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LONG-TERM MONITORING OF HABITAT DEVELOPMENT AT UPLAND AND WETLAND DREDGED MATERIAL DISPOSAL SITES 1974-1982

by

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During the Dredged Material Research Program, six wetland and three upland habitat development projects were established at seven sites to demonstrate the feasibility of creating productive habitat on dredged material deposits. Wetland sites were Windmill Point in the James River, Virginia; Buttermilk Sound near the Altamaha River, Georgia; Drake Wilson Island in Apalachicola Bay, Florida; Bolivar Peninsula in Galveston Bay, Texas; Salt

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20. ABSTRACT (Continued).

Pond #3 in South San Francisco Bay, California; and Miller Sands Island in the Columbia River, Oregon. Sites were also located in upland areas at Nott Island in the Connecticut River, Connecticut; Bolivar Peninsula; and Miller Sands. These sites have continued to be monitored since their construction (1975-77) until the present time. In addition, three natural marsh upland reference sites have been selected for comparison to the man-made sites. Data and research results are presented in this report. Results over an 8-year period indicate that all of the sites have developed and stabilized, and that they have all been highly successful. Despite a complete lack of management since construction, the sites maintain plant communities generally comparable to or more productive than those on the reference areas. Wildlife use exceeds that occurring on reference areas, and the sites are compatible with and contributing to the ecosystems of which they are a part.

EXECUTIVE SUMMARY

During the Dredged Material Research Program (DMRP), completed in 1978, six wetland and three upland habitat development projects were established at seven sites to demonstrate the feasibility of creating productive habitat on dredged material deposits. Wetland sites were Windmill Point, James River, Virginia; Buttermilk Sound, Altamaha River, Georgia; Drake Wilson Island, Apalachicola, Florida; Bolivar Peninsula, Galveston Bay, Texas; Salt Pond #3, South San Francisco Bay, California; and Miller Sands Island, Columbia River, Oregon. Sites were also located in upland areas at Nott Island, Connecticut River, Connecticut; Bolivar Peninsula; and Miller Sands.

In response to questions regarding the ecological contribution and longevity of the sites, a decision was made at the conclusion of the DMRP to continue monitoring the sites over a longer period of time. Concern had been expressed that the habitat development sites, particularly the wetland sites, would not withstand erosive forces. Further, there had been no provision made under the DMRP for measuring the relative biological contribution that these man-made habitats would make compared to similar natural habitats. This report documents the results of that monitoring effort obtained from 1974 until 1982. It was conducted under the Dredging Operations Technical Support Program (DOTS).

Three reference areas were selected in the vicinity of each experimental habitat development field site. Reference areas were chosen on the basis of their habitat quality, similarity of hydrologic conditions, proximity to the field site, and similarity to the type of habitat that had been the object of habitat development. The same parameters were monitored on both the reference areas and on the habitat development sites. Results from the reference areas established the range of natural variability to which data from the experimental sites were compared.

Objectives for the monitoring program were to:

a. Document the long-term stability of the field sites.

b. Determine successional changes of the sites, and relate their value and function to natural systems.

Two levels of monitoring effort were developed. The first level included an annual general reconnaissance of all sites conducted by the U. S. Army Engineer Waterways Experiment Station (WES) personnel. General

reconnaissance was intended to address the third objective above and to provide qualitative information on changes that might require closer scrutiny, i.e. massive erosion or large-scale plant mortality.

The second level was intensive sampling and was planned to provide quantitative data from the major field sites: Windmill Point, Buttermilk Sound, Bolivar Peninsula, Salt Pond #3, and Miller Sands. Intensive sampling was done at least once at each major site and included plant and substrate/soil sampling at all wetland sites, and benthos and sediment sampling at Windmill Point, Bolivar Peninsula, and Miller Sands. Most of the intensive sampling was conducted by WES personnel; however, some of the work was done under contract to outside consulting firms and universities. Findings are briefly summarized by site as follows.

Dredged material consisting of sand from the main channel of the lower Connecticut River and silt from a nearby recreational channel was placed on an upland disposal site on Nott Island, Connecticut, in 1975-76. The sediments were mixed, limed, and planted with legumes and grasses in the summer of 1976. The sediments made a rather harsh environment for some domestic plant species: soil salinity was high and acidity was low. Grasses established themselves and grew better than legumes. Wildlife response to vegetation establishment was evident primarily through feeding activity and loafing and resting.

Grasses were very successful, and tall fescue dominated the site. Orchard grass and timothy were subdominants from 1978 until 1981, but declined from 1981 to 1982. Legumes were sparse throughout the study. Where considerable amounts of silt were mixed with sand, the planted pasture species achieved a lush growth. Where there was a poor mix and the substrate was primarily sand, the growth was poor and slow. The species composition was relatively stable from 1978 until 1981. In 1981 the first signs of the onset of old field succession were observed with the appearance of red cedar seedlings and invading goldenrod stands at the edges of the site. This trend intensified in 1982. The plant community of the site is presently well developed despite no management of the area since its initial liming and planting. The site is in close proximity to a number of other cover types and wildlife use is moderate to heavy.

Windmill Point is an 8-ha island of freshwater intertidal marsh habitat. It was developed using fine-textured sediments dredged from the James River navigation channel in the winter of 1974-75. The island was created by construction of a relatively inexpensive sand dike placed on a soft river bottom foundation. Fine-grained sediments were hydraulically dredged and placed in the diked interior of the island at intertidal elevations; this area was rapidly colonized by native plant species. The marsh construction effected a displacement of the original shallow riverine aquatic habitat and produced a habitat of equal or greater value to the fish and benthic communities. The dredged material marsh also provided habitat for a large variety of birds that found cover, food, and loafing areas on the site's vegetated and unvegetated substrates.

The intertidal interior of the island supports a lush growth of broad-leaved and robust emergent marsh plant species comparable to that in the reference marshes. From 1978 until 1981, pickerelweed was the dominant. Between 1981 and 1982, wild rice became the dominant over 60 percent of the intertidal interior of the site. In 1982 the dikes were intact but eroding and had breached in several places. Woody plant species colonizing the dike were slowly stabilizing the remaining substrate. The experimental site provided excellent fish and wildlife habitat. The benthic community was comparable to that of the reference sites and wildlife use exceeded the reference sites.

The <u>Buttermilk Sound</u> marsh development site is a 2-ha intertidal marsh created by plantings in the intertidal zone during 1975 and 1976 on a deposit of sandy, infertile, hydraulically placed dredged material. Success of the plantings was related to the period of tidal inundation and type of propagule: sprigs were more successful than seeds, and smooth cordgrass was the most successful species planted.

From the outset, the experimental site has been very successful. Since 1979 it has been visually indistinguishable from natural reference marshes. Although tidal scouring initially washed out plantings and eroded the lower one third of the intertidal zone, the site quickly stabilized. It attained a contour similar to that of the natural marshes and its plant community occupies the same portion of the intertidal zone. The plant community has trapped large amounts of fine material resulting in a thick layer of silt that now covers the original sandy substrate. Smooth cordgrass dominates the entire upper two thirds of the intertidal zone of the site. Swards of big cordgrass and saltmeadow cordgrass remain at the middle elevations where they had been planted. Saltmeadow cordgrass has invaded and now dominates the higher elevations where it was not planted. Water hemp, an invading species, occurs throughout the site. The Buttermilk Sound site differs from its natural reference areas by possessing greater plant species diversity at lower elevations. This is probably due to plant species that were introduced in zones lower than those at which they would naturally occur. Aboveground biomass is similar to the reference areas, but belowground biomass is less. Wildlife use of the experimental site is greater than on the natural reference sites. This is probably the result of greater habitat interspersion at the Buttermilk Sound site.

The Apalachicola Bay marsh project was developed on hydraulically pumped fine- and coarse-grained material placed in a saline intertidal environment in early 1976. Smooth cordgrass was planted in the fine material and saltmeadow cordgrass was planted in the coarse material between December 1976 and September 1977. Both species were successful; in addition, invaders, particularly saltgrass, grew well in the coarse substrate at higher elevations but has since been largely displaced.

The smooth cordgrass stand in the interior of the site was closed by 1980 except for a single small ponded area in the center that is heavily used by wading and marsh birds. Plant growth equals or exceeds that on the reference areas. Wildlife use is heavy and exceeds that of the reference areas.

The Bolivar Peninsula habitat development site is located 16 km east of Galveston and includes both marsh and upland experimental areas. The site consists of 7.3 ha of hydraulically placed sandy dredged material. In January 1976, the site was graded and fenced, and a sandbag dike was constructed to protect the lower intertidal zone from the erosive forces of waves produced by north winds sweeping across the long fetch of Galveston Bay. Experimental plantings were established on both the intertidal and upland areas of the site in 1976 and 1977. Intertidal plantings demonstrated that both smooth cordgrass and saltmeadow cordgrass could be successfully established on coarse-grained dredged material in this vicinity. In the upland area, some of the experimental plant species that were initially successful included Bermuda grass, bitter panic grass, live oak, winged sumac, and wax myrtle. However, plant invasion was noted as a problem in plots planted to trees and shrubs.

The development and vigor of the plant community at the marsh establishment site at Bolivar Peninsula has continued to improve since its construction and first planting in 1976. Observations during October 1980 indicated that smooth cordgrass had spread throughout and thoroughly dominated the tidal marsh site. There was little evidence of the checkerboard appearance the site initially displayed due to the agronomic test plot design that was used in the original experiment. Dense stands of saltmeadow cordgrass remain, and there has been general invasion by both annual and perennial glasswort. The site has been heavily colonized by invertebrates such as the fiddler crab and receives much use by small fish during high tide. Oysters have densely colonized the sandbag dike area. Based on general field observations, use by birds seems to equal that of the reference areas. Preliminary data analysis indicates that plant growth and production based on stem height and aboveground biomass equals or exceeds that on the reference areas; however, root biomass is less. Although experimental plantings on the upland area continue to persist, general invasion by other plants, particularly saltmeadow cordgrass, seashore dropseed, and American three-square, has occurred.

The Salt Pond #3 marsh development site was established on a portion of a 40.4-ha saltwater evaporation pond that was partially filled hydraulically with clayey dredged material in 1974. Plantings of Pacific cordgrass and pickleweeds were established during 1976 and 1977. Pacific cordgrass planted by sprigging was successful in the lower two thirds of the intertidal zone. Planting of the upper one third was not necessary as it was noted that this area was rapidly invaded and dominated by pickleweeds.

The experimental plantings maintained themselves and have spread slowly into adjacent unvegetated areas. Production is somewhat less than in the natural reference areas due perhaps to the relatively early stage of site succession. The lower tidal zone dominated by Pacific cordgrass appears visually equivalent to the natural reference marshes. Wildlife use appears to be moderate to heavy, particularly by shorebirds.

Miller Sands, a long-term disposal area, is a horseshoe-shaped island in the freshwater intertidal region of the Columbia River, Oregon. Sandy dredged material was placed hydraulically in the intertidal region during 1975. The site was graded and plantings were established in 1976 and 1977. Plantings of tufted hairgrass and slough sedge were generally successful, especially at middle and higher elevations in the intertidal zone. Upland plantings of European beachgrass were established on a sandspit surrounding the marsh in 1977 to retard aeolian sand erosion and were very successful. An upland meadow on sandy dredged material dominated by a natural stand of scouring rush was plowed, fertilized, and planted to a mixture of grasses and legumes. The plantings were generally successful and produced more aboveground biomass in 1977 than did unplanted areas. However, it was noted that the soils retained little moisture and were very infertile. This indicates that high productivity probably would not be sustained without continued maintenance.

Since its planting in 1976, the Miller Sands wetland site has continued to progress, but at a slower rate than the other wetland habitat development sites. This may be due to slower growth rates of the planted species, but is more likely associated with the cooler climate of the area. Nonetheless, the original plantings that were successful in the upper one half of the intertidal zone have persisted and have continued to spread slowly into adjacent unoccupied areas. In addition, the site has experienced a considerable amount of invasion by other plant species common in surrounding marshes. Based on general observations, wildlife use appears to be slightly less than that observed in the more densely vegetated reference marshes, but there appears to be somewhat greater use of the experimental area by fish at high tides than observed in the reference areas.

The upland sandspit plantings of European beachgrass continue to thrive based on 1979 through 1982 observations. As anticipated, the upland site at Miller Sands no longer supports the lush pasturelike growth that occurred shortly after planting and fertilizing. The extreme droughtiness and infertility of the soils appear to require greater levels of management for enhanced growth. Although small numbers of all the grasses and legumes planted still remain throughout the upland experimental sites, the area appears to be reverting to a plant community similar to the one dominated by scouring rush that formerly existed. Only the tall fescue grass appears to have established and spread throughout the site. Additional periodic management will be necessary to enhance the productivity of such a site.

In summary, the wetland and upland dredged material habitat development sites have been highly successful. They have stabilized the dredged material on which they were established and in some cases have physically survived long beyond early predictions. Despite a complete lack of management, the sites maintain plant communities generally comparable to or more productive than those on natural reference areas. Most striking is wildlife use which generally exceeds that on the natural reference areas. By any measure, these sites are compatible with and contributing to the ecosystems of which they are a part.

Based on long-term monitoring data, the conclusion that habitats can be successfully developed on dredged material under a variety of site specific conditions can readily be drawn. While each site developed during DMRP is unique, each has successfully served as a representative of habitat types found in U. S. waterways, and each has shown that dredged material can be developed into a beneficial use fairly rapidly (generally less than three years).

The wetland sites have exceeded expectations, while the upland sites have reached a peak during the monitoring period, declined, and are stabilizing without management. Data obtained from monitoring can be and have been extrapolated to other, similar sites under consideration or being developed as habitat by Corps Districts. Information gained becomes part of technology transfer through the DOTS program to Corps Districts.

PREFACE

This report presents the results of long-term habitat development monitoring of seven dredged material sites built during the Office, Chief of Engineers (OCE), Dredged Material Research Program (DMRP) and continued under the Dredging Operations Technical Support Program (DOTS), assigned to the U. S. Army Engineer Waterways Experiment Station (WES), Environmental Laboratory (EL). DOTS is funded by OCE through the Dredging Division of the Water Resources Support Center. The report was written by Mr. Charles J. Newling and Ms. Mary C. Landin; assistance was provided by Mr. Steven D. Parris, Dr. James W. Webb, and Dr. Robert J. Diaz. Work progressed under the general supervision of Mr. Hollis H. Allen, Habitat Development Team; Dr. Hanley K. Smith, Chief, Wetlands and Terrestrial Habitat Group; Dr. Conrad J. Kirby, Chief, Environmental Resources Division (ERD); and Dr. John Harrison, Chief, EL. DOTS is managed through the EL Environmental Effects of Dredging Program (EEDP), Dr. Robert E. Engler, Manager, and Mr. Thomas R. Patin, EEDP DOTS Coordinator. Mr. Charles C. Calhoun, Jr. was EEDP Manager during preparation of the report.

Research synthesized in this report was performed by WES or by contractors to WES. The authors wish to acknowledge field assistance by Mr. Hollis H. Allen, Mr. E. Harrison Applewhite, Ms. Mary J. Berndt, Ms. Jennifer F. Buchanan, Mr. Michael S. Buchanan, Mr. Ellis J. Clairain, Jr., Mr. William E. Jabour, Mr. Harvey L. Jones, Ms. Jean H. O'Neil, Mr. C. Stuart Patterson, Mr. Christopher Rockwell, Mr. Samuel O. Shirley, and Dr. Bobby R. Wells of ERD. Dr. Robert J. Reimold provided data and assistance with the Buttermilk Sound field site. Corps of Engineer personnel who provided field assistance were: Mr. Richard Roach and Ms. Susan Brown, New England Division; Ms. Jody Zaitlin, San Francisco District; Mr. Dennis Wilson, Mobile District; Mr. Joseph Shephard, Norfolk District; and Messrs. Brian Lightcap and Bob Christensen, Portland District. Mr. Johnnie Roach, Harbormaster of Old Lyme, Connecticut, provided technical assistance at Nott Island.

During the preparation of this report, COL Tilford C. Creel, CE, and COL Robert C. Lee, CE, were Commanders and Directors of WES and Mr. F. R. Brown was Technical Director. At the time of publication, COL Allen F. Grum, CE, was Director and Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

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CONTENTS

LONG-TERM MONITORING OF HABITAT DEVELOPMENT AT UPLAND AND WETLAND DREDGED MATERIAL DISPOSAL SITES 1974-1982

PART I: INTRODUCTION

Background and Objectives

1. As part of the Dredged Material Research Program (DMRP) conducted between 1973 and 1978, seven wetland and upland habitat development field sites were established and studied at selected locations in U. S. waterways or estuaries where dredged material had been deposited. These sites were built for the purpose of demonstrating the feasibility of using dredged material for the establishment of productive plant and animal habitats. Because of the questions raised concerning plant and animal succession, stability, and ecological contribution of the sites, continued monitoring was conducted at the sites from their inception (1974) through 1982. From their inception through 1977, monitoring was conducted under the DMRP (Smith 1978), and from 1978 through 1981 under the auspices of the Dredging Operations Technical Support (DOTS) Program (Landin 1982, Newling 1981).

2. The two major objectives of the site monitoring efforts were:

   a. To document the long-term stability of the field sites.

   b. To determine successional changes of the sites, and relate their value and function to natural systems.

3. The seven study sites are located at Nott Island, Connecticut, in the Connecticut River; Windmill Point, Virginia, in the James River; Buttermilk Sound, Georgia, near the mouth of the Altamaha River; Drake Wilson Island, Florida, in Apalachicola Bay; Bolivar Peninsula, Texas, in Galveston Bay; Salt Pond #3, California, in South San Francisco Bay; and Miller Sands Island, Oregon, in the Columbia River (Figures 1-7). The seven site locations are widely representative of conditions found in U. S. coastal waterways; all are intertidal, three in fresh water, one in brackish water, and three in salt water. Three are characterized by sandy dredged material substrate, three have silty dredged material, and one has both types. Miller Sands and Bolivar Peninsula are both wetland and upland habitats. Nott Island is an upland site, and the remainder are wetland development sites.

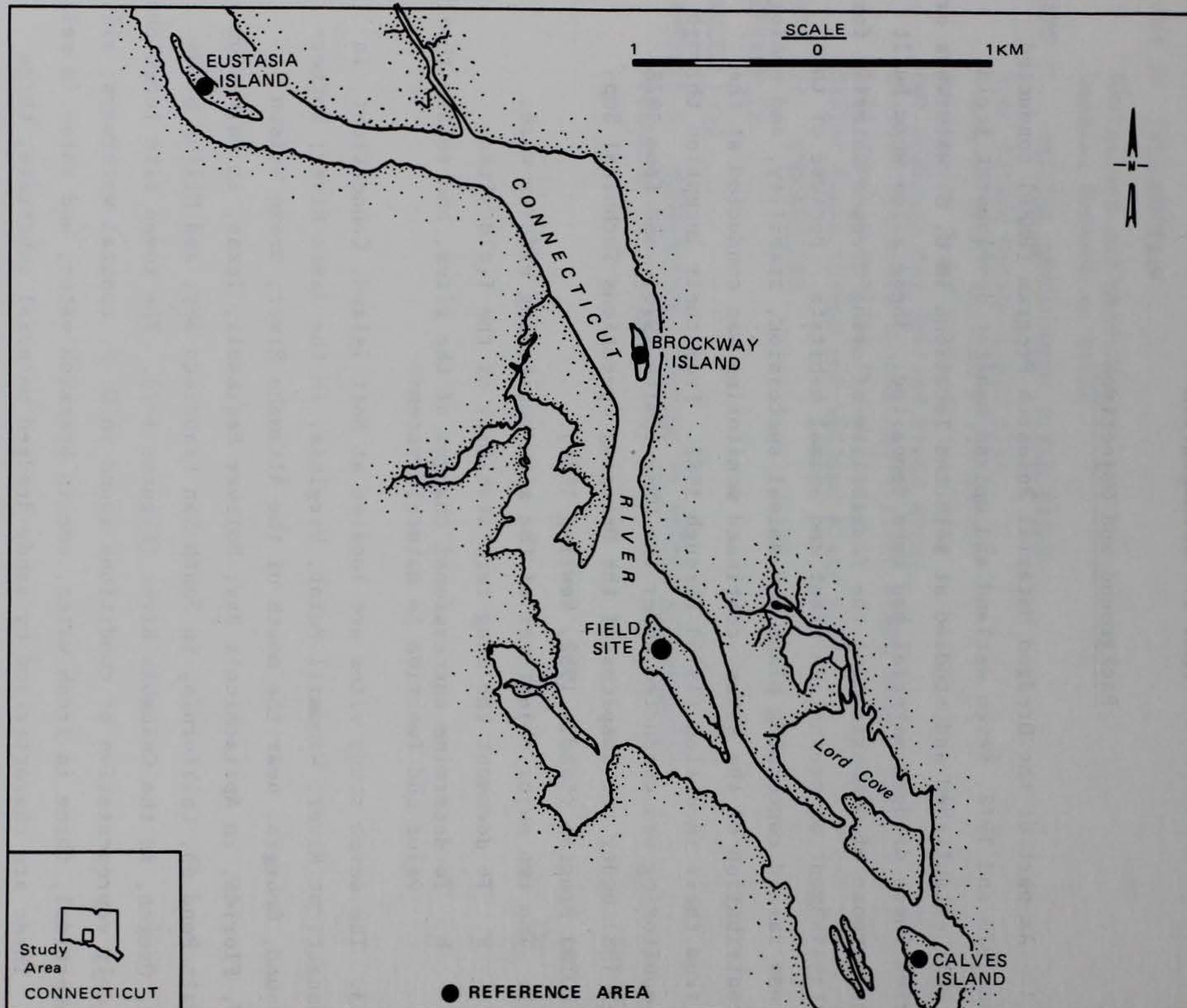

Figure 1. Nott Island upland habitat development field site, Connecticut River, Connecticut

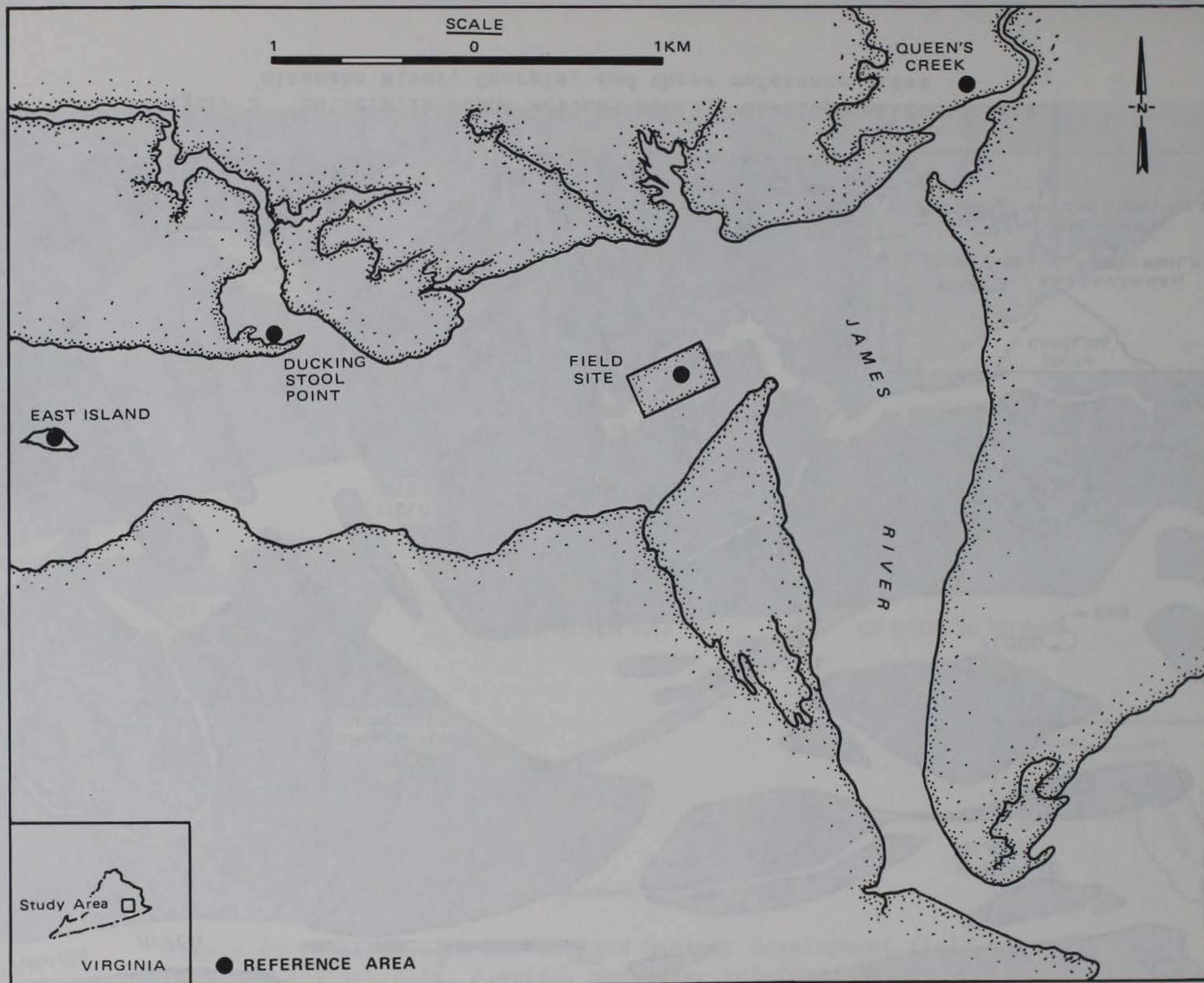

Figure 2. Windmill Point wetland habitat development field site, James River, Virginia

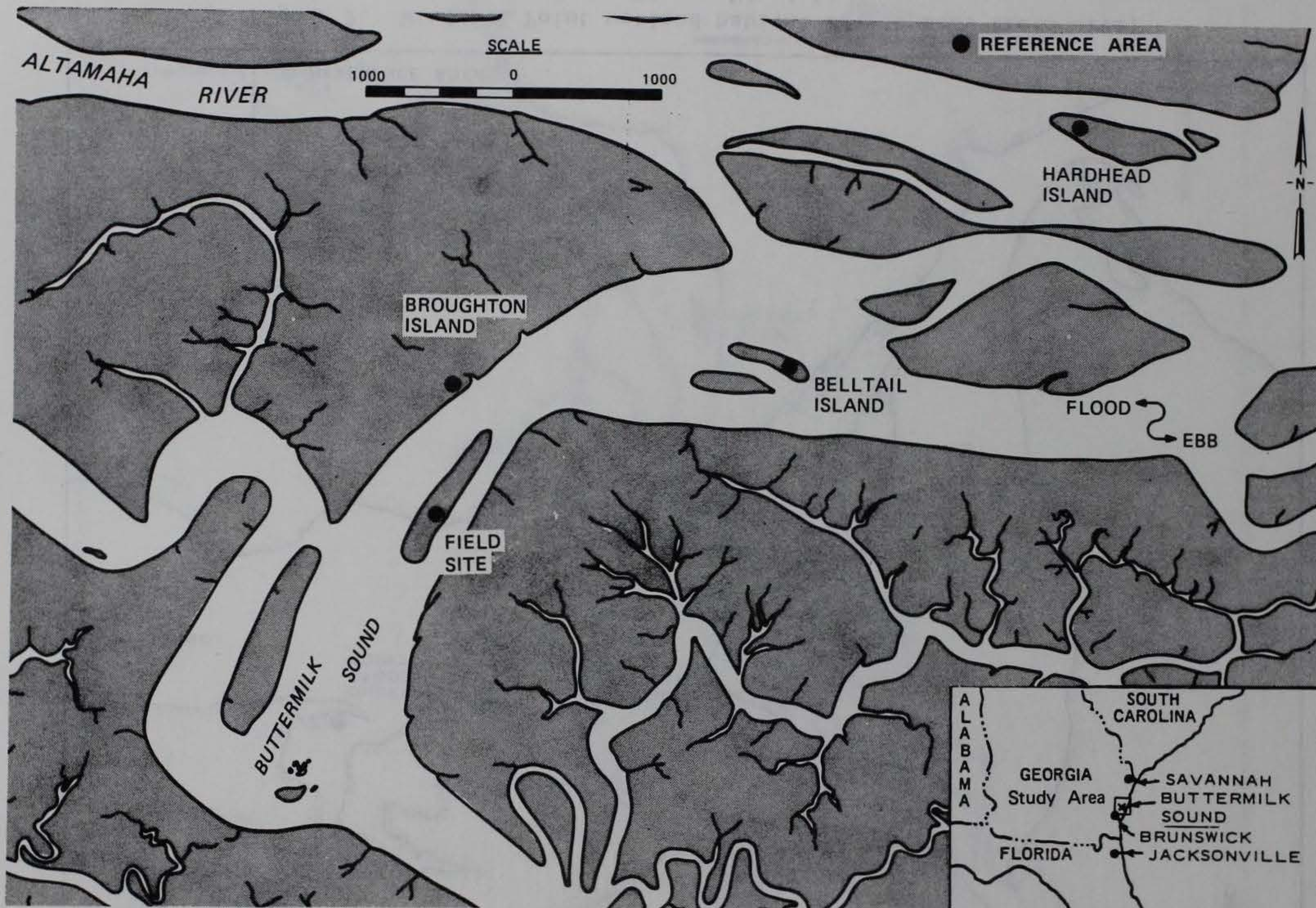

Figure 3. Buttermilk Sound wetland habitat development field site, Altamaha River, Georgia, and three reference areas

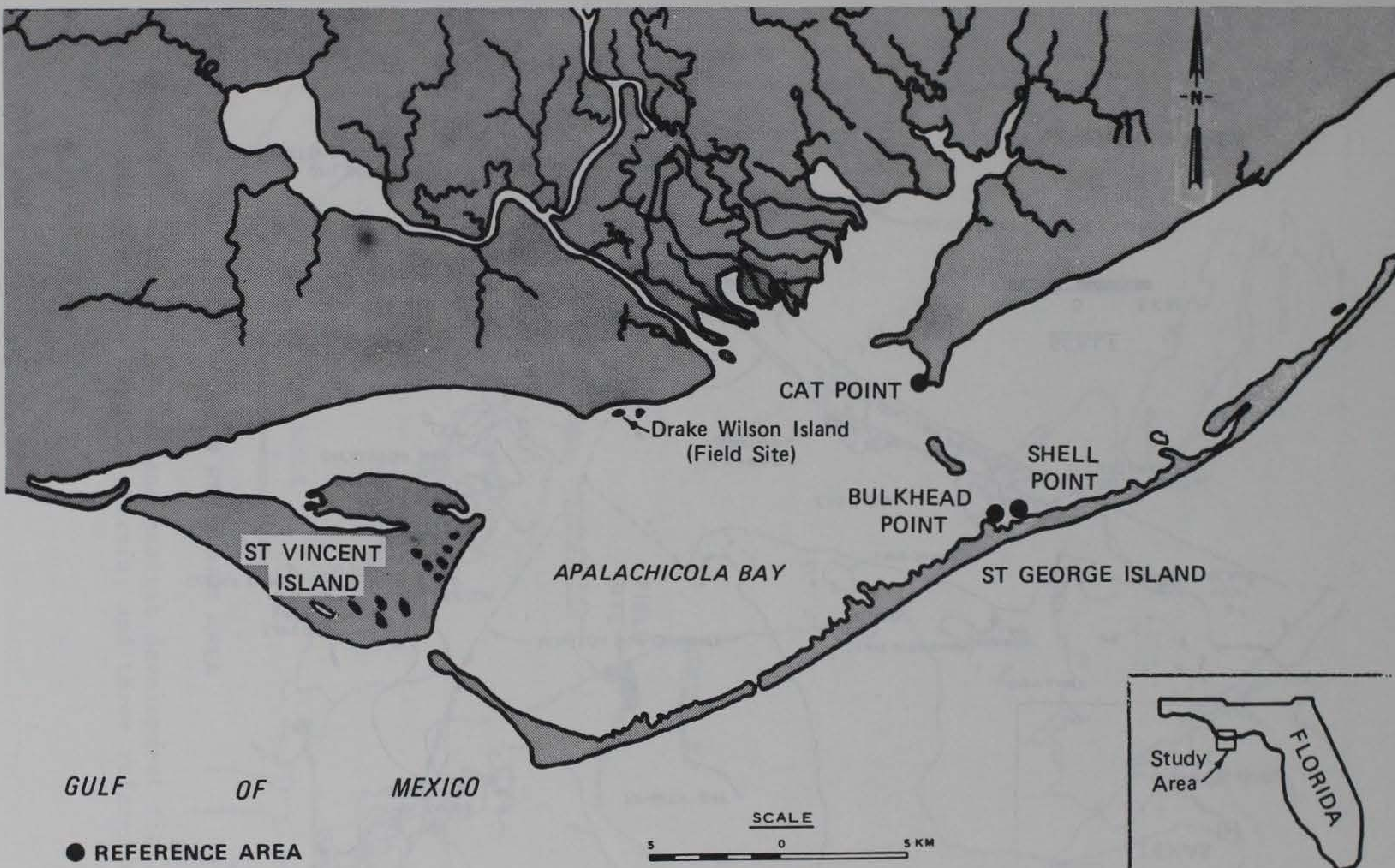

Figure 4. Apalachicola Bay wetland habitat development field site, Apalachicola, Florida, and three reference areas

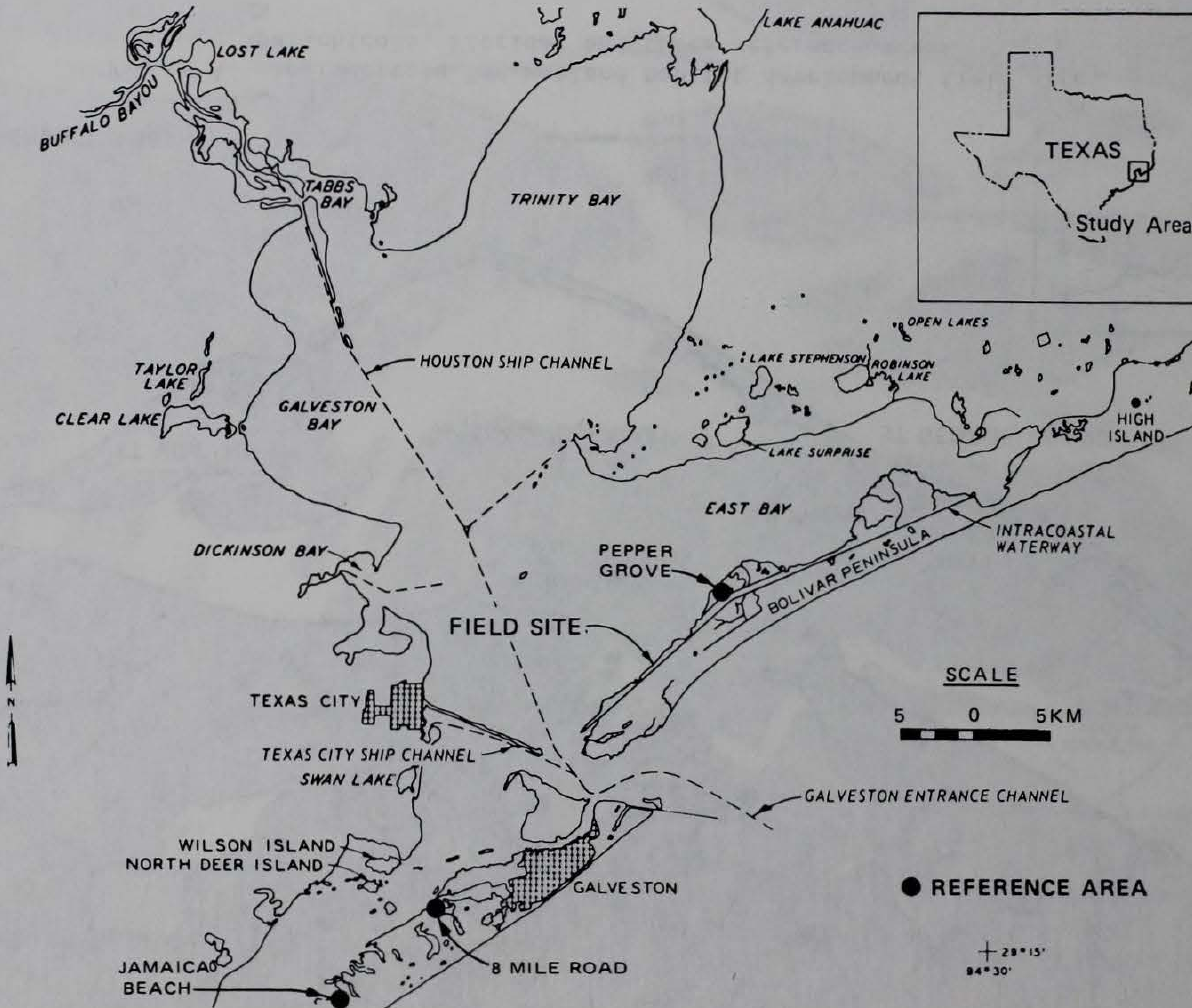

Figure 5. Bolivar Peninsula wetland and upland habitat development field site, Galveston Bay, Texas, and three reference areas

