanoleucus				+	+	+	+	+	+	+				+	+	+	
Tringa flavipes								+	+	+							
Catoptrophorus semipalmatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Calidris melanotos											+						
Calidris fuscicollis											+						
Calidris minutilla	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Calidris alpina				+	+	+	+	+	+	+	+					+	+
Calidris pusillus										+	+	+					
Calidris mauri			+		+	+	+	+	+	+				+	+	+	
Calidris alba	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Limnodromus sp.	+	+	+	+	+		+		+	+		+	+	+	+	+	+
Limosa fedoa														+	+		
Recurvirostra americana			+		+		+	+									
Himantopus mexicanus			+							+				+	+		
Larus argentatus				+			+	+									+

(Continued)

Table 83

	Months of the Study																
	1976						1977										
Species	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Larus delawarensis		+	+	+	+	+	+	+	+								+
Larus atricilla		+	+	+	+	+		+	+	+	+	+	+	+	+	+	+
Gelochelidon nilotica									+								
Sterna forsteri						+	+		+	+	+		+				+
Sterna albifrons	+	+	+							+	+	+	+	+	+		
Sterna maxima		+	+			+	+					+	+	+	+	+	+
Sterna caspia									+	+			+			+	
Sterna sandvicensis			+										+	+	+		
Chlidonias niger	+	+											+	+			
Rynchops niger	+								+		+	+	+	+	+		
Zenaida macroura		+					+		+	+	+			+	+	+	+
Coccyzus americanus		+									+			+	+		
Asio flammeus								+									
Chordeiles minor	+	+	+							+			+	+			
Chaetura pelagica										+							
Archilochus colubris									+						+		
Megaceryle alcyon		+	+	+												+	+
Colaptes auratus						+										+	
Tyrannus tyrannus		+								+	+	+		+	+		
Muscivora forficata	+	+	+						+	+	+	+		+	+		
Sayornis phoebe											+						
Contopus virens			+														
Eremophila alpestris	+							+	+			+				+	
Iridoprocne bicolor									+								
Riparia riparia										+							
Stelgidopteryx ruficollis	+									+				+	+	+	
Hirundo rustica		+								+			+	+	+	+	
Progne subis									+			+	+				

(Continued)

Table 83

	Months of the Study																
	1976						1977										
Species	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Cyanocitta cristata				+													
Troglodytes aedon				+												+	+
Cistothorus platensis																	+
Mimus polyglottos											+			+			
Dumetella carolinensis										+							
Turdus migratorius							+										
Catharus guttatus				+													
Catharus ustulatus											+						
Catharus fuscescens										+							
Polioptila caerulea			+	+											+		
Regulus calendula				+	+	+											
Anthus spinoletta					+	+	+	+	+								
Lanius ludovicianus		+	+		+	+	+	+				+	+		+	+	+
Vireo griseus									+								
Vireo olivaceus											+						
Mniotilta varia									+								
Protonotaria citrea										+							
Helmitheros vermivorus									+								
Vermivora peregrina										+							
Vermivora celata										+							
Dendroica petechia											+						
Dendroica magnolia											+						
Dendroica coronata			+				+	+	+	+						+	+
Dendroica virens											+						
Dendroica dominica									+								
Dendroica striata											+						
Dendroica palmarum																+	
Seiurus aurocapillus											+						

(Continued)

Table 83 (Concluded)

Species	Months of the Study																
	1976						1977										
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Seiurus noveboracensis										+							
Geothlypis trichas										+	+						
Icteria virens										+							
Wilsonia citrina									+	+					+		
Setophaga ruticilla											+						
Sturnella magna	+				+	+		+						+	+	+	+
Agelaius phoeniceus	+	+				+	+				+	+	+	+	+	+	
Icterus spurius		+	+											+			
Icterus galbula										+	+				+		
Quiscalus mexicanus		+			+						+			+	+		
Quiscalus quiscula		+											+	+			
Molothrus ater											+	+					
Cardinalis cardinalis										+							
Pheucticus ludovicianus											+						
Guiraca caerulea										+	+						
Passerina cyanea										+							
Passerina ciris		+															
Passerculus sandwichensis				+			+			+							
Ammospiza leconteii																	+
Junco hyemalis					+	+											
Spizella pusilla				+	+												
Melospiza georgiana																	+
Melospiza melodia					+	+										+	
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Total Species 135	28	38	40	40	36	32	31	29	44	54	48	28	27	45	32	35	30

Table 84

Birds Orders Recorded on the Bolivar Peninsula Study Site*

Order	Number of Species Seen	Number of Species Known**	Percent of Order Seen
Podicipediformes (grebes)	1	4	25
Pelecaniformes (pelicans, cormorants)	4	8	50
Ciconiiformes (herons, egrets, ibises, spoonbills)	11	16	69
Anseriformes (geese, ducks)	6	34	18
Falconiformes (vultures, hawks, ospreys, falcons)	5	23	22
Gruiformes (rails, coots)	2	10	20
Charadriiformes (oystercatchers, plovers, turnstones, sandpipers, avocets, gulls, terns, skimmers)	37	57	65
Columbiformes (doves)	1	5	20
Cuculiformes (cuckoos)	1	4	25
Strigiformes (owls)	1	6	17
Caprimulgiformes (nighthawks)	1	4	25
Apodiformes (hummingbirds, swifts)	2	3	67
Coraciiformes (kingfishers)	1	1	100
Piciformes (flickers)	1	7	14
Passeriformes (swallows, warblers, etc.)	62	153	41
Totals	136	335	--
Average	--	--	40

* Nomenclature follows American Ornithologists' Union (1957), as amended by supplements 32 and 33.

** From Feltner and Pettingell (1974). Number of species in each order recorded on the upper Texas coast.

Table 85

Density of Bird Species Per Hectare and Total Number of Species

In Marsh and Upland Habitats for the Fall 1976 Season*

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Ardea herodias	0.04	0.13	-	-
Casmerodius albus	0.11	-	-	-
Egretta thula	0.04	-	-	-
Dichromanassa rufescens	0.04	-	-	-
Rallus longirostris	0.04	-	-	-
Fulica americana	0.04	-	-	-
Charadrius semipalmatus	0.11	-	-	-
Charadrius melodus	0.14	-	-	-
Charadrius wilsonia	0.11	-	-	-
Charadrius vociferus	0.39	-	-	-

(Continued)

* Density figures were calculated by dividing the total counts by the number of census trips and dividing this value by the average area of the habitat type for the fall 1976 season. The marsh area varied due to tidal changes.

Table 85

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Pluvialis squatarola	0.21	-	-	0.07
Arenaria interpres	0.14	-	-	-
Actitis macularia	0.04	-	-	-
Catoptrophorus semipalmatus	0.11	0.38	-	-
Calidris minutilla	0.68	1.12	-	-
Calidris alpina	0.25	-	-	-
Calidris mauri	1.28	0.25	-	-
Calidris alba	0.53	1.38	-	-
Calidris sp.	-	2.00	-	-
Recurvirostra americana	-	0.13	-	-
Sterna albifrons	0.04	-	-	-
Zenaida macroura	-	-	2.13	-
Chordeiles minor	-	-	-	0.07
Archilochus colubris	-	-	0.13	-

(Continued)

Table 85

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Megaceryle alcyon	-	-	-	0.07
Muscivora forficata	0.11	-	0.25	-
Polioptila caerulea	-	-	0.50	0.07
Regulus calendula	-	-	0.50	0.20
Anthus spinoletta	0.04	-	-	-
Lanius ludovicianus	-	-	0.13	0.07
Sturnella magna	-	-	0.25	-
Agelaius phoeniceus	-	-	1.88	-
Icterus galbula	-	-	0.50	-
Quiscalus mexicanus	-	-	0.38	-
Quiscalus quiscula	-	-	1.50	-

(Continued)

Table 85 (Concluded)

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Passerculus sandwichensis	-	-	0.13	-
Spizella pusilla	-	-	-	0.15
Melospiza melodia	-	-	-	0.07
Total Species	21	7	12	8
Average Density	0.21	0.77	0.69	0.10

Table 86

Density of Bird Species Per Hectare and Total Number of Species In Marsh and Upland Habitats for the Fall 1977 Season*

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Ardea herodias	0.41	-	-	-
Casmerodius albus	0.41	-	-	-
Egretta thula	0.20	1.66	-	-
Ajaia ajaja	-	8.30	-	-
Rallus longirostris	0.20	-	-	-
Charadrius semipalmatus	3.60	-	-	-
Charadrius melodus	0.60	-	-	-
Charadrius wilsonia	1.00	-	-	-
Pluvialis squatarola	0.62	1.66	-	-

(Continued)

* Density figures were calculated by dividing the total counts by the number of census trips and dividing this value by the average area of the habitat type for the fall 1977 season. The marsh area varied due to the tidal changes.

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
JUN 78 J W WEBB, J D DODD, B W CAIN DACW39-76-C-0109
UNCLASSIFIED WES-TR-D-78-15-APP-D NL

5 OF 6
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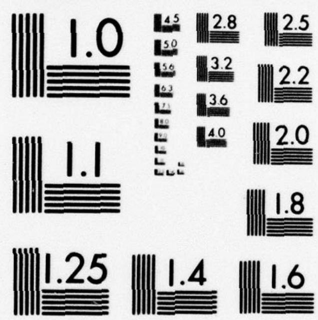

MICROCOPY RESOLUTION TEST CHART
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Table 86

Species	Marsh Experimental	Marsh Reference	Upland Experimental	Upland Reference
Arenaria interpres	0.41	-	-	-
Numenius americanus	0.20	-	-	-
Actitis macularia	0.41	-	-	-
Tringa melanoleucus	0.20	-	-	-
Catoptrophorus semipalmatus	1.20	-	-	-
Calidris minutilla	7.20	-	-	-
Calidris mauri	5.20	5.00	-	-
Calidris alba	0.60	1.66	-	-
Limnodromus sp.	3.00	-	-	-
Larus atricilla	-	25.00	-	-
Sterna maxima	-	3.32	-	-
Zenaida macroura	-	-	-	0.18
Coccyzus americanus	-	-	-	0.18
Archilochus colubris	-	-	-	0.18

(Continued)

Table 86 (Concluded)

Species	Marsh Experimental	Marsh Reference	Upland Experimental	Upland Reference
Tyrannus tyrannus	-	-	-	0.10
Muscivora forficata	-	-	-	0.72
Polioptila caerulea	-	-	-	0.18
Lanius ludovicianus	-	-	-	0.18
Dendroica petechia	-	-	-	0.18
Wilsonia citrina	-	-	-	0.18
Sturnella magna	-	-	-	0.54
Agelaius phoeniceus	2.60	-	-	9.00
Icterus spurius	-	-	-	0.90
Total Species	18	7	0	12
Average Density	1.56	6.66	0	1.04

Table 87

Density of Bird Species Per Hectare and Total Number of Species In Marsh and Upland Habitats for the Winter 1976-77 Season*

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Ardea herodias	0.04	-	-	-
Circus cyaneus	-	-	-	0.09
Charadrius melodus	0.08	-	-	-
Charadrius vociferus	0.50	-	0.83	-
Pluvialis squatarola	0.17	0.08	-	-
Arenaria interpres	0.21	-	-	-
Numenius americanus	-	1.08	-	-
Actitis macularia	0.04	-	-	-
Catoptrophorus semipalmatus	0.08	0.56	-	-
Calidris alpina	-	0.18	-	-

(Continued)

* Density figures were calculated by dividing the total counts by the number of census trips and dividing this value by the average area of that habitat type for the winter season. The marsh area varied due to tidal changes.

Table 87

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Calidris alba	0.08	0.13	-	-
Limnodromus sp.	0.04	0.08	-	-
Zenaida macroura	-	-	-	0.09
Eremophila alpestris	-	-	0.50	0.37
Turdus migratorius	-	-	-	0.09
Regulus calendula	-	-	0.16	-
Anthus spinoletta	0.08	-	-	-
Lanius ludovicianus	-	-	0.50	0.09
Dendroica coronata	-	-	0.33	0.09
Sturnella magna	0.04	-	-	0.27
Agelaius phoeniceus	-	-	10.00	-

(Continued)

Table 87 (Concluded)

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Passerculus sandwichensis	-	-	0.67	0.18
Melospiza melodia	-	-	-	0.09
Emberizinae (species unknown)	0.04	-	-	0.06
Total Species	12	6	7	10
Average Density	0.12	0.35	1.86	0.14

Table 88

Density of Bird Species Per Hectare and Total Number of Species In Marsh and Upland Habitats for the Spring 1977 Season*

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Egretta thula	0.05	-	-	-
Hydranassa tricolor	0.15	-	-	-
Charadrius semipalmatus	0.60	-	-	-
Charadrius melodus	0.15	0.66	-	-
Charadrius wilsonia	1.09	0.33	0.50	-
Charadrius vociferus	0.05	-	2.66	0.64
Pluvialis squatarola	0.47	2.00	-	-
Arenaria interpres	0.78	-	-	-
Actitis macularia	0.05	-	-	-

(Continued)

* Density figures were calculated by dividing the total counts by the number of census trips and dividing this value by the average area of the habitat type for the spring 1977 season. The marsh area varied due to tidal changes.

Table 88

Species	Marsh Experimental	Marsh Reference	Upland Experimental	Upland Reference
Tringa melanoleucus	0.10	-	-	-
Catoptrophorus semipalmatus	0.62	0.33	-	-
Calidris fuscicollis	0.20	-	-	-
Calidris minutilla	0.25	0.33	-	-
Calidris alpina	5.30	9.32	-	-
Calidris pusillus	0.31	3.00	-	-
Calidris mauri	0.25	-	-	-
Calidris alba	2.03	10.30	0.50	-
Limnodromus sp.	0.41	1.00	-	-
Limosa fedoa	0.05	-	-	-
Calidris melanotos	0.15	-	-	-
Larus delawarensis	-	0.33	-	-
Larus atricilla	0.10	7.66	-	-
Gelochelidon nilotica	-	0.66	-	-

(Continued)

Table 88

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Sterna forsteri	0.05	0.66	-	-
Sterna albifrons	0.15	1.00	1.16	-
Rynchops niger	0.15	-	-	-
Chordeiles minor	-	-	0.50	0.09
Megaceryle alcyon	0.05	-	-	-
Tyrannus tyrannus	-	-	-	0.27
Muscivora forficata	-	-	-	0.27
Eremophila alpestris	-	-	0.50	0.18
Dumetella carolinensis	-	-	-	0.09
Catharus ustulatus	-	-	-	0.18
Anthus spinoletta	1.09	-	-	-
Dendroica coronata	-	-	-	0.18
Dendroica virens	-	-	-	0.09
Setophaga ruticilla	-	-	-	0.09

(Continued)

Table 88 (Concluded)

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Sturnella magna	0.05	0.33	0.33	0.36
Agelaius phoeniceus	-	-	-	1.66
Icterus spurius	-	-	-	0.09
Molothrus ater	-	-	-	0.45
Cardinalis cardinalis	-	-	-	0.09
Passerina cyanea	-	-	-	0.27
Passerculus sandwichensis	-	-	-	0.27
Total Species	27	15	8	17
Average Density	0.54	2.53	0.77	0.31

Table 89

Density of Bird Species Per Hectare and Total Number of Species In Marsh and Upland Habitats for the Summer 1977 Season*

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Casmerodius albus	0.50	-	-	-
Egretta thula	0.17	0.83	-	-
Hydranassa tricolor	0.33	-	-	-
Charadrius semipalmatus	0.33	-	-	-
Charadrius wilsonia	2.50	1.66	-	-
Charadrius vociferus	0.67	-	0.33	0.73
Pluvialis squatarola	-	2.49	-	-
Arenaria interpres	0.17	-	-	-
Actitis macularia	0.33	-	-	-

(Continued)

* Density figures were calculated by dividing the total counts by the number of census trips and dividing this value by the average area of the habitat type for the summer 1977 season. The marsh area varied due to the tidal changes.

Table 89

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Catoptrophorus semipalmatus	1.00	5.00	-	-
Calidris minutilla	0.67	3.33	-	-
Calidris alba	-	2.49	-	-
Larus atricilla	0.17	19.15	-	-
Sterna albifrons	1.00	4.16	-	-
Sterna maxima	0.17	6.64	-	-
Sterna caspia	-	1.66	-	-
Sterna sandvicensis	-	0.83	-	-
Chlidonias niger	0.17	-	-	-
Rynchops niger	0.33	-	-	-
Eremophila alpestris	-	-	0.33	-
Lanius ludovicianus	-	-	0.33	0.37
Sturnella magna	-	-	-	0.18
Agelaius phoeniceus	0.14	-	3.00	3.42

(Continued)

Table 89 (Concluded)

Species	Marsh		Upland	
	Experimental	Reference	Experimental	Reference
Quiscalus mexicanus	0.17	-	-	2.70
Quiscalus quiscula	-	-	2.31	-
Molothrus ater	-	-	0.33	0.18
Total Species	17	11	6	6
Average Density	0.52	4.39	1.1	1.26

Table 90

Mean Diversity of Bird Species Per Transect

By Season*

Marsh transect	Fall 1976	Winter 1976	Spring 1977	Summer 1977	Fall 1977
1	1.12	1.14	2.07	1.86	1.56
4	0.60	0.91	2.25	1.54	1.66
5	1.41	1.28	2.05	1.96	1.28
8	1.11	1.94	1.97	1.97	0.85
Upland transect					
3	1.07**	0.35	1.22	1.19	0.00
7	0.57+	1.12	1.47	0.53	0.89
9	--	1.19	1.07	1.20	1.30

* Diversity data are calculated according to Lloyd et al. 1968.

** Includes the six upland stations of transects 1, 4, and 5.

\+ Includes the two upland stations of transect 8.

Table 91

Bird Nesting Activity in Upland Habitat by Species

Habitat	Size	Species	Number Of Nests	Average Nest Success	Nest Density
Experimental upland	2.34 ha	*Charadrius wilsonia*	2	80%	0.85/ha
		Charadrius vociferus	4	100%	1.71/ha
		Sterna albifrons	23	90%	9.83/ha
Totals		3 species	29		12.39/ha
Reference upland	0.81 ha	*Muscivora forficata*	1	0%	1.23/ha
Totals		1 species	1		1.23/ha
Control upland	0.95 ha	*Agelaius phoeniceus*	2	0%	2.11/ha
		Molothrus ater	2	0%	2.11/ha
Totals		2 species	4		4.22/ha

Table 92

Bird Nesting Activity in Marsh Habitat by Species

Habitat	Size	Species	Number Of Nests	Average Nest Success	Nest Density
Experimental marsh	4.13 ha	*Sterna albifrons*	4	60%	0.97/ha
		Molothrus ater	1	100%	0.24/ha
		Agelaius phoeniceus	2	100%	0.48/ha
Totals		3 species	7 nests		1.69/ha
Reference marsh	1.36 ha	none			
Totals		none			

Table 93

Total Rainfall Collected from the Bolivar Site and Quantities of Nitrogen, Phosphorus, Calcium, Potassium, and Sodium in Precipitation

Date	Precipitation		Nitrogen				Phosphorus		Ca^{++}	K^{+}	Na^{+}
	(cm)	(ml/station)	NH_4^+-N (kg/ha)	NO_2^--N (kg/ha)	NO_3^--N (kg/ha)	Kjeldahl (kg/ha)	Ortho (kg/ha)	Total (kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)
9/8/76–9/22/76	15.3	3,197	ND*	ND	ND	2.16	ND	ND	ND	ND	2.45
9/22/76–10/6/76	0.3	63	0.08	ND	ND	0.23	ND	0.01	0.02	ND	0.03
10/6/76–10/20/76	3.2	668	ND	ND	0.16	ND	ND	ND	0.48	ND	0.74
10/20/76–11/3/76	7.4	1,544	ND	ND	ND	ND	ND	ND	0.58	ND	2.74
11/3/76–11/17/76	0.7	138	ND	0.002	0.08	0.07	ND	ND	0.25	ND	1.40
11/17/76–12/1/76	14.1	3,938	ND	ND	0.28	ND	ND	ND	ND	ND	1.63
12/1/76–12/15/76	12.4	2,592	ND	ND	0.30	ND	ND	ND	ND	ND	1.70
12/16/76–12/29/76	7.49	1,563	ND	ND	0.09	0.54	ND	ND	ND	ND	0.72
12/30/76–1/12/77	3.09	645	ND	ND	ND	ND	ND	ND	0.15	ND	0.95
1/13/77–1/26/77	0.73	151	ND	ND	0.02	ND	ND	ND	0.06	0.02	0.03
1/27/77–2/9/77	2.44	510	0.14	ND	0.14	0.35	ND	ND	0.20	0.12	0.09
2/10/77–2/23/77	2.34	488	ND	ND	0.12	0.08	ND	0.01	0.23	0.14	0.08
2/24/77–3/9/77	1.46	304	ND	0.002	0.11	0.22	ND	0.02	0.46	0.11	0.13
3/10/77–3/23/77	1.07	222	0.02	0.004	0.13	0.48	ND	ND	0.40	0.16	0.07
** 3/24/77–5/24/77	7.14	1,490	ND	ND	0.17	1.25	ND	ND	2.56	0.93	4.76
** 5/25/77–7/15/77	12.37	2,581	0.10	ND	0.12	2.47	ND	0.01	0.92	0.25	2.93
** 7/16/77–9/20/77	29.26	6,106	0.49	0.006	0.57	0.54	0.05	0.09	0.22	0.20	0.69
** 9/21/77–11/23/77	17.98	3,752	0.33	0.002	0.06	0.52	0.08	0.08	0.23	0.17	0.46
Totals	138.81	29,952	1.16	0.016	2.35	8.91	0.13	0.22	6.76	2.10	21.60

* ND = not detectable

** 2-month intervals

Table 94

Soil Temperatures (^{o}C) of the Upland and Marshland Areas of the Bolivar Peninsula Site from 10/15/76 through 12/3/77

Depth		10/15/76	11/11/76	12/17/76	1/20/77	2/25/77	3/31/77	4/15/77
					Upland			
	$\overline{X}$ *	24.2	22.1	15.2	13.2	24.4	31.3	31.6
2.5 cm	N	12.0	12.0	12.0	12.0	12.0	12.0	12.0
	SD	0.8	0.8	2.4	1.5	0.5	1.4	1.5
	$\overline{X}$	23.4	22.3	15.5	11.0	21.5	27.4	29.5
10.0 cm	N	12.0	12.0	12.0	12.0	12.0	12.0	12.0
	SD	0.7	0.8	0.9	0.9	1.2	1.4	1.2
					Marshland			
	$\overline{X}$	23.6	23.8	14.6	15.5	24.4	29.8	29.4
2.5 cm	N	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	SD	0.8	1.1	1.7	0.9	1.1	2.1	1.1
	$\overline{X}$	23.2	23.1	13.8	12.8	22.6	27.8	28.1
10.0 cm	N	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	SD	0.5	0.6	0.8	1.0	0.8	1.7	1.0

* $\overline{X}$ = Mean soil temperature, N = number of observations, SD = standard deviation

(continued)

Table 94 (Concluded)

Depth		5/18/77	6/27/77	7/25/77	8/25/77	10/14/77	11/15/77	12/3/77
					Upland			
	$\overline{X}$	32.8	40.7	43.0	32.7	29.4	24.7	21.8
2.5 cm	N	12.0	12.0	12.0	12.0	12.0	12.0	12.0
	SD	2.0	3.8	2.8	2.4	1.5	1.9	0.7
	$\overline{X}$	30.2	33.8	36.6	32.3	25.1	23.6	22.2
10.0 cm	N	12.0	12.0	12.0	12.0	12.0	12.0	12.0
	SD	1.8	1.2	1.9	2.1	0.9	2.3	0.9
					Marshland			
	$\overline{X}$	28.4	34.2	38.7	31.5	25.4	24.5	22.6
2.5 cm	N	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	SD	1.7	3.0	0.9	1.4	2.02	0.9	1.1
10.0 cm	$\overline{X}$	27.2	32.1	36.5	30.2	23.7	23.1	22.7
	N	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	SD	1.1	2.0	1.7	1.8	0.8	0.7	1.1

Table 95

Physical Description of Soil Cores, Shallow Depth

Plot Area	Core No.*	Depth (cm)	Description**
Upland	(T-23-FO)	0 - 7.0	Sand, very fine grain, tan with coloring, well sorted; moist color 10 YR 5/3
		7.0 - 7.5	Clay, grey; moist color 2.5 YR 5/2
		7.5 - 29.0	Sand, fine to very fine grain, tan, moderately well sorted, some clay stringers, iron stained; moist color 10 YR 5/3
		0 - 9.5	Sand to very fine grain, tan, well sorted, shell fragments; moist color 10 YR 6/3
Upland	(S-49-F1)	9.5 - 10.0	Clay, grey; moist color 10 YR 5/3
		10.0 - 31.0	Sand, fine to very fine grain, tan, well sorted; moist color 10 YR 6/3
		0 - 26.5	Sand, fine to very fine grain, tan, well sorted, massive, some large shell fragments; moist color 10 YR 6/3
Upland	(G-45-F2)	0 - 6.0	Sand, fine grain, moderately well sorted, grey to black, rippled; moist color 7.5 YR 3/0
Marshland	(T3-B1-6)	6.0 - 18.0	Sand, fine grain, well sorted, grey, massive; moist color 7.5 YR 3/0
		18.0 - 29.0	Sand fine grain, well sorted, dark grey, vague laminations; moist color 7.5 YR 3/0
		0 - 10.0	Sand, fine grain, moderately well sorted, tan, some small shell fragments; moist color 10 YR 5/4

* Number relates to location identified in Figure 37.
For upland plots, T indicates trees, G indicates grass, and S indicates shrubs.
For marshland plots, T indicates the tier number and B the block number.