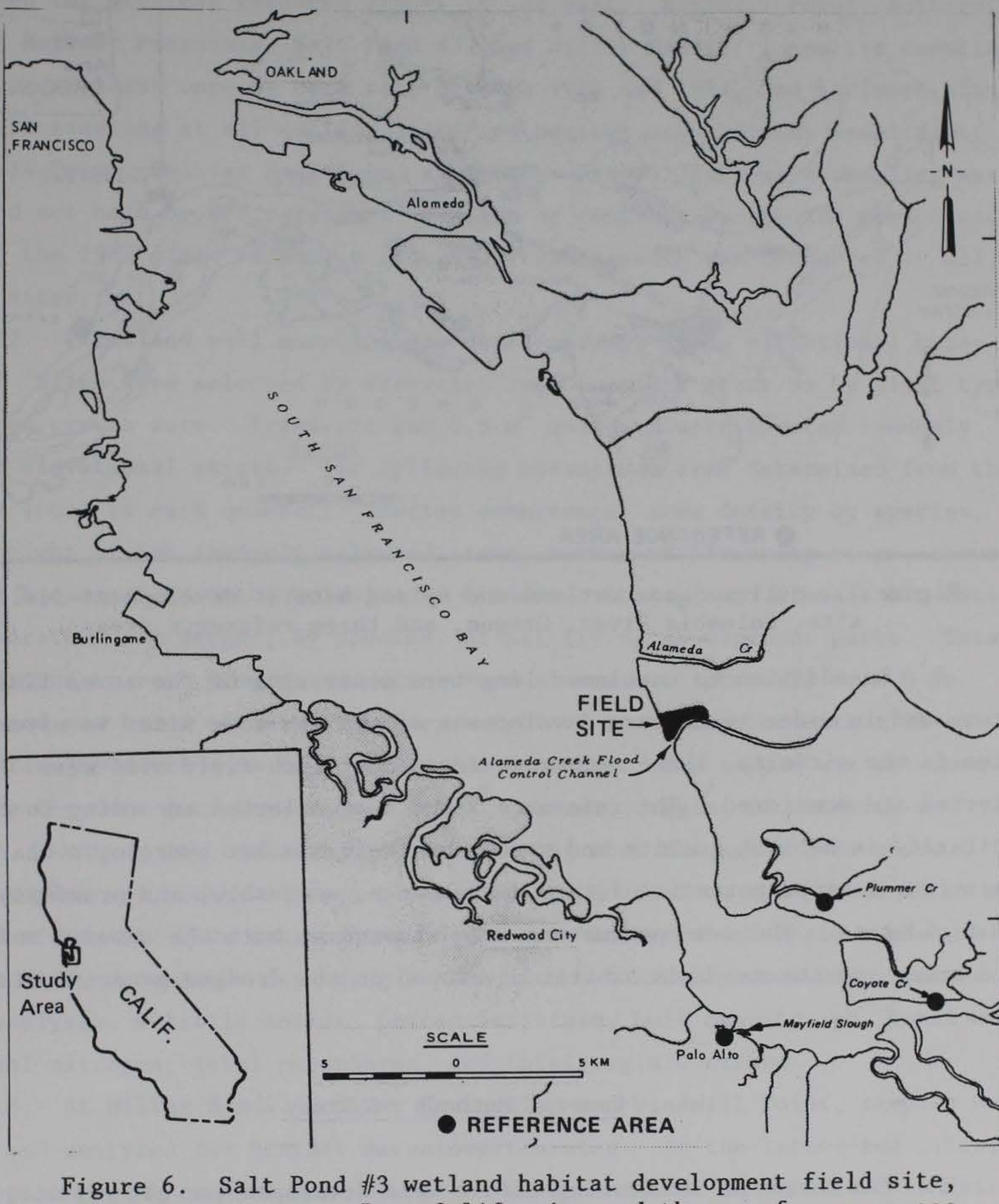

Figure 6. Salt Pond #3 wetland habitat development field site, South San Francisco Bay, California, and three reference areas

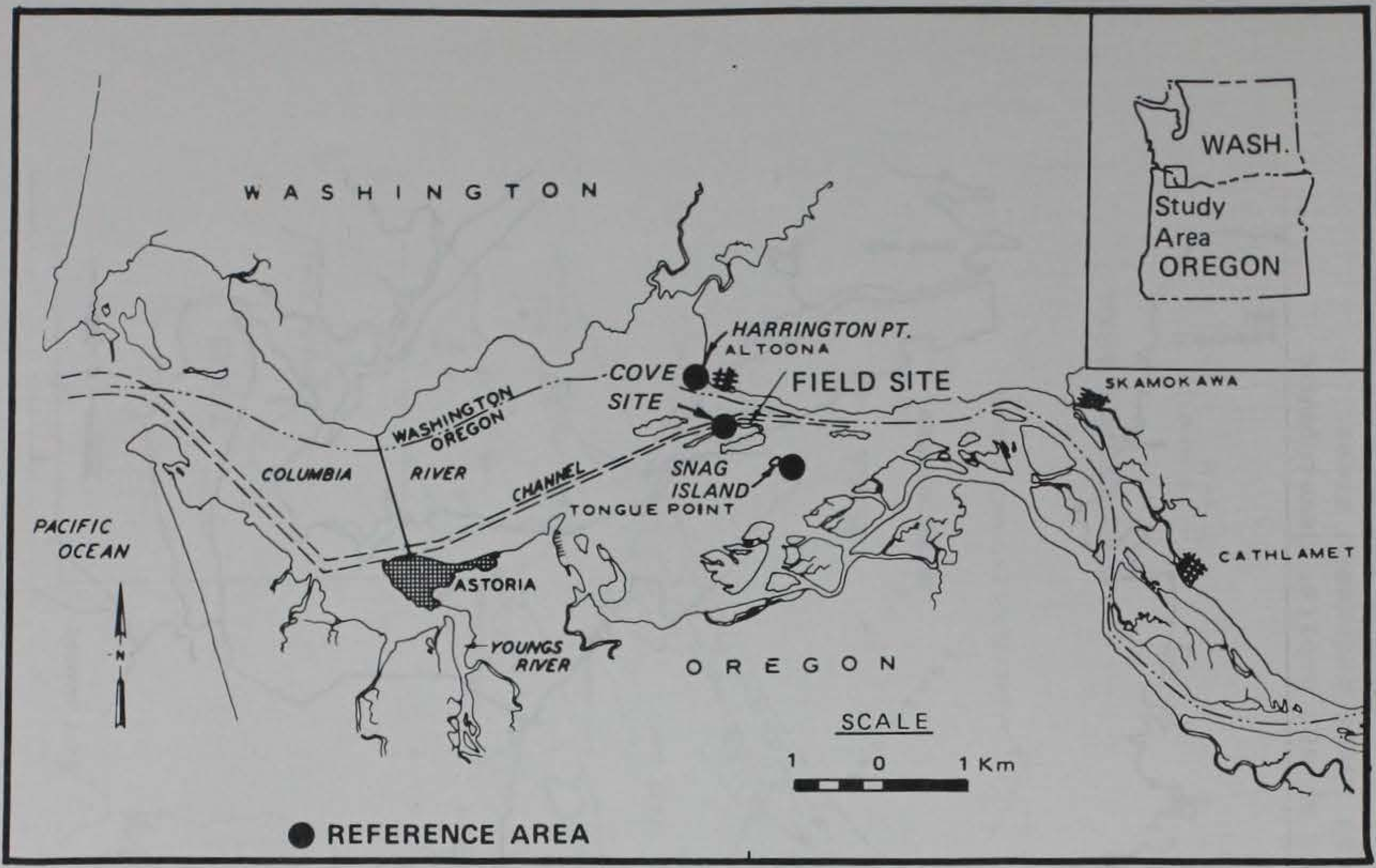

Figure 7. Miller Sands wetland and upland habitat development field site, Columbia River, Oregon, and three reference areas

4. In addition to continued long-term monitoring of the seven field sites, and in order to compare development of the man-made sites to natural sites in the vicinity, three reference areas near each field site were selected and monitored. The reference sites were selected according to their similarity in habitat quality and type, and their similar hydrologic characteristics, limited potential future disturbance, ownership, and proximity to the field site. The same parameters were studied at both the natural reference areas and the man-made habitat developed on the dredged material disposal sites.

General Methods of Study

5. Two levels of monitoring effort were developed for all sites. The first level of monitoring included an annual, general reconnaissance of all sites conducted by U. S. Army Engineer Waterways Experiment Station (WES) personnel. General reconnaissance was intended to address the third objective of paragraph 2 and to provide qualitative information on changes that might

necessitate closer scrutiny such as massive erosion or plant mortality.

6. The second level of monitoring was intensive sampling and was planned to provide quantitative data from the five field sites which had received the greatest research effort in the past: Windmill Point, Buttermilk Sound, Bolivar Peninsula, Salt Pond #3, and Miller Sands. Intensive sampling was done at least once at each site between 1978 and 1981, and included plant and soil sampling at all wetland sites and benthos and sediment sampling at Windmill Point, Bolivar Peninsula, and Miller Sands. Intensive sampling was carried out both by WES personnel and also by contract to outside consultants. During the 1982 field season, a general reconnaissance was conducted at all seven sites.

7. Plant and soil sampling was done randomly along elevational baselines. Sites were selected by elevation in intertidal areas or by plant type based on growth form. Transects and 0.5-m^2 quadrats were located randomly within elevational strata. The following parameters were determined from the plants found in each quadrat: species occurrence, stem density by species, mean height of ten randomly selected stems, number of flowering stems, aboveground biomass, and total belowground biomass. Aboveground biomass was based on laboratory dry weight, by species, of all living aboveground parts. Total belowground or root biomass was determined at various intervals from 0 to 25 cm and was based on laboratory dry weight of roots sampled with a 25-cm cylindrical plastic core of 10 cm inside diameter. The sample was obtained by driving the core into the clipped 0.5-m^2 quadrat, digging it out with a shovel, removing the contents, and wet-sieving them through a 1-mm sieve. Soil samples were taken at each plant-sampling quadrat to a depth of 25 cm and were divided into 5-cm increments. Soils were analyzed for various physical and chemical parameters depending on the site but usually included particle-size analysis, volatile solids, percent moisture, bulk density, pH, total Kjeldahl nitrogen, total phosphorus, and total organic carbon.

8. At Miller Sands, Bolivar Peninsula, and Windmill Point, samples were taken and analyzed for benthic macroinvertebrates. At the latter two sites, a three-part caging or exclosure study was also conducted in an effort to determine the rate of predation as well as to describe and quantify the benthic population. For each benthic invertebrate sample collected, a corresponding sediment sample was taken and analyzed for grain size and volatile solids.

9. For additional documentation of the status of the sites through

time, aerial and ground photographs were made of all the experimental sites and reference areas during the 1979 or 1980 growing season. Types of photographs taken included low-level stereo, black and white, and color infrared. Photographs are kept on file in the Environmental Laboratory at WES.

10. A series of technical reports synthesizing research information on the habitat development work during the DMRP was published in the form of practical guides by Soots and Landin (1978); Hunt et al. (1978); Smith (1978); Lunz, Diaz, and Cole (1978); and the Environmental Laboratory (1978) staff. Within Part II of this report, each of the seven habitat development field sites monitored will be discussed individually. Site histories and descriptions, site research and development, and details of long-range monitoring efforts will be presented and discussed for each.

PART II: HABITAT DEVELOPMENT FIELD STUDIES

Nott Island Upland Field Site

Site history and description

11. The Nott Island upland habitat development site is located in the Connecticut River in New London County, Connecticut, 10 km upriver from Long Island Sound, and is a 3.2-ha portion of the northern half of the 31-ha Nott Island.

12. Average precipitation is 116.8 cm, including 88.9 cm of snowfall; 195 days per year are frost-free. Average temperature is 10.5°C, the highest in Connecticut, which is due to a moderating influence by the Sound. The average tide is 0.75 m and the salinity ranges from fresh to brackish.

13. Area vegetation is oak-hickory mixed forest with eastern red cedar* dominating old-field areas such as Nott Island (Hunt, Wells, and Ford 1978). Upland meadows in the area are characterized by vetches, clovers, fescue, orchard grass, and other cold-tolerant grasses.

14. Wildlife in the area includes many species of birds, white-tailed deer, raccoons, small rodents, and other common small mammals. Waterfowl of the Atlantic Flyway use the Connecticut coast area extensively (Bellrose 1976).

15. A diversity of upland habitats occur in the area due to intensive land uses of farming, forestry, and industry. Soils are predominantly sand or sandy silt. Nott Island is a natural island that has been used nine times since 1936 for dredged material disposal. The island has also widened considerably through land accretion since 1947. Predevelopment baseline data were collected, analyzed, and summarized by Warren and Niering (1978). Since 1968, the island has been owned by the State of Connecticut and is used primarily for recreational purposes.

Site research and development

16. Engineering. An old disposal site of partially vegetated sand was cleared and graded, and dikes were formed from the existing dredged material. This diked area was filled with 14,520 m^3 of both sand and silt dredged from

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* Common and scientific names of all plants and wildlife mentioned in the text are listed in alphabetical order in Appendix A.

the Connecticut River channel in 1975-76 (Figure 8a). After placement and leveling of sand, the silt material was placed over it and allowed to dewater. Then the two soils were mixed using heavy equipment and standard farming implements. Engineering details are provided in Hunt, Wells, and Ford (1978).

17. Soils. Soil samples were taken from the channel in 1975 and analyzed for pH, calcium, magnesium, potassium, phosphorus, organic matter, nitrate, and ammonium nitrogen. Samples were also taken from the site and analyzed for texture, pH, nitrate, ammonium nitrogen, phosphorus, potassium, and soluble salts. Methods, techniques, and analyses are discussed in Hunt, Wells, and Ford (1978).

18. The samples revealed that soil pH levels were too low for plant growth and survival, which made liming essential. Salinity was higher than expected, and potassium levels were low. All-purpose fertilizer was added to raise potassium levels, but no adjustments were made for salinity.

19. Vegetation. After addition of the soil amendments, an experimental test plot was seeded in 1976 with tall fescue, orchard grass, timothy, perennial ryegrass, red clover, and white clover according to the experimental design outlined in Warren et al. (1978) and Hunt, Wells, and Ford (1978). The remainder of the site was seeded as a large-scale planting in 1976 with tall fescue and white clover.

20. Measurements were taken of percent cover, plant height, natural invasion, stem density, phenology, biomass, and seed production. Details of botanical sampling are given in Barry et al. (1978).

21. In general, the grasses were successful and the legumes were not. Within one season, orchard grass, perennial ryegrass, tall fescue, and timothy covered 70 to 80 percent of the test plots while the clovers achieved less than 20 percent cover. There are several suspected reasons for legume failure: low pH despite liming, soil salinity, low potassium levels, and lack of soil nitrogen-fixing bacteria. The seeds were not inoculated prior to planting, although low pH would probably have destroyed the bacteria if they had been present. By 1978, tall fescue was the dominant species of the entire site. Orchard grass and timothy were present as associated species, but only a residual population of white clover remained in the large-scale planting area.

22. Wildlife. Predisposal and postdisposal surveys of mammal, bird, amphibian, and reptile populations were made. Methods, techniques, and

a. Prior to site habitat development

b. Site in 1982, looking south across the meadow area

Figure 8. Nott Island field site in the Connecticut River, Connecticut

analyses are discussed in Coastal Zone Resources Corporation (1977); Warren and Niering (1978); Warren et al. (1978); and Hunt, Wells, and Ford (1978).

23. Nine species of mammals were found at Nott Island: short-tailed shrew, eastern mole, white-footed mouse, meadow vole, muskrat, Norway rat, meadow jumping mouse, raccoon, and white-tailed deer.

24. A total of 85 species of birds were recorded on Nott Island. Canada geese grazed on the field site each year. Four species of swallows, and song sparrows and mourning doves were among the seedeaters that fed at the site. Most common nesting species were red-winged blackbirds, song sparrows, long-billed marsh wrens, yellow warblers, and common yellowthroats. The greatest nesting density occurred in the marsh area of the island, while more species nested in the upland area.

25. Three species of amphibians and six reptile species were found on Nott Island.

Long-range monitoring

26. Calves Island, Brockway Island, and Eustasia Island were selected as nearby reference areas for comparison purposes. Annual observations were made at Nott Island during mid to late summer from 1978 through 1982 (Figure 8b). The physical conditions and status of the plant community at the experimental site and the three reference areas were noted. Observations of wildlife at each site were also made. In 1982, quantitative data were collected from eight 0.25-m^2 quadrats placed in four random pairs on the large-scale planting area. The data are summarized in Table 1. Plant species observed on and adjacent to the experimental area are listed in Table 2. Table 3 lists wildlife species observed at Nott Island during the 1982 site visit. The Calves Island reference area includes an area of sandy dredged material. Plant and wildlife observations made on and adjacent to this site in 1982 are listed in Table 4.

27. The 1982 observations typify the annual conditions found at Nott Island and its associated reference areas in earlier years. The dominant portions of the plant community on Nott Island have shown very little change or have been virtually stable since 1978; wildlife use of the area has been substantial. Stability of the plant community on the large-scale planting area is notable, especially considering that the area has received no management (mowing, burning, fertilizing, liming) since its initial development in 1976. Production of pasture grasses, particularly tall fescue, appears to continue

at a constant pace. Growth is least vigorous in the southwest quadrant which contains the highest percentage of sand; growth is most vigorous in the northeast quadrant where the greatest mixture of silt exists. Marestail fleabane is the most common invader.

28. However, some changes have been observed. Little or no evidence remains of the test plantings in the experimental plots. Goldenrod has invaded more than 60 percent of the test area and a heavy thatch of dead plant material covers the remainder. There is little or no trace of the species originally planted there.

29. After a period of relative stability (1978-1980), subtle changes have been observed since 1981 in the large-scale test planting area. Percent cover and plant vigor have not changed. However, tall fescue appears to have slightly increased in dominance while the associated pasture grasses, orchard grass, and timothy have reduced their contribution. Legumes such as white clover, which were very low in number in 1978, were almost absent by 1982. Goldenrod, which was abundant only in the southeast quadrant of the large-scale area, expanded even more between 1981 and 1982. Bull thistle, with an incidental occurrence in 1981, changed to a major invader along the east side of the site, particularly in the southeast quadrant. On the west side of the site, eastern red cedar has been a noticeable invader since 1981. The source of the invasion may be a small grove of eastern red cedars adjacent to the northwest corner of the site.

30. Wildlife use of the site appears to be substantial, probably due to the proximity of the pasture community to other existing communities. Originally, the site had been planned as a feeding site for Canada geese. Management agreements for mowing or burning the site did not materialize, so the vegetation remains too tall for geese to feed. However, wintering Canada geese as well as a resident flock frequently use the sparsely vegetated portions of the site to roost. Deer have used the site since its inception and, between 1981 and 1982, this use appears to have increased. Ringneck pheasants have been observed every year except 1982. Stable numbers of bobwhite quail have been observed every year, with a slight increase noted in 1982. Songbirds and small mammals have made moderate to heavy use of the site every year. Raptors commonly noted resting or hunting on or adjacent to the site include the kestrel and osprey.

Summary

31. Despite the lack of any additional management after its 1976 establishment, the Nott Island habitat development site has been successful. The plant community has become established and has stabilized within 2 years. Where the desired mix of sand and silt has been achieved, vigorous growth of pasture grasses has occurred without additional fertilization or soil amendment. The plant community has stabilized the dredged material and there has been no evidence of loss by either wind or water erosion. After 5 to 6 years, the stable pasture community shows signs of initiating natural old-field succession. Although the target wildlife species use has not been achieved (feeding by Canada geese), the target species has been attracted and it uses the site for roosting. A variety of other wildlife species regularly use the site.

Windmill Point Wetland Field Site

Site history and description

32. The Windmill Point wetland habitat development site is located in the James River in Prince George County, Virginia. The James River watershed drains a 16,000-km^2 area in Virginia and West Virginia. The surrounding area is characterized by intensive row-crop agriculture and commercial pine plantations, with large industrial areas at Richmond and Hopewell, Virginia. The James River estuary experiences much urban and industrial use. The river has semidiurnal tides ranging from 0.79 to 0.97 m up to the City of Richmond; the tidal water at Windmill Point is essentially fresh. Rarely, the salinity may reach 2 to 3 ppt in late summer months. The river carries large sediment loads and is highly turbid.

33. Enriched, contaminated, fine clay, and clayey silt sediments were dredged from the navigation channel and used to build the Windmill Point island site (U. S. Army Engineer District, Norfolk 1977; Lunz et al. 1978). The primary sources of contamination were agricultural runoff of fertilizers, herbicides, and insecticides, and the chlorinated hydrocarbon, Kepone, from an industrial site at Hopewell.

34. The area averages 112.3 cm of rainfall per year and has a mean annual temperature of 14.5°C, with an average of 216 frost-free days per year. Climax vegetation near the Windmill Point field site is oak-hickory, pine, and

mixed floodplain forest, with bald cypress bordering freshwater marshes. The natural marshes along the river and its tributaries occur in eddys and protected spots and are dominated by arrow arum, arrowhead, and pickerelweed, with isolated large patches of wild rice and smartweed. Wetland plant species occurrence and dominance are tied closely to elevation.

35. Much wildlife use occurs in the general vicinity of the site, especially by birds and small mammals. Both freshwater and estuarine fish occur. Anadromous species such as American shad, blueback herring, alewife, striped bass, and white perch use the area for spawning, nursery, and/or migration. Commercially or recreationally important fish include channel catfish, carp, sunfishes, crappie, and largemouth bass.

36. A diversity of open water, upland, and wetland habitats and abundant natural and cultivated wildlife foods attract numerous songbirds, shorebirds, waterbirds, waterfowl, and raptors to the area.

Site research and development

37. Engineering. Material from winter maintenance dredging in 1974-75 was used to build the wetland island site. The Norfolk District expanded an existing small island by creating a hydraulically pumped sand dike and dredging silty material into the diked area (Figure 9a). The engineering aspects of the site were finished by 1975; the details of dike and island design and construction, and problems encountered, are discussed in Lunz et al. (1978). The island was 8 ha in size, and had four permanently placed corner posts to measure island creep and erosion. The dike was breached on each side to allow tidal exchange.

38. Vegetation. The island site was monitored for colonization of vegetation from February 1975 through 1982. In July 1975, a total floristic survey of the site was made. Also in July 1975, portions of the site, including the dike, were planted. A small area inside the dike that had not been naturally colonized was planted with tall fescue, orchard grass, ladina white clover, switch grass, and coastal panic grass. The dike was planted with smooth cordgrass, big cordgrass, arrow arum, saltmarsh bulrush, and common threesquare (Garbisch 1978).

39. Heavy grazing of the island by Canada geese reduced planted areas making detailed vegetation studies impossible in 1975-76. Ground-truth cover estimates were made of each plant zone and community at the field site and

a. Immediately after construction in 1975

b. Site in 1982, north side of the dike

Figure 9. Windmill Point Island field site in the James River, Virginia

reference marshes. Plant cover within each plant zone was visually estimated bimonthly.

40. Unexpected and rapid natural colonization occurred, resulting in the documentation of 75 plant species on the site by July 1975. Although plantings initially responded well in both fertilized and unfertilized treatments, goose grazing and washouts from ship and barge traffic and high currents caused a decline that continued until all unconfined intertidal plantings were gone. However, natural invasion of plants rapidly replaced those that were lost. Test plots within confined areas were generally successful (Silberhorn and Bernard 1977, Doumlele and Silberhorn 1978).

41. Sediment and water quality. Sediment and water quality studies of predredging and postdredging of the navigation channel, an associated reference area, and the habitat development site were carried out from January 1975 through January 1977 under the DMRP. Effluent from the dike was monitored while dredging took place. Details of these studies are discussed in Adams, Darby, and Young (1978) and Lunz et al. (1978). Both physical and chemical parameters were examined. Sediments pumped to form Windmill Point Island were modified by the dredging. They became more oxidized, and they contained less water and organic material than the reference area. Documentation of chemical changes in sediments showed very little about water quality effects of wetland development in the James River. Within 2 years after construction, the field site's soils appeared to stabilize and compared closely with the reference area's soils.

42. Contaminant analysis. Samples of marsh soils and plants including barnyard grass, cattail, and arrow arum were collected from the reference area and field site and analyzed for five heavy metals and fourteen chlorinated hydrocarbons in order to determine presence and uptake of contaminants by marsh plants. The three plant species occurred in both places. Details of bioavailability and uptake are discussed in Lunz (1978) and Lunz et al. (1978).

43. Benthic sampling. Macrobenthos sampling using a Ponar grab and fish sampling using a variety of seines, traps, and fyke nets was conducted from 1976-77. Asiatic clams, tubificid worms, and larval chironomids were dominant during sampling. The substrate was acutely affected by deposition of dredged material in localized areas. However, in 6 months, macrobenthos populations were back to original levels.

44. Benthos colonized the marsh site immediately, and within 6 months, tubificids and larval chironomids were abundant. Meiobenthos were primarily nematodes and small crustaceans. A major initial difference between macrobenthos and meiobenthos was that on the reference area, they were nearly equal in abundance, while on the habitat development site, macrobenthos were much greater in abundance. Analysis of fish caught showed that benthic animals were important diet components. While fish species composition was similar at both sites, the experimental site showed higher fish numbers and biomass than the reference area. Details of these findings are presented by Diaz and Boesch (1978), Diaz et al. (1978), and Lunz et al. (1978).

45. Wildlife. Observations of avian and mammalian wildlife use of both reference experimental sites were made bimonthly from July 1976 through August 1977. While some muskrats, house mice, and marsh rice rats were seen during this time, primary use of the site was by 85 species of birds. The site was most often used for resting and feeding by shorebirds and waterfowl during this study. However, mallards and red-winged blackbirds nested on the site during 1976 and 1977. The reference area had very different use; few species were seen there (Wass and Wilkins 1978, Lunz et al. 1978). In its initial stages, Windmill Point was most important to migratory species and waterbirds.

Long-range monitoring

46. Three reference areas were chosen for long-term comparison to the Windmill Point habitat development site: Queen's Creek marsh, Ducking Stool Point marsh, and East Island (Figure 2). All three are located close to the experimental site and are part of the James River system. Ducking Stool includes a very old, abandoned rice plantation. East Island appears to have been built of dredged material many years ago; its age is unknown, but it is presumed to have been at least 25 years since the last disposal, according to interviews with local residents. The history of Queen's Creek marsh is not known but it appears to have formed naturally at the mouth of Queen's Creek.

47. Much wildlife use has continued to occur at the experimental site, especially waterfowl and waterbird use. Mallard nesting has occurred yearly since 1977 along with use by four bald eagles and several ospreys. Numerous barn swallows feed at the site during their summer nesting seasons.

48. Vegetation. Qualitative observations on vegetation at the experimental area and at the reference sites have been made annually (Figure 9b). Quantitative observations were made in 1979 when all four locations were

sampled and in 1982 when all locations except Ducking Stool Point marsh were sampled. Stem density, stem height, and percent cover both at the surface of the vegetation and within the intertidal zone were recorded in both years. In 1979, total aboveground biomass in grams of dry weight per square metre was calculated.

49. Results of the 1979 and 1982 quantitative sampling are listed in Table 5. In both years, stem density at the Windmill Point habitat development site fell within the variability found among the reference areas. The substantially higher stem density at Queen's Creek in 1979 was the result of a higher diversity and abundance of narrow-leaved plant species as well as the presence of a high number of seedling broad-leaved emergents.

50. Mean stem height at Windmill Point in 1979 fell within the range found at the reference sites but exceeded their variability slightly in 1982. Mean percent cover was higher on all areas in 1982 than it was in 1979 but Windmill Point had mean percent cover values in both years that were lower than any of the reference areas. The surface elevation of the Windmill Point marsh appears to be slightly lower than the surfaces at Queen's Creek or East Island; it is approximately equivalent to the surface elevation at Ducking Stool Point marsh. Lower percent cover at Windmill Point and Ducking Stool may be partially due to lower numbers of narrow-leaved species growing among the dominant, broad-leaved emergents. Vegetative data collected in 1982 are summarized in Table 6.

51. Beginning in 1980, a small increase in the occurrence of wild rice was observed at Windmill Point; it had been virtually absent in 1979. In 1981, the increase became very noticeable with wild rice dominating approximately 25 percent of the diked marsh by late summer. By late summer of 1982, the increase was dramatic: approximately 60 percent of the diked marsh was dominated by 2- to 3-m-high wild rice with a decreasing component of broad-leaved emergents, mostly pickerelweed. No equivalent increase in wild rice populations at the reference areas was observed. Although biomass measurements were not made in 1982, the Windmill Point site appeared to be supporting much more biomass than it had when measurements were made in 1979. The rapid shift in dominance at Windmill Point suggests that the plant community was still developing and composition had not stabilized.

52. Physically, the Windmill Point levees have experienced erosion since their creation. Erosion was slow with a general downstream migration of

sediments until the winters of 1979-1980 and 1980-1981. During these periods, rapid rates of erosion breached or widened openings in several locations on all sides of the site. The erosion rate slowed again, to almost no change over the winter of 1981-1982. At the same time, natural invasion by woody tree and shrub species has been occurring at a moderate rate on the dikes. These may stabilize the dikes. Table 7 lists plant species observed on the dikes and in the interior of Windmill Point and in the interiors of the associated reference areas during the 1982 site visit.

53. Aquatic biology. Studies were conducted before the 1974-1975 site preparation and after construction of the marsh to establish the utilization of the area by aquatic organisms (summary of these studies are contained in Lunz et al. 1978). In 1979, additional aquatic studies were conducted to document the long-term changes (5 years) that had occurred and establish whether or not benthic communities at the developed habitat were similar to nearby natural marshes. The benthos were chosen for further study because of their importance to many of the fishes in the area and because the existing data base could be used for comparison of changes.

54. Samples for macrobenthos (invertebrates retained on a 500-μm sieve) were collected in April, June, and October 1979 from the habitat development site, Ducking Stool marsh, Queen's Creek, and East Island. Both marsh and intertidal mudflats were sampled at all four sites using the same methods as employed in previous studies of the habitat development site. Details are given in Diaz et al. (1978). In addition, four 0.25-m^2 exclosure cages (6-mm mesh) were placed on the marsh and four on the mudflat at the habitat development and Ducking Stool sites from April to June and again from June to October. These cages were used to assess the response of the benthos to protection from predation, an important structuring force acting on the benthic community composition.

55. Results of the 1979 sampling indicated that macrobenthic communities at all four marshes were dominated by tubificid oligochaete worms and larval chironomid insects. In both June and October, they constituted over 95 percent of all individuals and 51 percent of the species collected. The dominance of these two taxonomic groups is typical of tidal freshwater communities found in the James River (Diaz 1977). The Asiatic clam, *Corbicula flumenia (manilensis)* was the only mollusc that was a dominant species. It

was introduced into the James River in the late 1960's and is now the primary dominant biomass throughout the entire tidal freshwater James River.

56. The dominant species tended to occur in both the marsh and mudflat habitats, but there were differences among the four marsh sites in the distribution of dominant species. Dominant oligochaetes (*Branchiura sowerbyi, Ilyodrilus templetoni, Limnodrilus* spp., and *L. hoffmeisteri*) were most abundant at the habitat development marsh. *Branchiura sowerbyi* did not even occur at the Ducking Stool marsh or mudflat and was present in lower numbers at the Queen's Creek and East Island sites. In contrast, *Peloscolex freyi* was common at Ducking Stool but did not occur at the marsh development or East Island sites.

57. None of the chironomid larvae were very abundant in any of the marshes. The dominant species were in the genera *Chironomus, Coelotanypus, Cryptochironomus, Dicrotendipes, Procladius*, and *Tanypus*. On the mudflats, *Coelotanypus* and *Procladius* were abundant, particularly at the habitat development site. The chironomids accounted for 31 percent of all species collected, but most of these were uncommon. Even in the dominant genera, there was only one species that was abundant.

58. The Asiatic clam was most abundant at the habitat development site with the highest densities in the marsh. It was scarce at the other three sites with the exception of the Ducking Stool mudflat which had moderate densities.

59. The distribution patterns of the less common species were difficult to discern, but among the four sites there was a low percentage of species that were limited to one site. Most of these were insect larvae. The communities at the four sites were similar in terms of species composition with the biggest differences occurring in total abundance.

60. Within the marshes, highest densities occurred at the habitat development site, followed by East Island, Queen's Creek, and Ducking Stool sites. Within the mudflats, the highest densities occurred at East Island, followed by Ducking Stool, the habitat development site, and Queen's Creek. The marshes at all four sites had consistently higher densities of individuals than the mudflats. The differences among the sites were not very large, on the average. The approximate densities of the 13 most common taxa averaged over a season are listed in Table 8.

61. Results of the caging experiment indicated that the cages appeared to have a large effect on the sediment accumulation rate. Sediment accumulated in all cages at a rate from about 2 to 15 cm. These changes in the sediments may account for much of the change found in the benthos. Therefore, a comparison of Windmill Point and Ducking Stool sites would not necessarily reflect their response to predator exclusion (Virnstein 1977). For the two periods that the cages were used (April to June and June to October), the species that did respond to caging are listed in Table 9.

62. The two sites did not respond similarly to caging. At the marsh development site, there were only two species increases, while at Ducking Stool marsh there were seven species increases. The reverse was true on the mudflats with two species increases at Ducking Stool and seven at the habitat development site. The only species declines from the caging effects were at Ducking Stool. The largest increases in individuals occurred at the habitat development mudflat where there was a sixfold increase in macrobenthos. At the Ducking Stool mudflat, there was no change in densities as a result of caging. Densities inside the cages were the same as outside. In total, the macrobenthos in the marshes increased threefold in density from caging.

63. Between April and June, the cages were removed to check for effects of caging on macrobenthos. In October, the former caged area was resampled and the densities of macrobenthos were found to be similar to the surrounding uncaged areas. This is an indication that the high densities produced from the cage protection do not persist when unprotected. Predation by fishes or dispersal of the caged sediments are likely explanations.

64. Findings of 1979 were compared to those of previous years; species that were important dominants in 1974 prior to marsh construction, and in 1976-77 after the marsh had become established, were also the important dominants in 1979. The only changes in the macrobenthos seem to have occurred among the chironomids, with the addition of several new genera to both the habitat marsh and Ducking Stool marsh. The largest changes at the habitat development site were noted in 1976 after the marsh was built. The fauna of the Windmill Point site was at this time similar to the fauna of the subtidal James River but much more productive. By 1977, more marsh species were present at the habitat development site, but it was still not as species rich as the reference area (Ducking Stool). In 1979, the fauna of Windmill Point

was very similar to the three reference marshes. However, there were still some basic differences in the distributions of several important taxa.

65. The general trend from 1974 to 1976 was mainly increased productivity of macrobenthos in response to the newly created marsh habitat. From 1976 to 1979, the trend was toward increased species diversity and abundances at the experimental site relative to the three reference marshes studied. Based on the known utilization of the habitat development site by fishes in 1976-1977 and the continued growth of macrobenthos, it is likely that the developed marsh is still providing valuable habitat to fishes. The relative resource value of the experimental site still appears to be higher than the nearby reference marshes studied.

66. In summary, from 1974 to 1979, the changes in the macrobenthic communities that occurred as a result of marsh habitat development lead to a more productive habitat that was of greater value to fishes than the subtidal bottom. The developed habitat was also more productive than natural marshes in 1976. The continued increase in abundances at the developed marsh in 1979 was an indication that this higher productivity was still occurring.

67. Wildlife. Wildlife use of the Windmill Point habitat development site has been high and equals or exceeds that observed at the reference areas. The list of species observed at the various sites during the 1982 site visit (Table 10) is typical of the species observed during the annual mid- to late-summer visits since 1979. The annual use of the Windmill Point habitat development site by a family group of bald eagles is noteworthy. The eagles apparently use the site's dikes as feeding and resting areas, frequently carrying their catches of fish to a barren area of the dike to eat. They also use the dikes, old duck blinds, marker posts, and grounded snags as roosting places. The Windmill Point site offers little to attract human use or possible predator use and affords a clear view for long distances in all directions so the eagles can detect any sign of potential danger long before it approaches.

68. Other notable wildlife use of the Windmill Point site includes occasional visits by deer, annual nesting by mallards, and heavy use by fish in spring during high tides. Local fisherman set fyke nets at the breaches in the dikes in attempts to catch some of the channel catfish and carp on the falling tides.

Summary

69. The Windmill Point habitat development site continues to thrive

with fish and wildlife use equalling or exceeding that of nearby reference areas. The plant community on the site is not identical to that of the reference areas, but the parameters measured generally fell within the range of variability found at the other sites. Noticeable erosion of the site's dikes is taking place, but natural invasion of woody plants is slowing the rate of erosion to some degree. The benthic community at the site is also not identical to that at the reference areas. It is, however, diverse and productive. With no additional management since its inception, the Windmill Point habitat development site continues to provide valuable habitat for wildlife and fish species.

Buttermilk Sound Wetland Field Site

Site history and description

70. The Buttermilk Sound wetland habitat development site is a 2-ha island built of sandy dredged material mounded to 5 m above mean low tide over a 5- to 7-year period prior to 1974 (Figure 10a). A portion of this island was graded and sloped to the correct elevation for marsh establishment and planted in 1975 with seeds and transplants of seven marsh species: sea oxeye, saltgrass, marsh elder, black needlerush, smooth cordgrass, big cordgrass, and saltmeadow cordgrass. The experimental design and methodologies are discussed in Reimold and Linthurst (1977); Hardisky and Reimold (1977); Reimold, Hardisky, and Adams (1978); and Cole (1978).

71. The Buttermilk Sound wetland habitat development site is located in the Intracoastal Waterway near the mouth of the Altamaha River in Glynn County, Georgia. Most of the surrounding area is low salt marsh with scattered islands, some of which are remnants from disposal operations and rice farm dikes. The marshes are flooded twice daily by a 2-m tide that has cut numerous small creeks in the area (Cole 1978).

72. In the tidal marshes surrounding the site, the soil is primarily clay. At higher marsh elevations, the clays are often covered by an overburden of silty sand. The clay retains moisture well but is nearly impermeable; the sandy material is well drained. Smooth cordgrass is the dominant plant species. Other dominants at higher salt marsh elevations are big cordgrass, black needlerush, sea oxeye, saltgrass, saltmeadow cordgrass, wild rice, and marsh elder.

a. After elevational grading

b. Site in 1982, with measurements being taken in the intertidal zone

Figure 10. Buttermilk Sound habitat development field site, Altamaha River, Georgia

73. Climate in the area is considered mild and humid, with average temperatures of 20.05°C and average rainfall of 116.54 cm per year. Tidal waters surrounding the experimental site range from fresh to brackish, usually with 2 to 7 ppt salinity. Water quality in the area is more influenced by the runoff from the Altamaha River rather than by the tides; the river discharge is usually high in summer and fall and low in winter and spring.

74. Wildlife making use of the site and surrounding areas prior to planting were alligators, gulls, terns, herons, blackbirds, raccoons, and muskrats. Estuarine animals in surrounding waters included oysters, fiddler crabs, periwinkles, mullet, anchovies, and white shrimp. Salt marsh grasshoppers and leafhoppers were the most abundant insects found in vegetation of the area.

Site research and development

75. Engineering. Portions of the sand mound on the site were graded and gently sloped from mean high to below mean low tidal elevation to create planting substrate along an elevational gradient. Engineering details are discussed in Reimold, Hardisky, and Adams (1978).

76. Vegetation and soils. The site was planted in June 1975 and April 1976 according to the split plot experimental design outlined in Cole (1978) which tested combinations of seven plant species, five fertilizer levels, and two types of propagules. Additional plantings of smooth cordgrass were made in May 1976.

77. Soils and soil water were sampled in smooth cordgrass, saltgrass, and saltmeadow cordgrass plots. Soils were analyzed for 11 micronutrients, organic matter, pH, Eh, extractable and total phosphorus, nitrite, ammonium nitrate, total dissolved nitrogen, total nitrogen, and cation exchange capacity. Results and analysis are provided in Reimold, Hardisky, and Adams (1978).