** Color designations from Munsell color chart. Moist freshly exposed surface.

(continued)

Table 95 (Concluded)

Plot Area	Core No.	Depth (cm)	Description
Marshland	(T3-B2-11)	10.0 - 23.5	Sand, fine grain, moderately well sorted, black, some lenses of finer grain material; moist color 7.5 YR 3/0
		23.5 - 23.5	Sand, fine grain, moderately well sorted, tan, shell fragments and clay balls; moist color 7.5 YR 3/0
Marshland	(T3-B3-29)	0 - 16.0	Sand, fine grain, moderately well sorted, light grey, massive; moist color (0-1cm) 7.5 YR 3/0 (1-16cm) 2.5 YR 4/2
		16.0 - 28.5	Sand, fine to very fine grain, moderately well sorted, black 30-degree cross-beds; moist color 7.5 YR 3/0
		0 - 14.0	Sand, fine grain, moderately well sorted, black, massive; moist color 7.5 YR 3/0
Marshland	(T2-B1-17)	19.5 - 29.5	Sand, fine grain, moderately well sorted, black, some silt, moist color 7.5 YR 3/0
		0 - 18.5	Sand, fine grain, moderately well sorted, black, some silt and clay stringers; moist color 7.5 YR 3/0
Marshland	(T1-B2-11)	18.5 - 28.0	Sand, fine grain to very fine grain, moderately well sorted, black, 10-degree cross-beds, some clay stringers; moist color 7.5 YR 3/0
		0 - 11.0	Sand, fine to very fine grain, moderately well sorted, black, some clay balls; moist color 7.5 YR 3/0
Marshland	(T1-B3-6)	11.0 - 27.0	Sand, fine grain, well sorted, black, massive, few clay stringers; moist color 7.5 YR 2/0

Table 96

Physical and Chemical Properties, Cation Exchange Capacity, and Exchangeable Cations Taken from the Bolivar Peninsula Study Site Prior to Fertilization

		Moisture			Organic	Partical Size				Nitrogen				Phosphorus		Total	
	Depth	Content		Eh	Matter	Sand	Silt	Clay	Salinity	TKN	NH_4^+-N	NO_2^--N	NO_3^--N	Total	Extractable	Sulfide	Lime
Core No.*	(cm)	(%)	pH	(m)	(%)	(%)	(%)	(%)	(mmhos/cm)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	Requirement
(T-23-F0)	0-15	16.8	8.13	+596	0.594	96.0	0.5	3.5	0.25	57.6	<0.60	<0.03	<0.62	156.6	52.8	4.18	0.0
	15-30	15.6	8.28	+551	0.110	99.6	0.4	0.0	0.18	54.8	<0.60	<0.03	<0.62	69.9	22.3	0.22	0.0
(S-49-F1)	0-15	13.1	8.40	+786	0.192	97.0	0.9	2.1	2.28	103.2	<0.60	<0.03	<0.62	46.6	21.8	0.21	0.0
	15-30	13.2	8.71	+750	0.059	99.7	0.0	0.3	0.57	26.0	1.77	<0.03	<0.62	36.6	16.0	0.08	0.0
(G-45-F2)	0-15	5.2	8.61	+536	0.050	97.1	0.0	2.9	0.18	46.9	2.21	<0.03	<0.62	76.5	14.8	0.59	0.0
	15-30	5.7	8.37	+356	0.048	98.8	0.6	0.6	0.20	75.2	<0.60	<0.03	<0.62	139.9	15.4	3.55	0.0
(T3-B1-6)	0-15	23.0	8.49	+671	0.124	99.1	0.0	0.9	1.88	30.3	1.24	<0.03	<0.62	76.4	2.8	0.17	0.0
	15-30	22.7	8.37	+586	0.033	99.8	0.0	0.2	1.88	24.8	<0.60	<0.03	<0.62	45.0	15.2	0.22	0.0
(T3-B2-11)	0-15	25.8	8.37	+ 86	0.145	99.4	0.0	0.6	7.28	53.1	1.56	<0.03	<0.62	61.6	18.1	0.27	0.0
	15-30	22.6	8.16	+ 43	0.124	98.0	0.1	1.9	7.96	30.9	<0.60	<0.03	<0.62	72.1	21.6	2.83	0.0
(T3-B3-29)	0-15	23.6	8.53	+511	0.213	96.2	0.0	3.8	8.90	24.1	<0.60	<0.03	<0.62	80.0	23.0	<0.05	0.0
	15-30	17.5	8.42	+460	0.103	97.5	1.5	1.0	8.98	23.5	2.01	<0.03	<0.62	94.9	14.0	0.50	0.0
(T2-B1-17)	0-15	24.0	8.04	+ 81	0.266	99.0	0.1	0.9	4.35	94.9	<0.60	<0.03	<0.62	120.0	21.4	2.13	0.0
	15-30	24.7	8.09	+ 40	0.203	96.7	1.9	1.4	4.75	57.9	<0.60	<0.03	<0.62	90.0	16.9	5.90	0.0
(T1-B2-11)	0-15	26.3	8.10	+186	0.084	97.9	0.9	1.2	3.77	40.5	1.84	<0.03	<0.62	71.6	17.5	3.48	0.0
	15-30	25.7	8.04	-114	0.142	96.4	0.6	3.0	6.30	25.7	<0.60	<0.03	<0.62	83.1	16.6	1.04	0.0
(T1-B3-6)	0-15	22.9	8.13	+ 76	0.169	95.9	0.0	4.1	4.69	129.9	3.02	<0.03	<0.62	86.4	29.7	15.07	0.0
	15-30	24.1	8.16	+ 15	0.093	94.7	1.0	4.2	4.54	39.9	2.01	<0.03	<0.62	64.2	31.7	3.70	0.0

* Number relates to location identified on Figure 37. Cores T-23-F1, S-49-F1, and G-45-F2 were from the upland area. Core number = plot number.

(continued)

Table 96 (Concluded)

Core No.	Depth (cm)	Cation Exchange Capacity (meq/100 g)	Exchangeable Bases Ca^{++}	(meq/100 g) Mg^{++}	K^{+}	Na^{+}	Exchangeable Cations Fe^{+3}	Cu^{+2}	(meq/100 g) Mn^{+2}	Ni^{+2}	Zn^{+2}
(T-23-F0)	0-15	6.69	18.8	3.8	0.8	1.3	0.0031	ND*	0.023	ND*	0.0051
	15-30	2.65	10.2	1.5	0.3	0.2	0.0031	ND	0.0066	ND	0.0089
(S-49-F1)	0-15	2.02	4.5	0.9	0.2	14.5	0.0049	ND	0.028	ND	0.0030
	15-30	1.64	4.5	0.8	0.2	12.9	0.0016	ND	0.011	ND	0.0085
(G-45-F2)	0-15	1.51	42.0	0.5	0.1	1.1	0.0058	ND	0.017	ND	0.0089
	15-30	1.45	52.9	0.6	0.1	1.1	<0.0009	ND	0.012	ND	0.0110
(T3-B1-6)	0-15	2.27	16.0	1.5	0.3	13.4	0.0103	ND	0.043	ND	0.0068
	15-30	1.26	7.8	1.3	0.2	17.6	0.0045	ND	0.028	ND	0.0036
(T3-B2-11)	0-15	1.57	20.2	4.2	0.6	23.1	0.0048	ND	0.036	ND	0.0039
	15-30	1.70	48.8	4.5	0.6	23.8	0.0048	ND	0.022	ND	0.0160
(T3-B3-29)	0-15	1.76	10.8	1.5	0.6	23.1	0.0049	ND	0.049	ND	0.0029
	15-30	1.45	14.0	4.0	0.5	20.6	0.0040	ND	0.031	ND	0.0028
(T2-B1-17)	0-15	3.53	18.5	2.2	0.7	16.3	0.0027	ND	0.028	ND	0.0026
	15-30	2.58	12.2	2.6	0.5	18.7	<0.0009	ND	0.036	ND	0.0046
(T1-B2-11)	0-15	1.89	13.0	2.2	0.4	15.8	0.0013	ND	0.040	ND	0.0024
	15-30	2.77	12.0	2.4	0.4	17.4	0.0012	ND	0.021	ND	0.0027
(T1-B3-6)	0-15	4.11	10.5	2.8	0.6	15.4	<0.0009	ND	0.061	ND	0.0024
	15-30	2.40	12.0	4.0	0.4	15.0	<0.0009	ND	0.020	ND	0.0024

* Not detectable.

Table 97

Soluble Ca Collected in Ten Successive 50-ml Aliquots of NH_4OAc to Determine Exchangeable Bases for Sediments from two Bolivar Peninsula Research Plots

Aliquot	ml	T3-B1-6 (15-30cm depth) (meq/100g)	T2-B1-7 (15-30cm depth) (meq/100g)
1	0-50	4.45	4.46
2	50-100	2.01	2.08
3	100-150	1.86	1.66
4	150-200	1.64	1.24
5	200-250	1.41	0.94
TOTAL (0-250 ml)		11.37	10.38
6	250-300	1,38	0.77
7	300-350	1.14	0.52
8	350-400	0.97	0.42
9	400-450	0.72	0.36
10	450-500	0.68	0.21
TOTAL (250-500 ml)		4.89	2.28

Table 98

Analysis of Four Sets of Deep Cores Taken to 105 cm from the Marshland Area of the Bolivar Peninsula Site

Tier	Depth (cm)	N*	Moisture Content (%) $\bar{X}$*	Moisture Content (%) SD*	pH $\bar{X}$	pH SD	Nitrogen: TKN (μg/g) $\bar{X}$	TKN SD	NH_4^+-N (μg/g) $\bar{X}$	NH_4^+-N SD	NO_3^--N (μg/g) $\bar{X}$	NO_3^--N SD	NO_2^--N (μg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (μg/g) $\bar{X}$	Extractable Phosphorus SD
							Sample Date - 14 August 1976									
3	0-15	3	17.00	1.37	8.35	0.256	24.62	9.26	4.75	6.85	<0.62	-	0.09	0.04	47.00	28.94
	15-30	3	21.30	4.99	8.12	0.366	73.52	76.47	4.88	4.05	<0.62	-	0.19	0.13	21.40	5.85
	30-45	3	25.03	1.15	8.10	0.231	112.57	156.44	3.54	2.58	<0.62	-	0.06	0.04	19.70	6.42
	45-60	3	23.70	2.72	8.23	0.237	75.23	45.87	3.61	1.73	<0.62	-	0.06	0.03	20.80	5.79
	60-75	3	24.97	3.15	8.17	0.116	53.27	33.57	5.96	5.16	<0.62	-	0.06	0.03	16.00	2.21
	75-90	3	22.90	1.57	8.21	0.101	42.84	22.53	3.08	0.82	<0.62	-	0.09	0.07	20.77	6.08
	90-105	3	22.80	1.11	8.19	0.080	138.02	130.27	2.61	1.01	<0.62	-	0.06	0.04	19.00	2.01
2	0-15	3	26.40	2.92	8.06	0.131	88.70	19.27	23.51	21.91	<0.62	-	0.04	0.01	45.63	15.18
	15-30	3	24.27	1.65	8.04	0.051	51.96	5.56	8.98	8.20	<0.62	-	0.03	0.01	20.37	8.26
	30-45	3	24.70	1.48	8.09	0.062	44.20	27.40	8.44	3.04	<0.62	-	0.05	0.03	19.63	3.04
	45-60	3	24.37	1.53	8.12	0.127	80.93	5.52	5.76	2.02	<0.62	-	0.04	0.02	26.07	12.30
	60-75	3	23.20	2.01	8.09	0.040	74.43	9.16	5.76	1.03	<0.62	-	0.06	0.04	28.00	1.10
	75-90	3	24.43	2.97	8.05	0.046	88.15	25.11	6.96	4.11	<0.62	-	0.04	0.02	31.70	0.80
	90-105	3	22.87	1.85	8.11	0.075	72.43	17.54	4.76	2.52	<0.62	-	0.04	0.02	32.10	9.45
1	0-15	3	26.13	0.98	7.93	0.135	96.96	30.94	51.54	44.58	<0.62	-	0.06	0.03	29.53	2.40
	15-30	3	24.93	2.84	8.05	0.098	139.65	30.58	5.41	1.37	<0.62	-	0.07	0.03	37.40	12.32
	30-45	3	22.67	0.77	8.05	0.055	50.35	19.48	4.61	2.64	<0.62	-	0.06	0.02	22.13	4.16
	45-60	3	23.20	1.05	8.06	0.055	60.93	5.52	2.61	1.74	<0.62	-	0.06	0.03	21.40	0.70
	60-75	3	23.27	0.49	8.24	0.281	78.43	9.16	5.28	3.79	<0.62	-	0.05	0.03	24.47	9.77
	75-90	3	22.97	0.64	8.09	0.029	80.13	25.10	6.10	5.74	<0.62	-	0.04	0.02	22.63	4.14
	90-105	3	22.43	1.02	8.12	0.009	70.40	17.54	4.49	3.25	<0.62	-	0.07	0.06	20.37	2.89

*N = Number of observations, $\bar{X}$ = mean, SD = standard deviation.

(continued)

Table 98

Tier	Depth (cm)	N	Moisture Content (%) $\bar{X}$	Moisture Content (%) SD	pH $\bar{X}$	pH SD	Nitrogen TKN (µg/g) $\bar{X}$	TKN SD	NH_4^+-N (µg/g) $\bar{X}$	NH_4^+-N SD	NO_3^--N (µg/g) $\bar{X}$	NO_3^--N SD	NO_2^--N (µg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (µg/g) $\bar{X}$	Extractable Phosphorus SD
Sample Date - 20 November 1976																
3	0-15	3	26.17	1.56	8.48	0.36	131.94	178.29	3.69	1.16	0.75	0.22	0.066	0.012	112.93	131.85
	15-30	3	24.13	2.20	8.36	0.62	32.20	7.24	2.35	1.16	<0.62	-	0.063	0.04	24.70	3.77
	30-45	3	24.13	2.02	8.24	0.36	35.90	7.99	2.55	1.51	<0.62	-	0.043	0.015	23.20	11.45
	45-60	3	23.30	1.10	8.08	0.30	42.69	10.47	3.62	0.88	<0.62	-	0.043	0.006	30.77	7.60
	60-75	3	25.00	1.51	8.03	0.38	67.31	35.91	4.69	2.09	<0.62	-	0.047	0.012	21.70	3.77
	75-90	3	24.57	1.53	7.93	0.22	113.65	60.80	3.69	2.68	<0.62	-	0.037	0.006	34.27	13.72
	90-105	3	23.30	0.52	7.95	0.32	63.93	11.65	5.36	3.23	<0.62	-	0.037	0.015	25.73	6.50
2	0-15	3	44.10	25.03	7.90	0.38	361.18	191.98	10.04	7.04	<0.62	-	0.06	0.01	66.03	35.57
	15-30	3	24.90	2.08	8.03	0.30	62.53	27.82	9.05	4.02	0.66	0.08	0.04	-	22.70	6.54
	30-45	3	26.67	1.43	8.12	0.28	44.03	6.23	7.71	5.54	<0.62	-	0.04	-	20.70	2.29
	45-60	3	23.60	0.78	8.04	0.35	60.12	15.30	16.22	16.65	<0.62	-	0.04	0.02	59.93	63.37
	60-75	3	26.17	5.82	7.90	0.43	239.76	287.83	5.43	2.64	<0.62	-	0.03	0.01	38.30	14.27
	75-90	3	23.87	1.45	8.14	0.39	86.24	14.45	8.31	4.54	<0.62	-	0.05	0.01	27.13	9.01
	90-105	3	23.60	1.85	8.20	0.32	105.01	58.16	4.56	3.58	<0.62	-	0.043	0.006	36.83	21.59
1	0-15	3	26.90	6.65	7.62	0.10	203.97	125.12	8.18	6.50	0.72	0.18	0.047	0.012	85.73	34.02
	15-30	3	24.20	2.94	7.79	0.04	115.04	55.27	7.98	1.01	<0.62	-	0.043	0.015	36.27	15.99
	30-45	3	27.93	6.64	7.88	0.18	69.78	16.49	10.05	4.61	<0.62	-	0.043	0.015	27.67	5.46
	45-60	3	24.37	1.97	7.82	0.13	69.99	11.85	6.70	5.54	<0.62	-	0.033	0.006	21.87	3.75
	60-75	3	23.03	1.61	8.03	0.21	73.37	10.01	3.02	1.74	<0.62	-	0.05	0.017	22.63	4.05
	75-90	3	23.10	1.50	8.07	0.29	83.45	17.19	5.96	1.91	0.66	0.08	0.043	0.006	26.23	11.42
	90-105	3	27.60	4.55	8.04	0.33	92.84	19.83	2.68	1.53	<0.62	-	0.04	0.02	28.00	9.62

(continued)

Table 98

Tier	Depth (cm)	N	Moisture Content (%) $\overline{X}$	Moisture Content (%) SD	pH $\overline{X}$	pH SD	Nitrogen: TKN (μg/g) $\overline{X}$	TKN SD	NH_4^+-N (μg/g) $\overline{X}$	NH_4^+-N SD	NO_3^--N (μg/g) $\overline{X}$	NO_3^--N SD	NO_2^--N (μg/g) $\overline{X}$	NO_2^--N SD	Extractable Phosphorus (μg/g) $\overline{X}$	Extractable Phosphorus SD
Sample Date - 27 June 1977																
3	0-15	3	19.70	4.51	8.86	0.65	81.20	37.02	2.32	1.48	2.05	0.51	0.44	7.01	69.83	75.61
	15-30	3	23.80	4.30	8.42	0.20	42.03	17.95	1.97	0.61	0.76	0.33	0.04	0.03	22.37	6.88
	30-45	3	24.50	2.85	8.13	0.11	40.30	22.90	1.97	1.09	2.38	3.25	0.03	0.01	93.17	92.42
	45-60	3	24.60	0.21	8.25	0.11	49.30	21.57	2.25	1.16	<0.60	-	0.03	0.02	14.93	6.66
	60-75	3	24.60	0.59	8.10	0.23	45.47	31.23	1.69	1.47	<0.60	-	0.03	0.02	30.43	18.28
	75-90	3	25.40	0.82	8.17	0.35	48.13	21.75	1.90	0.63	0.76	0.46	0.04	0.02	29.10	15.30
	90-105	3	24.06	1.55	8.42	0.15	37.37	12.37	1.62	1.41	<0.06	-	0.05	0.03	29.47	24.97
2	0-15	3	30.43	6.37	7.93	0.47	393.37	307.91	23.00	19.57	0.95	0.40	0.05	0.02	76.37	74.51
	15-30	3	25.77	1.79	8.12	0.61	84.13	52.83	2.82	2.16	0.60	0.18	0.10	0.09	66.03	78.85
	30-45	3	25.77	1.40	8.17	0.29	64.20	31.28	2.04	2.45	0.60	0.18	0.06	0.02	24.20	3.15
	45-60	3	26.57	1.42	8.30	0.40	46.53	18.32	1.97	0.64	0.71	0.36	0.06	0.02	21.20	5.51
	60-75	3	26.97	1.10	8.05	0.15	148.83	126.39	5.49	5.91	<0.60	-	0.04	-	22.30	6.50
	75-90	3	27.57	2.29	7.99	0.36	81.30	56.95	6.19	4.99	<0.60	-	0.04	0.01	26.43	11.30
	90-105	3	27.23	5.68	8.30	0.26	145.17	151.67	6.19	5.80	0.60	0.18	0.04	0.02	27.23	9.35
1	0-15	3	26.07	4.02	7.95	0.64	199.23	71.89	11.11	6.36	<0.60	-	0.05	0.01	79.03	58.42
	15-30	3	27.13	3.52	7.73	0.12	168.37	74.94	4.50	3.06	<0.60	-	0.11	0.14	29.97	14.63
	30-45	3	25.73	0.31	7.85	0.15	95.60	19.60	2.69	1.31	0.55	0.09	0.03	0.02	25.87	9.77
	45-60	3	24.60	0.35	7.78	0.22	91.80	48.36	3.38	1.17	1.30	1.38	0.03	0.01	18.53	4.97
	60-75	3	25.33	0.85	7.97	0.19	73.53	3.67	4.50	0.32	0.76	0.46	0.04	0.02	18.60	2.85
	75-90	3	23.93	1.27	8.18	0.17	89.07	23.50	3.02	1.22	0.65	0.27	0.05	0.03	42.70	38.77
	90-105	3	23.53	0.42	8.11	0.19	42.77	34.74	1.62	1.61	0.65	0.09	0.03	0.01	19.63	5.30

(continued)

Table 98 (Concluded)