78. Survival of the marsh plants was keyed to elevations and tidal inundation. Only smooth cordgrass survived at lower elevations; some of all seven species survived at the middle zone; all but smooth cordgrass did well at higher elevations. Saltmeadow cordgrass grew best in the upper zone. It and smooth cordgrass comprised half of the total biomass grown on the experimental site. Forty-two plant species invaded the upper-zone test plots; most common were water hemp, a panic grass, crabgrass, and marsh fleabane.

79. Fertilization had virtually no effect on planted species regardless of the type of propagule or elevation. Soil nutrient levels increased during

the 1975-77 study; however, concentrations were still below those of natural areas.

80. Wildlife. Prior to development and immediately thereafter, monitoring of wildlife was carried out and compared to nearby natural reference areas. Methods are discussed in Reimold, Hardisky, and Adams (1978). Three species of crabs, primarily fiddlers, were present on the site, especially in the saltgrass and saltmeadow cordgrass plots. Anchovies, white shrimp, and grass shrimp were the most abundant marine species. Alligators, diamondback terrapins, banded watersnakes, marsh rice rats, raccoons, and muskrats were often seen on and around the site. Avian use was altered by development only slightly. Prior to development, the bare sandy mound was used by shorebirds and waterbirds, and they continued to use this area. After site development, wading and other marsh birds increased their site use, and ospreys and belted kingfishers hunted on the site. Large numbers of gulls, terns, and American oystercatchers continued to use the site through all phases of development.

Long-range monitoring

81. Site visits and qualitative observations were made annually at Buttermilk Sound and associated reference areas from 1979 through 1982. Quantitative observations were made in 1978, 1979, and 1982 (Figure 10b). In the two former years, major sampling efforts were conducted (Hardisky and Reimold 1979a and 1979c) and are summarized below.

82. During 1978, three natural marsh sites, Broughton Island, Belltail Island, and Hardhead Island (Figure 3), were selected to compare to the experimental site at Buttermilk Sound (Hardisky and Reimold 1979b). To ensure sampling at comparable elevation regimes, elevations were established in each plot by elevational surveys from a U. S. Geological Survey temporary bench mark established on Little St. Simons Island. Three elevations were determined for each plot. The mean of three replicate plots was used to designate the elevation zone classification.

83. The dominant plant communities surviving at the Buttermilk Sound site were selected for study. In the 1978 study (Hardisky and Reimold 1979a and 1979b), three elevational zones between mean low water and mean high water were identified. In the 1979 study (Hardisky and Reimold 1979c), a fourth zone between mean high water and the limit of spring tide inundation also was studied.

84. Data were collected from three replicated quadrats at each of the

elevations (Hardisky and Reimold 1979b and 1979c). Quadrat sizes were 0.05 m^2 for saltmeadow cordgrass and 0.5 m^2 for all other plant communities. Aboveground vegetation was clipped at ground level. Dry weight biomass of live, dead, and litter components was determined from a subsample dried at 95°C in a forced draft oven. Stem density counts were made on live stems. Mean stem height was calculated as the average distance from the clipped basal end to the tip of the tallest leaf of ten randomly selected stems from each sample. Crab burrow density, flowering stem density, and density of invaders also were determined.

85. Root biomass for each quadrat was determined from one 73-mm-diam core extracted within each plot. The cores were taken to a depth of 30 cm and subsequently segmented into 5-cm intervals. Roots and rhizomes were washed free of soil, divided, and weighed. The weight per core was extrapolated to 1 m^2.

86. Color infrared and panchromatic black-and-white aerial photography of the Buttermilk Sound site and reference marsh areas was obtained at a scale of 1:3000 and 1:6000 on 19 May 1979. Markers similar to those described by Reimold, Gallagher, and Thompson (1973) were fabricated prior to the overflight and deployed in key plant communities where sampling would occur.

87. In 1979, species composition differed from area to area. The Buttermilk Sound experimental site had the greatest species diversity (Table 11). Black needlerush, big cordgrass, smooth cordgrass, saltmeadow cordgrass, saltmarsh bulrush, and sea oxeye were present in Zone 3 (upper one third of the zone of daily inundation) of Buttermilk Sound. All six species had been planted in 1975 and 1976. In contrast, only one other site, Belltail Island, had 4 species present.

88. In Zone 3, total living aboveground biomass was somewhat greater at the Buttermilk Sound experimental site than at the reference areas and total dead aboveground biomass fell within the range observed at the reference marshes. The living aboveground biomass of black needlerush on Buttermilk Sound fell within the range of variability found at the reference sites, despite the lower elevation at which it was planted. Dead aboveground biomass of black needlerush was lower at the experimental site, probably reflecting the lower elevation and increased tidal flushing. The tall form of smooth cordgrass at Buttermilk Sound was as productive or more productive than comparable stands in adjacent wetlands. Big cordgrass at the experimental site remained

lower in overall standing crop biomass than all other areas sampled. Aboveground biomass of saltmeadow cordgrass at Buttermilk Sound and on Belltail Island was quite similar. Saltmarsh bulrush was mixed with smooth cordgrass (short form) at Belltail Island, and at the experimental site it was mixed with saltmeadow cordgrass, smooth cordgrass, water hemp, and others. Although the biomass per unit area was similar for both stands of saltmarsh bulrush, it is noteworthy that in both areas it occurred in mixed stands and that the plant species in the mix were not necessarily the same.

89. Inherent variability in plant communities may have accounted for differences among areas since differences occurred despite similar elevation and soil conditions. For example, black needlerush at Belltail Island and Hardhead Island had significantly less aboveground biomass than the black needlerush found at Broughton Island. Elevation was apparently not the separating factor since the Belltail and Hardhead Island stands were also in intertidal zone 4 (from mean high water to the limit of spring tide inundation). Soil type also failed to account for the observed differences.

90. In another example, standing crops of the tall form of smooth cordgrass were similar at all locales; however, the short form variety sampled at Belltail Island in Zone 3 had a significantly higher biomass than the tall smooth cordgrass at the comparable elevation at Buttermilk Sound. Saltmarsh bulrush aboveground biomass in Zone 3 at the experimental site (82 g/m^2) was much higher than that at Belltail Island (12 g/m^2).

91. Some differences in aboveground biomass did occur with elevation differences. The big cordgrass aboveground biomass in Zone 4 of Hardhead Island (421 g/m^2) was significantly greater than Zone 3 at Buttermilk Sound (158 g/m^2). Saltmeadow cordgrass aboveground biomass in Zone 3 at Buttermilk Sound (136 g/m^2) was higher than that at Zone 4 (97 g/m^2) of Buttermilk Sound.

92. Belowground or root biomass for most plant species at the Buttermilk Sound experimental site was generally less than the root biomass found for the same species at the reference sites. The belowground biomass of black needlerush at Buttermilk Sound was significantly lower ($p < 0.0001$) than that of Broughton and Hardhead Islands. Other differences among sites were not statistically significant.

93. Nonsignificant differences did exist among sites. Smooth cordgrass belowground biomass increased with increasing elevation in all areas. The experimental site root production was greater than or similar to the other

areas. Big cordgrass belowground biomass at Buttermilk Sound was about half or less of the quantity estimated for the reference wetland areas. Belowground biomass for saltmeadow cordgrass was similar for all sites and intertidal zones. Saltmarsh bulrush showed a larger belowground biomass at Belltail Island than was evident at Buttermilk Sound.

94. The Buttermilk Sound site typically showed a large accumulation of root material near the surface with deeper areas remaining rather sparsely populated by root material. The trend was evident in 1978 and continued into 1979 (Hardisky and Reimold 1979a, 1979b, and 1979c). An opposing profile configuration would display large quantities of root biomass throughout the active rhizosphere (0-25 cm), a situation exemplified by a number of plant stands adjacent to the Buttermilk Sound site. These plant stands are much older than the Buttermilk Sound stand and may be experiencing different soil conditions than those at the experimental site.

95. For black needlerush (Figure 11) and smooth cordgrass (Figure 12) stands, belowground biomass generally decreased with increasing soil depth. Exceptions were at Hardhead Island for black needlerush, and at Buttermilk Sound for smooth cordgrass where greatest belowground biomass was at the 5- to 10-cm depth. The smooth cordgrass in Zone 2 of Buttermilk Sound exhibited decreasing root biomass from the surface with an abrupt increase at the 25- to 30-cm depth (Figure 13). The amount of belowground biomass at each level was generally similar, except for short smooth cordgrass (short form) at Belltail Island which was considerably greater.

96. For big cordgrass, the quantity of belowground biomass differed among sites (Figure 14). Buttermilk Sound was lower than Hardhead Island and Belltail Island in biomass at each depth. The Buttermilk Sound site also differed from Belltail and Hardhead Islands in that the biomass increase observed at the 0- to 5- to the 5- to 10-cm depth at the reference sites was not found at the experimental site where root biomass generally decreased with increasing depth.

97. Belltail Island and Buttermilk Sound saltmeadow cordgrass exhibited decreasing belowground biomass with depth (Figure 15).

98. Saltmarsh bulrush belowground biomass varied somewhat in distribution between Belltail Island and Buttermilk Sound (Figure 16). The biomass at Buttermilk Sound was high at 0- to 5- and 5- to 10-cm depths but dropped sharply below these depths, indicating a shallow root system. At Belltail

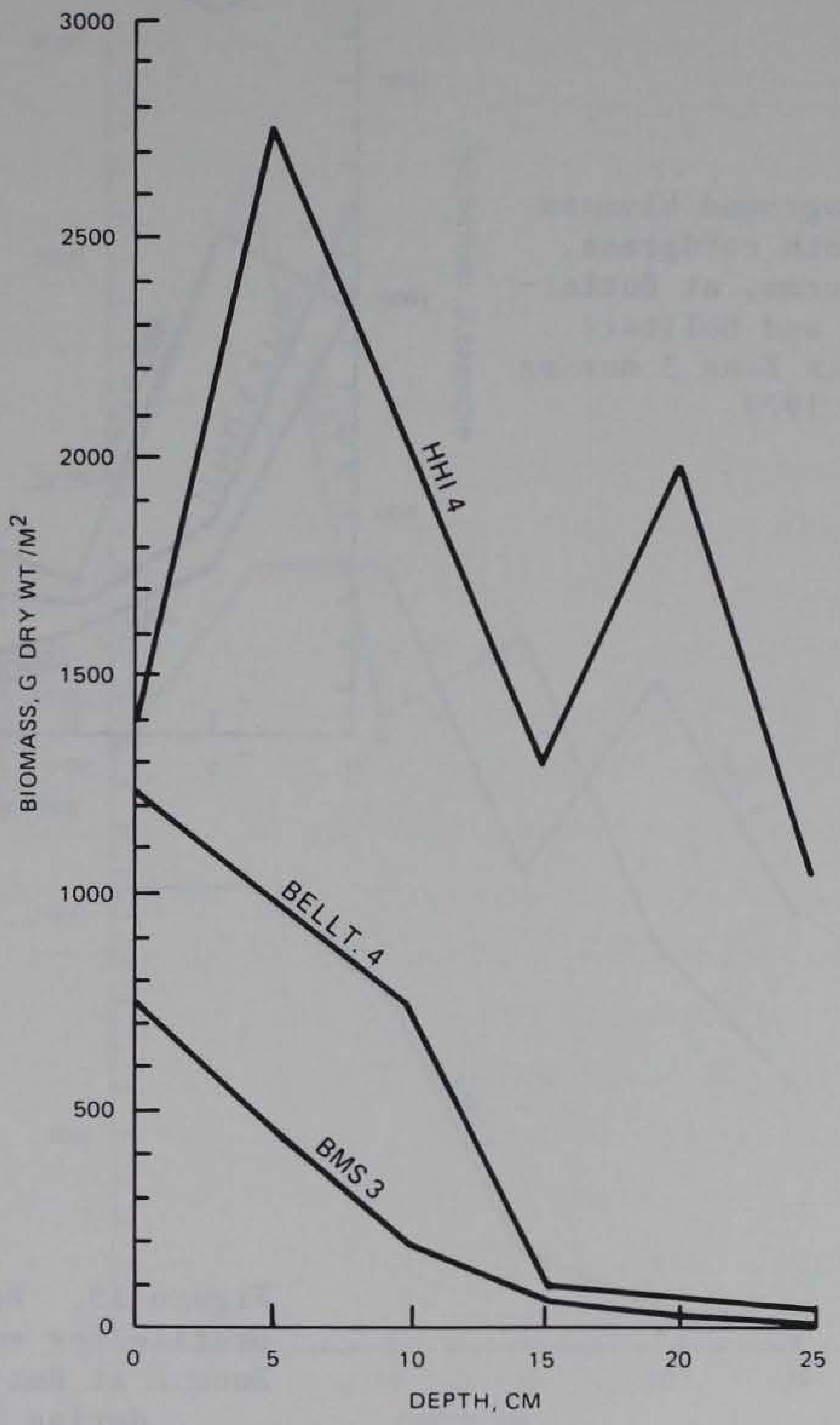

Figure 11. Belowground biomass profiles for black needlerush at Buttermilk Sound (BMS), Belltail Island (BELLT.), and Hardhead Island (HHI) in October 1979 (numerals indicate zone)

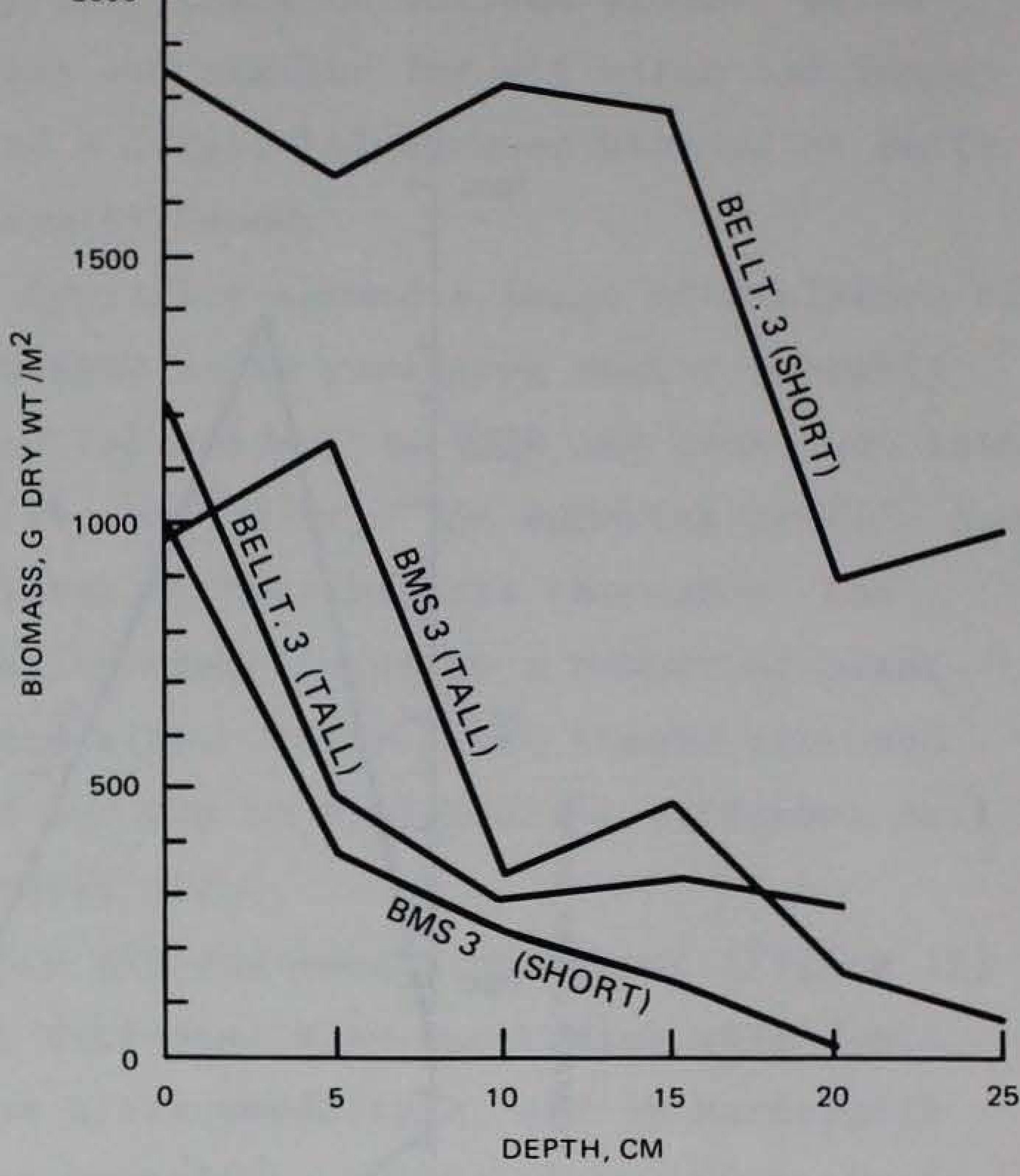

Figure 12. Belowground biomass profiles for smooth cordgrass, tall and short forms, at Buttermilk Sound (BMS) and Belltail Island (BELLT.) in Zone 3 during October 1979

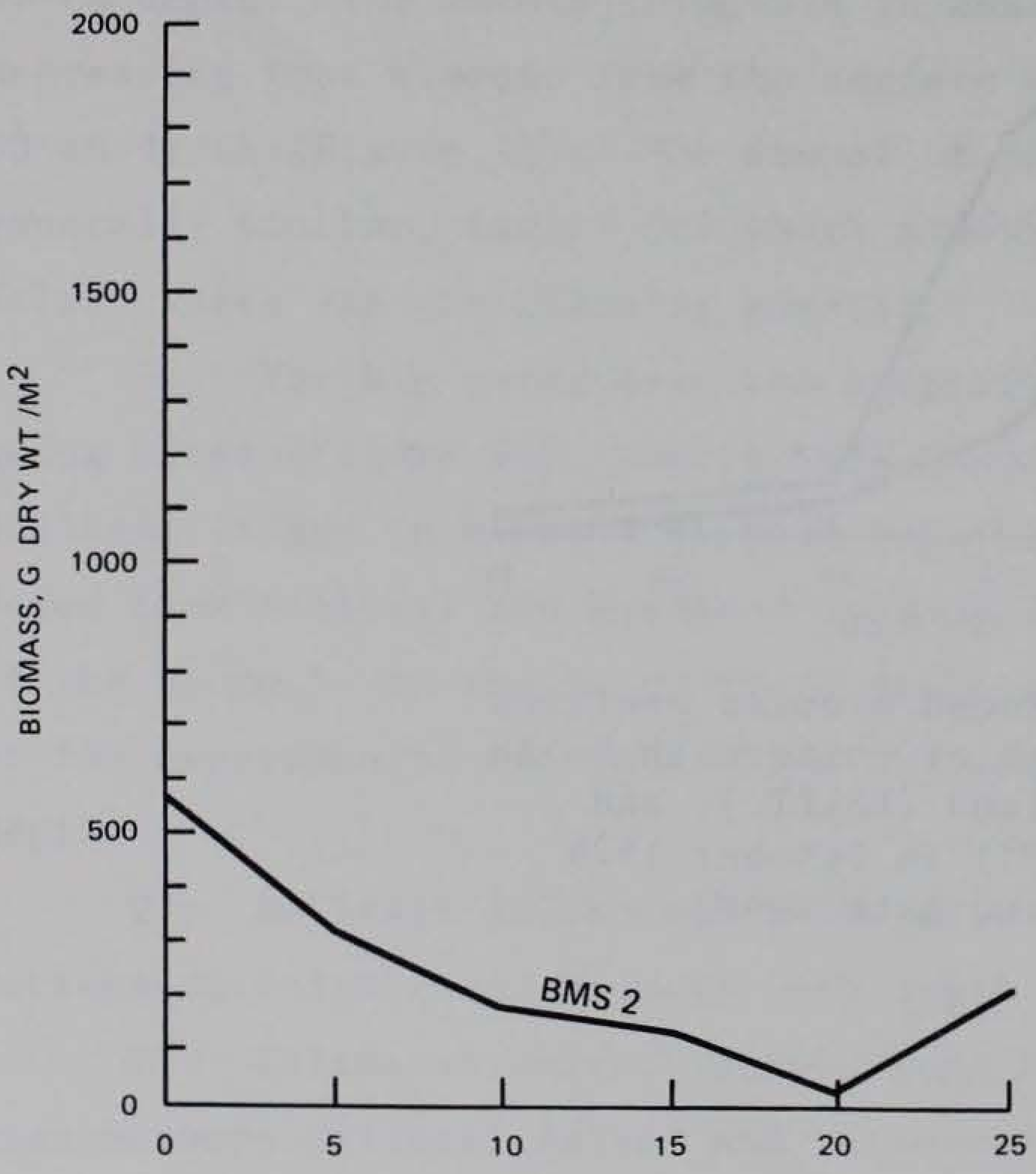

Figure 13. Belowground biomass profile for smooth cordgrass in Zone 2 at Buttermilk Sound (BMS) during October 1979

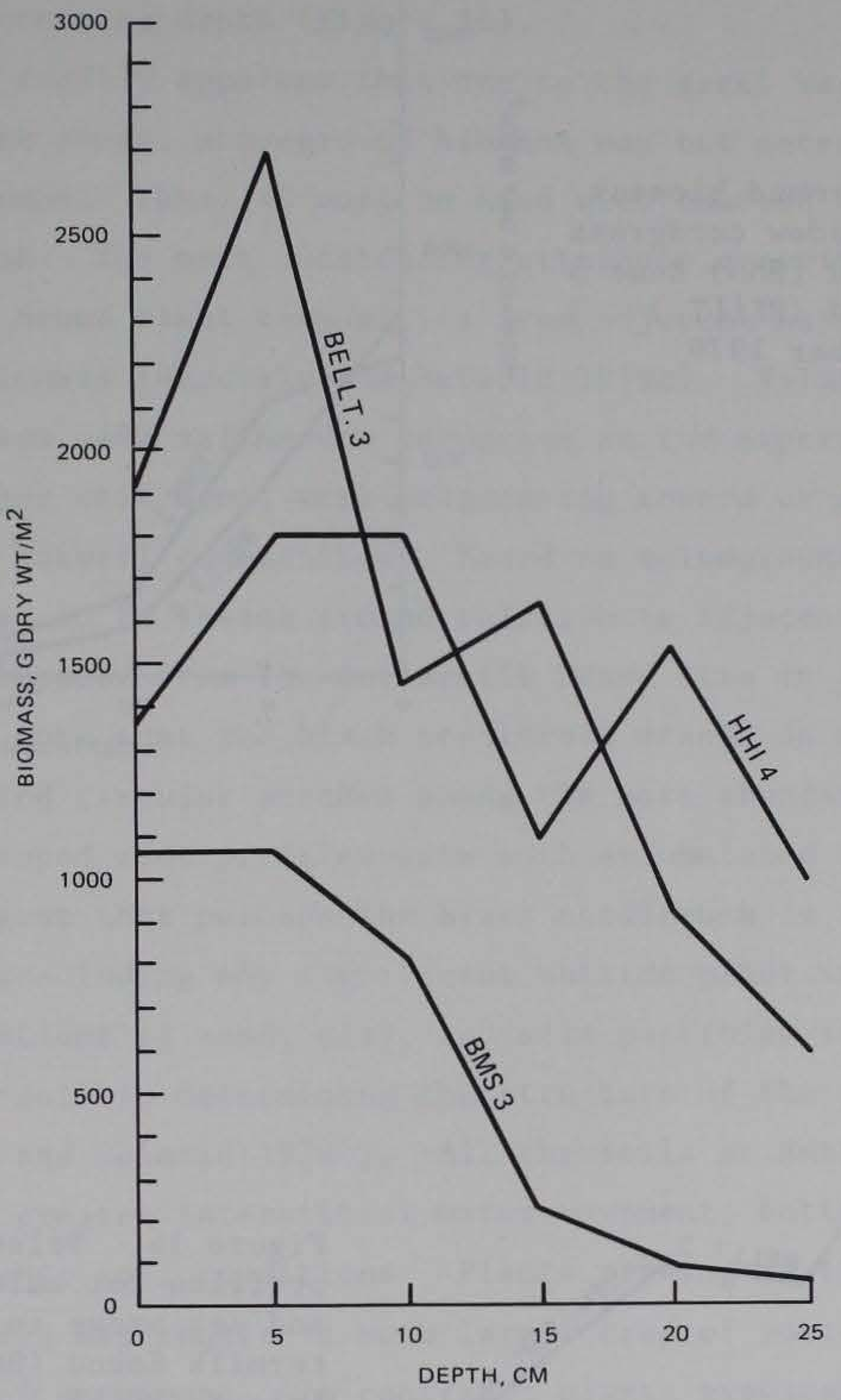

Figure 14. Belowground biomass profiles for big cordgrass at Buttermilk Sound (BMS), Belltail Island (BELLT.), and Hardhead Island (HHI) in October 1979 (numerals indicate zones)

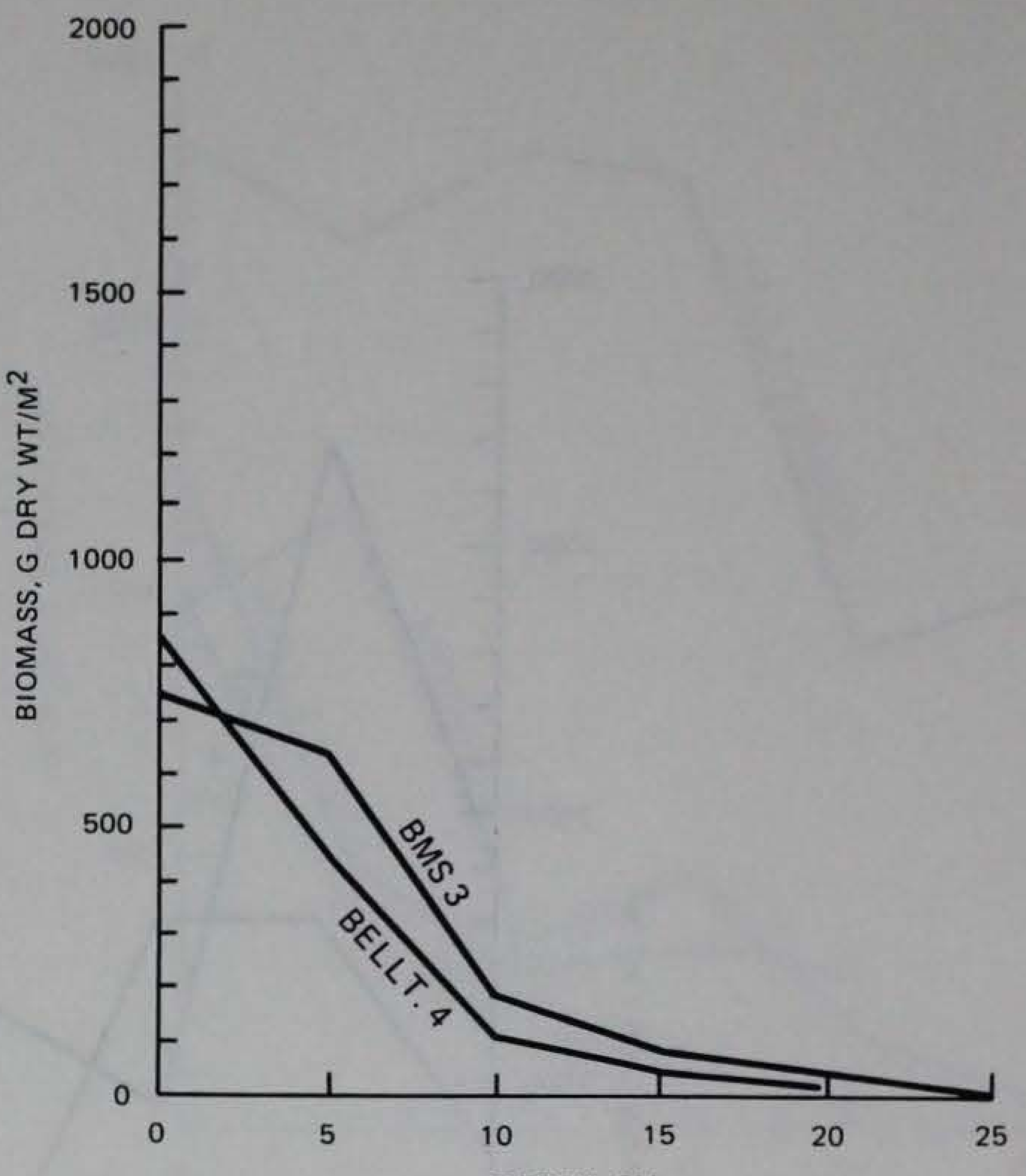

Figure 15. Belowground biomass profiles or saltmeadow cordgrass at Buttermilk Sound (BMS) Zone 3 and Belltail Island (BELLT.) Zone 4 in October 1979

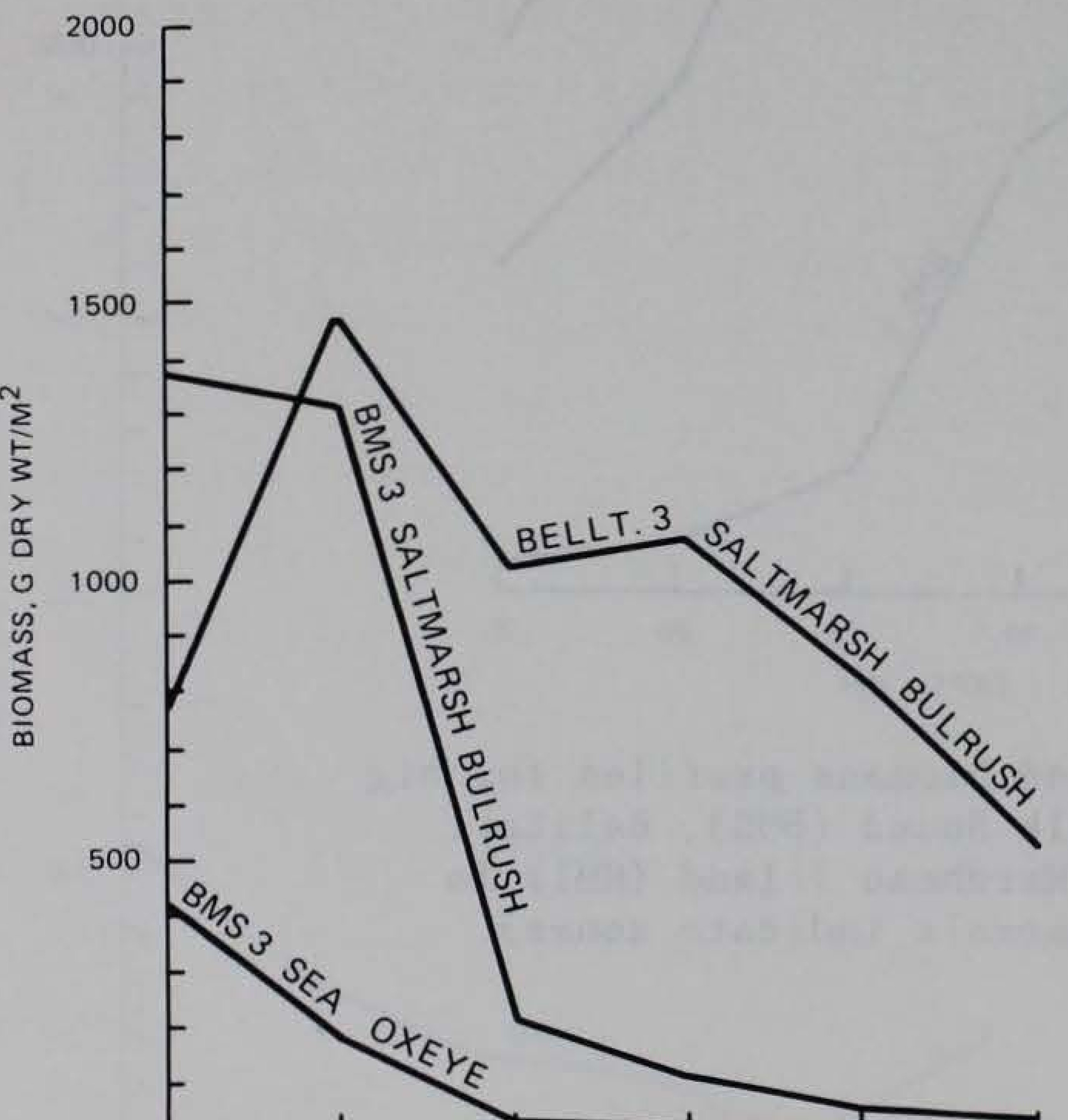

Figure 16. Belowground biomass profiles for saltmarsh bulrush and sea oxeye in Zone 3 at Buttermilk Sound (BMS) and Belltail Island (BELLT.) in October 1979

Island the quantity of root biomass was low (740 g/m^2) at 0 to 5 cm and increased to 1475 g/m^2 at the 5- to 10-cm depth. From there, root biomass decreased with increasing depth.

99. Sea oxeye was found only at Buttermilk Sound. Its root biomass decreased with increasing depth (Figure 16).

100. It is readily apparent that due to the great variation in values reported from other areas, aboveground biomass may not necessarily provide equitable comparisons. Thus, it must be used with caution when assessing the progress of a marsh. The most outstanding attribute describing the separation of the Buttermilk Sound plant communities from adjacent marsh communities is the belowground biomass (Hardisky and Reimold 1979c). Values for smooth cordgrass, big cordgrass, and saltmeadow cordgrass at the experimental site, in terms of biomass per unit area, were progressing toward or approaching values found in adjacent natural communities. Based on belowground biomass, black needlerush appeared to be losing ground relative to adjacent areas and might be expected to disappear from the Buttermilk Sound site in years to come. It is interesting to note that the black needlerush stands on Hardhead Island appeared as isolated circular patches among the more abundant big cordgrass and had well-developed root profiles with much accumulated root material. These factors suggest that perhaps the black needlerush is a relic population with its density precluding any significant outside plant invasion.

101. Proportions of sand, clay, and silt particles in the soil also play an important role in determining the structure of the plant community present (Hardisky and Reimold 1979c). All the soils at Buttermilk Sound are sands, suggesting greater interstitial water movement, better drainage, and predominantly aerobic soil conditions. Plants growing in those areas of poorly drained soils may require a much larger crop of roots to take up an optimum quantity of nutrients. In contrast, plants growing in the better drained sandy soils would require less root surface for nutrient take up simply because of additional groundwater movement. This situation might be likened to that resulting in the difference between short form and tall form smooth cordgrass. As demonstrated by this study and others, tall form or creekbank smooth cordgrass produces less root biomass and occupies the better drained creekbank areas, whereas short form or high marsh smooth cordgrass occupies the poorly drained marsh interior and produces much larger quantities of root

biomass (Hardisky and Reimold 1979c). Thus, simple comparisons of biomass or root profiles probably are not adequate indices of marsh health.

102. Another factor considered important for comparison of plant communities is elevation. A direct correlation of decreasing belowground biomass with decreasing elevation (more frequent tidal inundation) and increasing aerial biomass with decreasing elevation was evident for smooth cordgrass at Buttermilk Sound and Belltail Island. The soil type in both of these areas was sandy. The correlation could not be applied across a similar elevation to the loam soils of Broughton Island. Therefore, drainage related to both elevation and soil texture has a direct impact upon the aboveground and belowground biomass of smooth cordgrass. Other plant communities exhibited the same relationship, in that similarities were not simply across elevation regimes or across soil types, but rather a function of the two (Hardisky and Reimold 1979c).

Summary

103. 1978-1979 data. Based on the 1978 and 1979 data (Hardisky and Reimold 1979a, 1979b, and 1979c), the plant communities established at the Buttermilk Sound wetland habitat development site are, for the most part, similar to adjacent marsh areas. Black needlerush appears to be declining on the experimental site, and may be outcompeted by taller more rapidly colonizing plant species in the near future.

104. The greatest difference in the plant community of the Buttermilk Sound site and that of the adjacent marsh plant communities is belowground biomass. The difference is suspected to be consistent with similar natural drainage and, in reality, may be consistent with plant communities exposed to similar edaphic conditions.

105. Observations during 1982. Vegetation sampling was conducted again in 1982; however, time constraints permitted only small-scale sampling compared to the 1978 and 1979 efforts (Hardisky and Reimold 1979a, 1979b, and 1979c). The Buttermilk Sound experimental site and two reference areas were sampled; results are listed in Table 12. By 1982, little evidence remained of the individual species plots originally planted on the experimental site. As reported earlier (Reimold, Hardisky, and Adams 1978), Zone 1, or the lowest one third of the intertidal zone, has remained devoid of vegetation as it was at the reference areas. Further, erosion by the tides has contoured the site so that, in cross section, it closely resembles the reference sites with a flat

unvegetated toe in Zone 1 and a steeper, heavily vegetated slope in Zones 2 and 3. Species interpersion and dense growth in Zones 2 and 3 (the two thirds of the intertidal zone immediately below mean high water) present a marsh appearance on the Buttermilk Sound site visually indistinguishable from Zone 2 and 3 marshes at the reference areas.

106. The Buttermilk Sound experimental site exceeds the reference areas in mean percent cover and mean stem height, is intermediate in species diversity on sampled quadrats and in mean number of flowering stems, and is slightly lower in total stem density than the reference areas. By visual inspection alone, approaching the experimental site by the water yields no evidence that it had been a dredged material disposal site.

107. The heavy vegetation in Zones 2 and 3 has contributed to rapid silt deposition over the sandy dredged material that was originally deposited at the Buttermilk Sound site. The silt deposition in Zone 2 stands of tall smooth cordgrass is particularly heavy, exceeding 25 cm in some places. The surfaces of Zones 2 and 3 on the reference areas are also composed of silty material although it is often in a more hard-packed condition.

108. Wildlife. Limited wildlife observations have been made at Buttermilk Sound. Some observations were noted prior to 1978; however, no observations were made from 1978-1981.

109. Wildlife and plant observations made during the 1982 site visit are listed in Tables 13 and 14. The experimental site compares favorably with the reference areas for both plant species diversity and wildlife use. One interesting point of wildlife use concerns nesting of least terns. Approximately 20 least tern nests were found on the unplanted upland portion of the Buttermilk Sound disposal area which has developed a sparse cover of naturally invading herbaceous plants, primarily poor-joe. The only other place least tern nests were found in the nearby area was immediately west across the Buttermilk Sound Channel on the barren crest of the sandy disposal area on Broughton Island (Figure 3) where approximately 50 nests were located.