Tier	Depth (cm)	N	Moisture Content (%) $\bar{X}$	Moisture Content (%) SD	pH $\bar{X}$	pH SD	Nitrogen: TKN (µg/g) $\bar{X}$	TKN SD	NH_4^+-N (µg/g) $\bar{X}$	NH_4^+-N SD	NO_3^--N (µg/g) $\bar{X}$	NO_3^--N SD	NO_2^--N (µg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (µg/g) $\bar{X}$	Extractable Phosphorus SD
Sample Date - 14 October 1977																
3	0-15	3	24.47	1.87	8.91	0.48	41.37	24.70	2.32	2.95	<0.62	-	0.04	0.02	65.93	71.98
	15-30	3	22.40	4.06	8.70	0.47	61.60	70.69	1.61	1.58	<0.62	-	0.05	0.03	41.67	42.12
	30-45	3	23.03	0.32	8.62	0.43	50.70	44.99	1.41	1.00	<0.62	-	0.03	0.01	32.75	43.69
	45-60	3	25.30	2.33	8.66	0.32	43.83	23.59	1.10	0.35	<0.62	-	0.04	0.02	53.03	62.42
	60-75	3	24.23	0.32	8.75	0.27	30.87	5.35	1.30	0.77	<0.62	-	0.04	0.01	61.73	65.23
	75-90	3	23.70	1.35	8.70	0.07	52.47	25.98	1.81	1.64	<0.62	-	0.04	0.02	70.60	86.09
	90-105	3	23.77	1.84	8.71	0.07	45.67	12.59	1.31	1.40	<0.62	-	0.05	0.03	73.97	74.53
2	0-15	3	79.30	63.40	7.87	0.16	314.07	240.80	49.70	74.95	<0.62	-	0.05	0.02	239.80	181.94
	15-30	3	28.77	3.52	8.24	0.25	72.00	60.37	7.26	10.74	<0.62	-	0.10	0.09	61.67	42.57
	30-45	3	28.93	8.64	8.29	0.22	40.40	11.45	1.73	2.01	<0.62	-	0.06	0.02	71.07	49.36
	45-60	3	26.80	3.02	8.40	0.21	42.27	14.07	1.91	0.86	<0.62	-	0.06	0.02	55.30	45.76
	60-75	3	21.63	5.40	8.36	0.22	79.07	87.67	8.02	12.58	<0.62	-	0.04	0.01	82.27	86.64
	75-90	3	25.03	3.95	8.48	0.06	54.60	19.47	2.79	2.02	<0.62	-	0.04	0.01	66.27	66.49
	90-105	3	32.80	10.32	8.23	0.22	54.27	43.80	9.08	8.77	<0.62	-	0.04	0.02	70.90	80.65
1	0-15	3	64.40	20.12	8.07	0.32	314.13	325.58	11.82	6.22	<0.62	-	0.04	0.02	126.23	55.10
	15-30	3	33.53	15.65	8.07	0.25	64.43	15.50	3.71	3.25	<0.62	-	0.11	0.14	53.53	21.44
	30-45	3	23.13	2.16	8.16	0.35	62.47	13.51	1.53	1.07	<0.62	-	0.03	0.01	41.33	33.51
	45-60	3	26.30	1.87	8.10	0.48	68.90	12.99	1.12	1.07	<0.62	-	0.03	0.01	48.00	31.22
	60-75	3	39.70	25.04	8.15	0.47	45.93	16.56	0.77	0.46	<0.62	-	0.05	0.02	65.73	43.80
	75-90	3	25.53	13.48	8.03	0.28	98.80	76.52	2.18	1.53	<0.62	-	0.05	0.03	58.10	45.12
	90-105	3	23.77	2.37	8.26	0.34	49.30	14.90	0.82	0.55	<0.62	-	0.03	0.01	48.77	49.85

Table 99

Cation Exchange Capacity and Organic Matter Analysis of the Fourth Set of Deep Cores Taken 14 October 1977

Tier	Depth (cm)	N	Cation Exchange Capacity (meq/100g) $\bar{X}$	SD	Organic Matter (%) $\bar{X}$	SD
3	0-15	3	1.84	1.67	0.10	0.14
	15-30	3	2.20	1.89	0.24	0.31
	30-45	3	2.19	1.48	0.12	0.11
	45-60	3	1.30	0.95	0.08	0.04
	60-75	3	1.66	0.97	0.09	0.04
	75-90	3	1.80	0.76	0.10	0.03
	90-105	3	1.66	0.44	0.10	0.07
2	0-15	3	2.63	0.50	1.15	0.97
	15-30	3	2.20	1.79	0.20	0.12
	30-45	3	2.01	0.81	0.13	0.03
	45-60	3	1.93	0.48	0.14	0.08
	60-75	3	3.24	2.62	0.16	0.06
	75-90	3	1.80	1.28	0.16	0.13
	90-105	3	3.02	2.39	0.44	0.30
1	0-15	3	2.99	1.82	0.40	0.16
	15-30	3	1.99	1.19	0.18	0.02
	30-45	3	2.34	0.66	0.15	0.03
	45-60	3	2.49	1.05	0.19	0.03
	60-75	3	2.12	0.84	0.11	0.01
	75-90	3	2.63	0.76	0.27	0.13
	90-105	3	2.27	0.62	0.16	0.03

Table 100

Soil Analysis of 270 Marshland Plots Averaged Across Tiers for Three Sampling Dates

		Moisture (%)		pH		Eh (mv)		Nitrogen: TKN (µg/g)		Nitrogen: NH_4^+-N (µg/g)		Nitrogen: NO_3^--N (µg/g)		Nitrogen: NO_2^--N (µg/g)		Extractable Phosphorus (µg/g)	
Tier	N*	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Sample Date - 20 November 1976																	
1	90	28.21	6.86	8.01	0.22	-29.4	86.8	169.9	120.7	4.83	3.03	0.74	0.32	0.14	0.06	41.6	21.3
2	90	23.38	3.00	8.40	0.18	18.4	119.8	94.7	54.2	4.29	4.89	0.73	0.32	0.23	0.32	34.9	22.0
3	90	19.83	2.68	8.66	0.26	163.6	89.8	44.4	19.1	2.91	5.67	1.20	1.36	0.26	0.49	29.9	11.1
Sample Date - 27 June 1977																	
1	90	31.41	8.74	7.54	0.18	7.5	107.5	303.5	212.1	16.42	97.56	1.09	0.68	0.04	0.01	61.9	34.3
2	90	24.66	6.25	7.98	0.43	117.2	142.5	141.4	112.2	9.93	8.01	0.89	0.61	0.06	0.04	52.2	32.1
3	90	17.39	4.05	8.68	0.25	262.8	75.1	51.3	28.6	7.53	6.88	1.66	1.16	0.06	0.08	37.9	15.8

*N = Number of observations, $\overline{X}$ = mean, SD = standard deviation.

(continued)

Table 100 (Concluded)

								Nitrogen									
		Moisture (%)		pH		Eh (mv)		TKN (µg/g)		NH_4^+-N (µg/g)		NO_3^--N (µg/g)		NO_2^--N (µg/g)		Extractable Phosphorus (µg/g)	
Tier	N	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Sample Date - 14 October 1977																	
1	90	35.60	12.03	7.94	0.20	-146.0	9.04	287.5	149.8	9.86	8.08	<0.62	-	0.04	0.02	95.6	43.4
2	90	29.18	8.50	8.03	0.41	- 53.4	111.3	213.4	209.6	6.82	7.35	<0.62	-	0.04	0.02	56.9	35.8
3	90	22.91	4.20	8.62	0.32	+103.0	53.4	66.4	78.8	3.67	3.55	<0.62	-	0.04	0.02	27.5	16.1

Table 101

Change in Cation Exchange Capacity and Organic Matter Concentration in Three Tiers of Marshland Plot Area

Tier	N*	Cation Exchange Capacity (meq/100g) $\overline{X}$	SD	Organic Matter (%) $\overline{X}$	SD
		Sample Date - 29 June 1976			
1	2	3.00	-	0.12	-
2	1	3.53	-	0.26	-
3	3	1.87	-	0.16	-
		Sample Date - 14 October 1977			
1	90	7.38	4.61	0.50	0.25
2	90	2.95	1.13	0.35	0.27
3	90	3.96	2.03	0.14	0.09

* N = Number of observations

Table 102

Soil Analysis of Sprigged and Seeded *Spartina alterniflora* and Control Plots in the Marshland Area of the Bolivar Peninsula site

			Nitrogen								Extractable Phosphorus ($\mu g/g$)	
			TKN ($\mu g/g$)		NH_4^+-N ($\mu g/g$)		NO_3^--N ($\mu g/g$)		NO_2^--N ($\mu g/g$)			
Tier	Fertilizer Rate*	N**	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
			Sample Date - 20 November 1976									
			Sprigged									
1	0	3	189.85	105.21	7.38	3.81	<0.62	0.00	0.11	0.08	41.67	21.83
	1	3	233.25	65.76	5.69	1.57	0.91	0.51	0.12	0.07	50.00	12.17
	2	3	143.80	90.91	3.35	1.54	<0.62	0.00	0.14	0.12	67.00	54.95
	3	3	233.62	129.20	6.03	5.32	<0.62	0.00	0.16	0.02	46.00	19.08
	4	3	184.62	206.26	5.36	1.16	<0.62	0.00	0.16	0.07	37.33	97.71
2	0	3	116.82	51.26	2.95	0.91	<0.62	0.00	0.16	0.04	39.17	14.87
	1	3	159.19	113.31	6.03	4.02	<0.62	0.00	0.14	0.11	35.17	20.65
	2	3	104.64	68.88	8.98	5.43	<0.62	0.00	0.17	0.07	52.17	2.02
	3	3	81.06	32.35	1.54	1.29	<0.62	0.00	0.15	0.00	23.33	5.30
	4	3	102.49	54.01	3.77	1.85	<0.62	0.00	0.24	0.11	36.16	9.83
3	0	3	33.52	9.49	1.01	0.01	0.74	0.22	0.48	0.77	19.63	3.69
	1	3	38.35	12.32	1.54	0.81	0.70	0.14	0.14	0.09	32.40	8.79
	2	3	46.71	33.69	18.10	27.90	0.79	0.19	0.16	0.15	39.13	2.89
	3	3	31.38	6.07	2.68	1.54	<0.62	0.00	0.28	0.33	30.40	1.93
	4	3	51.76	40.23	5.29	5.01	4.75	1.14	1.18	1.84	42.73	30.81

* Fertilizer Rate
0 - no fertilizer
1 - 122 kg/ha
2 - 244 kg/ha
3 - split rate 1
4 - split rate 2

** N = Number of observations, $\overline{X}$ = mean, SD = standard deviation.

(continued)

Table 102

			Nitrogen								Extractable Phosphorus (µg/g)	
			TKN (µg/g)		NH_4^+-N (µg/g)		NO_3^--N (µg/g)		NO_2^--N (µg/g)			
Tier	Fert. Rate	N	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
						Control						
1	0	6	214.23	188.88	6.03	5.01	0.91	0.45	0.09	0.05	44.16	28.62
	1	6	144.24	71.83	4.16	1.87	0.75	0.33	0.19	0.08	35.57	6.24
	2	6	102.91	34.84	4.18	1.61	0.99	0.66	0.11	0.05	37.33	16.23
	3	6	148.90	77.10	6.20	5.14	<0.62	0.00	0.17	0.03	39.00	9.29
	4	6	203.51	225.14	4.69	3.22	<0.62	0.00	0.14	0.06	46.83	26.97
2	0	6	118.84	83.39	3.18	2.27	<0.62	0.00	0.13	0.04	23.09	2.87
	1	6	66.38	28.65	4.25	1.65	0.89	0.67	0.19	0.14	31.83	12.25
	2	6	87.48	59.95	4.79	4.12	<0.62	0.00	0.16	0.05	54.33	56.83
	3	6	84.02	39.23	1.80	1.09	0.74	0.31	0.28	0.13	40.83	13.67
	4	6	127.23	64.86	10.25	11.11	0.75	0.31	0.45	0.53	40.83	13.42
3	0	6	51.89	9.66	2.81	1.27	0.64	0.05	0.13	0.06	26.08	5.42
	1	6	34.24	10.74	1.41	0.99	0.64	0.05	0.06	0.02	29.85	6.28
	2	6	45.78	15.18	2.11	0.87	<0.62	0.00	0.19	0.14	41.17	5.89
	3	6	47.07	16.29	2.32	1.29	1.66	2.19	0.28	0.41	34.31	8.63
	4	6	47.20	20.80	1.85	1.17	3.04	2.31	0.81	0.83	39.28	13.77

(continued)

Table 102

Tier	Fert. Rate	N	Nitrogen: TKN (µg/g) $\overline{X}$	SD	NH_4^+-N (µg/g) $\overline{X}$	SD	NO_3^--N (µg/g) $\overline{X}$	SD	NO_2^--N (µg/g) $\overline{X}$	SD	Extractable Phosphorus (µg/g) $\overline{X}$	SD
Sample Date - 27 June 1977												
Sprigged												
1	0	3	195.18	182.18	5.56	4.36	1.33	0.006	0.04	0.015	58.80	25.71
	1	3	400.55	280.47	9.64	8.14	0.73	0.24	0.03	0.006	54.43	22.70
	2	3	188.60	75.28	5.06	2.56	0.85	0.17	0.03	0.006	46.70	14.53
	3	3	343.59	216.57	5.41	6.38	0.95	0.06	<0.03	0.000	55.43	33.41
	4	3	149.48	71.23	6.05	3.99	1.46	0.49	0.03	0.006	47.13	18.64
2	0	3	228.10	208.36	9.71	8.65	1.20	0.34	0.08	0.05	44.53	8.30
	1	3	150.21	25.16	9.21	1.47	0.77	0.26	0.09	0.09	41.83	8.81
	2	3	172.05	131.65	12.95	9.44	0.84	0.29	0.06	0.03	58.40	3.98
	3	3	157.75	37.74	9.01	3.17	0.64	0.13	0.08	0.09	60.67	22.19
	4	3	149.71	65.75	5.42	4.23	0.62	0.19	0.04	0.02	49.20	20.61
3	0	3	37.14	17.14	5.70	2.56	1.39	0.51	0.03	0.01	29.57	11.62
	1	3	43.05	17.44	6.47	7.21	1.59	1.56	0.04	0.01	40.40	31.40
	2	3	30.84	14.97	12.31	8.58	1.40	0.59	0.04	0.01	41.70	15.43
	3	3	58.92	48.85	13.30	17.76	1.18	0.73	0.04	0.01	33.73	3.33
	4	3	52.62	37.12	4.64	3.35	1.46	0.69	0.04	0.00	38.77	17.16

(continued)

Table 102

Tier	Fert. Rate	N	Nitrogen: TKN (μg/g) $\overline{X}$	TKN SD	NH_4^+-N (μg/g) $\overline{X}$	NH_4^+-N SD	NO_3^--N (μg/g) $\overline{X}$	NO_3^--N SD	NO_2^--N (μg/g) $\overline{X}$	NO_2^--N SD	Extractable Phosphorus (μg/g) $\overline{X}$	Extractable Phosphorus SD
						Control						
1	0	6	258.66	103.27	7.60	4.08	0.97	0.68	0.04	0.01	57.35	35.39
	1	6	300.87	116.88	8.07	2.76	0.80	0.21	0.03	0.005	65.02	15.84
	2	6	234.60	141.85	4.79	5.88	1.31	1.04	0.04	0.01	59.12	55.83
	3	6	501.67	248.64	5.10	3.16	1.15	0.32	0.04	0.005	68.82	32.04
	4	6	255.89	78.12	10.84	12.08	1.83	1.24	0.04	0.01	92.90	59.13
2	0	6	184.88	191.50	19.28	17.68	1.09	0.63	0.06	0.04	50.82	48.59
	1	6	84.99	41.50	7.94	3.38	0.79	0.32	0.06	0.05	44.88	9.33
	2	6	165.40	171.96	17.10	11.49	1.08	0.64	0.07	0.02	90.13	82.59
	3	6	110.11	65.06	5.17	3.97	0.62	0.21	0.05	0.03	59.72	38.29
	4	6	143.81	68.62	8.09	2.65	0.63	0.28	0.04	0.02	55.88	16.63
3	0	6	67.68	39.96	5.77	3.84	2.48	2.58	0.04	0.01	31.68	6.59
	1	6	38.13	22.57	7.03	4.86	1.46	0.90	0.04	0.01	43.35	27.26
	2	6	67.34	48.60	4.53	2.19	1.09	0.65	0.05	0.02	43.77	7.16
	3	6	55.30	15.09	6.40	2.59	1.00	0.37	0.06	0.04	38.53	5.93
	4	6	68.46	34.98	5.17	3.27	1.66	1.06	0.12	0.20	52.10	24.75

(continued)

Table 102

Tier	Fertilizer Rate	N	Nitrogen: TKN (µg/g) $\bar{X}$	TKN SD	NH_4^+-N (µg/g) $\bar{X}$	NH_4^+-N SD	NO_3^--N (µg/g) $\bar{X}$	NO_3^--N SD	NO_2^--N (µg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (µg/g) $\bar{X}$	SD	Cation Exchange Capacity (meq/100g) $\bar{X}$	SD	Organic Matter (%) $\bar{X}$	SD
Sample Date - 14 October 1977																
Sprigged																
1	0	3	389.60	61.86	8.47	3.53	<0.62	-	0.05	0.02	131.60	51.40	9.21	4.52	0.69	0.21
	1	3	306.90	133.07	11.55	5.55	<0.62	-	0.06	0.04	93.73	16.55	6.74	2.60	0.56	0.18
	2	3	183.13	158.72	4,36	2.92	<0.62	-	0.04	0.01	75.00	63.10	5.10	2.43	0.37	0.21
	3	3	302.93	211.05	4.88	3.88	<0.62	-	0.04	0.02	85.90	60.29	5.78	3.13	0.50	0.34
	4	3	208.83	50.27	7.19	5.83	<0.62	-	0.04	0.01	119.57	38.15	7.12	2.89	0.45	0.23
2	0	3	278.03	210.47	3.04	2.97	<0.62	-	0.04	0.02	76.67	48.88	3.36	0.35	0.41	0.33
	1	3	326.47	145.02	10.92	7.22	<0.62	-	0.05	0.02	94.07	26.56	2.93	2.72	0.64	0.17
	2	3	284.20	303.47	5.40	6.86	<0.62	-	0.04	0.02	100.67	36.40	2.82	0.72	0.46	0.48
	3	3	184.27	48.99	2.52	1.09	<0.62	-	0.03	0.01	38.57	22.99	3.03	0.71	0.40	0.18
	4	3	81.60	48.16	2.77	2.14	<0.62	-	0.03	0.01	45.17	10.79	2.50	0.62	0.37	0.44
3	0	3	35.90	10.83	3.49	1.78	<0.62	-	0.03	0.01	19.03	11.67	4.08	2.93	0.10	0.07
	1	3	84.17	37.17	2.72	0.32	<0.62	-	0.07	0.06	30.10	21.33	4.53	3.44	0.08	0.01
	2	3	51.33	8.74	2.21	1.72	<0.62	-	0.03	0.01	22.77	7.60	4.45	3.68	0.19	0.16
	3	3	41.80	21.13	2.31	0.86	<0.62	-	0.03	0.01	28.10	17.87	3.08	0.32	0.11	0.12
	4	3	50.80	28.15	3.80	3.27	<0.62	-	0.03	0.01	23.87	22.68	4.12	0.88	0.13	0.06

(continued)

Table 102

Tier	Fertilizer Rate	N	Nitrogen: TKN (μg/g) $\bar{X}$	TKN SD	NH_4^+-N (μg/g) $\bar{X}$	NH_4^+-N SD	NO_3^--N (μg/g) $\bar{X}$	NO_3^--N SD	NO_2^--N (μg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (μg/g) $\bar{X}$	SD	Cation Exchange Capacity (meq/100g) $\bar{X}$	SD	Organic Matter (%) $\bar{X}$	SD
							Seeded									
1	0	3	175.67	55.45	4.87	3.20	<0.62	-	0.04	0.02	83.60	43.99	6.10	2.30	0.34	0.13
	1	3	355.53	57.62	12.17	2.07	<0.62	-	0.04	0.01	118.27	25.63	8.60	2.39	0.64	0.04
	2	3	341.97	157.66	8.86	10.55	<0.62	-	0.05	0.02	102.33	21.33	6.21	1.84	0.50	0.19
	3	3	217.40	56.23	7.70	4.29	<0.62	-	0.04	0.01	102.17	5.03	6.68	1.92	0.41	0.06
	4	3	125.23	50.27	2.82	1.94	<0.62	-	0.05	0.03	62.27	3.93	4.68	2.72	0.24	0.11
2	0	3	97.40	102.56	5.03	2.79	<0.62	-	0.04	0.01	34.93	2.50	3.36	0.64	0.24	0.09
	1	3	288.70	383.93	12.79	20.40	<0.62	-	0.09	0.04	69.10	68.07	3.03	0.90	0.42	0.50
	2	3	219.70	81.90	5.04	4.77	<0.62	-	0.04	0.01	49.93	26.04	3.05	1.46	0.31	0.17
	3	3	267.63	168.71	9.80	5.82	<0.62	-	0.03	0.01	69.67	45.54	3.30	2.96	0.46	0.19
	4	3	332.60	431.89	2.94	3.99	<0.62	-	0.03	0.01	35.90	17.65	2.40	0.97	0.23	0.18
3	0	3	53.37	25.87	2.98	0.49	<0.62	-	0.07	0.06	22.93	12.92	4.27	1.77	0.16	0.09
	1	3	149.40	186.87	1.85	1.37	<0.62	-	0.04	0.02	34.10	25.74	4.36	3.76	0.18	0.09
	2	3	61.70	10.80	12.88	15.70	<0.62	-	0.03	0.01	39.20	15.52	5.30	3.17	0.10	0.06
	3	3	44.67	14.84	4.82	2.82	<0.62	-	0.03	0.01	23.93	11.36	3.04	1.67	0.14	0.07
	4	3	44.23	8.39	2.32	1.09	<0.62	-	0.03	0.01	27.97	8.36	3.67	1.09	0.19	0.06

(continued)

Table 102 (Concluded)

Tier	Fertilizer Rate	N	Nitrogen: TKN (μg/g) $\overline{X}$	TKN SD	NH_4^+-N (μg/g) $\overline{X}$	NH_4^+-N SD	NH_3^--N (μg/g) $\overline{X}$	NH_3^--N SD	NO_2^--N (μg/g) $\overline{X}$	NO_2^--N SD	Extractable Phosphorus (μg/g) $\overline{X}$	SD	Cation Exchange Capacity (meq/100g) $\overline{X}$	SD	Organic Matter (%) $\overline{X}$	SD
							Control									
1	0	6	224.70	143.87	5.75	4.94	<0.62	-	0.05	0.02	77.13	49.78	5.48	2.34	0.35	0.23
	1	6	350.60	196.19	7.73	4.22	<0.62	-	0.05	0.02	102.83	33.81	7.16	3.94	0.54	0.20
	2	6	171.03	85.69	4.01	3.34	<0.62	-	0.04	0.01	44.70	28.50	5.31	2.23	0.24	0.12
	3	6	388.33	189.54	12.05	8.07	<0.62	-	0.05	0.02	101.86	56.36	11.38	9.02	0.58	0.31
	4	6	378.23	164.28	20.67	12.31	<0.62	-	0.05	0.02	95.30	36.41	12.09	10.62	0.64	0.33
2	0	6	189.05	134.70	11.22	7.81	<0.62		0.04	0.01	67.88	37.26	3.56	0.71	0.41	0.31
	1	6	157.40	82.74	6.37	4.02	<0.62	-	0.04	0.01	58.62	19.49	2.76	1.33	0.34	0.14
	2	6	240.28	347.88	10.50	12.46	<0.62	-	0.03	0.01	75.62	69.09	2.42	0.50	0.43	0.50
	3	6	280.07	363.69	5.60	5.81	<0.62	-	0.04	0.01	45.50	27.79	2.99	0.66	0.22	0.14
	4	6	143.65	92.98	3.83	3.43	<0.62	-	0.03	0.01	58.92	52.35	3.05	0.81	0.36	0.28
3	0	6	135.78	234.85	5.03	2.25	<0.62	-	0.06	0.04	27.53	14.16	5.00	2.23	0.24	0.28
	1	6	55.45	19.57	3.59	1.75	<0.62	-	0.04	0.01	28.90	24.25	3.83	2.44	0.10	0.04
	2	6	78.40	97.13	3.08	1.79	<0.62	-	0.04	0.01	27.93	12.69	4.09	1.82	0.16	0.07
	3	6	46.20	18.14	2.69	1.95	<0.62	-	0.03	0.01	33.48	18.51	3.95	2.74	0.14	0.05
	4	6	49.42	14.03	2.27	1.22	<0.62	-	0.03	0.01	24.98	20.53	3.33	1.43	0.14	0.08

Table 103

Soil Analysis of Sprigged and Seeded *Spartina patens* and Control Plots in the Marshland Area of the Bolivar Peninsula Site

Tier	Fertilizer Rate	N	Nitrogen: TKN (µg/g) $\bar{X}$	TKN SD	NH_4^+-N (µg/g) $\bar{X}$	NH_4^+-N SD	NO_3^--N (µg/g) $\bar{X}$	NO_3^--N SD	NO_2^--N (µg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (µg/g) $\bar{X}$	Extractable Phosphorus SD	Cation Exchange Capacity (meq/100g) $\bar{X}$	Cation Exchange Capacity SD	Organic Matter (%) $\bar{X}$	Organic Matter SD
Sample Date - 14 October 1977																
Sprigged																
1	0	3	215.97	145.60	8.21	8.23	<0.62	-	0.04	0.02	82.27	73.73	5.90	1.66	0.46	0.25
	1	3	408.23	191.94	14.80	5.83	<0.62	-	0.03	0.01	146.67	16.27	9.03	2.55	0.65	0.20
	2	3	427.80	104.43	18.89	2.42	<0.62	-	0.04	0.01	122.00	35.19	7.49	2.07	0.84	0.28
	3	3	271.03	141.22	6.84	6.90	<0.62	-	0.05	0.02	99.33	32.86	6.17	3.09	0.46	0.18
	4	3	223.90	40.58	8.62	1.78	<0.62	-	0.05	0.03	88.67	46.63	6.43	2.19	0.36	0.06
2	0	3	117.20	48.43	4.31	2.00	<0.62	-	0.07	0.06	35.73	15.11	3.52	0.38	0.20	0.02
	1	3	110.90	34.06	5.03	3.14	<0.62	-	0.04	0.01	41.83	1.15	3.79	1.77	0.17	0.03
	2	3	301.73	209.61	13.65	14.86	<0.62	-	0.04	0.01	61.00	17.80	2.67	1.83	0.57	0.40
	3	3	155.10	107.10	4.36	1.71	<0.62	-	0.04	0.02	34.93	9.12	2.82	1.33	0.27	0.18
	4	3	196.40	139.58	4.83	4.25	<0.62	-	0.04	0.02	43.83	3.40	3.28	0.55	0.29	0.10
3	0	3	104.10	117.05	3.75	2.09	<0.62	-	0.07	0.06	18.60	10.66	4.54	0.99	0.16	0.06
	1	3	57.00	17.34	3.80	1.96	<0.62	-	0.04	0.01	23.83	1.15	3.18	1.43	0.17	0.05
	2	3	71.97	35.08	3.24	1.70	<0.62	-	0.03	0.01	32.87	28.19	4.36	2.66	0.12	0.04
	3	3	50.50	27.55	2.93	0.82	<0.62	-	0.03	0.01	22.37	18.44	3.77	0.90	0.14	0.02
	4	3	56.10	2.88	4.82	4.08	<0.62	-	0.03	0.01	43.60	13.52	3.63	2.63	0.18	0.05

(Continued)

Table 103

			Nitrogen								Extractable Phosphorus (μg/g)		Cation Exchange Capacity (meq/100g)		Organic Matter (%)	
			TKN (μg/g)		NH_4^+-N (μg/g)		NO_3^--N (μg/g)		NO_2^--N (μg/g)							
Tier	Fertilizer Rate	N	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
							Seeded									
1	0	3	337.60	120.37	16.22	8.06	<0.62	-	0.04	0.02	121.43	40.57	7.43	2.23	0.58	0.22
	1	3	325.33	84.05	7.73	8.93	<0.62	-	0.05	0.02	120.17	7.25	6.99	0.79	0.50	0.12
	2	3	353.17	234.78	10.52	9.93	<0.62	-	0.05	0.02	94.93	57.26	5.54	2.50	0.51	0.29
	3	3	228.57	113.50	19.10	16.19	<0.62	-	0.04	0.01	88.00	59.96	10.00	5.48	0.68	0.46
	4	3	167.13	95.58	10.88	13.25	<0.62	-	0.04	0.01	85.43	64.77	6.16	4.57	0.37	0.30
2	0	3	431.17	495.04	10.31	12.16	<0.62	-	0.04	0.01	52.17	42.80	1.98	1.30	0.45	0.33
	1	3	149.70	113.84	8.43	10.96	<0.62	-	0.03	0.01	43.00	13.11	2.82	0.83	0.19	0.11
	2	3	265.20	176.29	7.96	4.09	<0.62	-	0.04	0.02	62.83	35.50	2.87	2.13	0.42	0.25
	3	3	128.93	69.14	3.75	1.85	<0.62	-	0.03	0.01	48.07	10.05	3.09	1.55	0.27	0.06
	4	3	163.37	157.79	6.57	9.13	<0.62	-	0.04	0.01	55.07	52.13	2.37	0.89	0.35	0.31
3	0	3	39.53	28.46	3.34	1.46	<0.62	-	0.04	0.02	18.87	0.98	4.60	3.55	0.08	0.03
	1	3	107.10	107.00	3.95	1.14	<0.62	-	0.04	0.01	30.60	21.99	4.13	2.30	0.13	0.03
	2	3	62.10	42.32	5.44	4.77	<0.62	-	0.03	0.01	22.70	13.16	2.23	0.29	0.08	0.01
	3	3	44.13	12.44	3.38	3.34	<0.62	-	0.03	0.01	17.93	13.44	3.33	1.34	0.10	0.03
	4	3	46.23	13.17	2.41	1.29	<0.62	-	0.03	0.01	37.77	26.16	3.58	1.44	0.14	0.09

(Continued)

Table 103 (Concluded)

Tier	Fertilizer Rate	N	Nitrogen: TKN (μg/g) $\bar{X}$	TKN SD	NH_4^+-N (μg/g) $\bar{X}$	NH_4^+-N SD	NH_3^--N (μg/g) $\bar{X}$	NH_3^--N SD	NO_2^--N (μg/g) $\bar{X}$	NO_2^--N SD	Extractable Phosphorus (μg/g) $\bar{X}$	SD	Cation Exchange Capacity (meq/100g) $\bar{X}$	SD	Organic Matter (%) $\bar{X}$	SD
							Control									
1	0	6	224.70	143.87	5.75	4.94	<0.62	-	0.05	0.02	77.13	49.78	5.48	2.34	0.35	0.23
	1	6	350.60	196.19	7.73	4.22	<0.62	-	0.05	0.02	102.83	33.81	7.16	3.94	0.54	0.20
	2	6	171.03	85.69	4.01	3.34	<0.62	-	0.04	0.01	44.70	28.50	5.31	2.23	0.24	0.12
	3	6	388.33	189.54	12.05	8.07	<0.62	-	0.05	0.02	101.86	56.36	11.38	9.02	0.58	0.31
	4	6	378.23	164.28	20.67	12.31	<0.62	-	0.05	0.02	95.30	36.41	12.09	10.62	0.64	0.33
2	0	6	189.05	134.70	11.22	7.81	<0.62		0.04	0.01	67.88	37.26	3.56	0.71	0.41	0.31
	1	6	157.40	82.74	6.37	4.02	<0.62	-	0.04	0.01	58.62	19.49	2.76	1.33	0.34	0.14
	2	6	240.28	347.88	10.50	12.46	<0.62	-	0.03	0.01	75.62	69.09	2.42	0.50	0.43	0.50
	3	6	280.07	363.69	5.60	5.81	<0.62	-	0.04	0.01	45.50	27.79	2.99	0.66	0.22	0.14
	4	6	143.65	92.98	3.83	3.43	<0.62	-	0.03	0.01	58.92	52.35	3.05	0.81	0.36	0.28
3	0	6	135.78	234.85	5.03	2.25	<0.62	-	0.06	0.04	27.53	14.16	5.00	2.23	0.24	0.28
	1	6	55.45	19.57	3.59	1.75	<0.62	-	0.04	0.01	28.90	24.25	3.83	2.44	0.10	0.04
	2	6	78.40	97.13	3.08	1.79	<0.62	-	0.04	0.01	27.93	12.69	4.09	1.82	0.16	0.07
	3	6	46.20	18.14	2.69	1.95	<0.62	-	0.03	0.01	33.48	18.51	3.95	2.74	0.14	0.05
	4	6	49.42	14.03	2.27	1.22	<0.62	-	0.03	0.01	24.98	20.53	3.33	1.43	0.14	0.08

Table 104

Chemical Analysis of the Initial Six Marshland Plots from 29 June 1976 to 14 October 1977

	Nitrogen						
Plot No.	TKN (µg/g)	NH_4^+-N (µg/g)	NO_2^--N (µg/g)	NO_3^--N (µg/g)	Extractable Phosphorus (µg/g)	Cation Exchange Capacity (meq/100g)	Organic Matter (%)
			Sampling Date - 29 June 1976				
T3-B1-6	27.6	1.24	<0.03	<0.62	9.0	1.77	0.08
T3-B2-11	42.0	1.56	<0.03	<0.62	19.8	1.63	0.13
T3-B3-29	23.8	2.01	<0.03	<0.62	17.7	1.60	0.16
T2-B1-17	76.4	<0.60	<0.03	<0.62	19.2	3.06	0.23
T1-B2-11	33.1	1.84	<0.03	<0.62	17.0	2.33	0.11
T1-B3-6	84.9	2.51	<0.03	<0.62	30.7	3.26	0.13
			Sampling Date - 20 November 1976				
T3-B1-6	56.5	3.02	0.24	<0.62	22.5		
T3-B2-11	45.1	2.23	0.05	<0.62	32.5		
T3-B3-29	57.9	1.05	0.86	2.75	41.3		
T2-B1-17	163.6	3.02	0.11	<0.62	25.0		
T1-B2-11	176.2	4.02	0.14	<0.62	33.0		
T1-B3-6	98.6	2.01	0.06	1.50	23.0		
			Sampling Date - 29 June 1977				
T3-B1-6	139.3	4.22	<0.03	4.69	27.5		
T3-B2-11	39.7	9.08	<0.03	1.51	35.0		
T3-B3-29	82.4	5.91	0.05	1.00	68.8		
T2-B1-17	201.9	15.80	0.05	0.71	68.0		
T1-B2-11	194.2	8.06	<0.03	1.00	51.5		
T1-B3-6	143.5	4.85	<0.03	<0.62	35.0		
			Sampling Date - 14 October 1977				
T3-B1-6	60.1	2.16	0.07	<0.62	22.5	3.01	0.12
T3-B2-11	53.9	3.70	<0.03	<0.62	21.3	7.87	0.11
T3-B3-29	61.6	2.31	<0.03	<0.62	36.5	5.30	0.26
T2-B1-17	933.2	15.50	<0.03	<0.62	122.5	2.77	0.82
T1-B2-11	683.1	15.40	<0.03	<0.62	150.0	6.59	0.82
T1-B3-6	95.5	1.85	<0.03	<0.62	43.5	4.13	0.17

Table 105

Soil Analysis of Intertidal Reference Plots of the Marshland Area of the Bolivar Peninsula Site

	Area		Sampling Site			Nitrogen								Extractable Phosphorus ($\mu g/g$)	
						TKN ($\mu g/g$)		NH_4^+-N ($\mu g/g$)		NO_3^--N ($\mu g/g$)		NO_2^--N ($\mu g/g$)			
Tier	*Intertidal	**Reference	Cage	Vegetation Quadrat	N†	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
					Sample Date - 20 November 1976										
1	x		x		4	78.1	24.5	8.30	5.15	<0.62	-	0.21	0.11	30.25	5.81
	x			x	4	182.3	124.7	4.53	2.39	<0.62	-	0.07	0.04	23.63	12.80
		x	x		2	114.4	12.3	2.02	1.42	<0.62	-	0.05	0.02	39.00	1.41
		x		x	2	158.6	60.6	2.52	2.13	<0.62	-	0.05	0.02	32.50	9.90
2	x		x		4	140.7	190.0	8.30	8.10	<0.62	-	0.13	0.07	27.64	8.30
	x			x	4	115.6	77.6	5.03	3.28	<0.62	-	0.10	0.06	21.75	8.86
		x	x		2	66.6	28.0	2.02	1.41	<0.62	-	0.05	0.02	24.25	3.18
		x		x	2	79.3	17.2	5.03	5.69	<0.62	-	0.08	0.02	24.50	1.41
3	x		x		4	49.2	25.0	1.66	1.08	<0.62	-	0.16	0.07	23.13	3.97
	x			x	4	125.5	11.2	1.81	1.40	<0.62	-	0.16	0.03	21.00	5.40
		x	x		2	83.2	60.3	5.83	7.40	<0.62	-	0.05	0.02	22.75	3.18
		x		x	2	125.4	71.1	2.52	0.71	<0.62	-	0.06	0.01	35.00	9.90

* Intertidal area = inside fenced area.

** Reference area = outside fenced area.

† N = Number of observations, $\overline{X}$ = Mean, SD = standard deviation.

(continued)

Table 105

	Area		Sampling Site			Nitrogen								Extractable Phosphorus ($\mu g/g$)	
						TKN ($\mu g/g$)		NH_4^+-N ($\mu g/g$)		NO_3^--N ($\mu g/g$)		NO_2^--N ($\mu g/g$)			
Tier	Intertidal	Reference	Cage	Vegetation Quadrat	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
						Sample Date - 29 June 1977									
1	x		x		4	228.4	179.5	4.80	3.22	0.87	0.65	0.04	0.01	40.19	27.80
	x			x	4	197.2	147.4	7.39	5.26	0.66	0.51	<0.03	0.00	43.63	26.87
		x	x		2	83.9	29.4	0.95	0.45	0.27	0.33	0.04	0.01	20.38	4.07
		x		x	2	112.7	3.2	0.85	0.30	<0.50	0.00	<0.03	0.00	22.50	6.72
2	x		x		4	497.2	509.5	14.51	15.03	0.66	0.24	0.05	0.02	86.84	82.54
	x			x	4	758.0	613.8	15.78	25.09	1.09	0.77	0.04	0.01	117.81	117.21
		x	x		2	104.5	15.5	1.27	0.30	0.87	0.52	0.04	0.01	21.63	4.77
		x		x	2	101.7	25.6	1.59	0.74	0.73	0.33	0.04	0.01	27.13	6.54
3	x		x		4	57.2	14.9	2.75	2.07	2.60	2.86	0.04	0.02	26.13	6.33
	x			x	4	117.5	123.7	6.49	9.48	2.50	1.16	0.04	0.01	25.81	5.31
		x	x		2	147.5	49.1	14.77	7.47	<0.50	0.00	<0.03	0.00	67.13	53.21
		x		x	2	249.9	159.7	9.18	8.50	<0.50	0.00	0.04	0.01	65.63	50.03

(continued)

Table 105 (Concluded)

	Area		Sampling Site			Nitrogen								Extractable Phosphorus ($\mu g/g$)	
						TKN ($\mu g/g$)		NH_4^+-N ($\mu g/g$)		NO_3^--N ($\mu g/g$)		NO_2^--N ($\mu g/g$)			
Tier	Intertidal	Reference	Cage	Vegetation Quadrat	N	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Sample Date - 14 October 1977															
1	x		x		4	110.5	75.8	1.72	1.52	<0.62	-	0.04	0.01	34.21	14.32
	x			x	4	278.4	266.9	20.42	29.48	<0.62	-	<0.03	-	101.82	96.12
		x	x		2	92.1	22.8	2.84	3.31	<0.62	-	0.05	0.02	37.48	4.86
		x		x	2	113.2	31.1	0.73	0.32	<0.62	-	0.04	0.01	90.92	92.56
2	x		x		4	321.1	286.0	16.19	16.86	<0.62	-	0.04	0.01	102.09	89.68
	x			x	4	474.8	705.6	30.01	56.71	<0.62	-	<0.03	-	118.28	120.69
		x	x		2	74.3	11.3	1.14	0.20	<0.62	-	0.04	0.01	34.82	5.50
		x		x	2	85.3	8.6	0.76	0.36	<0.62	-	0.05	0.02	31.34	5.81
3	x		x		4	104.9	67.2	1.10	1.19	<0.62	-	0.04	0.01	36.30	11.99
	x			x	4	91.6	45.4	0.74	0.47	<0.62	-	<0.03	0.01	33.53	8.06
		x	x		2	270.7	179.1	13.38	15.87	<0.62	-	0.04	0.02	87.89	70.77
		x		x	2	169.7	96.2	1.15	0.62	<0.62	-	0.04	0.01	43.78	8.14

Table 106

Plant Analysis of Marshland Area of the

Bolivar Peninsula Site

1976 Growing Season

Tier	Fert. Rate	Plant Portion* above ground	Plant Portion* below ground	N	Nitrogen (%) X̄	Nitrogen (%) SD	Crude Protein (%) X̄	Crude Protein (%) SD	Phosphorus (μg/g) X̄	Phosphorus (μg/g) SD
				Spartina alterniflora (Sprigged)						
1	0	x		10	1.03	0.31	6.41	1.94	888	231
	1	x		6	0.97	0.19	6.06	1.21	955	346
	2	x		**20/18	0.73	0.39	4.59	2.42	738	399
	3	x		12	0.93	0.47	5.80	2.92	678	279
	4	x		8/7	1.57	0.43	9.90	2.69	1,192	414
	0		x	-	-	-	-	-	-	-
	1		x	-	-	-	-	-	-	-
	2		x	20/17	0.86	0.34	5.41	2.13	1,139	358
	3		x	15/14	0.75	0.26	4.64	1.65	1,047	215
	4		x	4/3	0.83	0.24	5.19	1.49	651	455
2	0	x		24	1.01	0.43	6.29	2.70	942	386
	1	x		23	1.03	0.52	6.41	3.24	1,087	660
	2	x		16/14	1.52	0.73	9.22	4.60	1,099	479
	3	x		28/27	0.92	0.38	5.51	2.38	889	577
	4	x		17/15	1.04	0.50	6.52	3.15	1,034	316
	0		x	24/20	0.91	0.52	5.64	3.24	1,210	305
	1		x	18	0.75	0.31	4.69	1.93	1,471	860
	2		x	2	1.40	0.21	8.75	1.33	1,096	244
	3		x	28/27	0.68	0.27	4.26	1.71	1,063	243
	4		x	9/10	0.88	0.33	5.51	2.08	1,520	767
3	0	x		4	1.08	0.41	6.72	2.56	1,131	694
	1	x		4/3	1.26	0.43	6.93	4.46	859	250
	2	x		5	1.11	0.29	6.97	1.81	993	446
	3	x		7/6	1.55	0.61	9.70	3.84	788	251
	4	x		9	1.29	0.41	8.07	2.55	972	301
	0		x	1	1.29	-	8.07	-	916	-
	1		x	-	-	-	-	-	-	-
	2		x	-	-	-	-	-	-	-
	3		x	-	-	-	-	-	-	-
	4		x	2	0.56	0.02	3.46	0.11	987	90

*Plant Portion
above ground = average of standing green, standing dead, and seeds
below ground = average of roots and rhizomes

**20/18 = 20 analysis for nitrogen and crude protein
18 analysis for phosphorus

(continued)

Table 106 (Concluded)

Tier	Fert. Rate	Plant Portion: above ground	Plant Portion: below ground	N	Nitrogen: Nitrogen (%) $\bar{X}$	Nitrogen: Nitrogen (%) SD	Nitrogen: Crude Protein (%) $\bar{X}$	Nitrogen: Crude Protein (%) SD	Phosphorus (μg/g) $\bar{X}$	Phosphorus (μg/g) SD
					Spartina patens (Sprigged)					
1	0	x		-	-	-	-	-	-	-
	1	x		1	1.74	-	10.88	-	1,265	-
	2	x		-	-	-	-	-	-	-
	3	x		-	-	-	-	-	-	-
	4	x		-	-	-	-	-	-	-
	0		x	-	-	-	-	-	-	-
	1		x	-	-	-	-	-	-	-
	2		x	-	-	-	-	-	-	-
	3		x	-	-	-	-	-	-	-
	4		x	-	-	-	-	-	-	-
2	0	x		2	1.64	0.68	10.42	4.27	1,273	674
	1	x		-	-	-	-	-	-	-
	2	x		2	1.69	1.12	10.57	6.97	862	254
	3	x		-	-	-	-	-	-	-
	4	x		-	-	-	-	-	-	-
	0		x	-	-	-	-	-	-	-
	1		x	-	-	-	-	-	-	-
	2		x	-	-	-	-	-	-	-
	3		x	-	-	-	-	-	-	-
	4		x	-	-	-	-	-	-	-
3	0	x		1	1.50	-	9.38	-	1,083	-
	1	x		2	1.41	0.11	8.79	0.65	1,233	349
	2	x		5/3	1.48	0.44	9.26	2.78	981	91
	3	x		6	1.49	0.41	9.30	2.54	1,301	223
	4	x		-	-	-	-	-	-	-
	0		x	-	-	-	-	-	-	-
	1		x	-	-	-	-	-	-	-
	2		x	-	-	-	-	-	-	-
	3		x	-	-	-	-	-	-	-
	4		x	-	-	-	-	-	-	-

Table 107

Plant Analysis of Sprigged and Seeded *Spartina alterniflora*

Tier	Fert. Rate	N	Nitrogen (%) X	Nitrogen (%) SD	Crude Protein (%) X	Crude Protein (%) SD	Phosphorus (μg/g) X	Phosphorus (μg/g) SD	Standing Green Biomass (g/0.1 m^2) X	Standing Green Biomass (g/0.1 m^2) SD
					Sample Date - 14 October 1977 (Sprigged)					
1	0	3	0.67	0.21	4.21	1.28	786.0	47.6	240.70	69.20
	1	3	0.57	0.25	3.96	1.92	705.3	108.1	225.93	30.90
	2	3	0.47	0.06	3.13	0.34	660.7	63.2	117.80	48.12
	3	3	0.63	0.23	3.94	1.17	666.3	116.5	210.03	82.51
	4	3	0.70	0.10	4.30	0.64	669.0	12.8	244.50	76.65
2	0	3	0.70	0.36	4.42	2.08	805.3	111.1	90.40	38.62
	1	3	0.73	0.12	4.36	0.71	821.7	126.1	151.63	52.27
	2	3	0.77	0.12	4.79	0.52	822.0	25.5	136.30	109.41
	3	3	0.53	0.15	3.31	0.71	810.7	38.7	156.20	52.75
	4	3	0.63	0.06	4.11	0.22	749.7	33.5	81.97	104.00
3	0	3	0.57	0.06	3.57	0.34	711.0	110.7	20.37	15.25
	1	3	0.73	0.25	4.55	1.65	787.3	328.3	23.70	14.17
	2	3	0.67	0.12	3.93	0.71	738.6	97.9	20.07	1.59
	3	3	0.67	0.15	4.05	0.87	727.3	161.5	21.93	6.80
	4	3	0.47	0.06	2.69	0.25	766.3	72.61	15.90	14.58