Summary

110. The Buttermilk Sound marsh is one of the most successful sites built during the DMRP. Vegetation grew rapidly, and has formed a salt marsh so vigorous and lush that cordgrasses are over 3 m high and almost too dense to traverse. Perhaps because the east side of the island has stabilized so successfully, vegetation is steadily colonizing the low dune area on the

island proper. This site should remain stabilized for years to come, and can be used as a model for other sites in tidewater areas of the southeast Atlantic coast. Wildlife use is greater at the site than for reference areas and seems to be increasing primarily because of the habitat diversity the site offers. Should the entire island site become totally and densely vegetated in years to come, wildlife species diversity and numbers will probably decline slightly.

Apalachicola Bay Wetland Field Site

Site history and description

111. Apalachicola Bay wetland habitat development site is located on Drake Wilson Island in Apalachicola Bay, Florida. The bay is one of the most productive and least polluted estuaries in the United States (Kruczynski, Huffman, and Vincent 1978). Rainfall averages 142.8 cm yearly, and summers are hot and humid. Average annual temperatures are 20.4°C with an average of only 5 days of below 0°C weather. Tides are only 0.5 m in the bay; the salinity of the bay is brackish to sea strength.

112. The bay supports considerable commercial fishing for oysters, blue crabs, and shrimp, on which the local economy is based. The mild weather and sportfishing in the bay for seatrout, redfish, sheepshead, whiting, and flounder draw a large tourist business to the area.

113. The primary wildlife use around the experimental site is by waterbirds, shorebirds, and some waterfowl. Herons, egrets, gulls, terns, and skimmers frequent the site. Small mammals such as raccoons and muskrats are common on the mainland.

114. Drake Wilson Island is one of two islands that were enlarged in 1976 by diking with sandy clay dredged material from the bay, then by pumping coarse-grained sandy dredged material from adjacent Two-Mile Channel (Kruczynski, Huffman, and Vincent 1978).

Site research and development

115. Engineering. The site was enlarged by hydraulically pumping sandy clay dredged material from the bay bottom forming a triangular diked containment area island on the west side of and adjacent to Two-Mile Channel. The containment area was then filled with sandy dredged material from the channel. After filling, the dikes were graded to a more gentle slope and a weir was

placed on the bay side to allow tidal water influx. Finally, silty material was pumped over the sand to provide a more fertile and suitable substrate for planting. Despite attempts to achieve a more general distribution, the silty material dispersed primarily into the intertidal area, leaving the highest portions of the island with coarse sandy substrate (Figure 17a). Engineering details are discussed in Kruczynski, Huffman, and Vincent (1978).

116. Vegetation. Transplants of smooth cordgrass and saltmeadow cordgrass were planted in 1976 in the intertidal zone of the diked island's interior. Smooth cordgrass was planted at lower elevations and saltmeadow cordgrass was planted at the mean high tide line and above. Plantings were monitored for percent survival, percent cover, seed production, culm density, biomass, and numbers of new shoots. Methods, techniques, and analyses are discussed in Kruczynski (1977) and Kruczynski, Huffman, and Vincent (1978). Various spacings for plantings were tested.

117. By the end of two growing seasons, spacings of 1.0 m or less had 100-percent cover by smooth cordgrass. The plants were healthy, spreading rapidly, and producing seeds. Tidal energy at wider spacings caused transplants to either wash out or to grow poorly. Hand planted and mechanically planted transplants grew equally well (Kruczynski, Huffman, and Vincent 1978).

118. In the higher marsh area, saltmeadow cordgrass showed vigorous growth response at spacings wider than 1.0 m. After two growing seasons, all plots were growing and producing seeds; 100 percent cover was obtained by the end of the second year. Plantings at higher elevations survived better than those at mean high tide (Kruczynski, Huffman, and Vincent 1978). Fifty-two plant species had invaded the planted site on the island by September 1977. Saltgrass was the dominant invader covering a large area by the end of 1977, especially in open areas between the smooth cordgrass and saltmeadow cordgrass plots (Figure 17b).

119. Soils. Samples collected prior to and after dredged material disposal indicated no contaminants in the sediments. The sandy dredged material was infertile and the silty dredged material contained abundant nutrient levels for plant growth. Excessive soil salinity did not occur.

120. Aquatic biology and wildlife. Due to lack of funding, no baseline surveys were made of the wildlife or aquatic biota of the study area during the course of the initial (1975-77) investigation.

a. Prior to marsh development

b. Site in 1982

Figure 17. Apalachicola Bay field site in the Apalachicola Bay, Florida

Long-range monitoring

121. Annual visits were made from 1980 to 1982 during which qualitative observations of physical condition, plant community, and wildlife use were recorded for Apalachicola Bay habitat development site and three nearby reference areas, Bulkhead Point, Shell Point, and Cat Point (Figure 4). In 1982, quantitative observations were also made on the plant communities at the experimental site and three reference areas.

122. Physical condition. The unconsolidated condition of the silty material in the intertidal zone of the experimental site had not changed appreciably since the time of disposal. While the material would not support the weight of a man, it did support a dense growth of smooth cordgrass which now dominates most of the site. Strong wind-driven waves across the long fetch from the south had battered the south dike appreciably, eroding it in many places almost to the mean high tide elevation. These areas, as well as other low portions of the south dike, supported smooth cordgrass as the dominant plant cover. Storm tides appeared to overtop the south levee regularly. The weir was essentially nonfunctional although regular tidal exchange did occur by means of two small natural channels: one that has eroded around the weir itself, and a second that has breached the dike approximately 100 m west of the weir.

123. Vegetation. Results of quantitative sampling in 1982 of the intertidal planting in the diked disposal area and three comparable reference sites are listed in Table 15. Measurements for the Apalachicola Bay habitat development site fell within the range of variability for those measured at the intertidal plant communities at the three reference sites. The quantitative measurements supported qualitative observations noting strong comparability among the sites and, in some cases, even more vigorous growth at the experimental site. Since 1980, the interior of the diked disposal area at the Apalachicola Bay site has changed appreciably. Starting as a wetland stand with a patchwork of ponded openings, it has changed to a totally closed stand with a dense cover of smooth cordgrass, except for one small ponded area of subtidal elevation in the center of the site. This ponded area was heavily used for feeding by wading birds, primarily herons and egrets. The intertidal marsh supported a large population of clapper rails. In a band 20 to 30 m wide extending into the intertidal disposal area from the sandy upland areas on the east and north, the smooth cordgrass was regularly interspersed with saltmarsh bulrush. The

presence of this less salt-tolerant species near the upland edges of the intertidal marsh may have been partially the result of the mitigating influence of freshwater runoff from the upland.

124. The experimental plots planted to saltmeadow cordgrass at and just above the mean high tide elevation were surveyed for percent cover and species occurrence in 1982. The results of the survey are listed in Table 16. Percent cover and dominance of saltmeadow cordgrass declined markedly from earlier observations (Kruczynski, Huffman, and Vincent 1978). Invading species dominated the plots. These differences are due largely to physical changes on the plots that were most likely induced by the successful dense growth of the original saltmeadow cordgrass plantings themselves. Loose sand blowing from the adjacent, unplanted area was apparently trapped by the saltmeadow cordgrass initiating formation of low dunes over the plots. Much of the original saltmeadow cordgrass plantings appeared to have been smothered by 30 to 50 cm of sand. The site was sufficiently stable to allow invasion by species tolerant of the rather hostile environment of the experimental plots. The plots now exhibit a shifting, somewhat sterile substrate with alternating conditions of drought or saturation and the added stress of periodic salt spray. Despite the rigorous conditions, the plots now support moderate plant cover as described in Table 16.

125. Table 17 lists the other plants observed on the Apalachicola Bay habitat development site during the site visit in 1982. The 97 plant species observed was a substantial increase over the 52 reported by Kruczynski, Huffman, and Vincent (1978). Of special note were the freshwater wetland species observed such as royal fern, pennywort, pilewort, and coarse rush. None of these species are salt-tolerant yet they all occurred in flats or depressions at the base of dunes and just above the mean high water mark. Most, particularly royal fern, exhibited a stressed, stunted growth form. Their presence is another evidence of freshwater runoff through the dunes, probably forming a layer that floats above a saline or brackish water table as the fresh water reaches the saltmarsh elevation at approximately the mean high water elevation. The stunted growth forms are probably the result of periodic drought and salt stress.

126. Wildlife. Wildlife use of the entire Drake Wilson Island site was substantial (Table 18). Habitat interspersion on the island itself as well as of the entire island in relation to other nearby areas was probably a major

factor in its success for wildlife use. Most conspicuous was the use of the wetland habitat development site by wading birds for feeding. The large clapper rail population appeared to be more dense than that observed at any of the reference areas.

Summary

127. The habitat development site at Apalachicola Bay is highly successful. A vigorous marsh plant community comparable to those at nearby natural marsh areas dominates the site. Erosion from wind-driven waves from the long south fetch is eroding the main containment dike on the south side but the site is still intact. The site receives heavy wildlife use.

Bolivar Peninsula Upland and Wetland Field Site

Site history and description

128. The Bolivar Peninsula upland and wetland habitat development site is located on Goat Island in Galveston Bay, adjacent to the Gulf Intracoastal Waterway. The waterway is maintained by hydraulic pipeline dredging; material from this channel was used for the 7.3-ha Bolivar Peninsula habitat development field site (Figure 18a).

129. Bolivar Peninsula itself is at one end of a long chain of barrier islands along the Texas and Mexican coasts. It is connected to the mainland, forming an arm enclosing the East Bay portion of Galveston Bay on the southeast. Soils are generally heavy peat loams and clays overlain with sand. The experimental site is primarily sand. Feral goats roam in a large herd over Goat Island.

130. Ranching and petroleum industries are the major land uses in the general area. The climate is subtropical, windy, and humid, with an annual rainfall of 106.2 cm and a mean daily temperature of 19.0°C. Summer storms with south winds and winter storms with strong northerly winds occur often; hurricanes are not infrequent occurrences. Wind fetch across Galveston Bay from the north was an important consideration in the site's development. The feral goats were also an important consideration due to intense overgrazing of Goat Island, and had to be fenced out of the experimental site area.

131. Goat Island has six distinct plant communities dominated by bluestem grass, saltmeadow cordgrass, seashore dropseed, Drummond sesbania and mixed grasses, lemon beebalm, and smooth cordgrass. Most common are the

a. Site immediately after dike and fence construction and vegetation planting in 1977

b. Site in 1982 from the same ground observation point as in a above

Figure 18. Bolivar Peninsula field site in Galveston Bay, Texas

bluestem grass and saltmeadow cordgrass communities (Dodd et al. 1978).

132. Common wildlife living in the area are red-winged blackbirds, eastern meadowlarks, common grackles, boat-tailed grackles, laughing gulls, armadillos, raccoons, swamp rabbits, cotton rats, and the feral goats. Land invertebrates include grasshoppers, land snails, fiddler crabs, and tiger beetles; marine invertebrates include shrimp, marine worms, copepods, and barnacle larvae.

Site research and development

133. Engineering. The disposal site selected for habitat development was already in existence, but was graded to achieve the elevation and slope needed for marsh establishment. The preexisting vegetation was removed, a fence erected, and a discontinuous sandbag dike placed around the outside in 1975-76. The purpose of the discontinuous dike was to break high energy waves from the northern quadrant yet permit tidal flushing. Details of construction activities are given in Allen et al. (1978).

134. Vegetation and soils. The site was divided into intertidal and upland zones based on elevation, and each zone had a separate experimental design (discussed in detail in Webb et al. (1978)). In the intertidal zone in 1976, seeds and transplants of smooth cordgrass and saltmeadow cordgrass were planted according to the experimental design. In the upland area, sand pine, live oak, salt cedar, wax myrtle, gulf croton, winged sumac, coastal Bermuda grass, bitter panic grass, and bluestem grass also were planted according to the experimental design in 1976. Transplants were used for all upland species. Details of methods, sampling, and analyses are discussed by Webb et al. (1978); Lunz, Diaz, and Cole (1978); and Allen et al. (1978).

135. Sediment samples were taken in both zones just prior to and soon after initial planting.

136. Smooth cordgrass survived, grew, and spread best at lower intertidal elevations, while saltmeadow cordgrass was most successful at upper intertidal elevations. Few plants of either species survived at other than their aforementioned optimum elevations.

137. Elevation also influenced nutrient concentrations, soil moisture, soil texture, pH, Eh, and organic matter content of the dredged material soils. The dike greatly increased sedimentation rates and nutrient levels, an extremely important factor in areas of high energy regimes and low fertility soils. Transplants as propagules were uniformly successful in the intertidal

zone, while seeding only succeeded at the narrow intermediate tidal elevation. Seeds washed out at lower elevations and conditions were too dry to allow germination at higher elevations. Fertilization had no long-term effect.

138. In the upland zone, elevation had only a slight effect. Survival over 15 months ranged from 5.4 percent for bluestem grass to 96.5 percent for live oak. Fertilizer aided survival and growth in the grasses, wax myrtle, and sand pine, but showed no effect on other species. Invasion by Drummond sesbania and other weedy species was significant in the shrub and tree experimental plots and had to be weeded out for the duration of the initial study (through 1977) to allow transplant establishment. No seeding or fertilizing was done in the subsequent study (1978-82).

139. Aquatic biology. Presite and postsite development aquatic sampling made use of seines, trawls, hoop nets, corers, and traps for fish and other aquatic biota (Diaz 1977, Lyon and Baxter 1978, Webb et al. 1978). Forty-seven species of fish were caught prior to site development; most abundant were Atlantic croaker, gulf menhaden, and white mullet. After development, no change was found in total species, but the most abundant fish changed in rank to bay anchovy, white mullet, and Atlantic croaker, respectively. Species diversity was highest for reference and bare areas sampled rather than inside the sandbag dike, but it remained high on the outside edge of the dike.

140. Benthic invertebrates colonized the dike and the site in abundance within 7 months of site preparation; the dominant groups were polychaete worms, a tenanthurid isopod, and haustorid amphipods. Benthic abundance following dike construction was 1.5 times greater inside than outside the dike, and within the dike it was 1.5 times greater again in planted versus unplanted areas.

141. Wildlife. Avian, mammalian, reptilian, and amphibian populations at Bolivar Peninsula were studied to determine presite and postsite development densities and species composition. Details of methods and results are discussed in Allen et al. (1978), Dodd et al. (1978), and Webb et al. (1978). Ninety-eight species of birds were observed prior to site development. A total of 135 species were seen after site development. The least tern, Wilson's plover, killdeer, brown-headed cowbird, red-winged blackbird, and scissor-tailed flycatcher nested on the experimental site.

142. Seventeen mammal species were recorded at the experimental site from 1975-77; the fence kept 5 of the 17 from entering the interior of the

site. The vegetation planted and growing on the site attracted eastern cottontail rabbits, marsh rice rats, and hispid cotton rats onto the site (Webb et al. 1978).

143. Fourteen species of reptiles and amphibians were observed from 1975-77. All were in the upland area and all declined in numbers slightly during the 1975-77 sampling period.

Long-range monitoring

144. Vegetation. Utilizing overflights, boat and truck reconnaissance trips, and consultation by employees of both WES and the Texas Agricultural Experiment Station, three natural (non man-made) marshland areas were selected for comparison to the experimental Bolivar Peninsula habitat development site. One site, Pepper Grove, was on Bolivar Peninsula to the east of the habitat development site. The other two sites, the Eight-Mile Road site and the Jamaica Beach site, were located on Galveston Island (Figure 5).

145. Soil and plant samples were taken at the four sites 28 September-2 November 1978 (Webb et al. 1979) and 29 August-19 September 1979 (Webb and Newling 1980). Site visitations also were made during the fall in 1980, 1981, and 1982 with quantitative plant observations made in 1982 (Figure 18b).

146. The Galveston District established bench marks with known elevations near each reference area marsh. From these bench marks, survey lines were run to each site to establish sampling points at selected elevations within each site.

147. The elevations selected for sampling in 1978 were 0.655, 0.427, and 0.198 m above mean low water, roughly dividing the intertidal zone into thirds. During 1979, two additional elevations, 0.54 and 0.31 m, were sampled besides the three in 1978. Six sample points at each elevation in the three natural marshes were established at 20-step intervals along the elevation contours in each area. In 1978, the sample points of the experimental marsh were located only in smooth cordgrass plots.

148. Aboveground vegetation was measured within a 0.5-m^2 quadrat at each sampling point. Measurements taken were the following: standing live biomass, standing dead biomass, living stem density, and stem height of smooth cordgrass stem density and aboveground biomass of annual glasswort; aboveground biomass of all other species in the quadrats; percent cover; root biomass at three depth increments; and total aboveground biomass. (Unless specifically referred to as "dead," measurements refer to "living" or "green"

plants.) Aboveground biomass was clipped 2 cm above the ground, separated by species, oven dried to a constant weight, and weighed. Biomass was reported in units of grams dry weight per square metre. Height was the average extended leaf height or tallest portion of ten randomly selected plants of smooth cordgrass. Percent foliar cover was visually estimated without regard to species present.

149. During 1979, belowground biomass was determined at 10-cm increments to a depth of 30 cm (Webb and Newling 1980). Three 10.16-cm-diam polyvinyl chloride (PVC) pipes were driven into the marsh soil after aboveground biomass had been clipped. Each pipe was dug from the marsh and the sample of roots mixed with soil was extruded from the pipe. Each sample was cut into 10-cm sections and the segments from each of the three corresponding depths were placed into one plastic bag. Composite root cores were washed, dried, and weighed as in 1978. The root dry weight was multiplied by a conversion factor to transform the data to that equivalent to 1 m^2.

150. The Bolivar Peninsula experimental site appeared to be different from the natural marshes in various aspects in 1978. Height of smooth cordgrass and standing biomass were greater but biomass of invading species, belowground biomass, and percent cover were less than that of natural marshes (Table 19). An exception was percent cover of Pepper Grove. Pepper Grove and the Bolivar Peninsula experimental site, both located on Bolivar peninsula, were similar in percent cover while the two Galveston Island marshes were similar with substantially higher percent cover values.

151. By 1979, Bolivar Peninsula and the natural marsh reference areas were generally similar in most measurements. Standing biomass was still slightly greater in the experimental marsh than the natural marshes, but height was similar (Table 20). Belowground biomass was again lower at the experimental marsh than the natural marshes. In addition, living stem density of smooth cordgrass in the experimental marsh was lower than the natural marshes. Aboveground biomass and density of invading annual glasswort was much higher at the experimental site than the natural sites.

152. The data, in general, indicated that the Bolivar experimental site was still a young, developing site. The lower root mass, density, and percent cover but greater biomass of smooth cordgrass and annual glasswort in the experimental marsh seem to indicate that: (a) abundant nutrient supply from recent natural deposition of fine-grained sediments allowed robust growth of

existing stems, (b) density of stems and root biomass of smooth cordgrass had not yet reached that which normally exists in natural marshes, and (c) open spaces among plots of the experimental site allowed colonization by the annual glasswort in large numbers.

153. Considering all of the sites combined, the 1978 data indicated that a noticeable gradient in measurements occurred from the lowest elevation to the highest elevation in most parameters measured (Table 21). The greatest magnitude was measured at the lowest elevation and the least at the highest elevation for aboveground live biomass, aboveground dead biomass, density of dead stems, and percent foliar cover. Height was greatest at the lowest elevation, followed by the high elevation. The greatest number and biomass of invading species were at the upper elevation followed by the middle elevation. No invaders were recorded at the lower elevation (0.198 m). Litter biomass was greatest at the upper (0.655 m) elevation.

154. The 1978 data for the four sites combined also indicated that the greatest belowground biomass (2390.5 g/m^2) occurred at the middle (0.427 m) elevation (Table 21). The lowest combined belowground biomass (986.2 g/m^2) was at the upper elevation. Belowground biomass at the lowest elevation was relatively high (1992.3 g/m^2).

155. At the upper elevation, the amount of belowground biomass was greatest at the 0- to 5-cm depth (394.2 g/m^2) and declined at each successively deeper increment (Table 21). However, at the 0.427- and 0.198-m elevation, the greatest biomass was at the 5- to 10-cm depth followed by the 0- to 5-cm and 10- to 15-cm depth, respectively. Belowground biomass declined at each successively deeper increment from the 10- to 15-cm depth to the 20- to 25-cm depth. The lower biomass at the 0- to 5-cm depth seemed to be partially due to a layer of actively depositing silt at the substrate surface that contained no roots.

156. The 1979 data for all sites combined (Table 22) again indicated that elevation significantly influenced plant species composition, production, and density. Aboveground live biomass, stem density of live smooth cordgrass, percent foliar cover of all species, and belowground biomass at the 0- to 10-cm depth were greatest at the 0.3-m elevation. For all species except smooth cordgrass, measurements were higher at each successive increase in elevation. The data indicated that smooth cordgrass was the dominant vegetation from the 0.20-m through the 0.43-m elevation. However, at the 0.54-m elevation, weight

of aboveground biomass of all other species except smooth cordgrass and annual glasswort was twice as great as that for smooth cordgrass. Mean height of smooth cordgrass (100.7 cm) was highest at the 0.20-m elevation and declined in height with each successively higher elevation to a low of 32.3 cm at the 0.66-m elevation.

157. In general, belowground biomass increased at each depth increment with decreasing elevation, but there were four exceptions, the 0.66- and 0.31-m elevations at the 0- to 10-cm depth, 0.54-m elevation at the 10- to 20-cm depth, and the 0.43-m elevation at the 20- to 30-cm depth increment. Total belowground biomass was greatest at the 0.31-m elevation and decreased at each successively higher elevation. It was also relatively high at the lowest elevation. At each elevation, belowground biomass was greatest at the 0- to 10-cm depth, and decreased at each lower depth.

158. Considering site-by-site differences in elevation, 1978 data indicated that few parameters exhibited similar patterns. Aboveground live biomass was greatest at the lowest elevation and decreased with each higher elevation (Table 23). Except for the middle and upper elevation at the Bolivar Peninsula experimental marsh, height followed a similar pattern at each site. The lack of obvious patterns by other characters probably reflects variations both within and between sites.

159. The 1979 data for natural reference marshes were combined and compared to the experimental site by elevations (Table 24). Aboveground live biomass and stem density of smooth cordgrass, and biomass and density of annual glasswort at the two higher elevations (0.54 and 0.66 m), were much greater at the experimental site than the natural marshes. Height of smooth cordgrass at all elevations was greater at Bolivar Peninsula than the three natural marshes. Belowground biomass on Bolivar Peninsula was less than at the natural marshes at all elevations. Combined aboveground biomass of all other species was greater in the natural marshes than at Bolivar Peninsula at all elevations but 0.66 m. This greater aboveground biomass of other species at the 0.66-m (highest) elevation on Bolivar Peninsula resulted from biomass produced by saltmeadow cordgrass, which continued to maintain a population after being transplanted at that elevation in 1976. Percent cover was variable with elevation and area.

160. When comparing vegetation data, aboveground live biomass and stem density of smooth cordgrass at Bolivar Peninsula were about the same in 1978

and 1979 (Tables 19 and 20). However, in the three natural reference marsh areas, aboveground live biomass of smooth cordgrass was from 132 g/m^2 to 261 g/m^2 greater in 1979 than in 1978 and living stem density varied from 21 to 98 more $stems/m^2$ in 1979 more than in 1978. Between 1978 and 1979, number of stems of annual glasswort greatly increased at Bolivar Peninsula, but greatly decreased at Jamaica Beach. Despite the greater stem density, aboveground biomass of annual glasswort at the Bolivar experimental site was less in 1979 than in 1978. Aboveground biomass of other invading species increased substantially from 1978 to 1979 at each site except Eight-Mile Road where a decrease occurred. Total belowground biomass appeared to be greater in 1979 than in 1978 at Bolivar Peninsula and Pepper Grove, similar at Eight-Mile Road, but less at Jamaica Beach.

161. Belowground biomass was taken at 5-cm increments in 1978 and 10-cm increments in 1979. Belowground biomass declined with each increasing depth in 1979. In 1978, belowground biomass decreased with increasing depth below the 10-cm depth at all sites; Bolivar Peninsula and Pepper Grove had less biomass at the 0- to 5-cm increment than the 5- to 10-cm increment, Eight-Mile Road had more, and Jamaica Beach had about the same.

162. When measurements at each elevation were compared for 1978 and 1979, living stem density and aboveground biomass of glasswort at the 0.20-m elevation and percent cover at the 0.43-cm elevation were the only measurements similar between years (Tables 21 and 22).

163. The greater quantity of aboveground biomass and the lower belowground biomass at Bolivar Peninsula as compared to the three reference areas appeared to indicate differences between the habitat development site and the natural marshes. However, the broad range of values for each of the parameters measured in each marsh and the variations by elevations indicated that differences probably were not due to planting. The range of variability for the values obtained for each reference marsh was large. These differences may reflect particular site characteristics and variations in plant response to variable environmental conditions such as differences in substrate and in wave climate.

164. Large biomass values with low percent cover and low root biomass values indicated that the experimental marsh at Bolivar Peninsula was still in a developing stage. Large robust stems and aboveground plant parts were correlated with fewer stems and less belowground biomass per unit area.

165. Belowground biomass for smooth cordgrass was greater near the soil surface (upper 10 cm). Low root biomass at the 0- to 5-cm depth at some sites was apparently due to silt accumulation at the substrate surface and elevation of the site in relation to the tide. Belowground biomass declined with increasing soil depth. Few roots were present below the 25-cm depth, particularly at upper elevations.

166. Invading species occurred only at the elevations above mean high water. Annual glasswort was the most numerous plant invader. High values for stem density of annual glasswort at the experimental site were due to invasion by this plant at the unplanted "control" plots.

167. In 1982, eight random 0.5-m^2 quadrats were sampled in both low and high elevations throughout the intertidal zone with all data combined (Table 25). The Bolivar Peninsula habitat development site fell within the range of variability or exceeded that found at the three reference areas with regard to species diversity, stem density, mean stem height, frequency of occurrence, and mean percent cover for species that occurred on the experimental site. Mean number of flowering stems per unit area was lowest for saltgrass and highest for smooth cordgrass on the site. These data reinforce conclusions of the 1978-1979 data.

168. General observations. In 1982, the Bolivar Peninsula habitat development site was thriving with no areas unvegetated. Feral goats were abundant on the island, but the protective fence erected in 1975 and reinforced in 1982 was still keeping grazing goats off the site. The contrast between inside and outside the fence was striking. Inside the fenced experimental site, marsh grasses were 150 cm tall, and outside the fence, 5 to 10 cm tall. While the major effect of grazing was most easily observed in the marsh area, very little grass or edible forbs escaped grazing in the upland portion of the island.

169. The bayside or north segment of the sandbag dike that was placed to prevent washout of the marsh plants in 1975-76 was no longer visible at either high or low tides during the 1982 site visit. It had either rotted or sunk into the bay sediments, but on its remains and around it was a healthy oyster reef containing harvestable oysters. The oyster reef appeared to serve the same purpose that the sandbag dike did, and was preventing wave action from breaking up the marsh edges. On the east and west sides of the site where sandbags were placed intermittently to prevent bay waters from sweeping into

the site from the side, the sandbags were barely visible because of sand accumulation and dense vegetation.

170. Smooth cordgrass in the intertidal portion of the marsh averaged just under 1 m in height and was dense and vigorous. The tallest grass, some of it reaching 1-1/2 m in height, was behind the sandbag berm/oyster reef at the lowest marsh elevations. At the water's edge, the smooth cordgrass was approximately 1 to 1.3 m tall. In the higher marsh portion, the random plots which were sampled contained smooth cordgrass, saltmeadow cordgrass, perennial glasswort, fimbristylis, and saltgrass. On an elevational belt transect walked from intertidal zone to the uplands fence, the following species were encountered and are listed in order of their appearance: smooth cordgrass, saltmeadow cordgrass, saltgrass, perennial glasswort, fimbristylis, groundsel tree, marsh fleabane, seaside goldenrod, American three-square, perennial salt-marsh aster, plantain, Indian blanket, common ragweed, aster, camphorweed, soft camphorweed, Drummond sesbania, fleabane, broom sedge, bushy beardgrass, and beach-tea.

171. The Pepper Grove marsh reference site is located on the next island east of Goat Island, the location of the experimental site. It is a natural salt marsh with clayey/silty/sandy soils. The intertidal zone is dominated entirely by smooth cordgrass and is surrounded on the bay side by a natural gravel and shell berm that has been building progressively higher each year. Of the four intertidal quadrats sampled in 1982, two contained only smooth cordgrass, and two contained both smooth cordgrass and a small amount of saltgrass. Stem heights at Pepper Grove were much lower compared to those of the Bolivar site. The higher marsh quadrats all contained both smooth cordgrass and saltgrass. Again, the stem heights were lower than at the experimental site.

172. The Eight-Mile Road marsh reference site is located on the west side of the City of Galveston, along the bay. The site has a large salt pan in its center and has been and continues to be grazed by cattle. The low marsh here was all smooth cordgrass; the high marsh was dominated by perennial glasswort, saltwort, and saltflat grass, with some saltgrass and saltmeadow cordgrass occasionally occurring. In 1982, the intertidal marsh quadrats contained only smooth cordgrass; it was rather short, contained fewer flower heads per unit area than the experimental site, and occasionally had been grazed. The quadrats in the higher marsh contained smooth cordgrass,

perennial glasswort, saltwort, saltflat grass, and saltgrass. The smooth cordgrass appeared quite stressed in the higher marsh quadrats. Other plant species observed included sea oxeye, marsh elder, dropseed grass, black needlerush, annual glasswort, common ragweed, saltmeadow cordgrass, gulf cordgrass, maritime pinweed, and sea lavender.

173. The Jamaica Beach marsh reference site had a very high salinity with salt pans scattered throughout. It had patchy smooth cordgrass stands that seemed healthy where they occurred. It appeared that at least one high spot in the study area must have had decreased salinity. This was because black needlerush, sea oxeye, gulf cordgrass, and other high marsh brackish plants tolerant of less saline but brackish conditions were dominant. In the 1982 intertidal quadrats, smooth cordgrass was the only plant species present. Mean stem height and percent cover were lower than at the experimental site. The only two species present in the higher marsh quadrats were smooth cordgrass and perennial glasswort; the smooth cordgrass appeared quite stressed in these locations. Other plant species observed on this site were annual glasswort, saltwort, sea lavender, saltgrass, saltmeadow cordgrass, seaside goldenrod, camphorweed, saltflat grass, and marsh elder.

174. Wildlife. Limited wildlife observations were made at Bolivar Peninsula from 1978-1981. During the 1982 survey, signs of use by raccoons, armadillos, and cottontail rabbits were found at the site. Outside the fence, tracks of a large canid, many raccoon tracks, and many goat tracks were found. Goats grazed and walked to the edge of the fence. Birds sighted during the survey were long-billed curlews, willets, great blue herons, least terns, common terns, Forster's terns, royal terns, laughing gulls, mourning doves, clapper rails, seaside sparrows, marsh wrens, eastern meadowlarks, killdeer, least sandpipers, dunlins, and sanderlings. During the 1982 site visit to Pepper Grove site, the following bird species were observed: clapper rails, dunlins, least sandpipers, laughing gulls, great blue herons, willets, ruddy turnstones, and great egrets. Wildlife observed at Eight-Mile Road included long-billed curlews, great blue herons, clapper rails, common egrets, and belted kingfishers. Wildlife species sighted at Jamaica Beach included little blue herons, great blue herons, great egrets, clapper rails, belted kingfishers, and long-billed curlews.

175. Aquatic biology. Studies which were conducted before site preparation in January 1976 and after development of the marsh in June 1976 to

establish the utilization of the area by aquatic organisms were summarized by Allen et al. (1978). In 1978, additional aquatic studies were conducted to look at longer term changes (3 years) and establish whether or not the developed habitat was similar in benthic community structure to a nearby natural marsh. The benthos were chosen for further study because of their trophic importance to many of the fishes in the area.

176. Samples for macrobenthos (animals retained in a 500-μm sieve) were collected in May, July, and August of 1978 from both the habitat development marsh and Jamaica Beach. In addition, nine exclosure cages, 6-mm mesh and 0.25 m^2 in area, were placed at both marshes from May to July and again from July to August to assess the response of the macrobenthos to protection from predation. A 7.5-cm-diam by 10-cm-deep corer was used for all sampling. Four replicate core samples were collected at each of nine stations at each marsh. Four cores were also taken from each cage in July and August at each marsh location. Samples were washed in water over a 500-mm sieve, preserved in 10 percent buffered formalin solution and Rose Bengal stain, and transported in sealed plastic bags to the laboratory for picking, sorting, and identification.

177. Sediments from the two marshes were not the same. The Jamaica Beach marsh sediments were consistently higher in percentages of organic matter, water content, and fines (silts and clays) than were the experimental marsh sediments; the experimental site was sandier. Through time (May to August 1978), the amount of organic matter and water content of the experimental site increased, while at the natural marsh there was no change except in water content, which increased slightly in August (Table 26).

178. Macrobenthic communities at the habitat development and Jamaica Beach marshes were dominated by polychaete worms which constituted over 90 percent of all individuals and 55 percent of all species collected. This is typical of the estuarine communities found in the area (Lyon and Baxter 1978, Webb et al. 1978). From the total number of species collected (51) there were 14 dominants that accounted for over 95 percent of all individuals (Table 27). Only three of the dominant species were not polychaetes (*Paleomonetes* spp., *Corophium* sp., and *Hargaria rapax*). While the three dominant species of the highest order occurred at both marshes, densities of *Streblospio benedicti* and *Capitella capitata* were higher at the Jamaica Beach marsh than at the habitat development marsh. *Heteromastus filiformis* densities were

higher at the experimental site, except in late summer (August-September) when *Heteromastus* densities increased at Jamaica Beach. Other species occurred as dominants only at one of the marshes. *Paleomonetes* spp. and *Loandalia fauveli* occurred primarily at the experimental site, while *Corophium* sp., *Hargaria rapax*, *Polydora ligni*, *Laeoneris culveri*, and oligochaetes occurred at the Jamaica Beach marsh. The other four dominant species occurred sporadically at both sites (Table 27).

179. The distribution patterns of the less common species within each marsh are difficult to discern but between the marshes there were large numbers of species (60 percent of the total) that occurred predominantly at only one marsh. There were 19 less common species collected at the experimental habitat development marsh and 12 predominantly at the Jamaica Beach marsh. This large proportion of rarer species is not unusual and was also found to be the case in 1976-77 at the habitat development site (Lyon and Baxter 1978, Webb et al. 1978). The distribution of rarer species does reflect some basic differences between the two marshes, some of which are related to the sediments and others possibly to the age of the marshes. For example, *Macoma constricta*, a burrowing clam, was found only at the experimental site. It was present at the site before marsh construction and large individuals were found after construction in 1977 and 1978, indicating survival through the marsh preparation and planting phase. This clam was not found at the Jamaica Beach marsh probably because of the combination of higher percentages of organic matter and fines (silt and clay) in the sediment.

180. As the experimental site ages and the sediments become more marsh-like (with the accumulation of organic matter and fines), *Macoma constricta* abundance will probably decline. Others of the rarer species at the habitat development marsh are likely in the same category as *Macoma*. They were present before or during preparation and planting of the experimental site and will slowly be displaced as the marsh habitat develops. The isopod *Xenanthura brevitelson* changed most dramatically from a dominant in 1976 to only two occurrences in 1978. It did not occur at the Jamaica Beach marsh in 1978.

181. There were, on average, more macrobenthos at the Jamaica Beach marsh for all sampling dates. In May, the two marshes were most similar with about 8,000 individuals/m^2 at each marsh. In July, numbers dropped at both marshes with about 1,600+ individuals/m^2 at the habitat development site and 3,800 at the Jamaica Beach marsh. By August-September, the habitat

development site was unchanged (1,700+) and the Jamaica Beach marsh increased to about 23,000+ individuals/m^2. It is likely that the differences between the sites were due to differences in recruitment, predation pressure, or sediments. The habitat development marsh, being more of an isolated or island habitat, may attract greater numbers of the transient species as they migrate along Bolivar Peninsula and be subject to heavier utilization than the Jamaica Beach marsh which is part of a larger marsh system.

182. Results of the caging experiment indicated that the cages appeared to have very little effect on the sediment properties measured (Table 26). The only noticeable exception occurred in September at the Jamaica Beach marsh when the average percent of organic matter, water content, and fines within the cages all increased. The changes in sediments at Jamaica Beach in September made comparison to the habitat development marsh difficult since the macrobenthos may have been responding more to the changed sediments (a cage effect) than to predator exclusion (Virnstein 1977). Therefore, only the May to July cage experiments were used to evaluate the two marshes.

183. From the May-July cages, 4 of the 14 dominant species showed a positive increase in densities as a result of caging (Table 27). *Streblospio benedicti*, the overall dominant at both marshes, was the only species to increase at both sites. *Heteromastus filiformis* was the only other species to increase in abundance at the experimental site. At the Jamaica Beach marsh, *Capitella capitata* and *Laeoneris culveri* also increased. All four of these species have opportunistic life histories. They can reproduce quickly to take advantage of unoccupied space and may form an important trophic base for other species (Rhodes, McCall, and Yingst 1978). Although the response observed to caging was not as great as reported by other workers (Virnstein 1977), there was indication that both marshes responded as predicted (increased populations of some species) to caging and were likely functioning similarly with respect to utilization by predators.

184. Samples collected in September and August from the sites where the cages had been in May-July indicated more species declined in abundance at the experimental site after removal of the cages than at the Jamaica Beach marsh. Most of the dominant species at the Jamaica Beach marsh seemed to increase in abundance by September (Table 27). The differences between the two marshes have been related to differences in predation pressures. The habitat development marsh may be more heavily utilized by fish and crabs than the Jamaica

Beach marsh. It is known that fish heavily utilize the habitat development site (Allen et al. 1978). The differences could also have been related to differences in the sediments or a combination of these factors.

185. Sediments sampled in 1978 appeared to have become considerably finer (increased silts and clays) since 1975. The experimental site was almost 100 percent sand in 1975. Shortly after marsh construction a veneer of fine sediment started to accumulate on the surface of the sandy dredged material, which formed the foundation for the developed marsh. By May 1978, the sediments were about 78 percent sand. In September, the accumulating fines decreased the sand percentage to approximately 70 percent. Organic matter also accumulated in the developed marsh sediments. In 1976-77 there was virtually no organic matter in the sediments and by September 1978 there was about 2.5 percent.