(continued)

Table 107 (Concluded)

Tier	Fert. Rate	N	Nitrogen (%) X	Nitrogen (%) SD	Crude Protein (%) X	Crude Protein (%) SD	Phosphorus (μg/g) X	Phosphorus (μg/g) SD	Standing Green Biomass (g/0.1 m²) X	Standing Green Biomass (g/0.1 m²) SD
Sample Date - 14 October 1977 (Seeded)										
1	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
2	0	2	1.05	0.78	6.86	5.30	1,249.5	118.1	9.40	8.49
	1	2	0.60	0.42	5.33	4.60	1,033.0	353.5	17.10	21.07
	2	1	0.40	-	2.60	-	733.0	-	22.70	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
3	0	3	0.90	0.40	5.71	2.46	1,061.0	194.5	10.50	8.84
	1	3	0.70	0.17	4.57	1.12	1,010.6	236.0	22.70	24.06
	2	2	0.55	0.07	3.48	0.26	866.5	23.3	28.00	15.13
	3	3	0.50	0.10	2.94	0.45	783.0	88.3	31.20	16.30
	4	3	0.90	0.26	5.58	1.62	1,233.0	192.5	7.03	2.59

Table 108

Plant Analysis of Sprigged and Seeded

***Spartina patens* plots**

Tier	Fert. Rate	N	Nitrogen (%) X	Nitrogen (%) SD	Crude Protein (%) X	Crude Protein (%) SD	Phosphorus (μg/g) X	Phosphorus (μg/g) SD	Standing Green Biomass (g/0.1 m²) X	Standing Green Biomass (g/0.1 m²) SD
					Sample Date - 14 October 1977 (Sprigged)					
1	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
2	0	1	0.60	-	3.45	-	616.0	-	83.80	-
	1	1	1.20	-	7.36	-	500.0	-	163.60	-
	2	1	0.90	-	5.47	-	833.0	-	48.70	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
3	0	2	0.75	0.49	4.67	2.88	654.0	229.1	44.10	27.86
	1	2	0.80	0.14	4.91	0.77	620.5	88.4	79.20	36.63
	2	2	0.35	0.07	2.01	0.29	758.0	271.5	129.60	95.67
	3	3	0.57	0.21	3.38	1.19	661.0	167.1	74.03	20.73
	4	2	0.85	0.49	5.25	2.98	916.5	94.0	46.80	14.57

(continued)

Table 108 (Concluded)

Tier	Fert. Rate	N	Nitrogen (%) X	Nitrogen (%) SD	Crude Protein (%) X	Crude Protein (%) SD	Phosphorus (μg/g) X	Phosphorus (μg/g) SD	Standing Green Biomass (g/0.1 m²) X	Standing Green Biomass (g/0.1 m²) SD
					Sample Date - 14 October 1977 (Seeded)					
1	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
2	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
3	0	3	0.83	0.47	5.16	2.75	861.0	439.2	20.47	12.87
	1	1	0.50	-	2.95	-	1,083.0	-	41.70	-
	2	3	0.53	0.06	3.53	0.44	978.0	193.9	43.80	11.05
	3	3	0.60	0.26	3.71	1.46	772.3	265.6	52.93	27.86
	4	1	0.70	-	4.63	-	700.0	-	79.10	-

Table 109

Analysis of Variance Table Showing the Influence of Experimental Variables on *Spartina alterniflora* Standing Green Biomass at the Nov 76 Sample Date

Source of Variation	Degrees of Freedom	Mean Square	F Value
Block	2	7	0.21
Tier	2	24	0.72
Block X Tier	4	24	0.72
Propagation Method	0	0	0.0
Fertilizer	4	11	0.33
Propagation Method X Fertilizer	0	0	0.0
Species	1	11	0.32
Fertilizer X Species	3	12	0.36
Propagation Method X Fertilizer X Species	0	0	0.0
TKN - (μg/g)	1	13	0.38
NH_4^+-N - (μg/g)	1	9	0.26
NO_3^--N - (μg/g)	1	12	0.35
NO_2^--N - (μg/g)	1	2	0.05
Extractable Phosphorus - (μg/g)	1	2	0.10
pH	1	6	0.18
Eh - (mV)	1	26	0.78
Elevation (m)	1	9	0.26
Error	22	34	

Table 110

Analysis of Variance Table Showing the Influence of Experimental Variables on *Spartina alterniflora* and *Spartina patens* Standing Green Biomass at the Oct 77 Sample Date

Source of Variation	Degrees of Freedom	Mean Square	F Value
Block	2	14,187	6.80**
Tier	2	26,250	12.59**
Block X Tier	4	5,029	2.41
Propagation Method	1	28	0.01
Fertilizer	4	2,214	1.06
Propagation Method X Fertilizer	4	558	0.27
Species	2	3,625	1.74
Fertilizer X Species	8	565	0.27
Propagation Method X Fertilizer X Species	0	0	0.0
TKN - (μg/g)	1	5,025	2.41
NH_4^+-N - (μg/g)	1	2,339	0.12
NO_3^--N - (μg/g)	0	0	0.0
NO_2^--N - (μg/g)	1	729	0.35
Extractable Phosphorus - (μg/g)	1	10,000	4.80*
Cation Exchange Capacity - (meq/100g)	1	198	0.10
Organic Matter - (%)	1	8,650	4.15*
pH	1	1,113	0.53
Eh (mV)	1	812	0.04
Elevation - (m)	1	3,123	0.15
Error	81	2,085	

** Significant at the .01 level

* Significant at the .05 level

Table 111

Nekton Captured from July 1976 through June 1977 in Decreasing Order of Total Abundance.

Species	Total Catch			Seine			Push Nets		
	Number	Weight (g)	Average wt. (g)	Number	Weight (g)	Average wt. (g)	Number	Weight (g)	Average wt. (g)
VERTEBRATES									
Anchoa mitchilli	4047	2130.6	0.5	4016	2116.7	0.5	31	13.9	0.4
Leiostomus xanthurus	2669	4522.2	1.7	2337	4459.2	1.9	332	63.0	0.2
Mugil cephalus	2424	8871.1	3.7	2249	8799.2	3.9	175	71.9	0.4
Micropogon undulatus	2285	2610.4	1.1	2100	3551.3	1.7	185	59.1	0.3
Cyprinodon variegatus	1425	1214.6	0.9	1220	1105.8	0.9	205	108.8	0.5
Mugil curema	1409	5667.1	4.0	1408	5667.0	4.0	1	0.1	0.1
Fundulus similis	1227	1746.0	1.4	1101	1508.4	1.4	126	237.6	1.9
Mugil sp.	425	662.0	1.6	425	662.0	1.6			
Menidia beryllina	272	644.4	2.4	267	642.5	2.4	5	1.9	0.4
Harengula jaguana	207	45.9	0.2	50	26.8	0.5	157	19.1	0.1
Membras martinica	179	198.7	1.1	168	190.7	1.1	11	8.0	0.7
Brevoortia patronus	163	161.3	1.0	163	161.3	1.0			
Oligoplites saurus	79	43.0	0.6	77	42.2	0.5	2	0.8	0.4
Arius felis	45	210.1	4.7	45	210.1	4.7			
Atherinidae	43	7.7	0.2	43	7.7	0.2			

(Continued)

Table 111

Species	Total Catch Number	Total Catch Weight (g)	Total Catch Average wt. (g)	Seine Number	Seine Weight (g)	Seine Average wt. (g)	Push Nets Number	Push Nets Weight (g)	Push Nets Average wt. (g)
Menticirrhus americanus	40	26.4	0.7	40	26.4	0.7			
Fundulus grandis	20	77.4	3.9	25	75.3	3.0	3	2.1	0.7
Polydactylus octonemelus	28	257.0	9.2	28	257.0	9.2			
Ophidion welshi	14	12.9	0.9	2	2.6	1.3	12	10.3	0.9
Cynoscion arenarius	13	26.7	2.1	13	26.7	2.1			
Menticirrhus littoralis	10	4.0	0.4	10	4.0	0.4			
Pogonias chromis	9	29.0	3.2	9	29.0	3.2			
Sciaenops ocellata	8	0.8	0.1	8	0.8	0.1			
Citharichthys spilopterus	8	13.7	1.7	8	13.7	1.7			
Sphoeroides parvus	8	18.6	2.3	8	18.6	2.3			
Paralichthys lethostigma	7	6.3	0.9				7	6.3	0.9
Gobionellus boleosoma	7	2.1	0.3	6	2.0	0.3	1	0.1	0.1
Synodus foetens	5	8.3	1.7	5	8.3	1.7			
Anchoa hepsetus	4	1.2	0.3	4	1.2	0.3			
Gerres cinereus	4	2.8	0.7	4	2.8	0.7			
Hemicaranx amblyrhynchus	4	6.0	1.5	4	6.0	1.5			
Gobionellus schufeldti	4	0.4	0.1				4	0.4	0.1
Symphurus plagiusa	4	3.5	0.9	2	3.3	1.7	2	0.2	0.1
Prionotus tribulus	3	1.9	0.6	3	1.9	0.6			

(Continued)

Table 111

Species	Total Catch			Seine			Push Nets		
	Number	Weight (g)	Average wt. (g)	Number	Weight (g)	Average wt. (g)	Number	Weight (g)	Average wt. (g)
Syngnathus louisianae	3	0.9	0.3	2	0.6	0.3	1	0.3	0.3
Anchoa sp.	2	0.5	0.3	2	0.5	0.3			
Chaetodipterus faber	2	0.6	0.3				2	0.6	0.3
Eucinostomus lefroyi	2	1.7	0.9	2	1.7	0.9			
Lagodon rhomboides	2	13.1	6.6	2	13.1	6.6			
Chloroscombrus chrysurus	1	0.1	0.1	1	0.1	0.1			
Dorosoma cepedianum	1	1.8	1.8	1	1.8	1.8			
Etropus crossotus	1	0.1	0.1				1	0.1	0.1
Gobionellus sp.	1	0.1	0.1				1	0.1	0.1
Gobiidae	1	0.1	0.1	1	0.1	0.1			
Opisthonema oglinum	1	1.3	1.3	1	1.3	1.3			
Paralichthys albigutta	1	1230.0	1230.0	1	1230.0	1230.0			
VERTEBRATE TOTALS	17,117	30,484.0	1.8	15861	30,879.7	1.9	1264	604.7	0.5
INVERTEBRATES									
Penaeus setiferus	1678	1071.6	0.6	1158	849.6	0.7	520	222.0	0.4
Palaemonetes pugio	1456	227.1	0.2	663	117.1	0.2	793	110.0	0.1
Callinectes sapidus	611	4039.6	6.6	405	3836.5	9.5	206	203.1	1.0
Clibanarius vittata	562	2117.9	3.8	493	1887.7	3.8	69	230.2	3.3

(Continued)

Table 111 (Concluded)

Species	Total Catch			Seine			Push Nets		
	Number	Weight (g)	Average wt. (g)	Number	Weight (g)	Average wt. (g)	Number	Weight (g)	Average wt. (g)
Penaeus aztecus	503	1013.0	2.0	378	910.5	2.4	125	102.5	0.8
Palaemonetes sp.	170	26.5	0.2	92	15.4	0.2	78	11.1	0.1
Callinectes similis	140	55.9	0.4	79	37.4	0.5	61	18.5	0.3
Palaemonetes vulgaris	81	16.7	0.2	80	16.6	0.2	1	0.1	0.1
Penaeus sp.	65	26.7	0.4	64	26.6	0.4	1	0.1	0.1
Palaemonetes intermedius	51	8.4	0.2	39	7.0	0.2	12	1.4	0.1
Loliguncula brevis	47	120.6	2.6	42	107.3	2.6	5	13.3	2.7
Neopanope texana texana	1	0.1	0.1				1	0.1	0.1
Pagurus polycarpus	1	0.5	0.5				1	0.5	0.5
Decapoda (unident.)	1	0.1	0.1				1	0.1	0.1
INVERTEBRATE TOTALS	5367	8724.7	1.6	3493	7811.7	2.2	1874	913.0	0.5
GRAND TOTALS	22,484	39,208.7	1.7	19,354	38,691.4	2.0	3138	1517.7	0.5

Table 112

Summary of Nekton Captured in Hoop Nets and Minnow Traps in Order of Abundance from July 1976 Through June 1977

Species	Annual Catch			Hoop Net			Minnow Traps		
	Number	Weight (g)	Average Wt. (g)	Number	Weight (g)	Average Wt. (g)	Number	Weight (g)	Average Wt. (g)
VERTEBRATES									
Micropogon undulatus	8	26.9	3.4				8	26.9	3.4
Fundulus similis	2	3.8	1.9				2	3.8	1.9
Mugil curema	2	3.3	1.7				2	3.3	1.7
Lagodon rhomboides	1	5.9	5.9				1	5.9	5.9
Mugil sp.	1	0.2	0.2				1	0.2	0.2
VERTEBRATE TOTAL	14	40.1	2.9				14	40.1	2.9
INVERTEBRATES									
Palaemonetes pugio	79	13.6	0.2				79	13.6	0.2
Palaemonetes vulgaris	23	4.1	0.2				23	4.1	0.2
Callinectes sapidus	8	945.5	118.2	4	938.0	234.5	4	7.5	1.9
Palaemonetes sp.	4	1.5	0.4				4	1.5	0.4
Callinectes similis	3	1.4	0.5				3	1.4	0.5
Clibanarius vittata	1	0.8	0.8				1	0.8	0.8
Penaeus aztecus	1	3.6	3.6				1	3.6	3.6
INVERTEBRATE TOTALS	119	970.5	8.2	4	938.0	234.5	115	32.5	0.3
GRAND TOTALS	133	1010.6	7.6	4	938.0	234.5	129	73.3	0.6

Table 113

Summary of Nekton Data, Day and Night, Collected Monthly by Beach Seines from July 1976 Through June 1977. (No Samples Were Collected in December.)

Month and Time	Total Numbers	Average No. and SD	Total Weight (g)	Average Wt. (g) and SD	Average Diversity
July					
Day	1206	172 ± 256	10314.0	1973.4 ± 3182.7	1.74
Night	528	75 ± 72	1396.0	199.4 ± 225.7	0.94
August					
Day	1769	253 ± 116	2275.0	325.1 ± 190.4	0.21
Night	1400	200 ± 80	3244.1	407.3 ± 165.6	1.57
September					
Day	246	35 ± 30	358.2	51.2 ± 44.0	1.18
Night	359	51 ± 28	331.3	47.3 ± 21.2	1.24
October					
Day	197	28 ± 56	117.6	16.8 ± 26.8	0.36
Night	285	41 ± 60	200.8	28.0 ± 34.1	0.62
November					
Day	61	9 ± 23	44.5	6.4 ± 16.8	0.04
Night	254	36 ± 37	197.6	28.2 ± 30.1	0.33
January					
Day	168	24 ± 28	141.8	20.3 ± 21.0	1.00
Night	652	93 ± 60	1296.4	185.2 ± 139.9	0.86

(Continued)

Table 113 (Concluded)

Month and Time	Total Numbers	Average No. and SD	Total Weight (g)	Average Wt. (g) and SD	Average Diversity
February					
Day	26	4 ± 5	65.2	9.3 ± 17.3	1.74
Night	260	37 ± 18	297.8	42.5 ± 39.4	1.25
March					
Day	566	81 ± 70	336.9	48.1 ± 30.0	0.91
Night	1835	262 ± 397	954.2	136.3 ± 139.2	1.26
April					
Day	647	92 ± 74	966.0	138.0 ± 156.5	1.31
Night	1644	235 ± 141	2381.9	340.3 ± 179.3	1.25
May					
Day	628	90 ± 54	831.1	118.7 ± 92.6	1.58
Night	2679	383 ± 336	3590.6	512.9 ± 256.9	1.53
June					
Day	1526	218 ± 94.3	2685.9	383.7 ± 348.1	1.38
Night	2319	331 ± 204	7156.9	1022.4 ± 760.9	1.72

Table 114

Summary of Nekton Data, Day and Night, Collected Monthly by Push Nets from July 1976 Through June 1977. (No Samples Were Collected in Decmeber.)

Month and Total	Total Numbers	Average No. and SD	Total Weight (g)	Average Wt. (g) and SD	Average Diversity
July					
Day	113	16 ± 10	82.1	11.7 ± 10.9	1.02
Night	36	5 ± 10	11.3	1.6 ± 3.5	0.20
August					
Day	229	33 ± 6	185.7	26.5 ± 14.2	1.33
Night	156	22 ± 16	121.1	17.3 ± 14.4	1.26
September					
Day	285	41 ± 52	334.9	47.8 ± 87.0	0.74
Night	269	38 ± 33	159.3	22.8 ± 17.2	0.98
October					
Day	217	31 ± 67	57.9	8.3 ± 12.2	0.22
Night	489	70 ± 170	78.5	11.2 ± 23.1	0.33
November					
Day	49	7 ± 13	6.9	1.0 ± 1.7	0.18
Night	184	26 ± 33	47.8	6.8 ± 9.9	0.63
January					
Day	143	20 ± 35	32.6	4.7 ± 5.9	0.63
Night	198	28 ± 23	57.6	8.2 ± 5.8	1.03

(Continued)

Table 114 (Concluded)

Month and Time	Total Numbers	Average No. and SD	Total Weight (g)	Average Wt. (g) and SD	Average Diversity
February					
Day	51	7 ± 10	17.9	2.6 ± 4.3	0.39
Night	164	23 ± 17	43.7	6.2 ± 4.7	1.13
March					
Day	210	30 ± 16	99.5	14.2 ± 9.6	0.59
Night	359	51 ± 26	183.4	26.2 ± 14.3	1.46

Table 115

Summary of Nekton Captured in Seines by Station and Time of Day from July 1976 Through June 1977. (No Samples Were Obtained During December.)

Station and Time	Total Numbers	Average Number/Mo. and SD	Total Weight (g)	Average Wt./Mo. and SD (g)	Mean Diversity
Reference Area					
Sta. J5 - Day	1150	105 ± 143	1604.0	145.8 ± 223.6	0.88
Sta. J5 - Night	1556	141 ± 145	2806.5	255.1 ± 291.3	1.07
Sta. Z5 - Day	1009	92 ± 112	1485.7	135.1 ± 171.2	1.09
Sta. Z5 - Night	1399	127 ± 114	2128.0	193.5 ± 203.2	1.34
Bare Unprotected					
Sta. A5 - Day	1310	119 ± 219	9515.3	865.0 ± 2592.0	0.99
Sta. A5 - Night	2476	225 ± 311	2566.3	233.3 ± 233.8	1.09
Sta. I5 - Day	649	59 ± 68	882.5	80.2 ± 83.7	1.04
Sta. I5 - Night	3110	283 ± 360	4705.0	427.7 ± 661.4	1.24
Marsh					
Pos. E - Day	958	87 ± 107	1292.0	117.4 ± 129.1	0.79
Pos. E - Night	764	69 ± 66	1418.1	128.9 ± 150.3	0.77
Bare Protected					
Sta. X5 - Day	1084	99 ± 109	2472.7	224.8 ± 370.2	1.12
Sta. X5 - Night	1367	124 ± 112	3012.5	273.9 ± 362.3	1.22
Sta. Y5 - Day	880	80 ± 70	884.2	80.4 ± 94.9	1.16
Sta. Y5 - Night	1543	140 ± 128	4013.5	364.8 ± 517.5	1.29

Table 116

Summary of Nekton Captured in Push Nets by Station and Time of Day from July 1976 Through March 1977. (No Samples Were Collected in December.)

Station and Time	Total Number	Average Number/Mo and SD	Total Weight (g)	Average Wt/Mo and SD (g)	Mean Diversity
Reference Area					
Sta. J5 - Day	235	29 ± 53	328.6	41.4 ± 83.3	0.78
Sta. J5 - Night	230	29 ± 37	138.9	17.4 ± 20.3	0.77
Sta. Z5 - Day	154	19 ± 14	93.6	11.7 ± 10.5	0.73
Sta. Z5 - Night	311	39 ± 32	127.4	15.9 ± 16.4	1.09
Marsh					
Pos. E - Day	126	16 ± 20	71.3	8.9 ± 13.3	0.41
Pos. E - Night	97	12 ± 13	45.8	5.7 ± 5.6	0.56
Bare Unprotected					
Sta. A5 - Day	226	28 ± 34	67.8	8.5 ± 8.2	0.69
Sta. A5 - Night	243	30 ± 23	76.9	9.6 ± 7.9	0.95
Sta. I5 - Day	100	13 ± 12	60.6	7.6 ± 10.7	0.52
Sta. I5 - Night	169	21 ± 26	106.8	13.4 ± 19.0	0.68
Bare Protected					
Sta. X5 - Day	215	27 ± 9	108.5	13.6 ± 10.8	0.90
Sta. X5 - Night	166	21 ± 13	61.6	7.7 ± 5.6	1.09
Sta. Y5 - Day	241	30 ± 61	87.1	10.9 ± 15.6	0.42
Sta. Y5 - Night	639	80 ± 153	145.3	18.1 ± 19.9	1.00

Table 117

Mean Annual Catch of Blue Crabs (*Callinectes sapidus*) in Crab Traps Set at Stations 3 and 5 Along Transects in the Marshland and Protected Areas, Day and Night, from July 1976 through June 1977.*

Parameter	Marshland		Protected Mixture		Protected Bare	
	Day	Night	Day	Night	Day	Night
Number of males (annual)	4	6	3	12	11	20
Number of females (annual)	2	1	1	3	2	2
Percentage of males (annual)	66.7	85.7	75.0	80.0	84.6	90.9
Percentage of females (annual)	33.3	14.3	25.0	20.0	15.4	9.1
Number of males/month (mean & SD)	0.4 ± 0.7	0.5 ± 1.0	0.3 ± 0.6	1.1 ± 1.7	1.0 ± 1.8	1.9 ± 2.2
Number of females/month (mean & SD)	0.2 ± 0.7	0.1 ± 0.3	0.1 ± 0.3	0.3 ± 0.6	0.2 ± 0.4	0.2 ± 0.4
Percentage gravid (annual)						
Percentage hard (annual)	100	100	100	93.3	100	100
Percentage soft (annual)						
Percentage peeler (annual)				6.7		
Mean carapace width (mm)						
Males	126	123	146	137	127	135
Females	113	112	128	122	119	134
Mean weight (g)						
Males	141	120	197	190	131	160
Females	86	85	114	96	146	137

*No crabs were taken in crab traps from November 1976 through February 1977.