186. Species dominance differed at each sampling period (Table 28). The shift in dominance reflected the major changes associated with the transition from a shallow-intertidal sandy community to a marsh community. *Xenanthura brevitelson* and haustoriid amphipods, two taxa very characteristic of sandy intertidal areas, dropped drastically in abundance from 1975 to 1976-77 and by 1978 were virtually absent from the habitat development site. Other species were favored by the marsh development. *Mediomastus* spp., *Streblospio benedicti*, and oligochaetes increased greatly in abundance. These species in particular, as well as many of the other species found at the site, have life histories that take advantage of areas that are disturbed or changed. By 1978, these species, along with *Loandalia fauveli*, became the top four dominants at the site. *Paleomonetes* spp., grass shrimp, which are very typical of vegetated areas, also appeared there in 1978, indicating that the developed marsh was also attracting common marsh species.

187. From 1975 to 1976-77, there was a trend of reduced diversity among the dominants, which, by 1978, was reversed with the influx of grass shrimp. In terms of trophic support to fisheries, the decline in taxa and particularly the loss of the important isopod *Xenanthura brevitelson* may have been offset by the colonization of grass shrimp and increased abundance of polychaete worms. By 1978, the habitat of the experimental site seemed to provide equal, if not greater, potential trophic support to fisheries. The site's trophic value will increase if additional epifaunal species, particularly amphipods, colonize the site. This is likely to happen if data collected at the

Jamaica Beach marsh are representative of older marshes along Bolivar Peninsula.

188. Sediments at the habitat development marsh have become finer (increased silts and clays) with corresponding increases in the percentage of organic matter and water content. This is a result of both the dike protecting the marsh and the marsh plants themselves. With time, the sediments should become very similar to those found at the Jamaica Beach marsh.

189. The macrobenthos have changed from a shallow-intertidal sand community toward a mud flat-marsh community as evidenced by taxonomic shifts in species occurring and increased abundance patterns. While the trophic role of the habitat development marsh could not be quantified, feeding habit studies of fish (Allen et al. 1978) combined with the macrobenthic data indicate an upward trend in trophic value. The increased numbers of polychaetes and presence of grass shrimp support this contention.

190. The developed marsh had lower densities of individuals as compared to the Jamaica Beach marsh. The two likely reasons for this are differences in sediments between the marshes or utilization by predators. The higher content of finer organic sediments at the Jamaica Beach marsh could possibly support larger populations of macrobenthos, or the developed marsh could be acting as an island habitat attracting greater numbers of predators as they migrate along Bolivar Peninsula. While both marsh communities responded positively to caging (predator exclusion), the response was not as great as expected or reported in other systems.

191. Two years after planting, the benthic community of the experimental habitat development marsh has attained a close resemblance to a nearby natural marsh. While there are still large differences in communities, they are less than in 1977. The fauna will likely become more similar to that of a natural marsh as the sediments at the habitat development site continue to become more marshlike.

Summary

192. The habitat development site at Bolivar Peninsula was successful. A vigorous wetland plant community comparable to that of nearby natural marshes dominates the intertidal portion of the site. A vigorous plant community dominated by grasses completely covers the upland portion of the site. The fence around the habitat development area appears to be an important factor protecting the site from intense grazing pressure by goats. Wildlife use

appears to equal or exceed that observed on the nearby natural reference areas. The protective sandbag dike is sinking but has been partially replaced by a developing reef of oysters and encrusting organisms. Surface sediments in the intertidal zone have progressively accumulated more fines and organic material.

193. By 1978, a benthic community had developed which appeared capable of providing equal if not greater potential trophic support to fisheries. Although there were differences, the benthic community had attained a resemblance with that of a nearby natural marsh. As the sediments continue to accumulate more fines and organic matter, they will resemble those natural marshes more closely, and it is likely that the benthic community will also become progressively similar to that of a natural marsh.

Salt Pond #3 Wetland Field Site

Site history and description

194. The Salt Pond #3 wetland habitat development site is located on the north side of Alameda Creek Flood Control Channel, in South San Francisco Bay, California, and was a 40.4-ha, confined, saltwater evaporation pond prior to marsh development (Figure 19a).

195. Area rainfall averages 40 cm, most of which usually occurs from November to March. The climate is characterized by cool, foggy, wet winters and cool, dry summers. Winter storms can be severe on the coast and in the general area.

196. San Francisco Bay marsh soils are usually predominantly clay with some very fine silt and sand. Soil moisture content and particle size are the primary factors affecting colonization, survival, and growth of marsh plants at and above the high tide line. The magnitude of the tides makes survival of salt marsh plants below high tide very difficult, and there are considerable stretches of mud flats in the bay at low tide (Morris and Newcomb 1977).

197. The area's tidal marshes are dominated by Pacific cordgrass and perennial glasswort (also known as Pacific glasswort). The higher marshes are primarily a mixture of frankenia, jaumea, saltbushes, sand spurry, and saltgrass.

198. Primary wildlife use in the bay area is by waterbirds and waterfowl, especially during migration. Gulls, terns, some wading birds, and

shorebirds frequent the mud flats and marshes. In winter, waterfowl use occurs at varying levels. The San Francisco Bay Wildlife Refuge borders Alameda Creek to the south and is used by 33 species of waterfowl. It also provides the remaining habitat for the California clapper rail and is used by least terns and brown pelicans.

199. Tidal ranges of 1.5 to 3.2 m, with averages of 2.7 m, occur at the site; water salinity is approximately 20 to 30 ppt.

200. Little predisposal biological assessment was made at the site; it was initially treated as a demonstration site not on an investigative level with Miller Sands, Bolivar Peninsula, Windmill Point, Nott Island, or Buttermilk Sound. No predisposal wildlife or benthic surveys were made, although some limited studies were conducted by the San Francisco District in 1973 (Morris and Newcomb 1977).

Site research and development

201. Engineering. From 1965-72, Salt Pond #3 had been dry; in December 1972, the dike was breached and some influx of tidal waters and invertebrate colonization took place. The dike breach was closed in early 1974, and approximately 500,000 m^3 of clay/silt dredged material from the Alameda Creek Flood Control Channel was hydraulically pumped into Salt Pond #3. In October 1975, a large, permanent breach was made in the dike to allow intertidal action to occur. Desiccation cracks of considerable size formed. As a result, the dredged material had to be "pulverized" by a tracked vehicle in 1976 to fill in the cracks and form a more suitable substrate for plant establishment, particularly for testing the potential success of seeds. No elevational or grading work was done. Engineering details are given in U. S. Army Engineer District, San Francisco (1976) and Morris and Newcomb (1977).

202. Vegetation. Transplants of three species of west coast intertidal plants, Pacific cordgrass, Pacific glasswort, and pickleweed, were obtained from nearby marshes and planted between April 1976 and February 1977 according to the experimental design, details of which are outlined in Morris and Newcomb (1977) and Morris et al. (1978). Plant survival, shoot density, and biomass were determined on all plots. Evaluations of optimum plant spacing, substrate preparation, planting techniques, and planting seasons were made at the site. Both seeds and transplants were used as propagules on some plots.

203. Seeds as propagules were uniformly unsuccessful while transplants, in general, were successful. Transplants on 0.5-m centers gave best results,

a. Site prior to development as a salt marsh

b. Site in 1982 from the same ground observation point

Figure 19. Salt Pond #3 field site in South San Francisco Bay, California

and those planted on unprepared substrate and those that were hand planted were the most successful over a 2-year period. Pacific cordgrass covered the lower two thirds of the intertidal area, and pickleweed and Pacific glasswort covered the upper one third. While spring appeared to be the best time to plant sprigs, survival was generally high throughout the April to February planting period. Hand-planted transplants had more than a 50 percent greater survival rate than mechanically planted sprigs, and grew and spread faster (Morris et al. 1978).

204. Substrate. Samples were taken in 1975 to characterize the dredged material substrate. Analyses showed extremely high salt concentrations ranging from 70 to over 100 ppt; normal sea strength is 30 to 35 ppt. In addition, pHs were higher than those usually found in salt marsh soils. The substrate was found to be 95 percent silty clay (U. S. Army Engineer District, San Francisco 1976). These high concentrations of salt were probably the reason no seeds survived in the dredged material, as cordgrass seeds and seedlings are known to germinate and survive best in fresh water up to 10 ppt, conditions often found in early spring in many estuaries (Mary C. Landin, unpublished data). Highly saline conditions are toxic to seeds and very young cordgrass plants. The high pH presented no apparent problem with plant survival.

205. Aquatic biology. Benthic invertebrates were collected in 1976-77 using an Ekman grab sampler. Major groups which were found in the lower two thirds of the new marsh included nine species of polychaetes, seven species of amphipods, one species of isopod, and one species of gastropod. Four other groups were found in low numbers. All benthic invertebrate populations increased as the salt marsh began to develop after planting. All populations were lower than in the nearby reference area on Alameda Creek. This difference was probably due to both the newness of the habitat and also to the very high salinity of the substrate which the animals had to colonize.

206. No fish data were collected either during the predisposal or postdisposal activities.

207. Insect population changes were monitored at the site from 1974-77. When the dredged material was first placed and until the site was planted, almost no insect occurrence was noted. By 1976-77, however, nine species were collected in the upper marsh. Only two species were found in the lower marsh, and both did not occur until 1977. Predominants were brine flies, spider

mites, and beetles in various life stages. Details of methodologies, techniques, and analyses are discussed in Morris and Newcomb (1977).

208. Wildlife. Only avian wildlife use of the site and reference marsh was noted during nine observation periods from May 1976 until July 1977. A total of 39 species were sighted in Salt Pond #3; 49 species were sighted on the Alameda Creek reference area. These were predominantly shorebirds, waterbirds, and waterfowl, and did not seem to be affected by seasons with the exception of the shorebirds. Shorebirds were more abundant in spring and fall during migration. Populations for all species increased in Salt Pond #3: 14 species were found in the initial survey and 20 species were found in larger numbers in the final survey. More species were seen during high tide than during low tide. All species were typical of the South San Francisco Bay area. Only five species of waterfowl used the site compared to eight species in the reference marsh; however, no significant difference in population levels was found (Moorhouse 1977).

Long-range monitoring

209. Annual visits were conducted from 1978 to 1982 to the Salt Pond #3 habitat development site to make qualitative observations on its physical condition, plant communities, and wildlife populations (Figure 19b). Observations were made of the plant community and site sediment characteristics in 1978 (Morris, Newcomb, and Wells 1979).

210. Three natural marshes in the South San Francisco Bay area were selected as reference areas with which to compare data collected at the experimental site. They were located near Mayfield Slough (Palo Alto area), Plummer Creek, and Coyote Creek (Figure 6). Each site had fine-textured sediments and possessed relatively gentle slopes as opposed to abrupt drop-off slopes of some creeks and sloughs. At each, a higher and a lower intertidal area were chosen for sampling depending on the dominance of glassworts, primarily perennial glasswort, or Pacific cordgrass, respectively, that usually occur in patches.

211. The Mayfield Slough reference site is a protected area on the west side of South San Francisco Bay. The slough is relatively short as a result of being diked to the west, and Palo Alto Yacht Harbor is on the north side. Perennial glasswort is the dominant intertidal plant species of the higher intertidal zone. Cordgrass growth is dense, but mostly restricted to a border of the deeper channel of the slough. The Plummer Creek marshland site is

protected from strong wave energies by two adjacent salt pond levees and by the general configuration of the creek. The Coyote Creek site is protected from wave energies by a salt pond levee on three sides and a narrow fetch on the north side.

212. In 1978, botanical and soil/substrate sampling at each of the four sites was conducted by establishing transects at two elevations, the high or "glasswort zone" and the low or "cordgrass zone." At each elevation, quadrats of plant material and soil cores were measured to provide data on biomass standing crop, plant height, depth profile of belowground or root biomass, and physical and chemical analyses of soil cores (see Morris, Newcomb, and Wells (1979) for details of sampling methods).

213. Botanical monitoring. The standing crop biomass for Pacific cordgrass differed significantly among the four sites in 1978 (Table 29). Mayfield Slough standing crop biomass was greater than that from the other three sites. Standing crop biomass did not differ for the Coyote Creek and Plummer Creek areas, while Salt Pond #3 standing crop biomass was not different from Plummer Creek but was significantly less than for Coyote Creek. Standing crop biomass of Pacific cordgrass for the experimental site was only 36 percent of that for Coyote Creek and only 43 percent of that from Mayfield Slough. The standing crop of perennial glasswort biomass of the experimental site was less than 10 percent of that for the three natural marshes (Table 29). There were no significant differences among the three natural marshes and all had greater biomass than Salt Pond #3.

214. Root biomass of Pacific cordgrass varied significantly among the four sites and five substrate depths at each site (Table 29). There was no significant site-by-substrate depth interaction. Pacific cordgrass root biomass was greatest at Mayfield Slough, equivalent at Plummer and Coyote Creeks, and least at Salt Pond #3. All results are reported as grams per 233 cm^3 (the volume of the 7.7- by 5-cm core section).

215. Pacific cordgrass biomass did not differ with soil depth for the 0- to 5-, 5- to 10-, 10- to 15-, and 15- to 20-cm sections. The 20- to 25-cm section had significantly lower biomass than did the 5- to 10-, 10- to 15-, and 15- to 20-cm sections; however, it was not less than the 0- to 5-cm section. These data indicate a trend toward maximum Pacific cordgrass root biomass at the 5- to 20-cm depth with reductions above and below this depth within the soil.

216. Perennial glasswort root biomass showed significant differences among sites and substrate depths; however, there was not a significant interaction among sites and soil depth. As was true of standing crop biomass of perennial glasswort, root biomass for Salt Pond #3 was less than 10 percent of that measured for the three natural marshes. Perennial glasswort root biomass for the three natural marshes did not differ significantly.

217. Perennial glasswort root biomass at the natural marshes was significantly greater for the 0- to 5-cm depths as compared to the lower depths. There was a trend for root biomass to continue to decrease with soil depth; however, there were no significant differences among the four lower depths (5 to 25 cm, at 5-cm increments).

218. Stem height of Pacific cordgrass at Mayfield Slough was significantly greater than that measured at the other three sites (Table 29). Stem height at the three remaining sites did not differ significantly.

219. Mean depth of the perennial glasswort plant biomass layer varied in decreasing order from site to site as follows: Mayfield Slough, Plummer Creek, Coyote Creek, and Salt Pond #3 (Table 29).

220. For plant cover, the lower elevations at all sites were dominated by Pacific cordgrass which provided 75 to 100 percent cover in all quadrats except one each at Plummer Creek and Salt Pond #3; the two exceptions represented bare areas occurring randomly in the marsh. There were occasional perennial glasswort plants in the low elevation quadrats; however, they did not provide any significant amount of ground cover.

221. Perennial glasswort dominated the upper elevation quadrats and also provided 75 to 100 percent ground cover at the three natural marsh sites. The Salt Pond #3 perennial glasswort cover averaged 10 to 25 percent. At the higher elevations of the natural marshes, salt grass and Pacific cordgrass occurred as occasional individuals in many quadrats; however, neither species provided significant plant cover.

222. The mean standing crop biomass of the three natural reference areas was 844 g/m^2 for cordgrass, which is 56 percent of the mean glasswort biomass (1501 g/m^2). The corresponding data for Salt Pond #3 were much lower (Table 29). The total of root biomass per 25-cm core sample extrapolated to biomass per square metre area for comparative purposes is approximately 362 g/m^2 for Pacific cordgrass and 680 g/m^2 for the glassworts. The actual total figure for root biomass is greater depending on the amount of root

biomass below the 25-cm depth sampled by the core. The amount of cordgrass standing crop growth is a fraction of the amount of belowground tissue; this provides an index of community age and development. However, the relationship is not so simple for the glassworts. The glasswort zone consisted almost entirely of perennial glasswort. In the San Francisco region, annual growth occurs at the tips of the branches and stems, but woody growth from previous seasons persists over long periods of time. This growth builds a thick layer of entangled stems and branches and sampling methods could not differentiate between the current season's biomass and that which was the result of prior accumulation. Therefore, glasswort standing crop biomass data should be interpreted with great care.

223. The standing crop biomass and the root biomass of Pacific cordgrass differed significantly at the four sites. The standing crop biomass of the planted area weighed 450 g/m^2 area. The corresponding weights for the three natural areas were significantly heavier, namely, 1052, 802, and 678 g/m^2 area at Mayfield Slough, Coyote Creek, and Plummer Creek, respectively. The standing crop biomass of glassworts at Salt Pond #3 (120 g/m^2) was significantly less than that at the three reference sites which ranged from 1373 to 1639 g/m^2. This difference may be accounted for by the sampling technique which did not permit differentiation between annual biomass increment and perennial stems remaining from previous years.

224. Pacific cordgrass root biomass was significantly lower at Salt Pond #3 than at the three natural areas and the Pacific glasswort root biomass at Salt Pond #3 was less than one tenth that of the three reference sites.

225. The two growth parameters of plant height and thickness of glasswort plant layers were lower in magnitude at Salt Pond #3 than at the natural area sites. Differences in standing crop biomass, root biomass, plant height, and thickness of plant layers all indicated that, in 1978, the experimental site was still in an early stage of successional development.

226. Soil/substrate. Soil or substrate texture was remarkably uniform within the cordgrass zone at all sites (Table 30). Sand constituted less than 1 percent while silt levels ranged from 34.8 to 39.2 percent and clay content ranged from 60.1 to 64.3 percent at all sites for both soil depths.

227. Sand, silt, and clay content of the soil from the glasswort zone was similar for the three reference sites (Table 30). Substrate at the Salt Pond #3 site had appreciably more silt and less clay than the reference sites.

Comparing the soils for the two plant zones shows only minor variations between the "cordgrass" (low) and "glasswort" (high) zones for the three reference sites whereas in Salt Pond #3, the silt content was increased and the clay content decreased in the pickleweed (high) zone.

228. Soil moisture content in the cordgrass zone at both the 0- to 5- and 5- to 25-cm depths was relatively uniform for all four sites; however, the moisture content tended to be higher in the 0- to 5-cm zone as compared to the 5- to 25-cm zone (Table 31). Moisture content of soils from the glasswort zone of Salt Pond #3 was much lower than for the three reference sites (Table 32) at both the 0- to 5- and 5- to 25-cm depths. As with the soils in the cordgrass zone, moisture content tended to be lower in the 5- to 25-cm zone as compared to the 0- to 5-cm zone.

229. Soil pH in the cordgrass zone varied slightly both with soil depth and with site (Table 31). The soils at Mayfield Slough showed a trend toward being slightly more acid than the other three sites. Substrate pH tended to be higher in the surface soils at Salt Pond #3, whereas it was highest in the 5- to 25-cm depth at the three reference sites.

230. Soil pH for the glasswort zone (Table 32) followed the same trends as were found in the cordgrass zones for both site and depth. Electrical conductivity data indicated that the soils from the cordgrass zone for the Coyote Creek site were less saline than at the other three sites. The data also indicated there were no appreciable salinity differences with depth among the four sites (Table 31).

231. Electrical conductivity data from the Coyote Creek site showed the same lower trend for the glasswort zone as was present in the cordgrass zone. At the Salt Pond #3 and Coyote Creek sites, conductivity was less at the 5- to 25-cm depth than at the other two sites.

232. The organic carbon content of the soil from the cordgrass zone was similar for all four sites (Table 31) and at both soil depths. For the glasswort zone, the organic carbon content of the soil from Salt Pond #3 was much lower at both soil depths (Table 32) as compared to the three reference sites. At the three reference sites, organic carbon content was lower in the 5- to 25-cm horizon as compared to the 0- to 5-cm surface horizon. Plummer Creek soils had higher organic carbon content than the other two reference sites.

233. Total phosphorus content in the cordgrass zone of the soils at Salt Pond #3 was lower than at the three reference sites (Table 31). There

was also a trend toward lower phosphorus content in the 5- to 25-cm horizon as compared to the 0- to 5-cm horizon at all sites. Trends for total phosphorus for the glasswort zone were similar to those indicated above for the cordgrass zone for all sites (Table 32).

234. Total nitrogen content of the soils for the cordgrass zone (Table 31) did not differ appreciably among sites nor with depth. Ammonium nitrogen values tended to be lower at Salt Pond #3 and Coyote Creek and in the 5- to 25-cm depth at all locations. The nitrate nitrogen values for all sites and depths varied considerably but had no established pattern. The relatively high nitrate value present in these apparently waterlogged soils (moisture content > 100 percent in most cases) raised the question of probable drying and nitrification during sample handling and analysis.

235. Total nitrogen content of the soils from the glasswort zone at Salt Pond #3 and Mayfield Slough appeared to be lower than for Plummer and Coyote Creeks (Table 32). Ammonium nitrogen concentrations appeared to be lower than nitrate values for both depths in the glasswort zone. Again, as in the cordgrass zone, a comparison of these values with high moisture contents (Table 32) raises the question of sample handling.

236. The substrate characteristics of the Salt Pond #3 site differed from those of the three natural sites (Tables 31 and 32). The variations in the physical and chemical parameters of the natural marshland soils are important in themselves in that they revealed a range of environmental conditions that occur in marsh communities. The natural marsh soils were well developed compared to Salt Pond #3. Hence, one may relate some of the chemical and physical differences to successional stage or age differences, a relationship on which little is known for marsh soils.

237. The soil parameters, as considered in terms of high elevation versus low elevations within the intertidal zone (glasswort zone versus cordgrass zone), may be expected to reflect differences in exposure time, a dominant factor of the intertidal zone. For the high elevations, water content in the planted area was significantly lower, 60.4 percent, than at the three natural sites which averaged 165 percent. The pH differences at the high and low intertidal areas and at the two depths were small and were not considered biologically significant.

238. Electrical conductivity values obtained revealed few statistically significant variations except in the case of Plummer Creek when the salinity

was unaccountably high, namely, 43 ppt (E.C. 75,000 μmhos) at the 5- to 25-cm core depth in the high zone (Table 32).

239. The total organic carbon concentrations in the experimental area were consistently lower than in the three natural areas in the case of both high and low intertidal zone. The differences were most significant in the high area (Tables 31 and 32).

240. Phosphorus concentrations were found to be consistently and significantly lower in the experimental area than in the three natural areas which were quite similar. The highest concentration of phosphorus obtained was in the low zone surface, 0- to 5-cm, layer at Coyote Creek, namely 184 ppm (Table 31).

241. In the high elevations of the intertidal zone, the concentrations of total nitrogen were much lower in the experimental area than in the natural areas (Table 32). However, in the low intertidal areas the concentrations were relatively similar at all sites, usually ranging from 0.20 to 0.25 percent (Table 31).

242. The physical and chemical properties of the marsh soils are favorable for survival of seed and seedlings as well as plant growth. The periodic exposures of intertidal soils limit the number of parameters suitable for characterization. Nutrient levels of the near-surface soils are probably among the most reliable chemical indices of environmental favorability. Other chemical parameters are highly variable in space and time and on a basis of existing data are therefore not considered to be sensitive or dependable indicators of marsh productivity.

243. <u>Vegetation.</u> The results of a small-scale quadrat study conducted during the 1982 site visit are listed in Table 33. Time available permitted sampling only on the Salt Pond #3 site itself. Comparing 1982 data to that collected in 1978 (Table 29), stem height of both Pacific cordgrass and glassworts had increased. Further, the glassworts had advanced into the lower elevation. Percent cover within the low zone had increased slightly over that in the upper zone. These results indicate that a slow, but steady maturation process is occurring in the experimental site's plant community.

244. The experimental site, which was bare, highly saline dredged material in 1974-75, was almost totally covered with marsh vegetation in 1982. In the intertidal portions, Pacific cordgrass dominated. All of the upper zones of the salt pond were covered in perennial glasswort and pickleweed.

The greatest diversity of plants was found on the dike containing the disposal area. A list of plant species observed on the site in 1982 is given in Table 34.

245. Wildlife. Salt Pond #3 receives considerable bird use, but perhaps not as much as the surrounding areas on a continuous basis. The open salt ponds and shallow bay, along with the protected flood control channel, offer more resting habitat than the vegetated salt pond. However, at high tide, birds (sea, wading, and shore) fly into the marsh and on the dike from the shallow bay and feed there around small mud-banked creeks and channels which have developed within the site. At low tide, the birds return to the bay. Avocets, Forster's terns, and saltmarsh song sparrows nested on the experimental site in 1982--all of these species are primarily marsh nesters and use dense, low vegetation for nesting. A list of birds observed using Salt Pond #3, the Alameda Flood Control Channel, and the open salt ponds in 1982 is presented in Table 35.

246. The only observed mammal use of the site in 1982 was by Norway rats living in riprap piled along one side of the dike, and by occasional stray dogs. Coyotes may hunt the site on occasion, but no tracks were present during the 1982 survey.

Summary

247. Vigorous stands of Pacific cordgrass and glassworts are established on the experimental habitat development site at Salt Pond #3. Measured plant parameters indicate that the plant community is not presently as vigorous as those in nearby natural marshes. Successional development is much slower at the Salt Pond #3 site with Pacific cordgrass than at the Buttermilk Sound, Apalachicola Bay, or Bolivar Peninsula sites with smooth cordgrass and longer growing seasons. Wildlife use of the site appears to be moderate, equalling that on similar natural sites. Greatest wildlife use occurs when feeding birds move into the site at high tides. From a larger perspective, the site seems to play a role in a wildlife use pattern that depends on an interspersion of a number of habitat types in the South Bay including the Bay itself and open salt ponds, tributary channels, dikes and levees, mud flats, and marsh stands. It is productive in this role.

Miller Sands Upland and Wetland Field Site

Site history and description

248. Miller Sands Island upland and wetland habitat development site is located in the Columbia River, 4 km from Astoria, Oreg., within the Lewis and Clark National Wildlife Refuge. It was built of dredged material in 1932 and has been used for subsequent disposal, the latest operations being in 1974 prior to initiation of the site planting (1976) and again in 1981; the island is 94.7 ha in size.

249. The site area averages 168.5 cm of rainfall per year and its climate is characterized by cool, foggy, wet winters and relatively cool, dry summers. Temperatures average 9.4°C. In the fall and winter, strong storms move from the south and southwest inland across the coast.

250. The Columbia River is tidal at Miller Sands Island, but the high discharge from the river causes the tide water to be fresh. Major erosive forces on the site are wave energies from wind and ship wakes, and river currents during high spring and summer discharges. Water quality in the area is usually good and the only major problems are temperature fluctuations and supersaturated levels of dissolved nitrogen caused by dam spillways (U. S. Army Engineer District, Portland 1975).

251. Benthic communities in the area are dominated by amphipods, oligochaetes, and Asiatic clams. Anadromous fish include chinook, coho, and sockeye salmon, American shad, smelt, and Pacific lampreys. Trout and sturgeon are freshwater species inhabiting the area as well (U. S. Army Engineer District, Portland 1975).

252. The island's intertidal marshes are dominated by common spikerush, Lyngbye's sedge, and tufted hairgrass, with several willow species and reed canarygrass in more protected spots.

253. The island's upland area is dominated by scouring rush, common velvetgrass, and dense patches of moss. Sitka spruce, black cottonwood, and red alder occur in isolated spots, and Scotch broom is found on the island's open meadow.

254. Large numbers of Pacific Flyway migratory and overwintering waterfowl and shorebirds use the waters and mud flats in the site area. While 108 species of birds were observed on the site, they were primarily migratory. Few species nested in the general area. Miller Sands' mammals include vagrant

shrews, Townsend's voles, muskrats, harbor seals, river otters, many Norway rats, and abundant nutria (Clairain et al. 1978).

255. Local land use is primarily forestry and farming, but it is changing due to rapid industrialization and increasing urban use. Commercial fishing is economically important, and the timber and related industries are of major importance in the area.

Site research and development

256. Engineering. The wetland habitat development site was prepared in 1974-75 by pumping over 1 million m^3 of sandy dredged material onto the Miller Sands Island sand spit to form a protected cove. The material was graded and sloped for marsh plant establishment (Figure 20a).

257. The upland site was prepared by disking and tilling operations on the original dredged material. Engineering details are provided in Clairain et al. (1978) and Cutshall and Johnson (1977). The actual wetland site planted was 5 ha in size. Erosive change in the wetland site was monitored by the Portland District throughout the initial study (1974-77).

258. Vegetation. Based on an experimental design, the intertidal area was planted in July and August 1976 with transplants and seeds of eight species including tufted hairgrass, Lyngbye's sedge, slough sedge, broadleaf arrowhead, common three-square, soft rush, yellow flag, and water plantain. Tufted hairgrass and slough sedge were seeded again in May 1978. The species were selected based on an earlier propagation pilot study and for their wildlife food value. Tufted hairgrass and slough sedge were planted in monotypic plots and all eight species were tested in mixed species plots. Details of the botanical study are discussed in Ternyik (1978), Heilman et al. (1978), and Clairain et al. (1978). Fertilizer was applied to all plantings at various rates. Laboratory seed germination tests were conducted on all species to determine optimum conditions (Maguire and Heuterman 1978). Botanical monitoring included survival, percent cover, and root and shoot biomass.

259. The upland area plantings were established in two areas: the above high tide area of the sand spit, where transplants of European beachgrass were planted in January and May 1977; and on the upland portion of the main island meadow, where plantings (seeds) of red clover, white Dutch clover, hairy vetch, barley, tall wheatgrass, Oregon bentgrass, reed canarygrass, red fescue, and tall fescue were established in October 1976. All plots were fertilized at various rates according to the experimental design.

a. Site after placement of dredged material and before planting of upland and wetland experimental plots

b. Site in 1982 from the same ground observation point

Figure 20. Miller Sands Island field site

260. The wetland area was successfully established with both tufted hairgrass and slough sedge from transplants; seeds were not successful. Fertilizer had no long-range effect. The mixed species plots using transplants also were all successful, but seeds failed.

261. The upland European beachgrass plantings were very successful; fertilization had no significant effect. Seven of the mixed species meadow plants established successfully, and fertilizer applications aided greatly in this success on the sandy, infertile meadow. Red fescue and reed canarygrass did not establish well in any of the tests.

262. By 1977, natural invasion by common velvetgrass, rattail fescue, and reinvasion by scouring rush was evident. Also in 1977, the hairy vetch plantings developed black stem rust disease. Without additional fertilizer applications, decline of planted species in the meadow area was expected to occur over time.

263. Soils. Substrate samples to monitor changes in both wetland and upland areas were collected three times in 1976-77. Details of methods, techniques, and analyses are given in Heilman et al. (1978). Elevation was the key factor affecting soil changes. In the wetland area, exchangeable potassium, phosphorus, ammonium nitrogen, total nitrogen, organic carbon, and cation exchange capacity were highest at the lowest elevation and decreased as elevation increased. Only nitrates increased with increasing elevation.

264. Fertilization tended to depress soil pH while increasing potassium, phosphorus, ammonium nitrogen, total nitrogen, and percent carbon in the upland area. However, these differences were not always significant. Fertilization had no apparent effect on the cation exchange capacity of the soils. For those parameters affected by fertilization, this effect appeared to be diminishing almost immediately.

265. Aquatic biology. These studies were designed to document changes in abundance, biomass, and compositional characteristics of aquatic communities at Miller Sands. A predisposal survey was made in 1975, and 11 postdisposal sampling sessions occurred from 1975-77. Beach seines, fyke nets, Ekman grab samplers, Clark-Bumpus samplers, and hand digging were used to obtain samples. Details are discussed in McConnell et al. (1978).

266. There were 21 species of fish caught at Miller Sands. Most abundant were chinook salmon, peamouth, starry flounder, and threespine stickleback. Site construction and plant propagation activities had no apparent

effect on species composition or abundance.

267. Benthic communities were overwhelmingly dominated by the amphipod *Corophium salmonis*, oligochaetes, chironomid larvae, and Asiatic clams. Again, activities at the site had no apparent effect on species composition or abundance, and the site compared favorably with a nearby reference marsh.

268. Wildlife. A prepropagation assessment of Miller Sands wildlife was made in 1975. Details of methods, techniques, and analyses are given in Woodward-Clyde Consultants (1978). Postpropagation assessments were made from 1975-1977; details are discussed in Crawford and Edwards (1978) and Clairain et al. (1978).

269. A total of 65 bird species were observed at Miller Sands prior to development; 55 percent of these were waterfowl, shorebirds, and perching birds. Species correlated closely with habitat diversity. Six species nested on the island prior to development. From 1976 through 1977, 108 bird species were observed on the site, 81 percent of which were waterfowl, shorebirds, or perching birds. Canada and snow geese fed in the planted meadow, mallards nested there, and swallows in large numbers fed over it. Nine species nested there after development.

270. Six species of mammals were seen prior to development; seven species were seen after development. By far, the most abundant species were nutria and Norway rats. A total of 774 nutria were removed from Miller Sands and 729 nutria were removed from nearby islands as part of this study. At least 145 Norway rats were seen and/or trapped as well. Other mammals occurred in very low numbers.

Long-range monitoring

271. Annual visits were conducted to Miller Sands and to three selected reference areas (Cove Site, Harrington Point, and Snag Island) from 1979 through 1982 to observe both the physical characteristics of the site and also the plant communities and wildlife use of the area (Figure 20b). Quantitative observations on the wetland plant community and sediments were made in 1978 (Heilman 1979) and 1980, and on the wetland plant community in 1982. Percent cover studies were conducted on the upland plant community in 1980 and 1982. A quantitative study of the benthic community in the wetland was conducted in 1980. Results of these studies are presented in the following sections.

272. Vegetation study in 1978. Vegetation and sediments on selected plots at the experimental planting site on intertidal dredged material were

examined in 1978 by Heilman (1979) after the third growing season following planting. Plant communities and sediment properties on the plots planted with tufted hairgrass and slough sedge were compared with conditions in three nearby naturally established marshes used as reference areas, two of which were on dredged material (Cove Site and Snag Island). Changes in the substrate and plants at the planted site were also evaluated. Three transects were selected at each of the areas to sample within-elevation ranges similar to those at the planted marsh. Ten quadrats were randomly located on each transect. At each of these transects, estimates were made of total plant cover and cover for each species; vegetation was clipped on 0.5-m^2 areas; sediment (soil) samples were collected at 0- to 5- and 5- to 25-cm depths; and core samples for root weights were collected at 5-cm intervals to a depth of 25 cm.

273. The lower transect in the vegetated area of the planted marsh was higher in elevation (0.98 m above mean lower low water (mllw)) than at the other sites (which ranged in elevation from 0.56 to 0.87 m above mllw). The lower boundary of vegetation at the natural marshes was defined mostly by common spikerush, a species which had invaded the planted site, but had not yet formed the pure stands found at lower elevations at the other sites.

274. Plantings at the highest elevation of the planted site were not growing well. These plantings extended above the upper range of vegetation in the nearby naturally established marsh (Cove Site), and were higher than the upper transects at the other sites. Slough sedge had disappeared and hairgrass, while still present, was growing poorly at the highest elevations at the planted site.

275. Accretion of silt was evident on the two older marshes naturally established on dredged material with silt accretion occurring mostly at the lower elevations in one and at the middle and upper elevations at the other marsh. Increases in silt and clay had occurred at the planted site since the initial sampling in June 1976, but because of differences in sampling, quantification of the increase was not possible.

276. Increases in Kjeldahl nitrogen were evident at the planted site since 1976. At the upper elevation, Kjeldahl N averaged 0.003 and 0.002 percent in 1976 at 0- to 15- and 15- to 30-cm depths compared with 0.005 and 0.004 percent at 0- to 5- and 5- to 25-cm depths in 1978. Nevertheless, these values are considerably lower than N levels in the natural marshes.

Kjeldahl N varied from 0.046 to 0.110 percent at the 0- to 5-cm depth in the three naturally established marshes.

277. Increases in organic carbon were also evident at the planted site, but the values were low compared to the older marshes. The natural marsh substrates varied from 0.46 to 1.33 percent carbon at the 0- to 5-cm depths in upper elevations compared with less than 0.1 percent at the planted site.

278. Plant cover in 1978 (Table 36) was less at the planted site, particularly at the upper transect where the average cover was 37 percent compared with 100 percent at the other marshes. Middle transects averaged from 90 to 99 percent cover and lower elevations had 44 to 82 percent cover with the values for the planted site being included in both ranges.

279. Aboveground biomass (Table 36) was less at the planted site. At the middle and upper transects, mean aboveground biomass on the naturally established marshes varied from 650 to 874 g/m^2. At the planted site, the aboveground biomass averaged 82 g/m^2 for the upper transect and 408 g/m^2 for the middle transect. Highest mean root biomass to a depth of 25 cm at the experimental site was 138 g/m^2 at the middle elevation. Root biomass at the upper and middle elevations in the naturally established marshes varied from 797 to 4,420 g/m^2 to a depth of 25 cm.

280. Comparison of data from 1977 indicated that cover and vigor of both tufted hairgrass and slough sedge transplants had decreased in the upper tier and increased in the middle tier.

281. Lyngbye's sedge was the most important species at upper and middle elevations on the natural marshes but was not present in significant numbers on the planted site (Table 37). Other major species in the natural marshes that were only sparingly present at the planted site were Douglas' aster, pointed rush, and water parsnip. Major species found to be of more importance at the planted site than in the natural marshes were water smartweed, nodding beggarticks, yellow monkey flower, and Watson's willow-weed.

282. Common spike rush was the plant with the highest importance values at the lower elevations in natural marshes and was present in significant numbers at the planted site. This species was rapidly invading the planted site. In 1977, cover was 0.1, 2.9, and 0 percent for upper, middle, and lower tier transplant plots, respectively. One year later, this species had increased to a cover value of 10.2 percent on the lower transect.

283. Vegetation study in 1980. Three elevations at each site were

established for sampling based on elevations used at Miller Sands. At Miller Sands, the lowest elevation was established at the lowest edge of appreciable plant cover. The highest elevation was established in vegetation just below the higher high tide mark. The middle elevation between these two elevations also was sampled. At Snag Island, the upper and lower vegetation types seemed to correspond very well to that of Miller Sands. However, at Harrington Point, the upper tidemark limit of marsh vegetation was not reached with the above technique. The lower limit of vegetation appears to have occurred at a lower elevation. Thus, the vegetation sampled at the three elevations at Harrington Point may not have corresponded closely to the elevations at the other three sites.

284. Ten 0.5-m^2 quadrats were measured at random intervals along each elevation contour at each site. Measurements taken at each plot were aboveground biomass, stem density, stem height, and percent cover of each species. All plants were clipped, bagged, returned to the laboratory, subsampled, dried to a constant weight, and weighed.

285. Belowground biomass was determined by driving a 10-cm-diam, beveled PVC pipe into the substrate after clipping. One sample was taken in each quadrat. The soil core was extruded from the pipe and cut into 5-cm lengths at 0- to 5-, 5- to 10-, 10- to 15-, 15- to 20-, and 20- to 25-cm depth increments. Each 5-cm section was washed through a 1-mm mesh screen. The plant portion remaining on the screen was oven dried and weighed. The average root biomass for the five sections was converted to the equivalent for 1 m^2.