Table 118

Mean Annual Catch of Blue Crabs (*Callinectus sapidus*) in Crab Traps Set at Stations 3 and 5 Along Transects in the Unprotected and Reference Areas Day and Night, from July 1976 through June 1977.*

Parameter	Unprotected Mixture Day	Unprotected Mixture Night	Unprotected Bare Day	Unprotected Bare Night	Reference Area Day	Reference Area Night
Number of males (annual	24	27	13	16	8	16
Number of females (annual)	15	7	20	9	9	19
Percentage of males (annual)	61.5	79.4	39.4	64.0	47.1	45.7
Percentage of females (annual)	38.5	20.6	60.6	36.0	52.9	54.3
Number of males/month (mean and SD)	2.2 ± 2.2	2.5 ± 2.6	1.3 ± 1.9	1.5 ± 1.4	0.7 ± 1.1	1.5 ± 1.8
Number of females/month (mean and SD)	1.4 ± 3.3	0.6 ± 1.0	1.8 ± 2.8	0.8 ± 1.3	0.8 ± 1.8	1.7 ± 3.0
Percentage gravid (annual)		5.9	6.1		5.9	14.3
Percentage hard (annual)	97.4	94.1	90.9	100	88.2	85.7
Percentage soft (annual)			3.0			
Percentage peeler (annual)	2.6				5.9	
Mean carapace width (mm)						
Males	131	134	131	135	130	128
Females	150	144	140	142	139	149

(Continued)

Table 118 (Concluded)

Parameter	Unprotected Mixture		Unprotected Bare		Reference Area	
	Day	Night	Day	Night	Day	Night
Mean weight (g)						
Males	143	158	130	151	128	144
Females	174	142	184	144	140	155

*No crabs were taken in crab traps from November 1976 through February 1977.

Table 119

Monthly Food Habits Summary for *Micropogon undulatus* of Less Than 20 mm Standard Length From November 1976 through March 1977. (No *M. undulatus* Were Collected During Deleted Months).

Parameter	November	January	February	March	Totals
Number of stomachs with food	2	7	17	11	37
Number of empty stomachs		15			15
Percentage empty		68			29
Copepoda					
Harpacticoids	91	42	59	1	193
Calanoids		9	247	1	257
Cirripedia					
cyprid larvae	12	35	24	1	72
Decapoda					
Penaeidae mysids		1			1
crab zoea			4		4
Ostracoda			4	1	5
Osteichthys eggs			3		3
Totals (stomach contents)	103	87	341	4	535
Volume of stomach contents (ml)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.4

Table 120

Monthly Food Habits Summary for *Micropogon undulatus* of 20 to 50mm Standard Length From June 1976 Through June 1977. (No *M. undulatus* Were Collected During Deleted Months).

Parameter	June	January	February	March	April	May	June	Totals
Number of stomachs with food	11	25	25	25	25	25	25	161
Number of empty stomachs		10	2	1	2	1		16
Percentage empty		29	7	4	7	4		9
Ploychaeta								
Eteone heteropoda	12	2			2	4	10	30
Articidae sp.	23				1	1	10	35
Hetermostus filiformis	6							6
Parandalia fauveli	2							2
Nereis sp.		1	3		1	1		6
Diopatra cuprea							2	2
Unidentified						2		2
Ostracoda		3		3	2	5		13
Copepoda								
Harpacticoida	10	67	147	9	6	89	37	365
Calanoida	8	62	341	2	4	137	303	857
Cirripedia								
Cyprid larvae		85	51		3	21	137	297

(Continued)

Table 120 (Concluded)

Parameter	June	January	February	March	April	May	June	Totals
Isopoda (Unidentified)							1	1
Xenanthura brevitelson					18	15	8	41
Amphipoda								
Gammaridae		28	11		3			42
Unidentified					5	27		32
Decapoda								
Penaeus mysid						41		41
Penaeus sp.		2		1				3
Crab megalops		1						1
Unidentified crab	1							1
Callianassidae		2						2
Crustacean larvae				1				1
Unidentified eggs							248	248
Mollusca								
Pelyceopoda	1							1
Gastropoda					1	1		2
Osteichthys								
Unidentified		3		3				6
Eggs	3	4			2	1		10
Totals (stomach contents)	66	260	553	19	48	345	756	2047
Volume of stomach Contents (ml)	0.1	0.1	0.3	0.7	0.3	0.4	0.5	2.4

Table 121

Monthly Food Habits Summary for *Micropogon undulatus* of 51 to 100mm Standard Length From June 1976 Through June 1977. (No *M. undulatus* were Collected During Deleted Months.)

Parameter	June	July	August	April	May	June	Totals
Number of stomachs with food	25	9	2	19	25	25	105
Number of empty stomachs	1		2	7	1		11
Percentage empty	4		50	27	4		10
Oligochaeta		36	126				162
Polychaeta							
Eteone heteropoda	41	1	1	4	3		50
Capitella sp.				21			21
Aricidea sp.						6	6
Diopatra cuprea						1	1
Parandalia fauveli						1	1
Unidentified individuals						3	3
Ostracoda				1			1
Insecta							
Coleoptera larvae			3				3
Copeda							
Harpacticoida	5	31			3	65	104
Calanoida	9		13	111	1	88	222
Cyclopoida						1	1
Cirripedia							

Table 121 (Concluded)

Monthly Food Habits Summary for *Micropogon undulatus* of 51 to 100mm Standard Length From June 1976 through June 1977. (No *M. undulatus* Were Collected During Deleted Months.)

Parameter	June	July	August	April	May	June	Totals
Cyprid larvae					2	18	20
Amphipoda				3			3
Isopoda							
Xenanthura brevitelson				6	15	1	22
Decapoda							
Penaeus sp.	1	18			1	26	46
Unidentified crabs		3	1		1	1	6
Osteichthys							
Unidentified remains	1						1
Totals (stomach contents)	57	89	144	146	26	211	673
Volume of stomach contents (ml)	0.8	1.0	0.3	0.4	0.9	0.6	4.0

Table 122

Monthly Food Habits Summary for *Micropogon undulatus* of Greater Than 100 Standard Length From May 1976 through June 1977

Parameter	May	June	Totals
Number of stomachs with food	2	1	3
Number of empty stomachs	1		1
Percentage empty	33		25
Polychaeta			
Heteromastus filiformis		1	1
Nereis sp.		1	1
unidentified individuals	1		1
Cirripedia			
cyprid larvae	1		1
Decapoda			
Penaeus mysid		2	2
unidentified crab	1		1
Mollusca			
Ensis minor		1	1
Osteichthys			
Micropogon undulatus	1		1
Totals (stomach contents)	4	5	9
Volume of stomach contents (ml)	0.8	0.1	0.9

Table 123

Summary of Food Habits of *Leiostomus xanthurus* less than 20 mm in Standard Length From June 1976 Through June 1977. (No *L. xanthurus* Were Collected During Deleted Months.)

Parameter	March	April	Totals
Number of stomachs with food	25	17	42
Number of stomachs empty			
Percentage empty			
Polychaeta			
Eteone heteropoda	31	1	32
Ostracoda	1		1
Copepoda			
Harpacticoida	581	906	1487
Cirripedia			
Cyprid larvae	1	1	2
Isopoda			
Xenanthura brevitelson	1	10	11
Crab zoea	9	1	10
Amphipoda			
Gammaridae	4		4
Totals (Stomach contents)	628	919	1547
Volume of stomach contents (ml)	<0.1	<0.1	<0.2

Table 124

Summary of Food Habits of *Leiostomus xanthurus* of 20 to 50 mm in Standard Length From June 1976 through June 1977. (No *L. xanthurus* Were Collected During Deleted Months)

Parameter	June	March	April	May	June	Totals
Number of stomachs with food	25	25	25	25	25	125
Number of Empty stomachs				3	8	11
Percentage empty				11	24	8
Polychaeta						
Eteone heteropoda	2	314	5	19	1	341
Aricidea sp.			12	11		23
Capitella sp.			1			1
Nereis sp.			1			1
Ostracoda			2	32	2	36
Copepoda						
Harpacticoida	3686	8067	1051	442	436	13682

(Continued)

Table 124 (Concluded)

Parameter	June	March	April	May	June	Totals
Calanoida				15	2	17
Cirripedia						
Cyprid larvae		1	3	8	28	40
Insecta pupae				1		1
Isopoda						
Xenanthura brevitelson		1	15			16
Amphipoda						
Gammaridae	4					4
Decapoda						
Penaeus sp. mysids					2	2
Mollusca (Unidentified)			1			1
Gastropoda			22	8	2	32
Osteichthys eggs					4	4
Totals (Stomach contents)	3692	8383	2113	536	477	15201
Volume of stomach contents (ml)	0.2	0.3	0.2	0.2	0.2	1.1

Table 125

Summary of Food Habits of *Leiostomus xanthurus* of 51 to 100 mm in Standard Length From June 1976 Through June 1977. (No *L. xanthurus* Were Collected During Deleted Months).

Parameter	June	July	April	May	June	Totals
Number of stomachs with food	25	2	7	25	25	84
Number of empty stomachs	2		2		3	7
Percentage empty	7		22		11	8
Nemertea						
Polychaeta						
Eteone heteropoda	31			21		52
Aricidea sp. fragments	-	-	-	-	-	-
Nereis sp.			4	2		6
Ostracoda				14		14
Copepoda						
Harpacticoida	1734	125	1	364	161	2385

(Continued)

Table 125

Parameter	June	July	April	May	June	Totals
Calanoida					13	13
Cirripedia						
Cyprid larvae			1		4	5
Isopoda						
Amphipoda						
Gammaridae			9			9
Isopoda						
Xenanthura brevitelson			13	1		14
Decopoda						
Penaeus sp.			1			1
Penaeus sp. fragments			0		6	6
Crab megalops			1	1		2
Mollusca						
Gastropoda	1		1			2
Pelycepoda	1					1
Osteichthys						
Unidentified					1	1
Eggs			1	5	6	12

(Continued)

Table 125 (Concluded)

Parameter	June	July	April	May	June	Totals
Totals (Stomach contents)	1767	125	35	408	191	2526
Volume of Stomach contents (ml)	0.3	0.1	0.1	0.2	0.1	0.8

Table 126

Summary of Food Habits of *Fundulus similis* Less Than 20 mm in Standard Length

(*F. similis* of This Size Were Only Collected in May 1977)

Parameter	May	Totals
Number of stomachs with food	3	3
Number of empty stomachs		
Percentage empty		
Copepoda		
Harpacticoida	3	3
Totals (Stomach contents)	3	3
Volume of stomach contents (ml)	<0.1	<0.1

Table 127

Summary of Food Habits of *Fundulus similis* Equal to or Greater than 20 mm in Standard Length June 1976 Through January 1977. (No *F. similis* Were Collected During Deleted Months)

Parameter	June	July	August	October	November	January
Number of stomachs with food	3	25	25	25	25	25
Number of empty stomachs		22	7	1	1	10
Percentage empty		47	22	4	4	29
Ostracoda					20	28
Copepoda						
Harpacticoida	145			396	65	689
Cirripedia						
cyprid larvae		85	85	1	27	4
Isopoda						
Xenanthura brevitelson						32
Insecta						
Diptera pupae		13	13			
Diptera adults				4		
Coleoptera		7				
unidentified adults		20				

(Continued)

Table 127 (Concluded)

Parameter	June	July	August	October	November	January
Decapoda						
Penaeus sp.					1	
Hermit crab			1			
unidentified crab		1				
Mollusca						
Gastropoda	1					2
Osteichthys eggs				2	16	7
Totals* (Stomach contents)	146	126	99	403	129	759
Volume of stomach contents (ml)	<0.1	0.2	0.2	0.2	0.1	<0.1

*Totals for the whole sampling period appear in Table 128.

Table 128

Summary of Food Habits of *Fundulus similis* Greater Than 20 mm in Standard Length from February Through June 1977 With Summary of Data Collected From June 1976 Through June 1977

Parameter	February	March	April	May	June	Totals*
Number of stomachs with food	25	24	25	25	25	252
Number of empty stomachs	4	12	6	5	3	71
Percentage empty	14	33	19	17	11	22
Polychaeta						
Eteone heteropoda			2	3		5
Aricidea sp.	93	182	4	5		284
Heteromastus filiformis					1	1
Parandalia fauveli			1			1
Nereis sp.			1		1	2
Ostracoda	32	16	11		1	108
Copepoda						
Harpacticoida	56		1384	15		2747
Calanoida				4		4
Cirripedia						
cyprid larvae	4		7	17	2	232

(Continued)

Table 128

Parameter	February	March	April	May	June	Totals*
Isopoda						
Xenanthura brevitelson	94	93	29			248
Insecta						
Diptera pupae						26
Diptera larvae					1	1
Diptera adults	2					6
Coleoptera						7
Hymenoptera adults	8					8
unidentified adults		1	1	1	1	24
Amphipoda						
Gammaridae		14	24			38
Caprellidae			1			1
Decapoda						
Penaeus sp.			1	1		3
Hermit crab						1
unidentified crab			1			1
Crustacean larvae			1			1
Mollusca unidentified			4			4
Gastropoda	2					2

(Continued)

Table 128 (Concluded)

Parameter	February	March	April	May	June	Totals*
Osteichthys						
unidentified remains				1		1
eggs	2	11		3		41
Totals (Stomach contents)	293	317	1472	51	6	3801
Volume of stomach contents (ml)	0.3	0.5	0.6	0.4	0.3	3.0

* Totals include data from Tables 127 and 128.

Table 129

Summary of Food Habits of *Cyprinodon variegatus* Less Than 20-mm in Standard Length from June 1976 Through June 1977. (No *C. variegatus* Were Collected During Deleted Months.)

Parameter	October	November	January	February	March	Totals
Number of stomachs with food	25	5	25	9	2	66
Number of empty stomachs	10	10	6		3	29
Percentage empty	29	67	19		60	31
Unidentified organic matter only	-	+	+	-	+	
Ostracoda	11					11
Copepoda						
Harpacticoida	9					9
Cirripedia						
Cyprid larvae				1		1
Crustacean larvae				5		5
Mollusca						
Gastropoda	18					18
Totals (Stomach contents)	38			6		44
Volume of stomach contents (ml)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5

+ = present
- = absent

Table 130

Summary of Food Habits of *Cyprinodon variegatus* Equal to or Greater Than 20 mm in Standard Length Collected from June 1976 Through June 1977. (No *C. variegatus* Were Collected During Deleted Months)

Parameter	July	October	November	January	February	March	April	May	Totals
Number of stomachs with food	9	25	25	25	25	7	12	14	142
Number of empty stomachs	2	10	22	9	1	15	5	1	65
Percentage empty	18	29	47	26	4	68	29	7	31
Unidentified organic matter only	+	-	+	+	-	+	-	+	
Copepoda									
Harpacticoida		12			1		1		14
Cirripedia									
Cyprid larvae					1		1		2
Crustacean larvae					3				3
Mollusca									
Gastropoda		9			2		3		14
Osteichthys eggs		1					3		4

(Continued)

Table 130 (Concluded)

Parameter	July	October	November	January	February	March	April	May	Totals
Totals (Stomach contents)		22			7		8		37
Volume of stomach Contents (ml)	0.1	<0.1	0.1	0.1	0.2	0.1	0.1	0.1	<0.9

Table 131

Summary of Food Habits of *Menidia beryllina* equal to or Greater Than 20 mm in Standard Length From June 1976 Through June 1977. (No *M. beryllina* Were Collected During Deleted Months)

Parameter	July	August	October	January	February	March	April	June	Totals
Number of stomachs with food	2	5	8	25	25	25	25	21	136
Number of empty stomachs		1	2	1	1		1	6	12
Percentage empty		17	20	4	4		4	22	8
Polychaeta									
Eteone heteropoda							4		4
Nereis sp.				3	1				4
Polychaete fragments	-	-	-	+	-	-	-	-	
Ostracoda							1		1
Copepoda									
Harpacticoida						2			2
Calanoida						0	761	193	954
Cyclopoida			100			1			101
Cirripedia									
Cyprid larvae				180	6225	9	310	151	6875

(Continued)

Table 131

Parameter	July	August	October	January	February	March	April	June	Totals
Insecta									
Diptera pupae		41							41
Diptera larvae		95							95
Diptera adult			2	1					3
Hymenoptera adult			2		5	8			15
unidentified larvae			1						1
unidentified adult			1				2		3
Amphipoda									
Gammaridae					10	1			11
unidentified larvae		2							2
unidentified adult				2					2
Decapoda									
Penaeus sp.	19			2			2		23
Penaeus mysis			22					2	24
Crab zoea					17				17
Crustaceans, unidentified			4						4
Mollusca									
Gastropoda	1								1

(Continued)

Table 131 (Concluded)

Parameter	July	August	October	January	February	March	April	June	Totals
Osteichthys									
Unidentified remains				34		28	4		66
Eggs		5		8	6			4	23
Totals (Stomach contents)	20	143	112	230	6264	49	1084	350	8252
Volume of stomach contents (ml)	<0.1	<0.1	<0.1	1.0	0.3	1.9	0.2	<0.1	<3.8

+ = present
- = absent

Table 132

List of Benthic Invertebrates Collected at Bolivar Peninsula

Phylum Annelida
- Class Oligochaeta
  - Oligochaete sp. 1
  - Oligochaete sp. 2

Phylum Rhynchocoela
- Class Polychaeta
  - Family Amphinomidae
    - *Pseudeurythoa ambigua*
  - Family Capitellidae
    - *Mediomastus californiensis*
    - *Heteromastus filiformis*
    - *Capitella capitata*
  - Family Glyceridae
    - *Glycera americana*
  - Family Goniadidae
    - *Glycinde solitaria*
  - Family Nereidae
    - *Nereis succinea*
    - *Laeonereis culveri*
  - Family Onuphidae
    - *Diopatra cuprea*
  - Family Orbiniidae
    - *Scoloplos foliosus*
    - *Scoloplos fragilis*
  - Family Paraonidae
    - *Aricidea* sp. 1
    - *Aricidea* sp. 2
  - Family Pectinariidae
    - *Pectinaria gouldi*
  - Family Phyllodocidae
    - *Eteone heteropoda*
  - Family Pilargidae
    - *Parandalia fauveli*
    - *Sigambra tentaculata*
  - Family Spionidae
    - *Streblospio benedicti*
    - *Spiophanes bombyx*
    - *Scolelepsis squanata*
    - *Polydora* sp.
  - Family Terebellidae
    - *Pista palmata*

Phylum Arthropoda
- Class Insecta
  - Order Diptera
  - Order Coleoptera

(Continued)

Table 132 (Concluded)

Family Cicindelidae
Family Carabidae
Family Staphylinidae
Class Crustacea
Order Decapoda
Family Callinassidae
Family Xanthidae
Family Ocypodae
Ocypode quadrata
Uca pugilator
Order Cumacea
Order Isopoda
Family Anthuridae
Xenanthura brevitelson
Order Amphipoda
Suborder Gammaridea
Family Haustoriidae
Family Oedicerotidae
Order Cyclopoida
Order Harpacticoida
Phylum Mollusca
Class Gastropoda
Family Naticidae
Polinices duplicata
Class Pelecypoda
Family Mactridae
Mulinia lateralis
Family Solenidae
Ensis minor
Family Tellinidae
Macoma constricta
Family Psammobiidae
Tagelus plebius
Order Pholadomyoida
Family Periplomatidae
Periploma inequale

Table 133

Macroinvertebrate Taxa in Order of Mean Annual Abundance from all Stations at Bolivar Peninsula, July 1976 Through June 1977

Taxon	Number/m^2	Dry Weight g/m^2
Mediomastus californiensis	1049.8	0.1105
Aricidea sp.	314.1	0.0117
Xenanthura brevitelson	234.4	0.0081
Parandalia fauveli	164.0	0.0703
Streblospio benedicti	145.1	0.0051
Oligochaete sp. 2	129.4	0.0082
Diptera	107.8	0.0385
Staphylinidae	102.5	0.0246
Capeitella capitata	93.4	0.0144
Eteone heteropoda	80.0	0.0102
Rhynchocela	42.1	0.0140
Nereis succinea	30.9	0.0579
Polydora sp.	26.7	0.0021
Pseudeurythoa ambigua	20.1	0.0024
Scoloplos fragilis	15.0	0.0185
Tellinidae	9.9	0.0051
Aricidea sp. 2	7.9	0.0039
Macoma constricta	7.9	1.3310
Diopatra cuprea	4.6	0.0247
Haustoriidae	3.6	0.0010
Sigambra tentaculata	3.6	0.0003
Heteromastus filiformis	2.8	0.0053
Ensis minor	2.2	0.3271
Glycinde solitaria	2.0	0.0012
Ocypode quadrata	1.8	0.0185
Tagelus plebius	1.5	0.3751
Pectinaria gouldi	1.4	0.0009
Laeonereis culveri	1.3	0.0008

(Continued)

Table 133 (Concluded)

Taxon	Number/m^2	Dry Weight g/m^2
Oedicerotidae	1.1	0.0001
Coleptera	0.8	0.0005
Harpacticoid copepod	0.6	0.0007
Mulinia lateralis	0.6	0.0072
Cumacea	0.4	0.0001
Scoloplos foliosus	0.4	0.0002
Uca pugilator	0.4	0.0458
Cyclopoid copepod	0.3	< 0.0001
Polinices duplicata	0.2	0.0991
Oligochaete sp. 1	0.2	0.0057
Xanthidae	0.1	0.0002
Periploma inequale	0.1	0.0081
Cicinellidae	0.1	0.0001
Callinassidae	< 0.1	0.0014
Pista palmata	< 0.1	< 0.0001
Glycera americana	< 0.1	< 0.0001
Carabidae	< 0.1	< 0.0001
Scolelepsis squamata	< 0.1	< 0.0001
Spiophanes bombyx	< 0.1	< 0.0001

Table 134

Benthos Mean Monthly Abundance and Diversity at Bolivar Peninsula, July 1976 Through June 1977

Month	Mean Abundance ($No./m^2$)	Mean Diversity
July	745	0.79
August	792	0.68
September	803	0.94
October	970	0.93
November	862	1.05
December	1619	0.98
January	2604	1.10
February	4835	1.04
March	5456	0.89
April	5651	0.93
May	3898	1.02
June	3162	0.91

AD-A063 781 TEXAS AGRICULTURAL EXPERIMENT STATION COLLEGE STATION F/G 13/3
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA MAR--ETC(U)
JUN 78 J W WEBB, J D DODD, B W CAIN DACW39-76-C-0109

UNCLASSIFIED WES-TR-D-78-15-APP-D NL

6 OF 6
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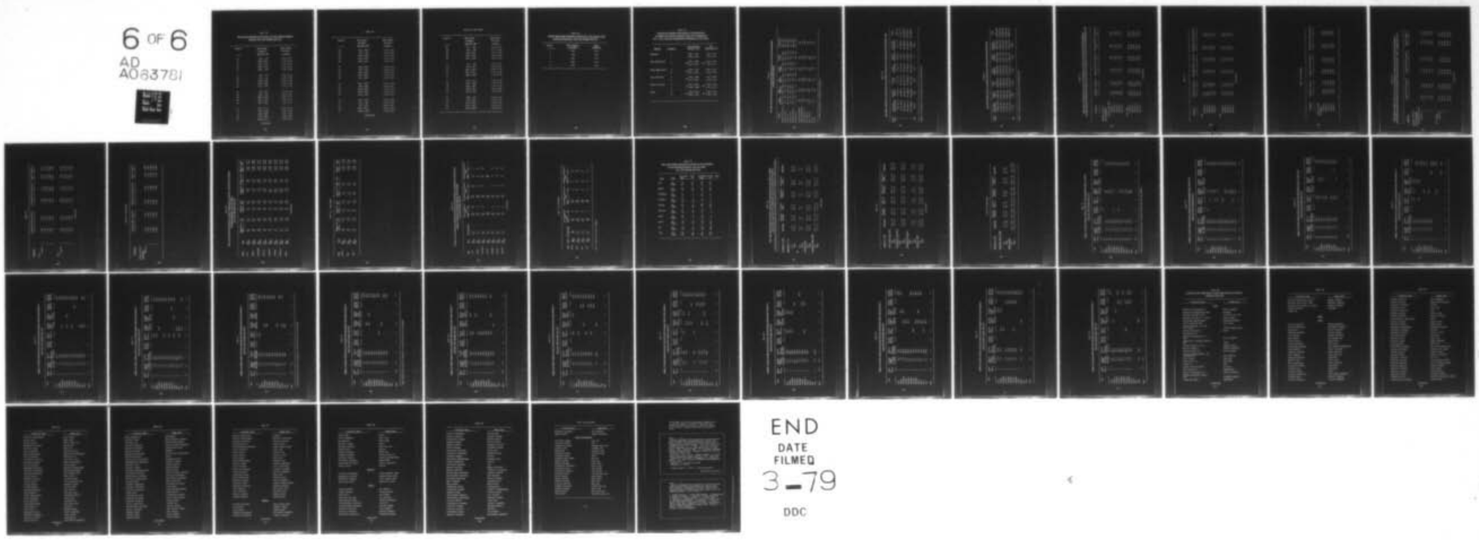

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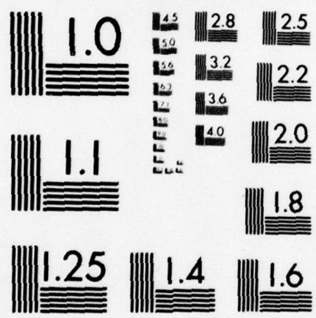
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5.0
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Table 135

Mean Annual Abundance and Diversity at Each Benthos Sampling Station, July 1976 Through June 1977

Station	Mean Annual Abundance (No./m^2 ± SD)	Mean Annual Diversity (± SD)
Z1	830 ± 572	0.69 ± 0.47
Z2	3082 ± 2891	1.48 ± 0.33
Z3	4126 ± 2710	1.19 ± 0.30
Z4	3614 ± 3140	1.12 ± 0.31
Z5	3060 ± 1739	1.28 ± 0.38
A1	444 ± 257	0.50 ± 0.31
A2	133 ± 196	0.35 ± 0.36
A3	2755 ± 2107	0.85 ± 0.31
A4	3434 ± 3138	1.04 ± 0.49
A5	4174 ± 2713	1.22 ± 0.30
B1	878 ± 1014	0.61 ± 0.38
B2	284 ± 552	0.47 ± 0.57
B3	3085 ± 3618	0.94 ± 0.31
B4	3467 ± 2794	1.46 ± 0.18
B5	2209 ± 1852	1.32 ± 0.27
C1	4243 ± 7174	0.49 ± 0.37
C2	915 ± 2120	0.53 ± 0.40
C3	3664 ± 4085	1.02 ± 0.42
C4	4732 ± 5011	1.29 ± 0.34
C5	6008 ± 6879	1.23 ± 0.27

(Continued)

Table 135

Station	Mean Annual Abundance (No./m^2 ± SD)	Mean Annual Diversity (± SD)
D1	2781 ± 2962	0.54 ± 0.34
D2	332 ± 298	0.27 ± 0.35
D3	1769 ± 2199	1.37 ± 0.36
D4	4526 ± 4017	1.23 ± 0.28
D5	4569 ± 5119	1.29 ± 0.27
F1	1368 ± 2362	0.80 ± 0.28
F2	699 ± 1147	0.59 ± 0.31
F3	1654 ± 3186	1.04 ± 0.46
F4	7653 ± 9412	1.13 ± 0.34
F5	2711 ± 2557	1.22 ± 0.24
G1	1861 ± 1587	0.40 ± 0.33
G2	908 ± 1259	0.61 ± 0.41
G3	1838 ± 2059	1.24 ± 0.30
G4	6532 ± 7885	1.33 ± 0.41
G5	7190 ± 7378	0.95 ± 0.46
Y1	1697 ± 1790	0.44 ± 0.29
Y2	519 ± 465	0.52 ± 0.40
Y3	702 ± 1373	0.82 ± 0.61
Y4	3245 ± 2744	0.97 ± 0.36
Y5	7866 ± 11910	1.03 ± 0.59

(Continued)

Table 135 (Concluded)

Station	Mean Annual Abundance (No./m^2 ± SD)	Mean Annual Diversity (± SD)
H1	811 ± 802	0.44 ± 0.31
H2	426 ± 738	0.41 ± 0.46
H3	3132 ± 4071	0.97 ± 0.28
H4	5233 ± 2990	0.81 ± 0.26
H5	1607 ± 1232	1.32 ± 0.42
I1	414 ± 360	0.66 ± 0.31
I2	835 ± 1171	0.50 ± 0.52
I3	3001 ± 3031	0.92 ± 0.32
I4	3817 ± 2527	0.73 ± 0.26
I5	2299 ± 1968	1.42 ± 0.34
J1	655 ± 813	0.91 ± 0.66
J2	2527 ± 1931	1.43 ± 0.26
J3	2629 ± 2267	1.44 ± 0.21
J4	1890 ± 1367	1.64 ± 0.39
J5	1620 ± 1520	1.51 ± 0.44
X1	686 ± 679	0.82 ± 0.32
X2	533 ± 1252	0.53 ± 0.59
X3	1200 ± 1368	1.18 ± 0.26
X4	5234 ± 5901	1.22 ± 0.42
X5	4640 ± 6039	1.29 ± 0.51

Table 136

Benthos Mean Annual Abundance and Diversity with Station Level at Bolivar Peninsula, July 1976 Through June 1977

Station	Mean Abundance ($No./m^2$)	Mean Diversity
1	1459	0.61
2	923	0.64
3	2431	1.08
4	4504	1.16
5	4074	1.26

Table 137

Mean Annual Abundance and Diversity of Macrobenthos by Habitat at Bolivar Peninsula, July 1976 through June 1977. (NS = Pair Not Significantly Different at 0.05 Level).

Habitat	Transect		Mean Abundance (No/m^2 ± SD)		Mean Diversity ± SD
Reference	J		1856 ± 1748		1.38 ± 0.48
	Z		2942 ± 2585		1.15 ± 0.44
Bare Unprotected	A	NS	2156 ± 2568	NS	0.78 ± 0.46
	I		2021 ± 2336		0.84 ± 0.47
Mixed Unprotected	B	NS	2015 ± 2576		0.98 ± 0.52
	H		2201 ± 2891		0.78 ± 0.48
Bare Protected	X	NS	2518 ± 4290		1.01 ± 0.50
	Y		2774 ± 5917		0.74 ± 0.51
Mixed Protected	C	NS	3912 ± 5464	NS	0.91 ± 0.49
	G		3556 ± 5388		0.90 ± 0.52
Marsh	D	NS	2735 ± 3571	NS	0.93 ± 0.55
	F		2955 ± 5140		0.95 ± 0.40

Table 138

Mean Annual Macroinvertebrate Numbers per Square Metre, Sediment Particle Size, and Volatile Solids Percentages Associated with Different Habitats

Parameter	Bare Unprotected	Mixed Unprotected	Bare Protected	Mixed Protected	Marshland	Reference Area
Mediomastus californiensis	601.5 ± 1263.3*	824.5 ± 1893.8	1523.3 ± 4512.2	1775.5 ± 3978.2	1212.3 ± 3224.5	460.2 ± 712.4
Parandalia fauveli	34.3 ± 67.4	57.8 ± 124.2	218.3 ± 418.1	254.0 ± 560.1	236.1 ± 534.1	185.4 ± 243.7
Aricidea sp. 1	841.0 ± 1511.3	565.4 ± 1158.7	28.6 ± 148.9	7.6 ± 27.8	16.0 ± 65.9	438.0 ± 662.0
Eteone heteropoda	73.6 ± 105.1	118.4 ± 204.8	74.0 ± 131.2	101.3 ± 184.6	57.3 ± 113.5	57.7 ± 86.5
Xenanthura brevitelson	314.5 ± 872.3	143.1 ± 439.5	43.8 ± 163.5	6.9 ± 26.7	5.4 ± 18.3	882.4 ±1267.3
Macoma constricta	2.3 ± 10.4	1.6 ± 9.1	7.8 ± 29.0	17.8 ± 43.7	8.0 ± 26.2	8.5 ± 26.7
Annual Mean (number/m^2)	2205	2152	2646	3915	2704	2447
Species Diversity (mean)	0.82	0.88	0.88	0.91	0.95	1.27
Volatile Solids (%)	0.799	0.821	0.928	1.229	1.058	0.948
Sand > 250μm (%)	1.33	1.26	1.31	2.84	1.27	0.97
Sand < 250μm (%)	92.51	92.11	89.84	85.63	88.87	77.52
Silt (%)	3.57	4.14	5.42	6.80	5.86	9.70
Clay (%)	2.77	2.50	3.53	4.70	4.04	4.31

* The mean of 10 replicates on 12 sampling dates (120 samples)

Table 139

Mean Annual Numbers per Square Metre with Standard Deviations for Important Macroinvertebrate Taxa

Station Level	*Mediomastus californiensis*	*Parandalia fauveli*	*Aricidea* sp. 1	*Eteone heteropoda*	*Macoma constricta*	*Xenanthura brevitelson*	Total
1	29.6± 143.1*	3.8± 25.1	3.1± 18.2	3.5± 15.2	0.0± 0.0	1.1± 7.5	6.9± 11.2
2	212.4± 589.6	75.6±211.1	131.1± 414.4	28.7± 80.9	3.1±17.2	115.9±368.1	94.5± 75.8
3	860.3±1734.2	89.4±146.5	402.9± 717.9	122.5±179.8	4.0±16.2	262.8±830.5	290.3±312.7
4	2105.2±3837.2	380.3±604.0	747.6±1605.9	141.7±182.6	14.4±38.6	381.9±984.0	628.5±765.7
5	2247.3±4844.0	290.7±485.6	326.6± 621.4	109.7±134.8	16.4±39.6	431.0±886.7	570.3±835.3
Mean	1091.0	168.0	322.3	81.2	7.6	238.5	

* Mean of 12 replicates at each elevation over the sampling period.

Table 140

Mean Annual Weight (g/m^2) with Standard Deviations for Important Macroinvertebrate Taxa

Station Level	*Mediomastus californiensis*	*Parandalia fauveli*	*Aricidea* sp.1	*Eteone heteropoda*	*Macoma constricta*	*Xenanthura brevitelson*	Total
1	0.0089±0.0050*	0.0007±0.0046	0.0002±0.0007	0.0005±0.0024	0.0000± 0.0000	0.0001±0.0006	0.0017±0.0035
2	0.0324±0.0836	0.0421±0.1233	0.0055±0.0173	0.0036±0.0106	0.1657± 0.7525	0.0048±0.0150	0.0424±0.0626
3	0.1686±0.3623	0.0430±0.0784	0.0158±0.0274	0.0174±0.0251	0.2688± 1.7399	0.0091±0.0282	0.0871±0.1073
4	0.1702±0.2555	0.1580±0.4414	0.0261±0.0647	0.0174±0.0188	1.4997± 7.3967	0.0122±0.0305	0.3139±0.5853
5	0.1877±0.3920	0.1035±0.2698	0.0112±0.0197	0.0137±0.0200	4.7499±16.2677	0.0151±0.0296	0.8469±1.9134
Mean	0.1136	0.0695	0.0118	0.0105	1.3368	0.0083	

* Mean of 12 replicates at each elevation over the sampling period.

Table 141

Mean Annual Sediment Particle Size (as Percentage of Total) and Volatile Solids Percentage in the Unprotected and Reference Transects of the Bolivar Peninsula Site from July 1976 Through June 1977

Parameter	Reference Transects		Unprotected Bare Transects		Unprotected Mixed Transects	
	J	Z	A	I	B	H
Sediment Particle Size Percentage						
Greater than 250μm						
Station 1	0.78	1.24	1.73	1.09	1.88	0.63
Station 2	0.63	1.08	1.47	1.61	1.45	1.54
Station 3	0.86	0.91	1.97	0.85	1.21	1.15
Station 4	0.96	1.08	1.36	0.78	1.50	0.78
Station 5	0.89	1.26	1.53	0.86	1.42	1.03
63 to 250μm						
Station 1	81.08	75.38	93.05	93.90	92.00	92.00
Station 2	84.68	88.67	91.14	93.08	92.89	91.71
Station 3	84.59	85.23	93.18	93.76	93.29	91.93
Station 4	87.65	83.80	88.50	93.68	92.70	93.12
Station 5	91.86	87.68	91.99	92.81	88.61	92.86

(Continued)

Table 141

Parameter	Reference Transects		Unprotected Bare Transects		Unprotected Mixed Transects	
	J	Z	A	I	B	H
Silt						
Station 1	13.37	14.65	2.67	2.05	3.96	4.76
Station 2	10.37	7.10	3.32	3.25	2.99	3.80
Station 3	10.81	9.88	2.63	3.54	3.12	4.57
Station 4	7.40	11.68	7.04	3.49	3.35	4.22
Station 5	3.84	7.91	4.04	3.63	6.94	3.69
Clay						
Station 1	4.77	8.73	2.55	2.96	2.42	2.61
Station 2	4.32	3.16	4.07	2.07	2.67	2.95
Station 3	3.73	3.97	2.23	1.85	2.21	2.34
Station 4	3.98	3.44	3.31	2.05	2.45	1.87
Station 5	3.41	3.57	2.44	2.69	3.07	2.43

(Continued)

Table 141 (Concluded)

Parameter	Reference Transects		Unprotected Bare Transects		Unprotected Mixed Transects	
	J	Z	A	I	B	H
Volatile Solids						
Percentage						
Station 1	0.962	1.571	0.872	0.765	0.929	0.807
Station 2	0.885	0.861	0.893	0.708	0.897	0.883
Station 3	0.867	0.826	0.835	0.662	0.827	0.692
Station 4	1.028	0.884	0.920	0.710	0.724	0.686
Station 5	0.763	0.829	0.803	0.823	0.839	0.921

Table 142

Mean Annual Sediment Particle Size (as percentage of Total) and Volatile Solids Percentage in the Protected and Marsh Transects of the Bolivar Peninsula Site from July 1976 through June 1977.

Parameter	Protected Bare Transects		Protected Mixed Transects		Marsh Transects	
	X	Y	C	G	D	F
Sediment Particle						
Size Percentage						
Greater than 250μm						
Station 1	3.00	1.33	9.73	1.09	3.22	1.15
2	2.31	0.89	8.29	1.06	1.79	0.70
3	1.31	0.94	3.59	1.42	1.42	0.85
4	1.18	0.58	1.14	0.49	0.97	0.58
5	0.94	0.65	0.91	0.72	0.81	1.19
63 to 250μm						
Station 1	89.37	94.69	85.02	95.17	92.34	94.37
2	88.79	92.39	81.82	91.41	90.85	93.02
3	87.70	92.61	79.32	79.00	88.80	91.35
4	90.17	86.52	88.91	84.57	84.54	85.76
5	90.74	85.45	89.31	81.74	80.72	86.98

(Continued)

Table 142

Parameter		Protected Bare Transects X	Protected Bare Transects Y	Protected Mixed Transects C	Protected Mixed Transects G	Marsh Transects D	Marsh Transects F
Silt							
Station	1	4.80	2.07	3.18	2.17	2.36	2.47
	2	5.09	3.29	4.80	3.90	4.17	3.73
	3	6.50	4.07	7.89	11.02	5.87	4.61
	4	4.82	9.06	5.85	10.89	8.08	8.88
	5	4.74	9.81	5.63	12.63	10.53	7.87
Clay							
Station	1	2.85	2.24	2.08	1.57	2.08	2.02
	2	3.63	3.42	5.09	3.63	3.19	2.84
	3	4.47	2.42	9.26	8.07	3.92	3.19
	4	3.82	4.68	4.11	4.12	6.41	4.79
	5	3.66	4.09	4.16	4.91	7.95	3.96

(Continued)

Table 142 (Concluded)

Parameter		Protected Bare Transects		Protected Mixed Transects		Marsh Transects	
		X	Y	C	G	D	F
Volatile Solids							
Percentage							
Station	1	1.243	0.763	1.536	0.762	1.138	0.789
	2	1.085	0.811	1.913	1.155	1.057	0.945
	3	1.124	0.743	1.729	1.386	0.939	0.906
	4	0.938	0.938	0.918	1.005	1.322	0.966
	5	0.846	0.786	0.815	1.066	1.622	0.895

Table 143

Mean and Standard Deviations in Water Temperature, Salinity, and Dissolved Oxygen

Determined Monthly, Day and Night,

July 1976 Through June 1977

Date	Time	Temperature (C) Mean	SD	Salinity (ppt) Mean	SD	Dissolved Oxygen (ppm) Mean	SD	Ammonia (ppm) Mean	SD
July	Day	25	0.0	11	0.7	9.0	0.0	0.43	0.19
	Night	28	0.0	14	0.0	5.0	1.5	0.89	0.65
August	Day	28	0.6	19	0.8	7.0	0.0	0.09	0.08
	Night	28	0.7	22	0.5	5.6	0.5	0.18	0.09
September	Day	28	0.0	25	0.0	7.8	0.8	0.14	0.19
	Night	26	0.8	25	0.0	7.2	0.1	0.09	0.11
October	Day	23	0.6	20	1.3	9.8	0.5	0.04	0.03
	Night	13	0.0	17	0.4	8.7	1.0	0.04	0.02
November	Day	10	0.0	17	1.2	10.1	0.3	0.18	0.01
	Night	6	0.5	15	1.2	10.4	0.2	0.17	0.04
January	Day	11	0.5	14	1.5	10.4	0.3	0.74	0.40
	Night	11	0.5	14	1.6	10.2	0.3	0.48	0.40
February	Day	11	0.0	18	0.4	10.9	0.1	0.53	0.36
	Night	10	0.0	18	0.5	10.3	0.1	0.44	0.31
March	Day	19	0.0	18	0.5	8.3	0.4	0.06	0.07
	Night	18	0.0	17	0.5	7.8	0.3	0.16	0.22

(Continued)

Table 143 (Concluded)

Date	Time	Temperature (C) Mean	SD	Salinity (ppt) Mean	SD	Dissolved Oxygen (ppm) Mean	SD	Ammonia (ppm) Mean	SD
April	Day	26	0.8	33	0.4	7.4	0.2	0.10	0.10
	Night	20	0.0	33	0.4	7.1	0.2	0.02	0.03
May	Day	25	0.8	16	0.7	7.2	0.2	0.01	0.02
	Night	24	0.0	14	0.0	6.6	0.1	0.00	0.00
June	Day	33	0.8	25	0.6	6.8	0.2	0.09	0.08
	Night	27	0.5	22	0.8	4.9	0.6	0.04	0.04

Table 144

Log Mean of pH, Means with Standard Deviations of Total Alkalinity, Bicarbonate Alkalinity and Carbonate Alkalinity Determined Monthly, Day and Night, July 1976 Through June 1977

Date	Time	pH (log mean)	Total Alkalinity (ppm)		Bicarbonate Alkalinity (ppm)		Carbonate Alkalinity (ppm)	
			Mean	SD	Mean	SD	Mean	SD
July	Day	8.1	135	20	133	19	3	7
	Night	8.5	116	6	95	12	23	9
August	Day	7.2	133	7	133	7	0	0
	Night	7.2	143	9	133	18	10	11
September	Day	8.1	116	6	89	9	27	8
	Night	8.4	125	8	98	17	27	13
October	Day	8.2	ND*		ND		ND	
	Night	7.9	ND		ND		ND	
November	Day	8.2	111	7	111	7	0	0
	Night	8.1	116	9	116	9	0	0
January	Day	8.0	96	5	96	5	0	0
	Night	8.1	99	4	99	4	0	0
February	Day	7.5	97	6	97	6	0	0
	Night	7.5	96	5	96	5	0	0

(Continued)

Table 144 (Concluded)

Date	Time	pH (log mean)	Total Alkalinity (ppm)		Bicarbonate Alkalinity (ppm)		Carbonate Alkalinity (ppm)	
			Mean	SD	Mean	SD	Mean	SD
March	Day	ND	115	5	115	5	0	0
	Night	ND	116	5	116	5	0	0
April	Day	8.1	143	19	143	19	0	0
	Night	8.1	136	7	136	7	0	0
May	Day	7.7	118	6	118	6	0	0
	Night	7.9	115	5	115	5	0	0
June	Day	8.1	144	5	144	5	0	0
	Night	8.1	138	7	138	7	0	0

* ND - No data due to loss of samples

Table 145

Mean and Standard Deviations in Turbidity and Suspended Solids Determined Monthly, Day and Night, July 1976 Through June 1977

Date	Time	Turbidity (FTU) Mean	SD	Suspended Solids (ppm) Mean	SD
July	Day	76	19	59	22
	Night	60	24	30	32
August	Day	50	30	42	39
	Night	71	10	56	16
September	Day	17	5	11	5
	Night	25	1	19	2
November	Day	15	9	11	5
	Night	32	19	17	9
January	Day	92	25	68	20
	Night	42	10	32	10
February	Day	35	6	17	5
	Night	35	10	19	5
March	Day	26	8	12	5
	Night	21	5	8	3
April	Day	35	13	36	12
	Night	27	12	35	18
May	Day	65	17	64	18
	Night	65	18	63	38
June	Day	110	33	97	29
	Night	239	129	223	123

Table 146

Mean Annual Water Quality at Station 5 Within the Various Types of Environments Sampled, Day and Night, from July 1976 through June 1977. (All Values are Presented in Terms of Means and Standard Deviation with the Exception of pH Which is Presented in Terms of Log Mean.)

Parameter & Time	Marshland	Protected Mixture	Protected Bare	Unprotected Mixture	Unprotected Bare	Reference
Temperature (°C)						
Day	21 ± 8	22 ± 8	22 ± 8	21 ± 8	22 ± 8	22 ± 8
Night	19 ± 8	19 ± 8	20 ± 8	19 ± 8	19 ± 8	19 ± 8
pH						
Day	8.0	8.0	7.9	7.9	8.0	7.9
Night	8.0	8.1	8.1	7.9	8.0	7.9
Salinity (ppt)						
Day	19 ± 6	20 ± 6	20 ± 6	20 ± 6	20 ± 6	19 ± 6
Night	19 ± 6	19 ± 6	19 ± 6	20 ± 6	19 ± 6	19 ± 6
Dissolved Oxygen (ppm)						
Day	8.6 ± 1.5	8.5 ± 1.6	8.6 ± 1.6	8.6 ± 1.6	8.7 ± 1.7	8.5 ± 1.4
Night	7.1 ± 2.7	7.7 ± 2.1	7.6 ± 2.2	7.7 ± 2.1	7.9 ± 1.9	7.6 ± 2.1

(Continued)

Table 146

Parameter & Time	Marshland	Protected Mixture	Protected Bare	Unprotected Mixture	Unprotected Bare	Reference
Total Alkalinity (ppm)						
Day	119 ± 15	122 ± 21	119 ± 20	126 ± 24	121 ± 18	119 ± 19
Night	112 ± 16	120 ± 17	120 ± 17	119 ± 15	124 ± 16	118 ± 16
Bicarbonate Alkalinity (ppm)						
Day	116 ± 19	119 ± 25	116 ± 23	124 ± 25	115 ± 18	116 ± 22
Night	115 ± 19	116 ± 19	115 ± 19	113 ± 18	118 ± 16	110 ± 19
Carbonate Alkalinity (ppm)						
Day	3 ± 9	3 ± 9	3 ± 9	2 ± 6	6 ± 13	3 ± 9
Night	7 ± 13	4 ± 8	5 ± 11	6 ± 13	6 ± 10	8 ± 14
Turbidity (FTU)						
Day	56 ± 34	51 ± 36	47 ± 33	61 ± 46	54 ± 43	49 ± 31
Night	87 ± 146	60 ± 51	56 ± 48	50 ± 32	50 ± 50	44 ± 42

(Continued)

Table 146 (Concluded)

Parameter & Time	Marshland	Protected Mixture	Protected Bare	Unprotected Mixture	Unprotected Bare	Reference
Suspended Solids (ppm)						
Day	47 ± 37	41 ± 33	38 ± 30	49 ± 42	38 ± 35	37 ± 24
Night	73 ± 138	57 ± 54	48 ± 52	39 ± 29	43 ± 47	29 ± 38
Ammonia (ppm)						
Day	0.31 ± 0.42	0.26 ± 0.30	0.28 ± 0.32	0.25 ± 0.35	0.29 ± 0.36	0.15 ± 0.19
Night	0.26 ± 0.36	0.28 ± 0.29	0.19 ± 0.18	0.33 ± 0.45	0.26 ± 0.51	0.26 ± 0.27

Table 147

Summary of Annual Animal Activity Inferred from Photographs Taken in Block I

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	28			3.6					*
August	30	4.1	46.7			30.0			36.7
September	28	1.2	39.3			25.0			32.1
October	30	2.2	36.7			10.0			43.3
November	27	0.4	22.2	3.7		7.4			74.1
December	29	0.6	17.2						82.7
January	27	0.3	18.5	7.4		7.4			66.7
February	30	1.3	43.3			43.3			43.3
March	30	0.1	3.3			6.7			90.0
April	30	2.0	56.7			53.3			26.7
May	20	1.5	50.0			80.0			20.0
June	9	3.9	77.7			88.8			
Mean	26.5	1.5	---	---	---	---	---	---	---

* Site was tilled for fertilization, so animal activity may have been masked.