286. The Miller Sands experimental site generally had less aboveground biomass, root biomass, percent cover, and shorter stem height (overall mean by elevation) than each natural site (Table 38). Differences in stem density occurred between sites, but the experimental site was within the range of variability observed at the natural marshes.

287. Over 55 species were found throughout the study areas at the three elevations (Table 39). Many of these had less than 1 percent relative frequency. Twenty-four plant species commonly occurred throughout the sample sites (Table 40). Lyngbye's sedge was the most commonly occurring species (found in 71.7 percent of all plots) and had the greatest biomass (236.4 g/m^2) of any species.

288. Tufted hairgrass and pointed rush also showed high frequency and biomass. Slough sedge and birdsfoot-trefoil were low in frequency but high in

biomass and stem density. The aboveground biomass (Table 41), stem density (Table 42), percent cover (Table 38), and stem height (Table 43) of each species often varied among sites. For example, Lilaeopsis was not found at Cove Site while yellow monkey-flower was not found at the lower and middle elevations of Harrington Point. The low occurrence of some species versus the high occurrence of others may indicate differences in the developmental stage of the experimental marsh from that of the naturally established marshes. On the other hand, natural colonization may explain community differences.

289. Summary statistics in Table 38 indicate that the Miller Sands experimental site was generally at the lower end of the range for each measurement as compared to the other sites. The Miller Sands site had less aboveground biomass than any other site. The aboveground biomass at each elevation at Miller Sands also was less than corresponding elevations at each natural marsh site, except for the lower elevation at Harrington Point, although the differences were not statistically significant.

290. Except for the Cove Site, the lowest biomass at each site occurred at the lowest elevation. At the Cove Site, the greatest biomass occurred at the lowest elevation. Stem density varied considerably at each elevation for each site. This was partially due to the different mixtures of species found at each site and differing growth forms among those species.

291. Percent cover was different among sites and elevations. Percent cover was always least at the lower elevations of each site and, except for Snag Island, was greatest at the highest elevation.

292. For all sites, the average height of plants was greatest at the middle elevation (Table 43). Mean stem height was lowest at Miller Sands. Differences in stem height among areas may have reflected a greater percent cover of a shorter species and should be used primarily in species-by-species comparisons of height by locations and elevations.

293. The mean root biomass was lowest at the Miller Sands site (Table 44). Root biomass at each elevation was generally lower at Miller Sands than natural sites at all elevations. Root biomass at each elevation varied considerably between sites. Root biomass was greatest at the 0- to 5-cm depth at each site and generally was less at each greater depth. Root biomass by depth was lowest at Miller Sands.

294. Vegetation study in 1982. Data collected on the plant community at the Miller Sands wetland habitat development site are summarized in

Table 45. Stem density, mean stem height, frequency of occurrence, and mean number of flowering stems were recorded. Because of time limitations, only eight 0.5-m^2 quadrats were sampled at Miller Sands.

295. A belt transect was sampled in the European beachgrass planting. Ten randomly selected "bunches," each arising from a single transplant, were observed for mean number of stems per plant and mean number of flowering stems or seedheads per plant. In Table 46, these data are compared with similar data from 1977 (Heilman et al. 1978). Visual observation of the community itself suggested that the European beachgrass was thriving. Comparing the quantitative measurements between 1977 and 1982 confirmed substantial development of the community over time. It was observed in 1982 that the beachgrass stem density increased with increasing elevation on the dune. Likewise, the number of seedheads per plant increased with elevation.

296. Percent cover was estimated on the upland habitat development site in both 1980 and 1982. The data from those 2 years are compared in Table 47. It is noteworthy that the upland site was reverting to a droughty, rather sterile habitat with scouring rush, cat's ear, and moss gradually reverting to dominant status. However, planted species such as tall fescue, redtop, and red fescue were maintaining their populations and gradually increasing their percent cover. Figures 21, 22, and 23 show changes over time in percent cover of species planted in three experimental upland meadows at Miller Sands. In Meadow I, white clover and western wheatgrass have essentially disappeared, but tall fescue has steadily increased. In Meadow II, Oregon bentgrass and barley have also disappeared and red clover is almost gone. In Meadow III, hairy vetch was gone by 1980, but reed canarygrass and red fescue, which were thought to have disappeared in 1977, have established themselves and gradually increased since 1980. Plant species observed at Miller Sands and its associated reference areas during the 1982 site visit are listed in Table 48.

297. There was substantial evidence of grazing by nutria and other herbivores (e.g., muskrats, deer, rabbits) on the Miller Sands site. The plant communities within the exclosures erected to prevent grazing were not sampled, but visual observation revealed less scouring rush and denser, taller, and more vigorous growth of the grasses present. Two of the exclosures, one in the marsh and one in the uplands, were broken open, and the grasses and edible forbs inside were at the same levels as outside the exclosures showing strong signs of grazing pressure.

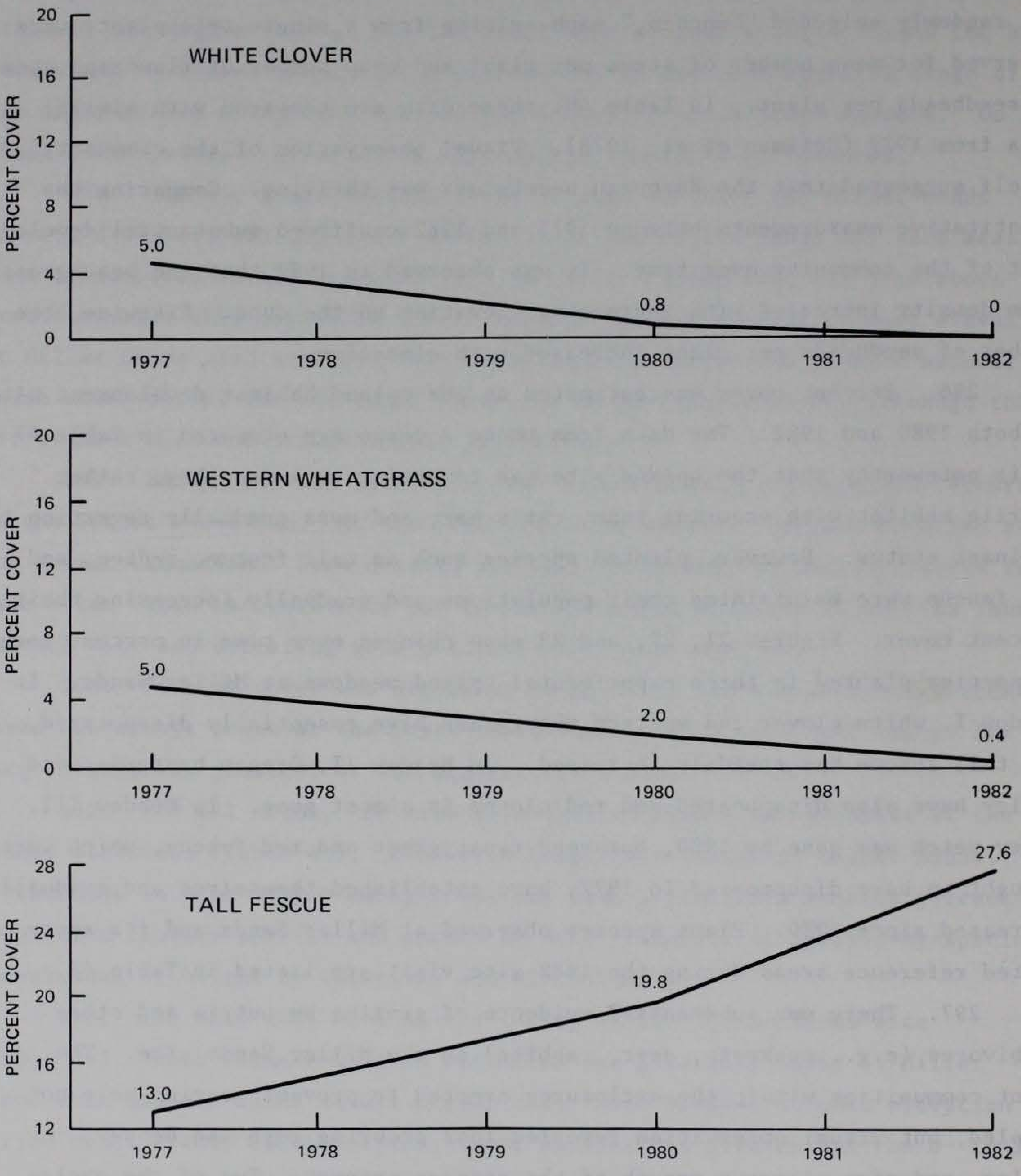

Figure 21. Percent cover by planted species in Meadow I during late summer (July-August-September)

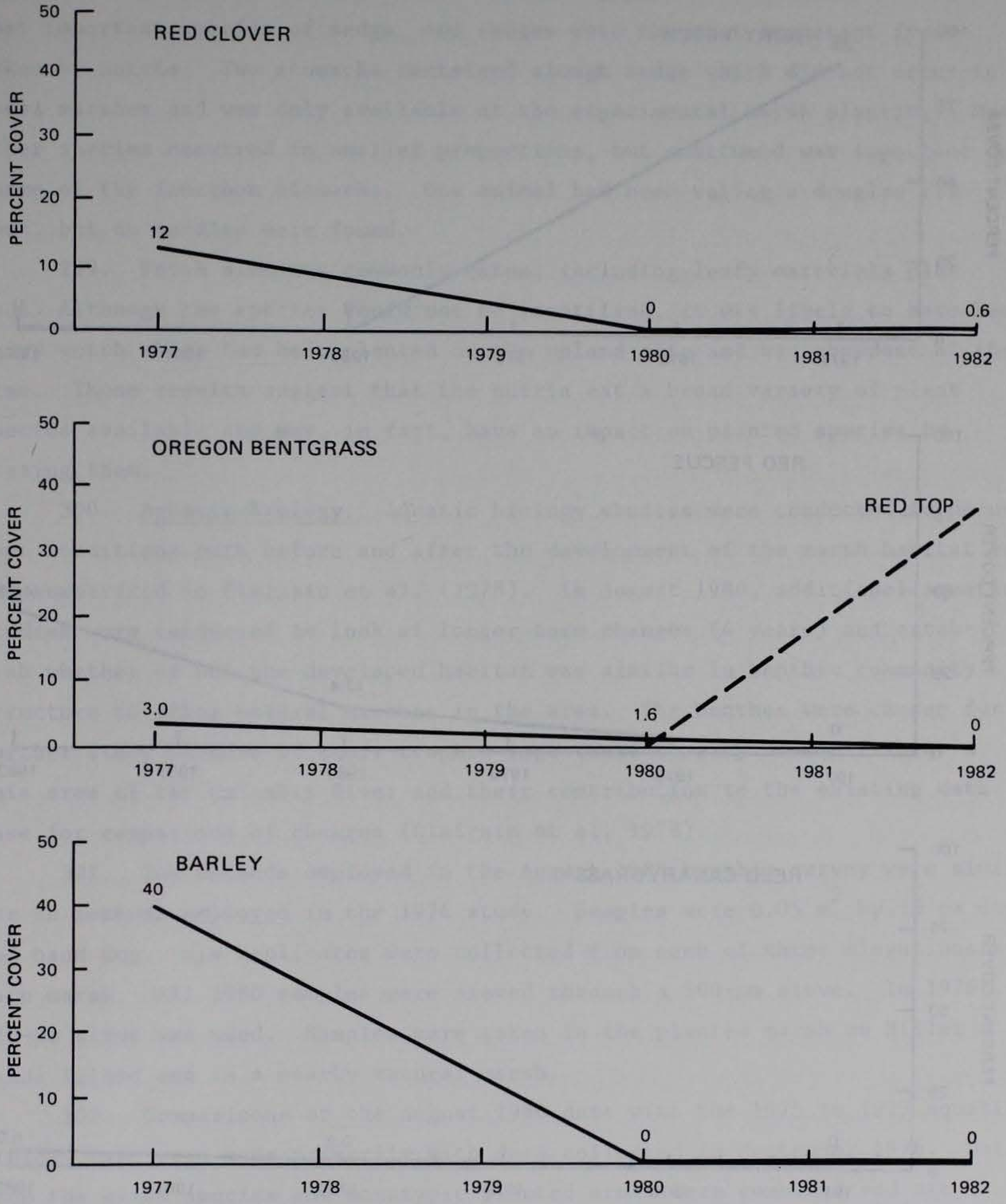

Figure 22. Percent cover by planted species in Meadow II during late summer (July-August-September)

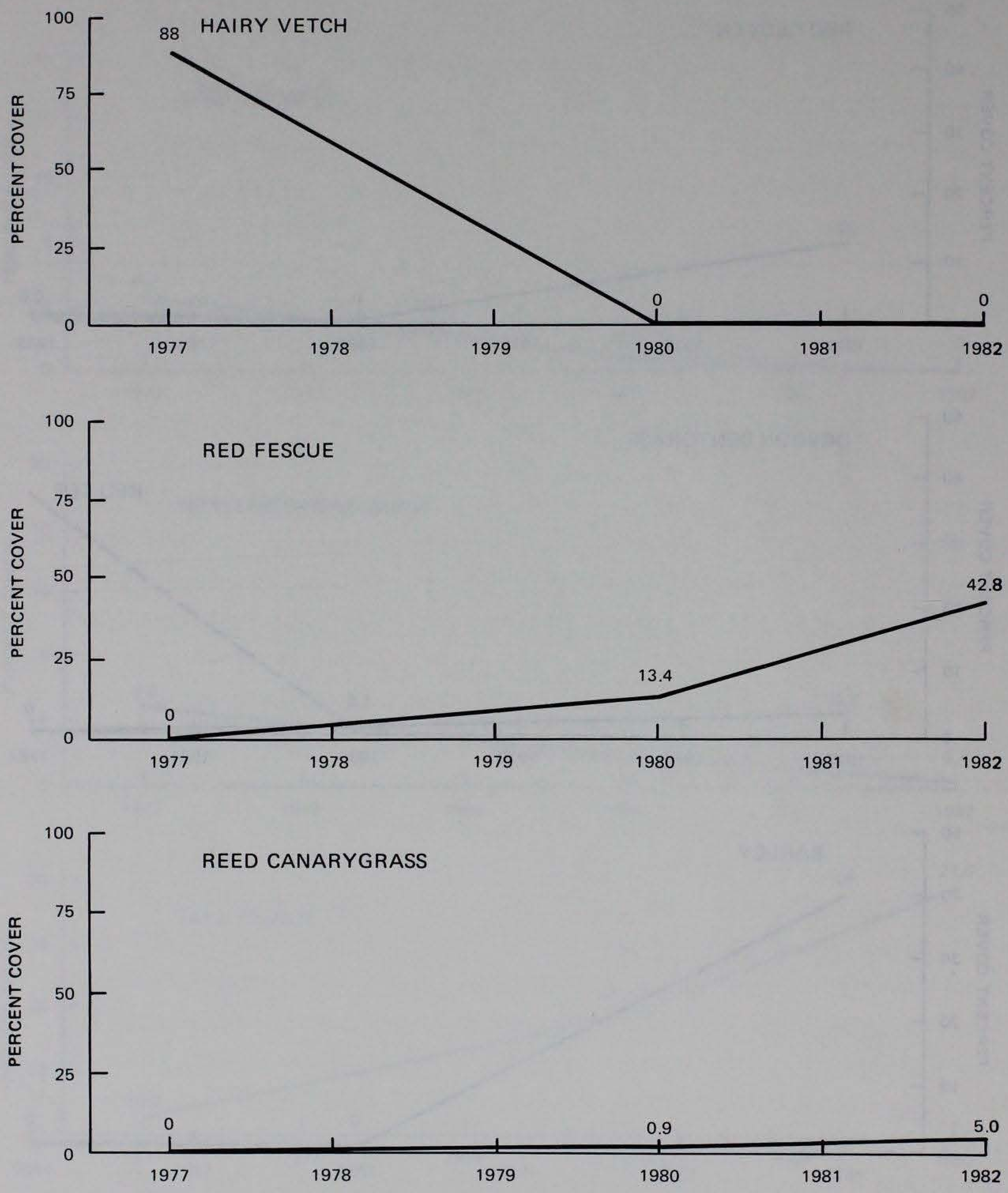

Figure 23. Percent cover by planted species in Meadow III during late summer (July-August-September)

298. To further investigate grazing pressure by nutria, the stomachs of 14 nutria trapped at Miller Sands from 8 December 1977 to 8 February 1978 were analyzed for their contents (Johnson 1980). Lyngbye's sedge seemed to be the most important species of sedge, and sedges were the most important foods taken by nutria. Two stomachs contained slough sedge which did not occur in local marshes and was only available at the experimental marsh planting. Most other species occurred in smaller proportions, but smartweed was important in three of the fourteen stomachs. One animal had been eating a douglas fir cone, but no needles were found.

299. Vetch also was commonly eaten, including leafy materials plus pods. Although the species could not be identified, it was likely to have been hairy vetch which had been planted on the upland site and was abundant at the time. These results suggest that the nutria eat a broad variety of plant species available and may, in fact, have an impact on planted species by grazing them.

300. Aquatic biology. Aquatic biology studies were conducted to document conditions both before and after the development of the marsh habitat and are summarized in Clairain et al. (1978). In August 1980, additional aquatic studies were conducted to look at longer term changes (4 years) and establish whether or not the developed habitat was similar in benthic community structure to other natural marshes in the area. The benthos were chosen for further study because of their trophic importance to many of the fishes in this area of the Columbia River and their contribution to the existing data base for comparison of changes (Clairain et al. 1978).

301. The methods employed in the August 1980 benthic survey were similar to methods employed in the 1976 study. Samples were 0.05 m^2 by 10 cm deep and hand dug. Six replicates were collected from each of three elevations at each marsh. All 1980 samples were sieved through a 500-μm sieve. In 1976, a 580-μm sieve was used. Samples were taken in the planted marsh on Miller Sands Island and in a nearby natural marsh.

302. Comparisons of the August 1980 data with the 1975 to 1977 aquatic biology data were made primarily with data collected in September 1976. Data from the mixed species and monotypic planted areas were combined and are referred to as the "planted marsh." The Cove Site natural marsh on Miller Sands used as a reference area is a naturally established marsh on dredged material. It is located in the same cove as the experimentally planted marsh,

just to the west of it. Trends and population densities referred to prior to July 1976 are from the shallow subtidal cove adjoining the natural and planted marshes.

303. Benthic communities at all four sites sampled (Miller Sands experimental site, Cove Site, Snag Island, and Harrington Point) were dominated by oligochaetes of the families Tubificidae, Lumbriculidae, and Enchytraeidae. Oligochaetes comprised 67 percent of all individuals at the experimental marsh, 80 percent at the Cove Site reference marsh, 89 percent at Harrington Point, and 93 percent at the Snag Island marsh. No other species were consistently dominant at all four sites (Table 49). Lymnaid snails were abundant (13 percent of total individuals) in only the planted marsh. Sphaerid clams were only abundant (8 percent) in the Cove Site reference marsh. Chironomid larvae were only abundant (3 percent) in the Snag Island marsh. Chrysomelid larvae were only abundant (5 percent) in the Harrington Point marsh. While quantitatively the four marshes were different, qualitatively they were very similar. Eight of the twenty-seven taxonomic groups occurred at only one marsh (Table 49). There was a great deal of overlap in the faunas of the four marshes. None of the taxa occurring at only one site were ever more than one-half percent of the individuals at the site.

304. Species considered important when the marsh was planted in 1976 had changed in abundance. *Corophium salmonis* was virtually absent in the 1980 collections; only 5 specimens were taken from all four marshes. In September 1976, there were 247 and 442 *Corophium salmonis*/m^2 at the experimental and natural marsh, respectively. This general decline in abundance is either indicative of area-wide changes in the species population dynamics or may reflect the summer minimum in *Corophium salmonis* abundance that was observed at Miller Sands in both 1975 and 1976 (Clairain et al. 1978). The Asiatic clam, *Corbicula fluminea*, also declined in abundance from 1976. In the experimental marsh, the clam dropped from 35 to 21 per m^2 and in the Cove Site reference marsh from 84 to 8. Chironomid larvae dropped from 163/m^2 in the experimental marsh and 408/m^2 in the Cove Site marsh in 1976 to about 75/m^2 in both marshes in 1980. While these species declined in abundance from 1976 to 1980, Gastropods, mainly lymnaids, increased greatly at the experimental marsh from 1/m^2 to 244/m^2. There was a slight increase from 64 to 88/m^2 at the Cove Site reference marsh. Total oligochaetes exhibited the greatest change from 1976 to 1980. There were 126 oligochaetes/m^2 in the experimental marsh in

September 1976 and 1226/m^2 in August 1980. At the Cove Site reference marsh, they increased from 693 to 3539/m^2. Population densities of *Anisogammarus confervicolus* appeared to remain the same. It was sporadically present in low numbers throughout 1976. In the 1980 collection, its densities were 2 to 15 individuals/m^2.

305. The sediments from the four marsh sites were not the same. The marsh on Snag Island had higher percentages of fines (sediment finer than 63 μm) and volatile solids than the other three marshes (Table 50). The Miller Sands experimental marsh had the lowest fines and volatile solids percentages of all four marshes. This is likely an indication of its young age relative to the others. Even the Cove Site natural reference marsh on Miller Sands Island, which naturally established itself on dredged material, had higher percentages of fines and volatile solids. Both Snag Island and Harrington Point marshes had the highest percentages of mud and volatile solids at their upper elevation. Both of the Miller Sands sites are protected by a sand spit and face into the protected cove (Figure 7).

306. Eleven of the twenty-seven taxa occurred frequently enough to analyze for trends. The only taxa to exhibit any clear trend with elevation were the lumbriculid oligochaetes and chrysomelids which were more abundant at the upper elevation. This follows with the semiaquatic nature of many of the species within these groups. Since there were no other elevation differences, the data were combined by elevation for comparison of marshes (Table 51). Gastropods were the only abundant taxon in the planted marsh. The Cove Site marsh had the second highest densities of gastropods. The other two reference marshes had fewer gastropods. The same trend was also exhibited by tipulids and dolichodid larvae and sphaerids, but more at the Miller Sands marshes than at Snag Island and Harrington Point marshes. Highest densities of sphaerids were at the Cove Site marsh. While there were 373 sphaerids per m^2 in the natural marsh, none were collected in the nearby planted marsh. With only a total of five *Corophium salmonis* collected from all marshes in 1980, it is not possible to accurately define distribution patterns among marshes, but it should be noted that four of the five occurred at the Miller Sands marshes (Table 51). Oligochaetes, the Asiatic clam, and chironomid larvae were all most abundant at the Snag Island marsh. This is possibly due to the higher mud and volatile solids content of the Snag Island marsh. All three of these taxa, when they occur in tidal freshwater and oligohaline

areas, are positively correlated with percent fines and volatile solids (Diaz and Boesch 1978, Diaz et al. 1978). Leeches, *Anisogammarus confervicolus*, and chrysomelid larvae were all more abundant at the Harrington Point marsh, but their highest abundance does not appear to be related to sediment type. Sediments at Harrington Point were within the range of percent fines and volatile solids at the Cove Site natural marsh (Table 50). The age of the Harrington Point marsh may be a factor; it is older than the Miller Sands sites and may be older than Snag Island, which appears to be an old dredged material island.

307. Harrington Point was the only marsh where polychaetes occurred, and two nereids were collected. This is not indicative of any structural differences among marshes, but rather is an indication of very low salinity (less than 1 ppt in August 1980 when samples were collected). Seven other taxa were collected from only one marsh (Table 49). There appears to be no pattern to the occurrence of these eight rarer taxa other than six of them occurred at the Snag Island and Harrington Point marshes. Species composition (total number of taxa) for the four marshes was very similar, ranging from 17 to 20 taxa per marsh. The planted marsh was most similar to the Cove Site which was naturally established at Miller Sands (Jaccard similarity coefficient of 0.76).* Its similarity with the Snag Island marsh was 0.70 and 0.64 for Harrington Point.

308. While sediments did not change much at the experimentally planted marsh from 1976 to 1980, there were changes in the abundance of many of dominant benthic taxa. *Corophium salmonis*, an abundant species in 1976, was virtually absent in August 1980. The Asiatic clam also declined. Oligochaetes and gastropods increased greatly in abundance by 1980. These changes appeared to be related to natural fluctuations in populations or seasonality. Summer was the period of low abundance for most of the benthos collected at the Miller Sands site.

309. Comparison of the experimental marsh with three natural marshes in the area indicated that the fauna of all four marshes were similar. However, there were differences in the total abundance of the fauna among the marshes. The experimental marsh had the lowest densities and Snag Island the highest. The major difference between the planted marsh and natural marshes appeared to

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* Jaccard's coefficient ranges from 1.00 for complete similarity to 0.0 for complete dissimilarity.

be one of quantity and not quality. Part of the observed differences was probably due to variation in sediment type among the four marshes. Four years after planting, the Miller Sands marsh habitat development site resembled the benthic community structure of the Cove Site natural marsh and approached the structure of the other reference marshes.

310. Wildlife. Observations of wildlife at the Miller Sands habitat development site and associated reference areas during the 1982 site visit (Table 52) were indicative of wildlife observations made in preceding years. Thirty-two bird species and seven mammal species were sighted on the Miller Sands complex in 1982, including two Columbia white-tailed deer does. This endangered subspecies has been using the Miller Sands island for a number of years. Nutria, muskrat, and Norway rat signs were abundant on both the marsh and sand spit, and on the island. In addition, signs of small mammals were evident. Voles, shrews, and mice have been reported in earlier studies on the island. Ten bird species were seen at Snag Island; five bird species were observed at Harrington Point. Reduced wildlife observations on Snag Island may have indicated a more restricted habitat. There was much less plant diversity on Snag Island than on the field site. Harrington Point is a marsh connected to the mainland and as a result is fairly diverse. Snag Island provides a low marsh habitat that is dominated by softstem bulrush, tufted hairgrass, and cattails with very few shrubs or trees. Since Harrington Point marsh is on the mainland, it could receive more mammal use than the islands including Miller Sands; however, no signs that this was the case were observed during the 1982 site visit.

Summary

311. Productive wetland habitat was established at the Miller Sands habitat development site. While the plant community is still less productive than that of nearby naturally established marshes, it is slowly but steadily becoming similar. The dune planting of European beachgrass was highly successful and continues to be very effective in stabilizing the sand spit. The upland planting was productive for a short period (1-3 years) but will not continue high levels of production on the sterile, droughty substrate without periodic management such as fertilization and reseeding. The benthic community in the Miller Sands marsh is similar to that of the naturally established marshes but is less abundant. This may be related to substrate differences among the sites. After 4 years, the Miller Sands community is very close in

structure to that at the Cove Site and is approaching the structure of the other reference marshes. The Miller Sands complex receives wildlife use equal to or greater than that at the reference sites.

PART III: CONCLUSIONS

312. Each of the seven sites built during the DMRP has been successful in its own way. Nott Island, Miller Sands, and Bolivar Peninsula were temporarily developed into vigorous and lush stands of meadow grasses, with some tree/shrub species planted at Bolivar Peninsula as well. Without management, all three of these upland sites have changed. Miller Sands and Nott Island have declined from their initial spurt of growth into stable conditions. Nott Island has retained its grassy meadow characteristics and some vitality, while Miller Sands has declined to a stable but depleted condition from intense grazing pressures by nutria and muskrats.

313. The Bolivar Peninsula site is completely covered with wet meadow grasses and forbs rather than with the originally planted species. Higher rainfall on the Gulf Coast and a higher water table probably are influencing this change.

314. The six marsh sites have all developed vigorous, stable wetlands, most within three years of planting. All six marshes have undergone successional changes that are still occurring. With each change they become more like the nearby natural reference areas in soils and plant communities.

315. Wildlife use has always been greater on the field sites than the reference areas, primarily due to the diversity of habitat and vigor of the new sites. Waterbirds, waterfowl, shorebirds, and furbearers have dominated the list of species at each site, and should continue to do so for some years to come.

316. While the upland sites have generally stabilized in their present condition, the wetlands are still in transition and will require further low-level monitoring to accurately document the ultimate fate of each. The information gained from long-term monitoring effort has been invaluable for three main reasons: (a) the sites serve as models for similar sites being considered for habitat development; (b) baseline data collected are important in documenting the methods, time periods, costs, and problems of habitat development; and (c) the sites are invaluable as tests for technological advances in habitat development, as teaching tools, and for providing experience and expertise to Corps Districts and Divisions whose dredged material disposal operations are being coupled with habitat development requirements.

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Table 1

Summary of Vegetation Data Collected at the Nott Island Upland Habitat Development Site, 30 July 1982*

Species	Mean Stem Density stems/m^2	Mean Stem Ht. cm	Frequency of Occurrence, %	Mean Percent Cover	Mean Flowering stems/m^2
Globe nutsedge	32.4	19.3	12.5	1.5	15.5
Marestail fleabane	95.6	7.7	50.0	3.1	0
Tall fescue	166.4	43.4	87.5	15.1	75.5
Timothy	7.6	21.9	12.5	0.6	2.0
Goldenrod	1.0	16.5	12.5	0.3	0
Moss	N/A**	N/A	75.0	18.6	N/A
	$\Sigma = 303$	$(\bar{X}) = 22.8$		$\Sigma = 39.2$	

Mean percent cover: living plants = 39.2
dead plant matter = 55.9
bare ground = 4.9

* Summary is based on data from eight 0.25-m^2 quadrats.
** N/A = Not Available.

Table 2

Plant Species* Observed on and Adjacent to the Nott Island Upland Habitat Development Site on 30 July 1982

Alder	Marestail fleabane
American beachgrass	Mosses
American three-square	Northern dewberry
Apple	Northern red oak
Asiatic bittersweet	Nutsedge
Asparagus	Orchard grass
Asters	Panic grasses
Barberry	Perennial pea
Bayberry	Perennial rye
Beggarticks	Pigweed
Bindweeds	Poison ivy
Black cherry	Purple loosestrife
Black oak	Pussytoes
Black willow	Rabbits-foot clover
Bracken fern	Red maple
Bull thistle	Redosier dogwood
Buttonbush	Red top
Cocklebur	River bulrush
Common mullein	Sand grass
Common reed	Sedges
Dandelion	Six weeks fescue
Dayflower	Skunk cabbage
Deer-tongue grass	Slough grass
Downy chess	Smooth cordgrass
Dwarf dandelion	Smooth sumac
Eastern cottonweed	Soft rush
Eastern red cedar	Softstem bulrush
Evening primrose	Staghorn sumac
Everlasting	Swamp milkweed
Fall panic grass	Switchgrass
False indigo bush	Tall fescue
Foxtail grass	Tansy
Globe nutsedge	Timothy
Goldenrod	Tree-of-heaven
Grapes	Vetch
Greenbriar	White clover
Groundnut	Wild lettuce
Hawthorn	Wild peppergrass
Lichens	Woodbine
Lobelia	Yarrow

* Scientific names appear in Appendix A.

Table 3

Wildlife Species Observed on Nott Island During the Site Visit on 30 July 1982

Alder flycatcher	Hairy woodpecker
American goldfinch	Herring gull
American robin	Mallard
Belted kingfisher	Marsh wren
Black racer	Mockingbird
Bobwhite quail	Mourning dove
Canada goose	Mute swan
Cardinal	Osprey
Catbird	Red-winged blackbird
Common crow	Savannah sparrow
Common yellowthroat	Song sparrow
Double-crested cormorant	Tree sparrow
Eastern cottontail rabbit (signs, droppings)	Unidentified sandpipers
Eastern robin	Vesper sparrow
Fox sparrow	White-footed mouse
Great black-backed gull	White-tailed deer (tracks, browse, droppings)
Green heron	Yellow warbler

Table 4

Plant and Wildlife Species Observed on Calves Island During a 30 July 1982 Site Visit

Plant Species

Alder	Long-spined sandspur
American germander	Marsh yellow cress
Asiatic bittersweet	Morning glory
Bayberry	Northern blackberry
Bindweed	Nutsedge
Blackgum	Poison ivy
Black oak	Pokeweed
Catalpa	Purple loosestrife
Cocklebur	Red maple
Common reed	Sand grass
Common three-square	Sassafras
Deer-tongue grass	Smooth cordgrass
Elderberry	Softstem bulrush
Evening primrose	Staghorn sumac
False indigo-bush	Switchgrass
Globe nutsedge	Tree-of-heaven
Goldenrod (three species)	Water hemp
Groundnut	Wild lettuce
Jewelweed	Winged sumac

Wildlife Species

American goldfinch	Osprey
Canada goose	Red-winged blackbird
Catbird	Savannah sparrow
Herring gull	Song sparrow
Killdeer	White-tailed deer (tracks, browse)
Mourning dove	

Table 5

Comparison of Mid-Summer Trends in Stem Density, Stem Height, and Percent Cover Between the Windmill Point Habitat Development Site and Three Reference Sites in the Immediate Vicinity

Parameter	1979	1982
Windmill Point		
No. of quadrats	15*	8**
Biomass, dry wt/m^2	2008.2	N/A†
Mean stem density, No. stems/m^2	211.5	93.3
Mean stem height, cm	112.0	126.8
Percent cover (surface)	46.8	56.3
Percent cover (intertidal)	33.3	33.8
Queen's Creek		
No. of quadrats	19	2
Biomass, dry wt/m^2	2070.5	N/A
Mean stem density, No. stems/m^2	380.1	108
Mean stem height, cm	111.8	114.8
Percent cover (surface)	90.7	96.5
Percent cover (intertidal)	59.3	67.5
East Island		
No. of quadrats	30	2
Biomass, dry wt/m^2	1269.0	N/A
Mean stem density, No. stems/m^2	183.3	61
Mean stem height, cm	98.6	128.1
Percent cover (surface)	65.1	95
Percent cover (intertidal)	43.4	65
Ducking Stool Point Marsh		
No. of quadrats	15	N/A
Biomass, dry wt/m^2	2814.2	N/A
Mean stem density, No. stems/m^2	253.0	N/A
Mean stem height, cm	101.3	N/A
Percent cover (surface)	79.9	N/A
Percent cover (intertidal)	55.5	N/A

* Quadrat size was 0.5 m^2 in 1979.
** Quadrat size was 1.0 m^2 in 1982.
† N/A = Not Available.

Table 6

Summary of Vegetative Data Collected at the Windmill Point Habitat Development Site and Two Reference Areas on 20 July 1982

Species	Windmill Point*				Queen's Creek**				East Island**			
	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2
Nodding beggarticks									12.5	154.8	100	0
Jewelweed					4.5	35.9	100	0				
Rice cutgrass					24.0	130.5	100	0				
Arrow arum					39.5	95.4	100	0	38.0	109.8	100	1.5
Pickerelweed	59.1	97.6	75	1.6								
Halberd-leaved tearthumb					23.0	116.6	100	0				
Broadleaf arrowhead									3.0	104.3	50	0
American three-square	5.4	64.8	25	1.5								
River bulrush					16.5	155.4	100	0				
Softstem bulrush	11.6	146.4	25	9.8								
Bur reed					0.5	176.0	50	0				
Big cordgrass	0.5	196.7	25	0.1								
Narrowleaf cattail	0.1	63.0	12.5	0								
Wild rice	16.5	236.5	50	2.1								
Southern wild rice									7.5	185.7	100	0
Total	93.2	126.8			108.0	118.3			61.0	128.1		

Windmill Point: Mean percent cover (surface): 56.3%; Mean percent cover (intertidal): 33.8%

Queen's Creek: Mean percent cover (surface): 96.5%; Mean percent cover (intertidal): 67.5%

East Island: Mean percent cover (surface): 95.0%; Mean percent cover (intertidal): 65.0%

* Based on eight 1-m^2 quadrats.

** Based on two 1-m^2 quadrats.

Table 7

Plant Species Observed at the Windmill Point Habitat Development Field Site and Associated Reference Areas on 20 July 1982

Plant Species	West Dike	South Dike	East Dike	North Dike	Interior	Queen's Creek	Ducking Stool	East Island
American elm	X	X		X				
American three-square	X	X	X	X				
Arrow arum	X	X	X	X	X	X	X	X
Arrow-leaved tearthumb			X					
Aster				X				
Bald cypress				X		X	X	X
Barnyard grass	X		X					
Bermuda grass	X			X				
Big cordgrass			X	X				
Big smartweed								
Bitter panic grass	X	X	X					
Black cherry			X					
Black locust			X					
Black swallowwort			X					
Black willow	X	X	X	X		X		X
Boneset			X					
Box elder		X		X			X	
Broadleaf arrowhead	X	X				X	X	
Broadleaf cattail	X			X				X
Bull tongue						X		
Bur cucumber			X					
Bur reed						X		
Buttonbush	X					X	X	X
Cocklebur								
Common alder			X	X				X
Common burdock		X		X				
Common elder		X						X
Common ragweed		X		X				
Common spikerush	X							

(Continued)

(Sheet 1 of 4)

Table 7 (Continued)

Plant Species	West Dike	South Dike	East Dike	North Dike	Interior	Queen's Creek	Ducking Stool	East Island
Crabgrass								
Cypress bulrush			X					
Dayflower		X						
Dodder				X				
Eastern cottonwood			X	X				
False aster	X	X	X	X				X
False indigo-bush			X					
False nettle		X	X			X	X	
Field mint			X					
Flowering spiderwort				X				
Foxtail grass				X				
Giant cutgrass	X				X	X		X
Goose grass								
Grape		X		X				
Green ash	X			X				
Greenbriar			X					
Groundnut			X	X				
Halberd-leaved tearthumb						X		
Hedge bindweed		X	X					
Horse nettle		X		X				
Indian hemp	X							
Ironweed		X						
Ivy-leaved morning glory	X	X						
Jewelweed			X	X		X		X
Lambsquarters				X				
Late flowering thoroughwort	X	X	X					
Leafy beggarticks			X	X				X
Mannagrass		X						
Marsh yellow cress	X	X						
Mild water pepper	X	X	X	X		X	X	X

(Continued)

Table 7 (Continued)

Plant Species	West Dike	South Dike	East Dike	North Dike	Interior	Queen's Creek	Ducking Stool	East Island
Mistletoe							X	
Mock bishop's weed			X					
Narrowleaf cattail	X	X			X	X		
Nodding smartweed	X			X			X	
Pickerelweed	X	X	X	X	X	X	X	X
Pigweed	X		X					
Pokeweed			X	X				
Pumpkin ash						X	X	X
Red maple				X			X	
Red top		X		X				
Rice cutgrass	X	X				X	X	
River birch	X							
River bulrush						X		X
Rose mallow	X	X	X	X		X	X	X
Seashore mallow			X					
Sedge			X					
Sericea lespedeza			X					
Sesbania			X	X				
Silver maple			X	X				
Smooth beggerticks	X		X	X				X
Smooth cordgrass			X	X				
Sneezeweed		X	X	X				
Soft rush			X					
Softstem bulrush			X	X		X		X
Southern hackberry			X					
St. John's wort							X	
Swamp dock				X				X
Swamp dogwood			X			X		
Swamp milkweed				X		X		X
Swamp rose				X			X	
Switchgrass		X	X	X				
Sycamore		X	X	X				

(Continued)

Table 7 (Concluded)

Plant Species	West Dike	South Dike	East Dike	North Dike	Interior	Queen's Creek	Ducking Stool	East Island
Tulip poplar			X					
Unknown	X							
Water hemlock		X	X	X				X
Water hemp	X	X	X	X			X	X
Water horehound		X		X				X
Water parsnip				X				
Water willow	X			X		X		
White clover								
White mulberry		X		X				
Wild bean		X	X	X				X
Wild lettuce			X					
Wild rice	X	X	X		X	X	X	X
Wild rye			X					
Wood nettle				X				
Woodbine			X					
Yellow flag		X		X				X

(Sheet 4 of 4)

Table 8

Approximate Densities of the 13 Dominant Taxa
Averaged Over All Samplings During the 1979 Season

Site	Individuals/m^2	
	Marsh	Mudflat
Windmill Point	4600	700
Ducking Stool	1700	1200
East Island	3200	1600
Queen's Creek	2100	650

Table 9

Species Response to Caging Treatments, 1979

	Apr-Jun				Jun-Oct			
	HD*		DS		HD		DS	
Species	Marsh	Mud-flat	Marsh	Mud-flat	Marsh	Mud-flat	Marsh	Mud-flat
Branchiura sowerbyi		+**				+		
Limnodrilus spp.	+		+				+	
L. hoffmeisteri			+				+	
Peloscolex freyi			+	-				
P. multisetosus			+				+	
Coelotanypus spp.		+		+		+		
Procladius spp.		+		-				
Corbicula flumenia		+	+	+		+		

* HD--Habitat development site.
DS--Ducking Stool site.