Table 148

Summary of Annual Animal Activity Inferred from Photographs Taken in Block II

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	27	3.0	48.1	3.7		7.4			40.7
August	27	7.9	70.4		3.7	3.7			25.9
September	26	5.2	53.8			23.1			26.9
October	26	2.5	61.5		3.8	3.8			34.6
November	27	1.1	44.4		7.4	7.4			44.4
December	27	0.9	33.3						66.7
January	27	0.5	25.9		14.8				59.3
February	30	1.7	60.0			10.0			40.0
March	30	2.4	30.0			3.3			70.0
April	24	5.7	66.7			20.8			25.0
May	7	1.1	28.6		57.1	28.6			14.3
June	9	5.3	22.2			11.1			66.7
Mean	23.9	3.1	---	---	---	---	---	---	---

Table 149

Summary of Annual Animal Activity Inferred from Photographs Taken in Block III

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	29	3.9	69.0		13.8				27.6
August	29	5.2	86.2		20.7		10.3		6.9
September	30	3.1	65.5		3.3		50.0		20.0
October	28	1.4	46.4		10.7		7.1		35.7
November	30	0.1	40.0		40.0				36.7
December	28	0.9	50.0						50.0
January	28	1.0	39.2		60.7				14.2
February	20	2.5	63.3		33.3			3.3	20.0
March	29	1.5	44.8		24.0		3.4		27.6
April									
May									
June									
Mean	21.8	1.7	---	---	---	---	---	---	---

Table 150

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect A

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	3	3.7	66.7		33.3	33.3	33.3		
August	4	1.0	25.0				25.0		50.0
September	3	1.3	33.3		33.3		33.3		33.3
October	5	1.2	60.0						49.0
November	5	3.0	40.0			20.0			40.0
December	3	0.3	33.3						66.7
January	5	7.8	100.0			20.0			
February	5	0.2	20.0					20.0	80.0
March	3								100.0
April	2					50.0			50.0
May									
June	2							50.0	50.0
Mean	3.3	1.5	---	---	---	---	---	---	---

Table 151

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect B

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	3	7.0	66.7						33.3
August	4	1.8	50.0						50.0
September	3	1.0	66.7			66.7			33.3
October	5	2.4	40.0						60.0
November	5	2.6	20.0			20.0	40.0		40.0
December	4	1.0	50.0						25.0
January	5	3.6	40.0			20.0			40.0
February	5	1.2	40.0					40.0	40.0
March	3	0.7	33.3						66.7
April	2	2.0	100.0			50.0			
May	2	0.5	50.0			50.0			50.0
June	3	0.3	33.3			33.3			66.7
Mean	3.7	2.0	---	---	---	---	---	---	---

Table 152

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect C

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	5.6	60.0		20.0				40.0
August	5	2.0	80.0		20.0				20.0
September	5	2.4	60.0			40.0			20.0
October	4	3.3	75.0						25.0
November	5	2.0	80.0		20.0				20.0
December	4	0.3	25.0						75.0
January	5	3.2	60.0		20.0				40.0
February	4	12.0	75.0					25.0	25.0
March	5	4.8	80.0		20.0		20.0		20.0
April	3	14.3	100.0			66.7			
May	2	1.0	50.0		50.0	100.0			
June	3	2.0	33.3			33.3			66.6
Mean	4.1	4.4	---	---	---	---	---	---	---

Table 153

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect D

from July 1976 Through June 1977.

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Racoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	4.0	60.0		20.0				40.0*
August	4	4.3	75.0						25.0
September	3	0.3	33.3			33.3			33.3
October	4	1.5	50.0			25.0			25.0
November	5	3.2	80.0						20.0
December	5	1.2	80.0						20.0
January	4	2.8	75.0						25.0
February	5	14.6	80.0			20.0			
March	5	3.8	60.0						40.0
April	3	1.7	66.7			66.7			33.3
May	1	2.0	100.0			100.0			
June									
Mean	3.7	3.3	---	---	---	----	---	---	---

* Some stations were tilled for planting, so activity could not be determined

Table 154

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect F

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Racoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	3.2	40.0						60.0*
August	5	6.0	60.0			20.0			40.0
September	5	2.2	40.0			20.0	20.0		40.0
October	5	2.2	60.0						40.0
November	5	0.4	40.0						60.0
December	5	0.4	40.0						60.0
January	5	0.6	60.0		20.0				40.0
February	5	3.8	100.0			40.0			
March	5	0.2	20.0						80.0
April	3	1.3	33.3						66.7
May									
June									
Mean	4.0	1.7	---	---	---	----	---	---	----

* Some stations were tilled for planting, so activity could not be determined

Table 155

<u>Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect G</u>

<u>from July 1976 Through June 1977</u>

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Racoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	1.2	40.0		20.0		20.0		60.0
August	4	1.5	25.0		25.0				75.0
September	4	14.5	50.0				25.0		50.0
October	5	1.6	40.0		20.0				60.0
November	5	1.6	80.0		40.0				20.0
December	4	2.0	50.0		20.0				50.0
January	5	5.4	60.0		40.0				40.0
February	5	14.0	100.0		60.0				
March	5	0.2	20.0		60.0		20.0		40.0
April	3	3.3	66.7			33.3			
May									
June									
Mean	3.8	3.8	---	---	---	---	---	---	----

Table 156

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect H

From July 1976 Through July 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Racoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	0.8	20.0		20.0		40.0		40.0
August	4	0.3	25.0						50.0
September	4	1.3	25.0		25.0				50.0
October	5	0.8	40.0					20.0	40.0
November	5	0.4	20.0			20.0		20.0	60.0
December	5	0.8	20.0		20.0				60.0
January	5	0.4	40.0					20.0	40.0
February	5	0.2	20.0		20.0			20.0	40.0
March	4							20.0	80.0
April	2	5.5	100.0			50.0			
May									
June									
Mean	3.7	0.9	---	---	----	---	---	---	----

Table 157

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect I

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Racoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	44.6	40.0		20.0		40.0		20.0
August	4	4.0	50.0			25.0			50.0
September	4					25.0	25.0		50.0
October	5					20.0		20.0	60.0
November	3	0.7	33.3		33.3				33.3
December	5							20.0	80.0
January	5	1.2	40.0					40.0	40.0
February	5	1.2	40.0			20.0		40.0	20.0
March	4	0.3	25.0				25.0	25.0	50.0
April	1	3.0	100.0			100.0			
May									
June									
Mean	3.4	4.7	---	---	---	---	---	---	---

Table 158

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect J

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	11.6	80.0		20.0		40.0		
August	3	27.3	100.0		33.3		66.7		
September	3	6.3	100.0		33.3		66.7		
October	5	24.4	80.0					20.0	
November	1	10.0	100.0						
December	4	3.3	50.0						50.0
January	4	5.8	100.0					50.0	
February	5	4.8	60.0		40.0			40.0	
March	3	5.0	100.0						
April									
May									
June	1	5.0	100.0						
Mean	2.8	8.6	---	---	---	---	---	---	---

Table 159

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect X

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	4.0	60.0						40.0*
August	5	3.6	80.0				20.0		20.0
September	4	5.8	100.0			25.0	25.0		
October	5	9.4	100.0			25.0			
November	4	2.8	100.0			25.0			
December	5	0.6	40.0						60.0
January	5	1.2	40.0		40.0				40.0
February	5	1.6	40.0			20.0			40.0
March	5	0.2	20.0			20.0	20.0		60.0
April	3	9.7	66.7			33.3			33.3
May	2	7.5	100.0		50.0	50.0			
June	3	2.3	100.0			66.7			
Mean	4.3	4.1	---	---	---	---	---	---	---

Table 160

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect Y

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	5	0.8	40.0				20.0		40.0
August	4	1.0	50.0		25.0		25.0		25.0
September	4				25.0				75.0
October	5	0.8	40.0					20.0	60.0
November	5	0.4	40.0					20.0	60.0
December	5	0.4	20.0					20.0	60.0
January	5	1.6	40.0		20.0			20.0	60.0
February	5	1.2	20.0					20.0	80.0
March	5								100.0
April	3	2.7	66.7			33.3			33.3
May									
June									
Mean	4	0.7	---	---	---	---	---	---	---

Table 161

Summary of Annual Animal Activity Inferred from Photographs Taken Along Transect Z

from July 1976 Through June 1977

Date	Number of Photos	Average Number of Holes per Photo	Percent of Stations With Holes	Percent Raccoon Activity	Percent Bird Activity	Percent Fiddler Crab Activity	Percent Hermit Crab Activity	Percent Diopatra Activity	Percent With No Activity
July	4	8.5	75.0						25.0
August	3	12.3	100.0			33.3			
September	3	4.3	66.7				33.3		
October	5	32.2	80.0					20.0	20.0
November	2	56.5	100.0					50.0	
December	4	3.3	50.0						50.0
January	5	3.2	100.0		20.0			60.0	
February	5	1.0	40.0					20.0	40.0
March	3	0.3	33.3					33.3	66.7
April									
May									
June	1	11.0	100.0			100.0			
Mean	2.9	11.1	---	---	---	---	---	---	---

Table 162

Scientific and Common Names of Flora and Fauna on the Bolivar Peninsula Study Site

Scientific Name	Common Name
FLORA	
Ambrosia psilostachya DC.	Western ragweed
Andropogon perangustatus Nash.	Bluestem
Aristida longespica Poir.	Slimspike three awn
Cenchrus incertus M. A. Curtis	Coast sandbur
Chenopodium ambrosioides L.	Wormseed goosefoot
Croton punctatus Jacq.	Gulf croton
Cynodon dactylon (L.) Pers. var. alezia	Coastal bermuda grass
Cyperus esculentus L.	Chufa
Dicanthelium sp.	
Digitaria sanguinalis (L.) Scop.	Hairy crabgrass
Fimbristylis castaneum (michx.) Vahl.	Fimbry
Lantana horrida H. B. K.	Common lantana
Myrica cerifera L.	Southern waxmyrtle
Panicum amarum Ell.	Bitter panicum
Paspalum setaceum Michx. var. ciliatifolium	Thin paspalum
Pinus clausa	Sand pine
Pinus elliottii	Slash pine
Prunus sp.	Plum
Quercus virginiana Mill.	Live oak
Rhus copallina L.	Winged sumac
Scirpus americanus Pers.	American bulrush
Sesbania drummondii (Rydb.) Cory	Drummond sesbania
Solanaceae family	Nightshade

(Continued)

Table 162

Scientific Name	Common Name
Spartina alterniflora Loisel.	Smooth cordgrass
Spartina patens (Ait.) Muhl.	Marshhay cordgrass
Sporobolus virginicus (L.) Kunth.	Seashore dropseed
Tamarix gallica L.	Saltcedar
Tridens sp.	
FAUNA	
Birds	
Actitis macularia	Spotted sandpiper
Agelaius phoeniceus	Red-winged blackbird
Ajaia ajaja	Roseate spoonbill
Ammospiza maritima	Seaside sparrow
Anas clypeata	Northern shoveler
Anas discors	Blue-winged teal
Anas fulvigula	Mottled duck
Anthus spinoletta	Water pipit
Archilochus colubris	Ruby-throated hummingbird
Ardea herodias	Great blue heron
Arenaria interpres	Ruddy turnstone
Asio flammeus	Short-eared owl
Aythya valisineria	Canvasback
Bubulcus ibis	Cattle egret
Buteo jamaicensis	Red-tailed hawk
Butorides striatus	Green heron
Calidris alba	Sanderling
Calidris alpina	Dunlin
Calidris fuscicollis	White-rumped sandpiper
Calidris mauri	Western sandpiper
Calidris melanotos	Pectoral sandpiper

(Continued)

Table 162

Scientific Name	Common Name
Calidris minutilla	Least sandpiper
Calidris pusillus	Semipalmated sandpiper
Cardinalis cardinalis	Cardinal
Casmerodius albus	Great egret
Catharus fuscescens	Veery
Catharus guttatus	Hermit thrush
Catharus ustulatus	Swainson's thrush
Catoptrophorus semipalmatus	Willet
Chaetura pelagica	Chimney swift
Charadrius melodus	Piping plover
Charadrius semipalmatus	Semipalmated plover
Charadrius vociferus	Killdeer
Charadrius wilsonia	Wilson's plover
Chen caerulescens	Snow goose
Chlidonias niger	Black tern
Chordeiles minor	Common nighthawk
Circus cyaneus	Marsh hawk
Cistothorus platensis	Short-billed marsh wren
Coccyzus americanus	Yellow-billed cuckoo
Colaptes auratus	Common flicker
Contopus virens	Eastern wood pewee
Cyanocitta cristata	Blue jay
Dendroica coronata	Yellow-rumped warbler
Dendroica dominica	Yellow-throated warbler
Dendroica magnolia	Magnolia warbler
Dendroica palmarum	Palm warbler
Dendroica petechia	Yellow warbler
Dendroica striata	Blackpoll warbler
Dendroica virens	Black-throated green warbler
Dichromanassa rufescens	Reddish egret

(Continued)

Table 162

Scientific Name	Common Name
Dumetella carolinensis	Gray catbird
Egretta thula	Snowy egret
Elanus leucurus	White-tailed kite
Eremophila alpestris	Horned lark
Eudocimus albus	White ibis
Falco sparverius	American kestrel
Fregata magnificens	Magnificent frigatebird
Fulica americana	American coot
Gelochelidon nilotica	Gull-billed tern
Geothlypis trichas	Common yellowthroat
Guiraca caerulea	Blue grosbeak
Haematopus palliatus	American oystercatcher
Helmitheros vermivorus	Worm-eating warbler
Himantopus mexicanus	Black-necked stilt
Hirundo rustica	Barn swallow
Hydranassa tricolor	Louisiana heron
Icteria virens	Yellow-breasted chat
Icterus galbula	Northern oriole
Icterus spurius	Orchard oriole
Iridoprocne bicolor	Tree swallow
Junco hyemalis	Dark-eyed junco
Lanius ludovicianus	Loggerhead shrike
Larus argentatus	Herring gull
Larus atricilla	Laughing full
Larus delawarensis	Ring-billed gull
Limnodromus sp.	Dowitcher
Limosa fedoa	Marbled godwit
Megaceryle alcyon	Belted kingfisher
Melospiza georgiana	Swamp sparrow
Melospiza melodia	Song sparrow
Mergus serrator	Red-breasted merganser

(Continued)

Table 162

Scientific Name	Common Name
Mimus ployglottos	Mockingbird
Mniotilta varia	Black-and-white warbler
Molothrus ater	Brown-headed cowbird
Muscivora forficata	Scissor-tailed flycatcher
Numenius americanus	Long-billed curlew
Numenius phaeopus	Whimbrel
Nycticorax nycticorax	Black-crowned night heron
Pandion haliaetus	Osprey
Passerculus sandwichensis	Savannah sparrow
Passerherbulus caudacutus	LeConte's sparrow
Passerina ciris	Painted bunting
Passerina cyanea	Indigo bunting
Pelecanus erythrorhynchos	White pelican
Palacrocorax auritus	Double-crested cormorant
Phalacrocorax olivaceus	Olivaceous cormorant
Pheucticus ludovicianus	Rose-breasted grosbeak
Plegadis chihi	White-faced ibis
Pluvialis squatarola	Black-bellied plover
Podiceps nigricollis	Eared grebe
Polioptila caerulea	Blue-gray gnatchatcher
Progne subis	Purple martin
Protonotaria citrea	Prothonotary warbler
Quiscalus mexicanus	Great-tailed grackle
Quiscalus quiscula	Common grackle
Rallus longirostris	Clapper rail
Recurvirostra americana	American avocet
Regulus calendula	Ruby-crowned kinglet
Riparia riparia	Bank swallow
Rynchops niger	Black skimmer
Sayornis phoebe	Eastern phoebe

(Continued)

Table 162

Scientific Name	Common Name
Seiurus aurocapillus	Ovenbird
Seiurus noveboracensis	Northern waterthrush
Setophaga ruticilla	American redstart
Spizella pusilla	Field sparrow
Stelgidopteryx ruficollis	Rough-winged swallow
Sterna albifrons	Least tern
Sterna caspia	Caspian tern
Sterna forsteri	Forster's tern
Sterna maxima	Royal tern
Sterna sandvicensis	Sandwich tern
Sturnella magna	Eastern meadowlark
Tringa flavipes	Lesser yellowlegs
Tringa melanoleucus	Greater yellowlegs
Tringa solitaria	Solitary sandpiper
Troglodytes aedon	House wren
Turdus migratorius	American robin
Tyrannus tyrannus	Eastern kingbird
Vermivora celata	Orange-crowned warbler
Vermivora peregrina	Tennessee warbler
Vireo griseus	White-eyed vireo
Vireo olivaceus	Red-eyed vireo
Wilsonia citrina	Hooded warbler
Zenaida macroura	Mourning dove
Mammals	
Blarina brevicauda	Short-tailed shrew
Bos indicus	Domestic cattle
Capra hircus	Domestic goat
Dasypus novemcinctus	Nine-banded armadillo
Didelphis virginiana	Virginia opossum

(Continued)

Table 162

Scientific Name	Common Name
Felis rufus	Bobcat
Lutra canadensii	River otter
Mus musculus	House mouse
Myocastor coypus	Nutria
Oryzomys palustris	Marsh rice rat
Procyon lotor	Raccoon
Rattus norvegicus	Norway rat
Sigmodon hispidus	Hispid cotton rat
Spilogale putoris	Eastern spotted skunk
Sylvilagus aquaticus	Swamp rabbit
Sylvilagus floridanus	Eastern cottontail
Vulpes vulpes	Red fox
Reptiles	
Heterodon platyrhinos	Eastern hognose snake
Lampropeltis getulus	Speckled king snake
Phrynosoma cornutum	Texas horned lizard
Terra pene ornata	Ornate box turtle
Fishes	
Anchoa mitchilli	Bay anchovy
Anchoa hepsetus	Striped anchovy
Arius felis	Sea catfish
Brevoortia patronus	Gulf menaden
Chaetodipterus faber	Atlantic spadefish
Citharichthys spilopterus	Bay whiff
Chloroscombrus chrysurus	Atlantic bumper
Cynoscion arenarius	Sand seatrout
Cynoscion nebulosus	Spotted seatrout
Cyprinodon variegatus	Sheepshead minnow

(Continued)

Table 162

Scientific Name	Common Name
Dorosoma cepedianum	Gizzard shad
Etropus crossotus	Fringed flounder
Eucinostomus lefroyi	Mottled mojarra
Fundulus grandis	Gulf killifish
Fundulus similis	Longnose killifish
Gerres cinereus	Yellowfin mojarra
Gobionellus boleosoma	Darter goby
Gobionellus schufeldti	Freshwater goby
Harengula jaguana	Herring
Hemicaranx amblyrhynchus	Bluntnose jack
Lagodon rhomboides	Pinfish
Leiostomus xanthurus	Spot
Membras martinica	Rough silversides
Menidia beryllina	Tidewater silversides
Menticirrhus americanus	Southern kingfish
Menticirrhus littoralis	Gulf kingfish
Micropogon undulatus	Atlantic croaker
Mugil cephalus	Striped mullet
Mugil curema	White mullet
Oligoplites saurus	Leatherjacket
Opisthonema oglinum	Atlantic threadherring
Ophidion welshi	Crested cuskeel
Paralichthys albigutta	Gulf flounder
Paralichthys lethostigma	Southern flounder
Pogonias chromis	Black drum
Polydactylus octonemus	Atlantic threadfin
Prionotus tribulus	Bighead searobin
Sciaenops ocellata	Red drum
Sphoeroides parvus	Least puffer
Symphurus plagiusa	Blackcheek tonguefish

(Continued)

Table 162 (Concluded)

Scientific Name	Common Name
Syngnathus louisianae	Chain pipefish
Synodus foetens	Inshore lizzardfish
Marine Invertebrates	
Callinectes sapidus	Blue crab
Callinectes similis	Crab
Clibanarias vittatus	Stripped hermit crab
Diopatra cuprea	Parchment worm
Ensis minor	Long razor clam
Glycinde solitaria	Stickney's worm
Loliguncula brevis	Squid
Neopanope texana texana	Mud crab
Ocypode quadrata	Ghost crab
Pagurus polycarpus	Hermit crab
Palaemonetes intermedius	Grass shrimp
Palaemonetes pugio	Grass shrimp
Palaemonetes vulgaris	Grass shrimp
Pectinaria gouldi	Ice cream cone worm
Penaeus aztecus	Brown shrimp
Penaeus setiferus	White shrimp
Periploma inequale	Mikes clam
Polinices duplicata	Moon snail
Sigambra tentaculata	Striped cane worm
Spiophanes bombyx	Pope's worm
Tagelus plebius	Short razor clam
Uca pugilator	Pugilated hermit crab

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Webb, J W
Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; Appendix D: Propagation of vascular plants and post-propagation monitoring of botanical, soil, aquatic biota, and wildlife resources / by J. W. Webb ... [et al.], Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
521, 251 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-15, Appendix D)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Contract No. DACW39-76-C-0109 (DMRP Work Unit No. 4A13F)
Appendix A' on microfiche in pocket.
References: p. 271-274.

1. Aquatic animals. 2. *Biota*. 3. *Bolivar Peninsula*.

(Continued on next card)

Webb, J W
Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; Appendix D: Propagation of vascular plants and post-propagation monitoring of botanical, soil, aquatic biota, and wildlife resources ... 1978. (Card 2)

4. Dredged material. 5. Field investigations. 6. Galveston Bay. 7. Habitat development. 8. Habitats. 9. Marsh development. 10. Marshes. 11. Plants (Botany). 12. Vascular plants. 13. Vegetation establishment. 14. Wildlife. I. Texas. Agricultural Experiment Station, College Station. II. United States. Army. Corps of Engineers. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15, Appendix D.
TA7.W34 no.D-77-15 Appendix D