** + = increase, - = decrease.

Table 10

Wildlife Species Observed on the Windmill Point Habitat Development Site and Associated Reference Areas on 20 July 1982

Species	Windmill Point	Queen's Creek	Ducking Stool	East Island
Birds				
Bald eagle	X			
Barn swallow	X			
Blue-gray gnatcatcher			X	
Cardinal		X		
Common gallinule			X	
Double-crested cormorant	X			
Fish crow	X			
Great blue heron	X		X	
Great crested flycatcher			X	
Green heron		X	X	
Hairy woodpecker			X	
Killdeer	X			
King rail	X			
Laughing gull	X			
Least tern	X			
Mallard	X		X	
Marsh wren	X			
Mourning dove	X	X	X	
Osprey	X			
Purple martin	X	X		X
Red-bellied woodpecker			X	
Red-winged blackbird	X	X	X	X
Rough-winged swallow				X
Song sparrow		X		
Tree swallow	X			X
Wood duck	X		X	
Yellow-billed cuckoo			X	
Yellow warbler		X		
Mammals				
Beaver	X		X	
Raccoon	X			

Table 11

Summary of Biomass Measurement Listed in Descending Order by Elevational Zone from Buttermilk Sound Habitat Development Site and Three Reference Marsh Sites During October 1979*

			Species								
Zone	Area	Biomass Measurement	Black Needlerush	Big Cordgrass	Tall Form Smooth Cordgrass		Short Form Smooth Cordgrass	Saltmeadow Cordgrass	Saltmarsh Bulrush	Sea Oxeye	Total
4	Buttermilk Sound	Live	-	-	-	-	-	97 ± 49**	-	-	97
		Dead	-	-	-	-	-	133 ± 34	-	-	133
		Combined	-	-	-	-	-	230	-	-	230
		Belowground	-	-	-	-	-	1,696 ± 275	-	-	1,696
4	Broughton Island	Live	541 ± 52	652 ± 29	-	-	-	-	-	-	1,193
		Dead	204 ± 52	641 ± 261	-	-	-	-	-	-	845
		Combined	745	1,293 ±	-	-	-	-	-	-	2,038
		Belowground	8,057 ± 984	7,032 ± 2,535	-	-	-	-	-	-	15,099
4	Belltail Island	Live	200 ± 67	-	-	-	55 ± 9	-	-	-	255
		Dead	206 ± 18	-	-	-	163 ± 29	-	-	-	369
		Combined	406	-	-	-	218	-	-	-	624
		Belowground	2,222 ± 760	-	-	-	1,473 ± 307	-	-	-	3,695
4	Hardhead Island	Live	276 ± 59	421 ± 114	-	-	-	-	-	-	697
		Dead	163 ± 42	661 ± 36	-	-	-	-	-	-	824
		Combined	439	1,082	-	-	-	-	-	-	1,521
		Belowground	10,679 ± 430	8,577 ± 3,442	-	-	-	-	-	-	19,256
3	Buttermilk Sound	Live	240 ± 10	158 ± 44	445 ± 80		-	136 ± 51	82 ± 23	662 ± 309	1,723
		Dead	63 ± 12	454 ± 45	179 ± 39		-	132 ± 13	334 ± 122	0	753
		Combined	303	612	624			268	416	662	2,885
		Belowground	1,537 ± 167	3,337 ± 972	4,659 ± 812		-	1,728 ± 171	3,098 ± 1,284	725 ± 428	15,084
3	Broughton Island	Live	-	-	429 ± 260		-	-	-	-	429
		Dead	-	-	155 ± 32		-	-	-	-	155
		Combined	-	-	584		-	-	-	-	584
		Belowground	-	-	3,695 ± 339		-	-	-	-	3,695
3	Belltail Island	Live	-	296 ± 44	369 ± 34		775 ± 118	-	12 ± 4	-	1,452
		Dead	-	918 ± 175	127 ± 59		537 ± 61	-	206 ± 74	-	1,788
		Combined	-	1,214	496		1,312	-	218	-	3,240
		Belowground	-	9,214 ± 1,978	2,636 ± 387		8,975 ± 2,220	-	5,670 ± 1,229	-	26,495
3	Hardhead Island	Live	-	-	-		-	-	-	-	
		Dead	-	-	-		-	-	-	-	
		Combined	-	-	-		-	-	-	-	
		Belowground	-	-	-		-	-	-	-	
2	Buttermilk Sound	Live	-	-	723 ± 201		-	-	-	-	723
		Dead	-	-	114 ± 14		-	-	-	-	114
		Combined	-	-	837		-	-	-	-	837
		Belowground	-	-	1,290 ± 17		-	-	-	-	1,290

Note: All values are grams dry weight per square metre.
* After Hardisky and Reimold (1979a) and (1979c).
** Values include the mean ± one standard error (n = 3).

Table 12

Summary of Data Collected at the Buttermilk Sound Habitat Development Site and Two Reference Areas on 25-26 August 1982

Species	Buttermilk Sound Site*				Broughton Island**				Hardhead Island**			
	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2
Annual saltmarsh aster									37.0	50.8	50	0
Big cordgrass	8.8	283.3	50	2.6	40	268.9	100	5.5	1.0	243.5	25	1.0
Mudwort					365	2.0	50	0				
Saltmarsh bulrush	10.0	150.8	50	0.5								
Seaside goldenrod									0.5	78.0	25	0
Smooth cordgrass	79.0	131.5	100	0	55.6	128.2	75	0	53.5	134.8	100	0
Softstem bulrush	7.0	179.0	25	1.2					285	126.7	100	8.0
	Σ=104.8	$\bar{X}$=186.2			Σ=460.6	$\bar{X}$=133.0			Σ=120.5	$\bar{X}$=158.4		
	Mean percent cover =88.8				Mean percent cover = 76.2				Mean percent cover = 66.2			

* Based on eight 0.5-m^2 quadrats.

** Based on four 0.5-m^2 quadrats.

Table 13

Wildlife Species Observed at the Buttermilk Sound Habitat Development Site and Nearby Reference Areas on 25-26 August 1982

Buttermilk Sound Site	Hardhead Island Marsh
Barn swallow	Barn swallow
Black-crowned night heron	Clapper rail
Black skimmer	Marsh wren
Boat-tailed grackle	Royal tern
Clapper rail	
Common crow	**Broughton Island Marsh**
Great blue heron	Clapper rail
Great egret	Little blue heron
Laughing gull	Red-winged blackbird
Least tern	Yellow-crowned night heron
Lesser yellowlegs	
Little blue heron	**Broughton Island Disposal Area**
Marsh wren	Common crow
Mourning dove	Laughing gull
Osprey	Least tern
Red-winged blackbird	Mockingbird
Royal tern	Red-winged blackbird
Snowy egret	White-tailed deer
Willet	Unidentified small mammals (mice, shrews, voles)
Yellow-crowned night heron	
Muskrat	
White-tailed deer	
Unidentified small mammals (mice, shrews, voles)	

Table 14

Plant Species Observed at Buttermilk Sound Disposal Area and Habitat Development Site on 25-26 August 1982

American three-square	Nodding smartweed
Annual saltmarsh aster	Ogeechee plum
Bahia grass	Pickerelweed
Beach morning glory	Pokeweed
Bermuda grass	Poor-joe
Big cordgrass	Rose mallow
Blue curls	Saltgrass
Broadleaf cattail	Saltmarsh bulrush
Cabbage palm	Saltmarsh cattail
Camphorweed fleabane	Saltmarsh fleabane
Common elder	Saltmarsh morning glory
Common greenbriar	Saltmeadow cordgrass
Cowpea	Sandspur
Crabgrass	Sea oxeye
Curly-leaf dock	Seashore mallow
Deer pea	Seaside goldenrod
Densely-flowered smartweed	Smooth cordgrass
Dog fennel	Softstem bulrush
Drummond sesbania	Switchgrass
Eastern red cedar	Water hemp
Groundsel tree	White thoroughwort
Marsh elder	Wisteria
Nightshade	Yerba
	Yucca

Table 15

Summary of Vegetation Data Collected at the Apalachicola Bay Habitat Development Site and Three Reference Areas on 24 August 1982

	Apalachicola Bay Site* (Drake Wilson Island)				Bulkhead Point**				Shell Point**				Cat Point**			
Species	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/m^2	Stem Density stems/m^2	Mean Stem Height cm	Frequency of Ocurrence %	Mean No. Flowering stems/m^2
Smooth cordgrass	137.8	93.7	100	0	83.5	79.2	100	0	190.0	52.3	100	0	161.0	111.4	100	0
Saltmarsh bulrush	1.8	80.1	25	0												
Total	139.6	86.9			83.5	$\bar{X}$=79.2			190.0	$\bar{X}$=52.3			161.0	$\bar{X}$=111.4		
	Mean percent cover = 73.1%				Mean percent cover = 48.8%				Mean percent cover = 75%				Mean percent cover = 88.8%			

* Based on eight 0.5-m^2 quadrats.

** Based on four 0.5-m^2 quadrats.

Table 16

Mean Percent Cover at the Apalachicola Bay Habitat Development Site on 24 August 1982*

Species	Mean Percent Cover			
	Plot A	Plot B	Plot C	Plot D
Bahia grass	14	3	3	5
Beardgrass	1	13	3	31
Blazing star		1		
Brome grass	1			
Club moss	22	35	21	6
Coarse rush	1	1		2
Dog fennel	2	2	1	2
Groundsel tree			1	
Marsh loosestrife			3	4
Pennywort	3			
Pilewort			1	trace**
Royal fern	1			
Saltmeadow cordgrass	5	9	14	9
Unidentified composite				1
Unidentified forb			trace**	
Unidentified moss			3	11
Unidentified sedge				10
Totals	50	64	50	81
Saltmeadow cordgrass (September 1977)	75-100	50-75	25-50	0-10
Salt meadow cordgrass original spacing, m	0.3	0.6	1.8	2.7

* Based on four 0.25-m^2 quadrats and species composition of saltmeadow cordgrass experimental plots.

** <1 percent cover.

Table 17

Plant Species Observed on Drake Wilson Island (Including the Apalachicola Bay Habitat Development Site) and Associated Reference Areas on 24 August 1982

Drake Wilson Island (Wetland and Upland)

American three-square	Crabgrass
Arrowhead	Curly-leaf dock
Bagpod	Dallis grass
Bahia grass	Dandelion
Bald cypress	Deer pea
Barnyard grass	Dog fennel
Bermuda grass	European beachgrass
Big smartweed	Fall panic grass
Bitter panic grass	Fimbristylis
Black cherry	Fleabane
Black needlerush	Globe nutsedge
Blazing star	Green ash
Broadleaf cattail	Ground pine
Brome grass	Groundsel tree
Broom sedge	Lead plant
Bushy beardgrass	Lichens
Cabbage palm	Live oak
Camphorweed fleabane	Loblolly pine
Centipede grass	Longleaf pine
Chufa	Marsh elder
Climbing hempweed	Marsh loosestrife
Club moss	Marsh rose mallow
Coarse nutsedge	Mosses
Coarse rush	Nutsedges (2 unid.)
Common plantain	Ogeechee plum
Common ragweed	Onion
Common reed	Panic grass

(Continued)

Table 17 (Concluded)

Pepperbush	Sensitive fern
Peppervine	Shortleaf pine
Perennial saltmarsh aster	Sicklepod
Pigweed	Small white morning glory
Pilewort	Smooth cordgrass
Plantain	Softstem bulrush
Pokeweed	Southern dewberry
Red rattlebox	Spiderwort
Rose mallow	Spikerush
Royal fern	Spiny sandspur
Saltgrass	Spurge
Saltmarsh cattail	St. Augustine grass
Saltmarsh fleabane	Swamp dock
Saltmarsh morning glory	Switchgrass
Saltmarsh sand spurry	Water hemp
Saw grass	Water hyssop
Sea oxeye	Water pennywort
Sea purslane	Water smartweed
Seashore mallow	Wax myrtle
Seaside goldenrod	Yerba
Sedge	Yucca

Drake Wilson Island (Wetland and Upland) (Continued)

Plants Observed in the High Marsh Zone on One or More of the Reference Areas but Not Seen on Drake Wilson Island

Common greenbrier	Prickly pear cactus
Glasswort	Sea lavender
Grapes	Sea oats
Live oak	Wooly croton
Perennial foxtail grass	Yaupon
Poison ivy	

Table 18

Wildlife Observed on Drake Wilson Island (Including the Apalachicola Bay Habitat Development Site) and Associated Reference Areas on 24 August 1982

Drake Wilson Island	Bulkhead Point
Barn swallow	Clapper rail
Belted kingfisher	Fish crow
Black-bellied plover	Laughing gulls
Black vulture	Yellow-crowned night heron
Brown pelican	Unid. plovers
Clapper rail	Fiddler crabs
Common crow	
Double-crested cormorant	**Cat Point**
Fish crow	Black-bellied plover
Great blue heron	Great blue heron
Great egret	Laughing gulls
Laughing gull	Eastern mole
Least tern	Fiddler crab
Little blue heron	
Louisiana heron	**Shell Point**
Red-tailed hawk	Clapper rail
Royal tern	Laughing gull
Sandwich tern	Osprey
Snowy egret	Robin
Cottontail rabbit	
Eastern mole	
Unidentified small mammals (mice, voles, shrews)	
Fire ants	
Native ants	
Blue crab	
Fiddler crab	
Hermit crab	

Table 19

Summary of Vegetation Data Collected at the Bolivar Peninsula Habitat Development Site and Three Reference Areas, Fall 1978

Measurement	Area: Bolivar Peninsula	Pepper Grove	Eight-Mile Road	Jamaica Beach
Mean aboveground biomass of live smooth cordgrass, g/m^2*	468.2	270.8	218.6	326.4
Mean aboveground biomass of dead smooth cordgrass, g/m^2*	86.2	116.8	2.8	11.4
Mean stem density of live smooth cordgrass, No./m^2*	199.4	148.6	201.4	335.4
Mean stem density of dead smooth cordgrass, No./m^2*	43.6	68.4	3.6	21.6
Mean percent cover*	19.0	18.1	29.4	28.5
Mean height of smooth cordgrass, cm	67.5	48.2	35.2	39.8
Mean stem density of annual glasswort, No./m^2	9.2	0.2	8.2	194.0
Mean aboveground biomass of annual glasswort, g/m^2**	32.8	7.6	18.6	63.8
Aboveground biomass of all other species, g/m^2**	1.6	48.4	132.2	50.8
Litter biomass, g/m^2	62.2	28.8	113.4	28.4
Mean belowground biomass (g/m^2) by depth				
0-5 cm	72.9	294.3	596.1	975.6
5-10 cm	157.7	435.3	491.4	985.5
10-15 cm	128.8	361.3	345.4	564.3
15-20 cm	88.7	300.5	251.9	335.7
20-25 cm	48.6	240.9	191.0	243.3
Total	496.7	1632.3	1875.8	3104.4

* Differences between sites were significant at $p \leq 0.001$.
** Differences between sites were significant at $p \leq 0.05$.

Table 20

Summary of Vegetation Data Collected at the Bolivar Peninsula Habitat Development Site and Three Reference Areas, Fall 1979

Measurement	Area			
	Bolivar Peninsula	Pepper Grove	Eight-Mile Road	Jamaica Beach
Mean aboveground biomass of live smooth cordgrass, g/m^2*	490.6 (75.6)**	448.2 (79.4)	479.6 (126.7)	458.5 (79.4)
Mean stem density of live smooth cordgrass, $No./m^2$*	201.7 (31.8)	246.4 (44.7)	255.0 (63.4)	356.2 (54.5)
Mean percent cover*	23.1 (2.9)	27.5 (5.1)	17.0 (4.1)	32.1 (4.0)
Mean height of smooth cordgrass, cm	77.9 (7.5)	79.6 (6.3)	81.6 (8.5)	63.0 (5.0)
Mean stem density of annual glasswort, $No./m^2$*	140.5 (53.6)	0 (0)	2.0 (1.4)	51.7 (40.1)
Mean aboveground biomass of annual glasswort, g/m^2†	25.4 (8.2)	0 (0)	2.7 (1.5)	14.5 (11.0)
Aboveground biomass of all other species, g/m^2	87.9 (40.2)	125.8 (53.2)	91.4 (21.7)	137.0 (42.6)
Total aboveground biomass, g/m^2	604.0 (64.9)	574.0 (84.4)	573.7 (118.2)	610.0 (64.3)
Belowground biomass (g/m^2)*				
0-10 cm	743.0 (96.3)	1076.4 (176.2)	1040.9 (146.4)	1567.7 (150.8)
10-20 cm	372.6 (44.3)	666.5 (108.3)	592.6 (95.4)	651.5 (66.7)
20-30 cm	166.2 (27.3)	401.1 (62.2)	340.2 (58.5)	375.0 (37.2)
0-30 cm	1281.8 (129.7)	2144.0 (329.4)	2007.7 (244.5)	2594.2 (197.2)

* Significant differences ($p < 0.05$) occurred between areas.
** Standard deviations of mean are in parentheses.
† Significant differences ($p < 0.10$) occurred between areas.

Table 21

Summary of Vegetation Data by Elevation (All Sites Combined) at the Bolivar Peninsula Habitat Development Site and Three Reference Areas, Fall 1978

Measurement	Elevation, m		
	0.196	0.427	0.655
Mean aboveground biomass of live smooth cordgrass, g/m^2*	609.4	268.4	82.4
Mean aboveground biomass of dead smooth cordgrass, g/m^2*	97.0	36.6	29.2
Mean stem density of live smooth cordgrass, No./m^2*	268.4	312.4	65.0
Mean stem density of dead smooth cordgrass, No./m^2*	56.0	36.6	12.8
Mean percent cover	34.5	25.0	11.8
Mean height of smooth cordgrass, cm*	66.1	36.7	40.2
Mean stem density of annual glasswort, No./m^2*	0.0	25.8	133.6
Mean aboveground biomass of annual glasswort, g/m^2	0.0	19.4	72.8
Aboveground biomass of all other species, g/m^2*	0.0	64.4	110.4
Litter biomass, g/m^2*	45.4	20.6	108.4
Total aboveground biomass, g/m^2	609.4	352.2	267.6
Belowground biomass (g/m^2) by depth			
0-5 cm	459.9	615.2	394.2
5-10 cm	547.5	744.6	262.8
10-15 cm	438.0	459.9	175.9
15-20 cm	306.0	329.9	87.6
20-25 cm	240.9	240.9	65.7
Total (25 cm)	1992.3	2390.5	986.2

* Differences by analysis of variance tests were significant at $p < 0.001$.

Table 22

Summary of Vegetation Data by Elevation at the Bolivar Peninsula Habitat Development Site and Three Reference Areas, Fall 1979

Measurement	Elevations Above Mean Low Water, m*				
	0.20	0.31	0.43	0.54	0.66
Mean aboveground biomass of live smooth cordgrass, g/m^2	738.2 (72.1)**	1076.0 (100.5)	449.7 (57.9)	66.6 (19.3)	15.6 (7.0)
Mean stem density of live smooth cordgrass, $No./m^2$	295.3 (30.0)	563.1 (48.6)	404.1 (58.1)	52.0 (15.4)	9.7 (4.1)
Mean percent cover	21.3 (2.6)	50.3 (3.9)	25.5 (3.6)	11.4 (3.8)	16.1 (4.6)
Mean height of smooth cordgrass, cm	100.7 (4.9)	98.3 (4.2)	57.2 (3.4)	36.0 (3.9)	32.3 (5.1)
Mean stem density of annual glasswort, $No./m^2$	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	43.7 (25.7)	198.6 (75.6)
Mean aboveground biomass of annual glasswort, g/m^2	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	14.4 (7.0)	38.9 (15.0)
Aboveground biomass of all other species, g/m^2	1.1 (1.1)	101.3 (55.3)	55.0 (24.2)	143.5 (44.1)	251.9 (59.6)
Total aboveground biomass, g/m^2	739.3 (72.3)	1177.3 (81.4)	504.8 (54.2)	224.5 (48.0)	306.3 (61.4)
Belowground biomass, g/m^2					
0-10 cm	1274.6 (155.8)	1837.0 (167.2)	901.8 (126.2)	691.4 (92.4)	830.2 (196.2)
10-20 cm	763.5 (106.3)	720.4 (98.8)	505.9 (61.1)	530.2 (103.6)	330.5 (66.5)
20-30 cm	495.6 (69.7)	312.3 (42.9)	314.4 (57.6)	280.6 (56.3)	200.3 (38.0)
0-30 cm	2533.7 (268.7)	2869.7 (253.9)	1722.1 (224.7)	1502.2 (228.7)	1361.0 (289.2)

* All measurements were significantly different ($p \leq 0.0001$) between elevations.

** Standard deviations of mean.

Table 23

Summary of Vegetation Data by Elevation and Site for the Bolivar Peninsula Habitat Development Site and Three Reference Areas, Fall 1978

Measurement	Bolivar Peninsula 0.65 ft	Bolivar Peninsula 1.40 ft	Bolivar Peninsula 2.15 ft	Pepper Grove 0.65 ft	Pepper Grove 1.40 ft	Pepper Grove 2.15 ft	Eight-Mile Road 0.65 ft	Eight-Mile Road 1.40 ft	Eight-Mile Road 2.15 ft	Jamaica Beach 0.65 ft	Jamaica Beach 1.04 ft	Jamaica Beach 2.15 ft
Mean aboveground biomass of live smooth cordgrass, g/m^2	936.0	267.4	201.2	378.6	327.4	106.6	601.2	43.0	0.0	522.0	435.8	21.6
Mean aboveground biomass of dead smooth cordgrass, g/m^2	226.0	14.8	17.8	141.6	111.0	98.0	0.8	7.2	0.0	19.8	13.2	1.2
Mean stem density of live smooth cordgrass, No./m^2	206.4	236.0	155.6	171.0	212.4	62.6	503.0	101.4	0.0	265.4	699.6	41.4
Mean stem density of dead smooth cordgrass, No./m^2	104.4	11.4	15.4	68.4	93.0	39.2	0.0	10.6	0.0	48.6	26.6	1.4
Mean percent cover	41.7	11.7	3.7	21.7	25.8	6.7	50.8	9.2	28.3	23.7	53.3	8.5
Mean height of smooth cordgrass, cm	95.7	44.3	57.4	59.3	41.8	34.2	46.4	18.3	--	63.1	31.3	17.5
Mean stem density of annual glasswort, No./m^2	0.0	1.4	26.0	0.0	0.0	0.6	0.0	4.0	20.0	0.0	94.4	487.6
Mean aboveground biomass of annual glasswort, g/m^2	0.0	8.6	90.0	0.0	0.0	22.6	0.0	12.6	43.2	0.0	56.0	135.4
Mean stem density of all other species, No./m^2	0.0	0.0	5.6	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	--
Mean aboveground biomass of all other species, g/m^2	0.0	0.0	4.6	0.0	137.0	8.4	0.0	120.2	276.2	0.0	0.0	152.2
Litter biomass, g/m^2	160.2	1.4	25.2	15.0	35.6	35.4	0.0	1.6	338.6	6.2	44.2	34.8
Belowground biomass to a depth of 25 cm, g/m^2	860.8	182.2	450.9	1671.7	2981.7	244.2	3635.4	1255.3	736.9	1784.4	5073.1	2454.9

Table 24

Summary of Vegetation Data by Elevation Comparing the Bolivar Peninsula Habitat Development Site and Three Reference Areas, Fall 1979

		Elevation, m					
Measurement	Area	0.20	0.31	0.43	0.54	0.66	$\bar{X}$
Mean aboveground biomass of live smooth cordgrass, g/m^2	Bol.	816.6	981.6	413.3	188.4	53.1	490.6
	Ref.	712.1	1107.5	461.9	26.0	3.0	462.1
Mean stem density of live smooth cordgrass, $No./m^2$	Bol.	192.0	489.0	193.7	107.0	26.7	201.7
	Ref.	329.8	587.8	474.2	33.7	4.0	285.9
Mean percent cover	Bol.	26.7	33.3	18.7	11.0	25.9	23.1
	Ref.	19.4	56.0	27.8	11.6	12.8	25.5
Height of smooth cordgrass, cm	Bol.	124.2	110.9	60.4	45.3	34.2	77.9
	Ref.	92.9	94.0	56.1	28.1	28.6	73.8
Mean aboveground biomass of annual glasswort, g/m^2	Bol.	0	0	0	54.6	72.7	25.4
	Ref.	0	0	0	1.0	27.6	5.7
Mean stem density of annual glasswort, $No./m^2$	Bol.	0	0	0	163.0	539.7	140.5
	Ref.	0	0	0.1	1.6	84.9	17.5
Aboveground biomass of all other species, g/m^2	Bol.	0	0	0	75.3	364.4	87.9
	Ref.	1.4	135.0	73.4	166.2	214.4	118.1
Total aboveground biomass, g/m^2	Bol.	816.6	981.6	413.3	318.3	490.2	604.0
	Ref.	713.5	1242.5	535.4	193.2	245.0	585.9
Belowground biomass, g/m^2							
0-10 cm	Bol.	505.7	1111.5	731.2	564.0	802.4	743.0
	Ref.	1530.9	2078.8	958.7	733.9	839.4	1228.3
10-20 cm	Bol.	616.0	419.4	302.9	283.0	241.9	372.6
	Ref.	812.7	820.7	577.5	612.6	360.0	637.4
20-30 cm	Bol.	413.2	120.6	71.3	113.1	113.1	166.3
	Ref.	523.1	376.2	295.9	336.5	229.3	372.1
0-30 cm	Bol.	1534.9	1651.5	1105.4	960.1	1157.4	1281.8
	Ref.	2866.6	3275.7	1931.6	1682.9	1428.7	2237.8

Table 25

Summary of Vegetation Data Collected at the Bolivar Peninsula Habitat Development Site and Three Reference Areas, 26-27 October 1982*

	Bolivar Peninsula				Pepper Grove Marsh				Eight-Mile Road Marsh				Jamaica Beach Marsh			
Species	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/ m^2	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/ m^2	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Occurrence %	Mean No. Flowering stems/ m^2	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Ocurrence %	Mean No. Flowering stems/ m^2
Saltwort									7.8	12.4	37.5	0				
Saltgrass	20%**	33.6	25	6.0	40.4%**	45.7	7.5	52.0	58.8	21.2	25	14.8				
Fimbristylis	1%**	42.3	25	1.8												
Saltflat grass									5%**	13.4	25	0				
Perennial glasswort	51.0	22.1	25	0					2.8	8.6	12.5	0	20%**	34.6	50	0
Smooth cordgrass	173.8	92.7	75	66.2	161.2	72.4	100	30.0	115.5	54.2	75	29.0	196.0	40.4	100	24.2
Saltmeadow cordgrass	1%**	59.6	25	1.2												
		X̄=50.1				X̄=59.0				X̄=22.0				X̄=37.5		
	Mean percent cover = 60.7%				Mean percent cover = 74.1%				Mean percent cover = 32.5%				Mean percent cover = 55.0%			

* Based on eight 0.5-m^2 quadrats per site at random locations throughout the intertidal zone.

** Estimate of percent species cover for area; stem count not obtained.

Table 26

Sediment Parameters from Bolivar Peninsula Habitat Development Site and Jamaica Beach Reference Marsh

Date	Area	Percent Sand	Percent Silt	Percent Clay	Percent Organic Matter	Percent Water Content
		Experimental Habitat Development Marsh				
5/78	Outside cage	78	10	12	1.0	39
	Inside cage	78	10	12	0.9	38
7/78	Outside cage	78	11	11	1.4	39
	Inside cage	70	14	16	2.1	46
9/78	Outside cage	70	13	17	2.3	46
	Inside cage	70	12	18	2.3	52
	Former cage	68	14	18	2.6	58
		Jamaica Beach Reference Marsh				
5/78	Outside cage	64	20	16	3.7	56
	Inside cage	62	22	16	3.5	64
7/78	Outside cage	64	20	16	3.5	62
	Inside cage	62	22	16	3.5	56
9/78	Outside cage	62	19	18	3.4	76
	Inside cage	48	29	23	4.7	90
	Former cage	62	22	16	3.3	64

Table 27

Abundance of the Highest Order Dominant Macrobenthos at Both the Bolivar Peninsula Habitat Development Site and Jamaica Beach Reference Marsh

Species	May 1978 Outside Cage HD*	May 1978 Outside Cage JB*	July 1978 Outside Cage HD	July 1978 Outside Cage JB	September 1978 Outside Cage HD	September 1978 Outside Cage JB
Streblospio benedicti	1,225**	4,066	63	3,092	220	16,711
Heteromastus filiformis	5,009	597	434	270	465	503
Capitella capitata	57	1,565	434	270	465	503
Nereis succinea	69	31	19	31	13	31
Laeoneris culveri	13	25	0	31	0	471
Mediomastus spp.	553	0	0	0	25	13
Loandalia fauveli	842	0	591	0	440	0
Polydora ligni	38	333	0	6	0	31
Eteone heteropoda	170	19	0	6	6	0
Glycinde solitaria	31	25	0	0	38	0
Oligochaetes	13	38	0	31	0	1,640
Corophium spp.	0	1,188	0	25	0	2,728
Hargaria rapax	0	390	0	19	0	371
Paleomonetes spp.	13	13	82	0	50	0
Total	8,033	8,290	1,623	3,781	1,722	23,002

Species	July 1978 Inside Cage HD	July 1978 Inside Cage JB	September 1978 Inside Cage HD	September 1978 Inside Cage JB
Streblospio benedicti	283	8,195	659	24,668
Heteromastus filiformis	880	264	402	559
Capitella capitata	136	4,226	25	2,292
Nereis succinea	25	38	157	50
Laeoneris culveri	0	276	0	364
Mediomastus spp.	0	0	38	88
Loandalia fauveli	723	0	666	19
Polydora ligni	0	0	0	13
Eteone heteropoda	0	6	0	6

(Continued)

* HD = Habitat development marsh, JB = Jamaica beach marsh.

** Individuals per square metre.

Table 27 (Concluded)

Species	May 1978 Outside Cage		July 1978 Inside Cage		September 1978 Inside Cage	
	HD	JB	HD	JB	HD	JB
Glycinde solitaria			13	0	25	0
Oligochaetes			0	132	0	942
Corophium spp.			0	50	6	4,547
Hargaria rapax			0	25	0	6
Paleomonetes spp.			107	0	63	0
Total			3,367	13,212	2,035	33,554

	Former Cage	
	HD	JB
Streblospio benedicti	301	20,686
Heteromastus filiformis	477	760
Capitella capitata	13	396
Nereis succinea	63	56
Laeoneris culveri	0	578
Mediomastus spp.	127	0
Loandalia fauveli	590	0
Polydora ligni	6	13
Eteone heteropoda	0	19
Glycinde solitaria	50	6
Oligochaetes	0	2,035
Corophium spp.	6	69
Hargaria rapax	0	352
Paleomonetes spp.	38	0
Total	1,671	24,970

Table 28

Ten Top Dominant Macrobenthic Taxa Collected at the Bolivar Peninsula Habitat Development Site, 1975 to 1978

Macrobenthic Taxa	Abundance Rankings		
	Preconstruction 1975	Postconstruction 1976-1977	Long Term 1978
Xenanthura brevitelson	1*	3	--
Haustoriids	2	--	--
Eteone heteropoda	3	8	6
Perioploma inedquale	4	--	--
Loandalia fauveli	5	4	3
Scoloplos spp.	6	--	--
Aricidea spp.	7	2	--
Heteromastus filiformis	8	--	1
Capitella capitata	9	7	10
Solitaria	10	--	--
Lineus socialis	11	9	5
Mediomastus spp.	--	1	4
Streblospio benedicti	--	5	2
Oligochaetes	--	6	--
Nereis succinea	--	10	8
Paleomonetes spp.	--	--	7
Glycinde	--	--	9

* 1 = most abundant.

Table 29

Summary of Biomass Measurements from the Salt Pond #3 Habitat Development Site and Three Reference Areas During 1978

Measurement	Site				
	Pond #3	Plummer Creek	Coyote Creek	Mayfield Slough	Mean
Standing crop biomass of Pacific cordgrass, g/m^2	450c*	678c	802b	1052a	746
Standing crop biomass of glassworts, g/m^2	120a	1373b	1491b	1639b	1156
Root biomass of Pacific cordgrass by depth					
0-5 cm	0.46**	1.23	1.00	2.78	1.37ab
5-10 cm	0.65	1.26	1.25	3.18	1.59a
10-15 cm	0.85	0.94	1.44	3.17	1.61a
15-20 cm	0.76	1.14	1.23	2.67	1.45a
20-25 cm	0.41	0.67	1.41	2.18	1.09b
Mean	0.60c	1.05b	1.21b	2.80a	1.42
Root biomass of glassworts by depth					
0-5 cm	0.34**	6.18	4.02	4.79	3.83a
5-10 cm	0.48	2.81	3.26	3.09	2.41b
10-15 cm	0.11	3.19	2.25	3.11	2.16b
15-20 cm	0.12	2.78	1.82	3.43	2.04b
20-25 cm	0.15	2.94	1.14	2.74	1.74b
Mean	0.24b	3.58a	2.50a	3.43a	2.44
Stem height of Pacific cordgrass, cm	86.8b	89.2b	90.7b	120.3a	96.8
Layer thickness of glassworts, cm	34	48	43	49	44

* Means followed by the same letter are not significantly different ($p \cong 0.05$).
** Root biomass reported as grams per 233 cm^3 (the volume of the 7.7- by 5-cm core section).

Table 30

Percent Sand, Silt, and Clay Content by Zone at the Salt Pond #3 Habitat Development Site and Three Reference Areas in 1978

Zone and Sample Depth	Substrate	Percent Substrate at Site			
		Pond #3	Plummer Cr.	Coyote Cr.	Mayfield S.
Cordgrass zone (low)					
0-5 cm	Sand*	0.5	0.5	0.8	0.7
	Silt	38.0	37.3	38.8	37.1
	Clay	61.5	61.6	60.4	62.2
5-25 cm	Sand	9.8	9.7	0.8	0.9
	Silt	38.5	39.2	39.1	34.8
	Clay	61.0	60.1	60.2	64.3
Glasswort zone (high)			%		
0-5 cm	Sand	5.0	8.0	2.2	2.3
	Silt	49.7	41.7	32.6	36.6
	Clay	45.3	50.3	65.2	61.1
5-25 cm	Sand	4.3	3.5	1.0	2.1
	Silt	54.4	34.2	35.1	37.1
	Clay	38.3	62.3	64.0	60.8

* Sand = 50-2000 μ; silt = 2-50 μ; clay < 2 μ.

Table 31

Soil/Substrate Chemical Parameters for the Cordgrass Zone at the Salt Pond #3 Habitat Development Site and Three Reference Areas in 1978

Parameter and Sample Depth	Site			
	Pond #3	Plummer Cr.	Coyote Cr.	Mayfield S.
Percent water				
0-5 cm	121	132	103	117
5-25 cm	82.8	96.3	95.3	106
pH				
0-5 cm	7.12	6.91	6.83	6.64
5-25 cm	6.96	7.34	7.27	6.87
Conductivity, μmhos				
0-5 cm	47,000	45,000	34,000	36,000
5-25 cm	46,000	51,000	37,000	46,000
Organic carbon, %				
0-5 cm	2.12	2.90	3.82	2.36
5-25 cm	2.04	2.80	1.84	2.73
Total phosphorus, μg/g				
0-5 cm	71.7	116	184	121
5-25 cm	57.9	86.5	105	104
Total nitrogen, %				
0-5 cm	0.244	0.244	0.204	0.280
5-25 cm	0.204	0.236	0.218	0.226
NH_4^+, μg/g				
0-5 cm	67	90	54	121
5-25 cm	36	22	34	17
NO_3^-, μg/g				
0-5 cm	78	79	59	143
5-25 cm	96	71	112	92

Table 32

Soil/Substrate Chemical Parameters for the Glasswort Zone at the Salt Pond #3 Habitat Development Site and Three Reference Areas in 1978

Parameter and Sample Depth	Site			
	Pond #3	Plummer Cr.	Coyote Cr.	Mayfield S.
Percent water				
0-5 cm	64	273	158	157
5-25 cm	56	163	115	110
pH				
0-5 cm	6.99	6.90	7.13	6.55
5-25 cm	6.80	7.31	7.38	6.94
Conductivity, μmhos				
0-5 cm	41,000	43,000	36,000	44,000
5-25 cm	31,000	75,000	35,000	55,000
Organic carbon, %				
0-5 cm	1.28	10.2	4.79	4.61
5-25 cm	1.12	5.86	3.79	3.13
Phosphorus, μg/g				
0-5 cm	72	108	137	124
5-25 cm	43	60	91	103
Nitrogen, %				
0-5 cm	0.137	0.571	0.331	0.236
5-25 cm	0.164	0.369	0.349	0.236
NH_4^+, μg/g				
0-5 cm	47	104	60	39
5-25 cm	26	49	58	16
NO_3^-, μg/g				
0-5 cm	67	84	87	82
5-25 cm	52	93	75	58

Table 33

Summary of Vegetation Data Collected at the Salt Pond #3 Habitat Development Site on 2 September 1982

	Lower Zone*				Upper Zone*				Mean of Both Zones**			
Species	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Occurrence, %	Mean No. Flowering stems/ m^2	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Occurrence, %	Mean No. Flowering stems/ m^2	Stem Density stems/ m^2	Mean Stem Height cm	Frequency of Occurrence, %	Mean No. Flowering stems/ m^2
Pacific cordgrass	154.0	96.4	100	102	1.0	29.5	25	0	104.8	83.1	62.5	51.0
Glasswort	61.0	51.3	100	--	457.5	36.6	100	--	259.2	44.0	100	--
	215.0	=73.8			458.5	=33.0			364.0	=63.6		

Mean percent cover = 81.5%   Mean percent cover = 78.2%   Mean percent cover = 79.9%

* Based on four 0.5-m^2 quadrats

** Based on eight 0.5-m^2 quadrats.

Table 34

Plant Species Observed on the Salt Pond #3 Habitat Development Site on 2 September 1982

Dodder	Pacific cordgrass
Frankenia	Perennial glasswort
Groundsel	Pickleweed
Gumweed	Rabbitfoot grass
Hedge mustard	Roseate orach
Horizonia pungens	Saltgrass
Ice plant	Saltmarsh sand spurrey
Jaumea	Smooth cordgrass
New Zealand spinach	Winterfat
Orach	

Table 35

Wildlife Observed On and Near the Salt Pond #3 Habitat

Development Site on 2 September 1982

Salt Pond #3	Alameda Channel	Open Salt Ponds & Bay
Avocet	Avocet	Avocet
Barn swallow*	Barn swallow	Barn swallow
Black-bellied plover*	Black-bellied plover	Black-bellied plover
Black-crowned night heron	Black-necked stilt	Black-necked stilt
Black-necked stilt	Blue-wing teal	Brant's cormorant
Brant's cormorant*	Brant's cormorant	Brewer's blackbird
Brewer's blackbird**	Brewer's blackbird	Brown pelican
California gull*	California gull	California gull
Caspian tern	Canvasback	Caspian tern
Cliff swallow*	Caspian tern	Cliff swallow
Domestic dog**	Cliff swallow	Double-crested cormorant
Double-crested cormorant*	Double-crested cormorant	Dunlin
Dunlin	Herring gull	Forster's tern
Forster's tern*,**	Killdeer	Great egret
Great blue heron	Least sandpiper	Herring gull
Great egret	Least tern	Least sandpiper
Herring gull	Lesser scaup	Least tern
Horned lark**	Long-billed curlew	Northern phalarope
Kestrel**	Mallard	Ruddy turnstone
Killdeer**	Marbled godwit	Snowy egret
Least sandpiper	Northern phalarope	Snowy plover
Long-billed curlew	Ringneck duck	Tree swallow
Long-billed dowitcher	Sanderling	Western gull
Long-billed marsh wren**	Semi-palmated plover	Western sandpiper
Marbled godwit	Snowy plover	White pelican
Marsh hawk**	Spotted sandpiper	Willet

(Continued)

* Flying over the salt pond.
** Present only in the high marsh zone.

Table 35 (Concluded)

Salt Pond #3	Alameda Channel	Open Salt Ponds & Bay
Norway rat**	Tree swallow	
Peregrine falcon*,**	Western sandpiper	
Saltmarsh song sparrow**	Willet	
Sanderling	Wimbrel	
Semi-palmated plover		
Snowy egret		
Tree swallow*		
Western gull		
Western meadowlark**		
Western sandpiper		
Willet		
Wimbrel		

* Flying over the salt pond.
** Present only in the high marsh zone.

Table 36

Elevation, Plant Cover, Aboveground Biomass, and Belowground Biomass at the Miller Sands Wetland Habitat Development Area and Three Nearby Reference Areas in 1978

Measurement	Elev.	Area			
		Miller Sands	Cove Site	Snag Island	Harrington Point
Elevation	Upper	2.10 ± 0.07	1.71 ± 0.01	1.36 ± 0.02	1.69 ± 0.03
(m above MLLW)	Middle	1.40 ± 0.02	1.24 ± 0.06	1.13 ± 0.01	1.23 ± 0.03
mean ± SE	Lower	0.98 ± 0.03	0.87 ± 0.02	0.84 ± 0.06	0.56 ± 0.01
Plant cover, %	Upper	37 ± 5	100 ± 0	100 ± 10	100 ± 0
mean ± SE	Middle	90 ± 5	98 ± 2	99 ± 1	98 ± 2
	Lower	56 ± 7	82 ± 3	74 ± 13	44 ± 10
Aboveground	Upper	82 ± 10	650 ± 78	798 ± 56	874 ± 58
biomass, g/m^2	Middle	408 ± 50	704 ± 84	820 ± 114	780 ± 78
mean ± SE	Lower	166 ± 30	122 ± 14	178 ± 22	74 ± 38
Belowground biomass,	Upper	138 ± 40	1300 ± 231	2410 ± 365	4420 ± 464
g/m^2	Middle	138 ± 40	797 ± 119	1170 ± 191	2620 ± 337
mean ± SE	Lower	121 ± 36	199 ± 59	780 ± 231	172 ± 70

Table 37

Importance Values* of Plant Species from the Upper and Middle Elevations at the Miller Sands Experimental Habitat Development Site and Three Nearby Reference Areas in 1978

	Importance Values							
	Miller Sands		Cove Site		Snag Island		Harrington Pt.	
Species	Upper	Middle	Upper	Middle	Upper	Middle	Upper	Middle
Lyngbye's sedge		5	86	61	67	78	62	92
Slough sedge	47	39						
Tufted hairgrass	77	56	23	28	30	15	14	16
Douglas aster		4	17	11	12	6	18	7
Water parsnip		3	2		12		22	23
Pointed rush		2	2	23	36	38	9	20
Yellow monkey flower	4	12	5	15	21	19	9	9
Nodding beggarticks	18	9	15	3	2		1	2
Water smartweed	35	24	10	10	2	2		2
Watson's willow-herb	4	10		1	8	5	6	2
Spikerushes		8	8	29		16	1	3
Lilaeopsis		31	16	17	2	4		12
Smaller grasses**	4	4	3	3	6	16	6	3
Larger grasses†					2		5	
Soft rush		2		1				
Slender rush			2	3			10	2

(Continued)

* Importance value is the sum of the relative density, relative dominance (derived from mean stem heights), and relative frequency of each species found in the sampling quadrats.

** Primarily red top with some water foxtail.

† Mostly reed canarygrass and tall fescue.

Table 37 (Concluded)

Species	Importance Values							
	Miller Sands		Cove Site		Snag Island		Harrington Pt.	
	Upper	Middle	Upper	Middle	Upper	Middle	Upper	Middle
Water plantain		4	2	4			3	2
Mudwort		2						
Field horsetail							10	
Sea watch							10	
Pacific silverweed							4	
Clammy hedge hyssop			2	3				3
Broadleaf arrowhead							1	
Flowering quillwort				2				
Nuttall's waterweed							3	2
American searocket	4							
Forget-me-not							1	
Marsh marigold							2	
Sneezeweed							2	
Softstem bulrush								2

Table 38

Summary of Vegetation Data for All Species Combined Collected from the Miller Sands Wetland Habitat Development Site and Three Reference Areas During August 1980

Measurement	Elev.	Miller Sands	Cove Site	Harrington Point	Snag Island	Mean
Mean aboveground biomass, g/m^2	U	372.7	599.2	471.8	638.1	520.4a
	M	270.9	772.5	382.6	791.5	554.4a
	L	160.1	729.5	76.0	185.2	287.7b*
	Mean**	267.8b	700.4a	310.0b	538.3a	454.2
Mean stem density, No./m^2	U	780.4	830.4	1689.6	426.6	931.7a
	M	1064.0	355.6	1589.4	323.0	833.0a
	L	804.6	513.6	415.6	240.4	493.5b*
	Mean**	882.9ab	566.5bc	1231.5a	330.0c	752.8
Mean percent cover	U	49.5	74.5	58.6	39.8	55.6a
	M	32.0	48.5	41.5	57.2	44.8b
	L	19.3	36.1	12.2	8.3	19.4c*
	Mean**	33.6b	53.6a	37.4b	38.1b	40.6
Mean stem height, cm	U	29.7	47.0	49.9	72.9	45.6b
	M	40.4	66.1	50.3	83.5	58.8a
	L	24.0	64.6	30.6	40.6	39.5c*
	Mean*	31.0d	56.5b	50.0c	67.4a	48.1
Mean belowground biomass, g/m^2	U	111.5	95.0	715.9	482.4	430.8
	M	164.3	839.8	785.3	295.0	421.9
	L	108.7	311.9	165.4	199.2	192.7
	Mean**	128.3c	374.7b	597.1a	325.5b	340.6

* Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

** Difference in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 39

Frequency of Occurrence (%) by Location and Elevation of Plant Species Found in Random 0.5-m^2 Quadrats

During August 1980 on the Miller Sands Marsh Habitat Development

Site and Three Nearby Reference Areas

	Miller Sands				Cove Site				Harrington Pt.				Snag Island				Grand	Rel.
Species	L*	M	U	Mean	L	M	U	Mean	L	M	U	Mean	L	M	U	Mean	Mean	Freq.
Algae	20	10	20	13.3	0	0	0	0	20	10	60	30	0	0	0	0	11.6	1.7
Alsike clover	0	0	20	6.7	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0.1
American three-square	0	0	0	0	0	0	0	0	10	50	80	46.7	0	0	0	0	11.7	1.7
Beggarticks	10	20	70	33.3	0	80	50	43.3	0	0	0	0	0	0	10	3.3	20.0	3.0
Birdsfoot-trefoil	0	0	20	6.7	10	0	100	36.7	0	0	0	0	0	0	0	0	10.8	1.6
Buttercup pennywort	0	0	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Clammy hedge hyssop	40	0	0	13.3	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0.1
Common forget-me-not	0	0	50	16.7	0	0	50	16.7	0	0	0	0	0	0	0	0	8.3	1.2
Common spikerush	100	50	40	63.3	40	10	50	33.3	80	80	10	56.7	20	20	10	16.7	42.5	6.3
Douglas aster	10	40	90	46.6	50	80	90	73.3	0	10	40	16.7	0	20	10	0	35.8	5.3
English plantain	0	0	0	0	0	0	20	6.7	0	0	0	0	0	0	0	0	1.7	0.1
European beachgrass	0	0	0	0	0	0	20	6.7	0	0	0	0	0	0	0	0	1.7	0.1
Field horsetail	0	0	0	0	0	0	10	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Lilaeopsis	70	100	80	83.3	50	0	0	16.7	80	100	80	36.7	10	0	0	3.3	47.5	7.0
Lyngbye's sedge	0	30	10	13.3	100	100	70	90	80	100	100	93.3	70	100	100	90	71.7	10.6
Marsh pepper	0	0	0	0	0	10	0	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Moss	0	0	30	10.0	0	0	40	13.3	0	0	40	13.3	0	10	10	6.7	10.8	1.6
Mouse-ear chickweed	0	0	0	0	0	0	10	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Mudwort	60	0	0	20	0	0	0	0	0	10	0	3.3	80	10	10	33.3	14.2	2.1
Nuttall's waterweed	60	0	0	20	0	0	0	0	0	0	0	0	60	30	20	36.7	14.2	2.1

(Continued)

* Number of quadrats for frequency calculations: L = 10, M = 10, U = 10, Mean = 30, Grand Mean = 120.

Table 39 (Continued)

Species	Miller Sands L	M	U	Mean	Cove Site L	M	U	Mean	Harrington Pt. L	M	U	Mean	Snag Island L	M	U	Mean	Grand Mean	Rel. Freq.
Pacific silverweed	0	0	10	3.3	0	0	40	13.3	0	0	0	0	0	0	0	0	4.2	0.1
Panic grass	0	0	0	0	0	0	10	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Pointed rush	40	10	0	16.7	70	60	10	46.7	30	30	80	46.7	0	60	70	43.3	37.5	5.6
Purple loosestrife	10	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Quillwort	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	3.3	0.8	0.1
Red top	0	0	0	0	0	0	10	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Reed canarygrass	10	0	50	20.0	0	10	30	13.3	0	0	0	0	10	30	20	20.0	13.3	2.0
Rush	0	0	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Saltgrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	3.3	0.8	0.1
Scouring rush	0	0	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Sea rocket	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	3.3	0.8	0.1
Sedges	30	20	0	16.6	10	0	0	3.3	0	0	0	0	70	0	0	23.3	10.8	1.6
Slender rush	10	0	0	3.3	0	0	0	0	0	0	20	6.7	0	0	0	0	2.5	0.1
Slough sedge	30	50	70	50	0	0	10	3.3	0	0	0	0	0	0	0	0	13.3	2.0
Smartweed	0	10	10	6.7	0	70	40	36.7	0	0	0	0	0	0	0	0	10.8	1.6
Soft rush	10	10	0	13.3	0	0	0	0	0	0	40	13.3	0	0	0	0	5.0	0.1
Softstem bulrush	0	0	0	0	0	0	0	0	0	0	0	0	30	70	40	46.7	11.7	1.7
Spikerushes	0	0	10	3.3	0	0	10	3.3	0	0	0	0	0	0	0	0	1.7	0.1
Suckling clover	0	0	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Tall fescue	0	0	0	0	0	0	50	16.7	0	0	0	0	0	0	0	0	4.2	0.1
Tapered rush	20	20	0	13.3	0	0	0	0	0	0	40	13.3	0	0	0	0	6.7	0.1

(Continued)

Table 39 (Concluded)

Species	Miller Sands L	M	U	Mean	Cove Site L	M	U	Mean	Harrington Pt. L	M	U	Mean	Snag Island L	M	U	Mean	Grand Mean	Rel. Freq.
Thistle	0	0	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Tufted hairgrass	70	100	100	90	70	50	100	73.3	0	50	70	40	0	70	60	43.3	61.7	9.1
Water cress	0	0	10	3.3	0	80	40	40	0	0	0	0	0	0	0	0	14.6	2.2
Water foxtail	30	50	80	53.3	20	30	100	50	0	0	0	0	0	0	0	0	25.8	3.8
Water horehound	0	0	0	0	0	0	10	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Water parsnip	0	10	0	3.3	0	40	0	13.3	0	0	30	10	0	50	40	30.0	14.2	2.1
Water plantain	40	30	10	26.6	20	10	0	10	0	0	0	0	40	20	0	20	13.3	2.0
Water purslane	0	10	0	3.3	0	0	0	0	0	0	0	0	40	0	10	16.7	5.0	0.1
Water smartweed	70	70	60	66.7	50	10	20	26.7	0	10	10	6.7	0	0	0	0	25.0	3.7
Watson's willow-herb	0	10	60	23.3	0	60	90	50	0	10	0	3.3	0	0	10	3.3	20.0	3.0
Willows	0	0	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
Yellow flag	0	0	0	0	0	0	10	3.3	0	0	0	0	0	0	0	0	0.8	0.1
Yellow monkey flower	40	60	60	53.3	50	60	100	70.0	0	0	30	10	30	30	20	26.7	40.0	5.9
Unknown species	10	30	60	33.3	0	10	30	13.3	0	0	20	6.7	0	0	0	0	13.3	2.0

(Sheet 3 of 3)

Table 40

Frequency of Occurrence of the Plant Species Observed in 10 Percent or More of the Quadrats Sampled at the Miller Sands Wetland Habitat Development Site and Three Reference Areas During August 1980*

Species	Frequency	Relative Frequency	Aboveground Biomass, g/m^2	Stem Density, No./m^2	Average Stem Height, cm
Lyngbye's sedge	71.7	10.6	236.4	133.6	94.4
Tufted hairgrass	61.7	9.1	63.2	122.7	70.4
Lilaeopsis	47.5	7.0	5.5	244.2	37.0
Common spikerush	42.5	6.3	9.1	63.5	45.9
Yellow monkey flower	40.0	5.9	3.6	8.8	28.0
Pointed rush	37.5	5.6	36.4	22.9	74.4
Douglas aster	35.8	5.3	12.8	7.6	48.4
Water foxtail	25.8	3.8	10.4	41.5	38.3
Water smartweed	25.0	3.7	1.9	5.7	18.8
Beggarticks	20.0	3.0	0.7	1.9	39.3
Watson's willow-herb	20.0	3.0	5.8	14.3	37.9
Water cress	14.6	2.2	0.1	0.1	--
Nuttall's waterweed	14.2	2.1	0.2	2.6	4.4
Mudwort	14.2	2.1	0.2	5.2	9.0
Water parsnip	14.2	2.1	1.7	1.5	92.6
Water plantain	13.3	2.0	0.3	1.8	12.5
Slough sedge	13.3	2.0	15.5	13.0	50.0
Reed canarygrass	13.3	2.0	10.8	5.3	57.7

(Continued)

* All quadrats combined. Species arranged in descending order of frequency.

Table 40 (Concluded)

Species	Frequency	Relative Frequency	Aboveground Biomass, g/m^2	Stem Density, No./m^2	Average Stem Height, cm
American three-square	11.7	1.7	1.6	7.6	62.2
Softstem bulrush	11.7	1.7	5.6	3.3	111.1
Algae	11.6	1.7	2.6	0.2	--
Birdsfoot-trefoil	10.8	1.6	19.0	15.8	58.4
Moss	10.8	1.6	0.6	--	5.0
Smartweed species	10.8	1.6	0.9	1.4	31.4

Table 41

Summary of Mean Aboveground Biomass (g/m^2) Data for Plant Species Sampled at the Miller Sands Wetland Habitat Development Site and Three Reference Areas During August 1980

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean*
Alsike clover**	U	0.7	0	0	0	0.2
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.2	0	0	0	0.1
American three-square††,‡	U	0	0	13.1	0	3.3a
	M	0	0	4.1	0	1.0b
	L	0	0	1.7	0	0.4b
	Mean†	0b	0b	6.3a	0b	1.6

(Continued)

* The mean for each elevation is based on 10 quadrats for each of four sites for a total of 40 quadrats; the grand mean is based on all 120 quadrats combined.

** No significant differences in elevation or location at P < 0.10.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

(Sheet 1 of 14)

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Beggarticks††,‡	U	3.2	1.5	0	0.1	1.2a
	M	0.7	3.3	0	0	1.0a
	L	0	0	0	0	0a
	Mean†	1.3a	1.6a	0b	0.1b	0.7
Birdsfoot-trefoil††,‡	U	2.0	209.6	0	0	52.9a
	M	0	0	0	0	0b
	L	0	16.8	0	0	4.2b
	Mean†	0.7b	75.5a	0b	0b	19.0
Buttercup pennywort**	U	0.1	0	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Clammy hedge hyssop††,‡	U	0	0	0	0	0b
	M	0	0	0	0	0b
	L	0.9	0	0	0	0.2a
	Mean†	0.3a	0b	0b	0b	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Common forget-me-not†† ‡	U	2.4	0.3	0	0	0.7a
	M	0	0	0	0	0b
	L	0	0	0	0	0b
	Mean†	0.8a	0.1b	0b	0b	0.2
Common spikerush††	U	2.8	2.8	0.7	1.4	1.9b
	M	9.6	0.1	3.5	4.4	4.4b
	L	41.8	2.6	16.1	23.9	21.1a
	Mean†	18.1	1.8	7.0	9.9	9.1
Douglas aster**	U	10.6	15.5	61.6	0	21.9
	M	6.8	46.3	3.8	1.4	14.6
	L	0	7.8	0	0	1.9
	Mean†	5.7	23.2	21.8	0.5	12.8
English plantain**	U	0	0.1	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
European beachgrass‡‡	U	0	0.4	0	-	0.1
	M	0	0	0	-	0
	L	0	0	0	-	0
	Mean†	0b	0.1a	0b	0b	0.1
Field horsetail**	U	0	0.2	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Lilaeopsis ‡,§	U	3.7	0	11.5	0	3.8
	M	13.0	0	16.0	0	7.2
	L	12.2	3.5	6.6	0.1	5.6
	Mean†	9.6a	1.2b	11.3a	0.1b	5.5
Lyngbye's sedge††,‡	U	0.1	58.5	235.0	560.1	213.4b
	M	11.9	552.8	297.3	568.1	350.0a
	L	0	423.3	32.0	127.6	145.7b
	Mean†	4.0c	334.8a	188.1b	418.6a	236.4

(Continued)

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡‡ Differences in location (sites) significant at $P < 0.10$.
§ Differences in elevation significant at $P < 0.10$.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Moss††	U	1.3	5.4	0.8	0.1	1.9a
	M	0	0	0	0.1	0.1b
	L	0	0	0	0	0b
	Mean†	0.4	1.8	0.3	0.1	0.6
Mouse-ear chickweed**	U	0	0.1	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Mudwort††,‡‡	U	0	0	0	0	0.1b
	M	0	0	0.1	0.1	0.1b
	L	1.1	0	0	1.2	0.6a
	Mean†	0.4a	0a	0.1a	0.4a	0.2
Nuttall's waterweed††,‡	U	0	0	0	0.2	0.1b
	M	0	0	0	0.1	0.1b
	L	1.7	0	0	1.0	0.7a
	Mean†	0.6a	0b	0b	0.4ab	0.2

(Continued)

** No significant differences in elevation or location at P < 0.10.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡‡ Differences in location (sites) significant at P < 0.10.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Pacific silverweed**	U	0.3	5.1	0	0	1.4
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.1	1.7	0	0	0.4
Panic grass**	U	0	0.3	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Pointed rush††,‡	U	0	0.1	13.2	23.0	9.1b
	M	1.5	79.7	9.7	146.6	59.4a
	L	11.5	136.3	15.9	0	40.9ab
	Mean†	4.4b	72.0a	12.9b	56.6a	36.4
Purple loosestrife	U	0	0	0	0	0
	M	0	0	0	0	0
	L	0.3	0	0	0	0.1
	Mean†	0.1	0	0	0	0.1

(Continued)

** No significant differences in elevation or location at P < 0.10.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Quillwort**	U	0	0	0	0	0
	M	0	0	0	0	0
	L	0	0	0	0.1	0.1
	Mean†	0	0	0	0.1	0.1
Red top**	U	0	0.2	0	-	0.1
	M	0	0	0	-	0
	L	0	0	0	-	0
	Mean†	0	0.1	0.1	0	0.1
Reed canarygrass**	U	38.0	87.1	0	1.8	31.7
	M	0	0.3	0	2.4	0.7
	L	0.1	0	0	0.1	0.1
	Mean†	12.7	29.1	0	1.4	10.8
Rushes**	U	0.1	0	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Saltgrass**	U	0	0	0	4.6	0.5
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	0	0	0.2	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Scouring rush**	U	0.1	0	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Sea rocket**	U	0	0	0	0	0
	M	0	0	0	0.5	0.1
	L	0	0	0	0	0
	Mean†	0	0	0	0.1	0.1
Sedges**	U	0	0	0	0.0	0.0
	M	1.7	0	0	0.0	0.4
	L	0.1	0	0	0.4	0.1
	Mean†	0.6	0	0	0.1	0.1
Slender rush**	U	0	0	1.1	0	0.3
	M	0	0	0	0	0
	L	1.1	0	0	0	0.3
	Mean†	0.4	0	0.4	0	0.2
Slough sedge	U	135.6	0.2	0	0	33.9
	M	25.9	0	0	0	6.5
	L	24.9	0	0	0	6.2
	Mean†	62.1a	0.1b	0b	0b	15.5

(Continued)

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

(Sheet 8 of 14)

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Smartweeds[††,‡]	U	0.7	0.6	0	0	0.3b
	M	0.1	9.3	0	0	2.4a
	L	0	0	0	0	0b
	Mean[†]	0.3b	3.3a	0b	0b	0.9
Soft rush	U	0	0	12.3	0	3.1
	M	1.5	0	0	0	0.4
	L	0.9	0	0	0	0.2
	Mean[†]	0.8	0	4.1	0	1.2
Softstem bulrush	U	0	0	0	12.9	3.2
	M	0	0	0	23.6	5.9
	L	0	0	0	30.9	7.7
	Mean[†]	0b	0b	0b	22.5a	5.6
Spikerushes	U	0.1	0.2	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean[†]	0.1	0.1	0	0	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Suckling clover**	U	0.6	0	0	0	0.2
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.2	0	0	0	0.1
Tall fescue**	U	0	56.6	0	0	14.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	18.9	0	0	4.7
Tapered rush**	U	0	0	0	0	0
	M	5.4	0	0	0	1.4
	L	2.2	0	0	0	0.6
	Mean†	2.5	0	0	0	0.6
Thistle**	U	1.0	0	0	0	0.2
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.3	0	0	0	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Tufted hairgrass‡	U	57.4	64.4	101.0	33.0	64.0
	M	163.1	83.2	37.2	36.5	80.0
	L	47.2	135.8	0	0	45.7
	Mean†	89.2a	94.5a	46.0ab	23.2b	63.2
Water cress**	U	0.1	0	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Water foxtail††,‡	U	55.2	51.1	0	0	26.6a
	M	13.0	3.3	0	0	4.1b
	L	1.4	0.3	0	0	0.4b
	Mean†	23.2a	18.1a	0b	0b	10.4
Water horehound**	U	0	0.2	0	0	0.1
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 41 (Continued)

Species	Elev.	Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
		Site				
Water parsnip	U	0	0	7.0	4.3	2.8
	M	0.7	0.9	0	7.4	2.3
	L	0	0	0	0	0
	Mean†	0.2	0.3	2.3	3.9	1.7
Water plantain‡‡	U	0.1	0	0	0	0
	M	0.8	0.1	0	0.2	0.3
	L	2.4	0.1	0	0.1	0.6
	Mean†	1.1a	0.1b	0b	0.1b	0.3
Water purslane‡‡	U	0	0	0	0.1	0.1
	M	0.1	0	0	0	0.1
	L	0	0	0	0.1	0.1
	Mean†	0.1ab	0b	0b	0.1a	0.1
Water smartweed‡	U	7.0	0.3	0.1	0	1.8
	M	5.9	0.7	0	0	1.7
	L	8.1	1.0	0	0	2.2
	Mean†	7.0a	0.7b	0.1b	0b	1.9

(Continued)

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡‡ Differences in location (sites) significant at $P < 0.10$.

Table 41 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Watson's willow-herb[††,‡]	U	35.6	29.6	0	0.1	16.3a
	M	0.1	4.4	0.1	0	1.1b
	L	0	0	0	0	0b
	Mean[†]	11.9a	11.3a	0.1b	0.1b	5.8
Willows**	U	5.0	0	0	0	1.2
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean	1.7	0	0	0	0.4
Yellow flag**	U	0	1.2	0	0	0.3
	M	0	0	0	0	0
	L	0	0	0	0	0
	Mean[†]	0	0.4	0	0	0.1
Yellow monkey flower[††,‡]	U	6.3	7.5	1.0	0.6	3.9ab
	M	8.2	16.8	0	0.2	6.3a
	L	0.7	2.1	0	0.1	0.7b
	Mean[†]	5.1ab	8.8a	0.3b	0.3b	3.6

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 41 (Concluded)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Unknown species**	U	1.1	0.4	1.0	0	0.4
	M	0.5	1.5	0	0	0.5
	L	1.0	0	0	0	0.3
	Mean†	0.9	0.6	0.1	0	0.4
Mean total aboveground biomass††,‡	U	6.9	11.1	8.7	11.8	9.6a
	M	5.0	14.3	7.1	14.7	10.3a
	L	3.0	13.5	1.4	3.4	5.3b
	Mean†	5.0b	13.0a	5.7b	10.0a	8.4

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

(Sheet 14 of 14)

Table 42

Summary of Mean Stem Density (No./m^2) Data for All Plant Species Sampled at the Miller Sands Wetland Habitat Development Site and Three Reference Areas During August 1980

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean*
Alsike clover**	Upper	2.8	0	0	0	0.7
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.9	0	0	0	0.2
American three-square††,‡	Upper	0	0	76.2	0	19.1a
	Middle	0	0	12.2	0	3.1b
	Lower	0	0	3.0	0	0.8b
	Mean†	0b	0b	30.4a	0b	7.6
Beggarticks ‡,‡‡	Upper	11.0	1.8	0	0.2	3.3a
	Middle	2.0	5.2	0	0	1.8ab
	Lower	2.4	0	0	0	0.6b
	Mean†	5.1a	2.3b	0b	0.1b	1.9

(Continued)

* The mean for each elevation is based on 10 quadrats for each of four sites for a total of 40 quadrats; the grand mean is based on all 120 quadrats combined.

** No significant differences in elevation or location at P < 0.10.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡‡ Differences in elevation significant at P < 0.10.

(Sheet 1 of 14)

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Birdsfoot-trefoil††,‡	Upper	9.6	179.6	0	0	47.3a
	Middle	0	0	0	0	0b
	Lower	0	0	0	0	0b
	Mean†	3.2b	59.9a	0b	0b	15.8
Buttercup pennywort**	Upper	0.2	0	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Clammy hedge hyssop††,‡	Upper	0	0	0	0	0b
	Middle	0	0	0	0	0b
	Lower	4.0	0	0	0	1.0a
	Mean†	1.3a	0b	0b	0b	0.3
Common forget-me-not‡‡	Upper	0.9	1.4	0	0	2.6a
	Middle	0	0	0	0	0b
	Lower	0	0	0	0	0b
	Mean†	3.0	0.5	0	0	0.9

(Continued)

** No significant differences in elevation or location at P < 0.10.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡‡ Differences in elevation significant at P < 0.10.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Common spikerush††,§	Upper	7.6	26.0	9.8	0	10.9b
	Middle	59.4	0.2	54.8	21.6	34.0b
	Lower	0	16.0	195.0	110.4	145.7a
	Mean†	109.5a	14.1b	86.5ab	44.0ab	63.5B
Douglas aster††,‡	Upper	12.6	21.8	23.2	0.4	14.5a
	Middle	3.4	22.2	1.1	0.6	6.9ab
	Lower	0	5.4	0	0	1.4b
	Mean†	5.3b	16.5a	8.2ab	0.3b	7.6
English plantain§	Upper	0	0.4	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0b	0.1a	0b	0b	0.1
European beachgrass§	Upper	0	0.4	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0b	0.1a	0b	0b	0.1

(Continued)

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

§ Differences in location (sites) significant at $P < 0.10$.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Field horsetail**	Upper	0	0.2	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Lilaeopsis ‡,‡‡	Upper	153.6	0	762.6	0	229.1ab
	Middle	480.2	0	1025.4	0	376.4a
	Lower	251.6	126.4	124.8	5.4	127.1b
	Mean†	295.1b	42.1bc	637.6a	1.8c	244.2
Lyngbye's sedge††,‡	Upper	0.2	34.0	279.2	301.8	153.8a
	Middle	9.2	201.0	360.8	177.8	187.2a
	Lower	0	125.4	77.2	37.0	59.9b
	Mean†	3.1c	120.1b	239.1a	172.2b	133.6
Moss**	Upper	0.2	0	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡‡ Differences in elevation significant at $P < 0.10$.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Mouse-ear chickweed**	Upper	0	0.6	0	0	0.2
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Mudwort††,‡	Upper	0	0	0	1.2	0.3b
	Middle	0	0	0.6	0.4	0.3b
	Lower	4.8	0	0	55.4	15.1a
	Mean†	1.6b	0b	0.2b	19.0a	5.2
Nuttall's waterweed††,‡	Upper	0	0	0	0	0b
	Middle	0	0	0	2.0	0.5b
	Lower	29.4	0	0	0	7.4a
	Mean†	9.8a	0b	0b	0.7b	2.6
Pacific silverweed‡‡	Upper	1.0	12.6	0	0	3.4a
	Middle	0	0	0	0	0a
	Lower	0	0	0	0	0a
	Mean†	0.3	4.2	0	0	1.1

(Continued)

** No significant differences in elevation or location at P < 0.10.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡‡ Differences in elevation significant at P < 0.10.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Panic grass**	Upper	0	0.4	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Pointed rush§	Upper	0	0.2	50.0	18.0	17.1
	Middle	1.4	29.6	12.8	40.0	21.0
	Lower	21.6	86.0	15.6	0	30.8
	Mean†	7.7b	38.6a	26.1ab	19.3ab	22.9
Purple loosestrife**	Upper	0	0	0	0	0
	Middle	0	0	0	0	0
	Lower	0.4	0	0	0	0.1
	Mean†	0.1	0	0	0	0.1
Quillwort**	Upper	0	0	0	0	0
	Middle	0	0	0	0	0
	Lower	0	0	0	0.4	0.1
	Mean†	0	0	0	0.1	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

§ Differences in location (sites) significant at $P < 0.10$.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Red top**	Upper	0	1.0	0	0	0.3
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	1.0	0	0	0.1
Reed canarygrass††,§	Upper	9.2	46.4	0	3.8	14.9a
	Middle	0	0.4	0	2.6	0.8b
	Lower	0.4	0	0	0.6	0.3b
	Mean†	3.2ab	15.6a	0b	2.3ab	5.3
Rushes**	Upper	0.2	0	0	0	0.1
	Middle	0	0	0	0	0
	Lower	8.0	0	0	0	2.0
	Mean†	2.7	0	0	0	0.7
Saltgrass**	Upper	0	0	0	2.0	0.5
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0	0	0.7	0.2

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

§ Differences in location (sites) significant at $P < 0.10$.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Scouring rush**	Upper	0.6	0	0	0	0.2
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.2	0	0	0	0.1
Sea rocket**	Upper	0	0	0	0	0
	Middle	0	0	0	0.2	0.1
	Lower	0	0	0	2.0	0
	Mean†	0	0	0	0.1	0.1
Sedges**	Upper	0	0	0	0	0
	Middle	0.8	0	0	0	0.2
	Lower	0	45.4	0	5.8	12.8
	Mean†	0.3	15.1	0	1.9	4.3
Slender rush**	Upper	0	0	21.2	0	5.3
	Middle	0	0	0	0	0
	Lower	11.4	0	0	0	2.9
	Mean†	3.8	0	7.1	0	2.7

(Continued)

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Slough sedge‡	Upper	99.4	0.1	0	0	24.9
	Middle	17.0	0	0	0	4.3
	Lower	39.6	0	0	0	9.9
	Mean†	52.0a	0.1b	0b	0b	13.0
Smartweeds ‡,‡‡	Upper	2.8	2.6	0	0	1.4ab
	Middle	0.6	11.0	0	0	2.9a
	Lower	0	0	0	0	0b
	Mean†	1.1b	4.5a	0b	0b	1.4
Soft rush**	Upper	0	0	104.2	0	26.1
	Middle	5.8	0	0	0	1.5
	Lower	10.2	0	0	0	2.6
	Mean†	5.3	0	34.7	0	10.0
Softstem bulrush‡	Upper	0	0	0	10.4	2.6
	Middle	0	0	0	18.8	4.7
	Lower	0	0	0	10.0	2.5
	Mean†	0b	0b	0b	13.1a	3.3

(Continued)

** No significant differences in elevation or location at P < 0.10.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

‡ Differences in location (sites) significant at P < 0.05. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡‡ Differences in elevation significant at P < 0.10.

Table 42 (Continued)

Species	Elev.	Site				Mean
		Miller Sands	Cove Site	Harrington Pt.	Snag Island	
Spikerushes**	Upper	0.2	3.6	0	0	1.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.1	1.2	0	0	0.3
Suckling clover**	Upper	0.8	0	0	0	0.2
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.3	0	0	0	0.1
Tall fescue**	Upper	0	10.2	0	0	2.6
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	3.4	0	0	0.9
Tapered rush‡	Upper	0	0	0	0	0
	Middle	19.4	0	0	0	4.9
	Lower	13.6	0	0	0	3.9
	Mean†	11.0a	0b	0b	0b	2.8

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Thistle**	Upper	0.4	0	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Tufted hairgrass††,‡	Upper	118.0	135.6	355.6	79.2	172.1a
	Middle	368.2	51.4	121.0	51.4	148.0a
	Lower	94.0	98.0	0	0	48.0b
	Mean†	193.4a	95.0bc	158.9ab	43.5c	122.7
Water cress**	Upper	0.6	0	0	0	0.2
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.2	0	0	0	0.1
Water foxtail††,‡	Upper	192.2	237.6	0	0	107.5a
	Middle	54.2	7.8	0	0	15.5b
	Lower	4.2	2.4	0	0	1.7b
	Mean†	83.5a	82.6a	0b	0b	41.5

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Water horehound**	Upper	0	0.2	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0.1	0	0	0.1
Water parsnip‡	Upper	0	0	3.4	4.2	1.9ab
	Middle	0.2	4.6	0	5.0	2.5a
	Lower	0	0	0	0	0b
	Mean†	0.1	1.5	1.1	3.1	1.5
Water plantain††	Upper	0.2	0	0	0	0.1b
	Middle	1.0	0.2	0	2.0	0.8b
	Lower	10.4	2.8	0	5.4	4.7a
	Mean†	3.9	1.0	0	2.5	1.8
Water purslane§	Upper	0	0	0	2.2	0.6
	Middle	0.6	0	0	0	0.2
	Lower	0	0	0	9.2	2.3
	Mean†	0.2b	0b	0b	3.8a	1.0

(Continued)

** No significant differences in elevation or location at $P < 0.10$.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in elevation significant at $P < 0.10$.
§ Differences in location (sites) significant at $P < 0.10$.

Table 42 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Water smartweed‡	Upper	24.8	1.6	0.2	0	6.7
	Middle	16. 0	2.6	0.2	0	4.7
	Lower	18.4	4.0	0	0	5.6
	Mean†	19.7A	2.7B	0.1B	0B	5.7
Watson's willow-herb††,‡	Upper	92.8	73.4	0	0.2	41.6a
	Middle	0.4	4.2	0.2	0	1.2b
	Lower	0	0	0	0	0b
	Mean†	31.1a	25.9a	0.1b	0.1b	14.3
Willows**	Upper	0.2	0	0	0	0.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0.1	0	0	0	0.1
Yellow flag**	Upper	0	0.8	0	0	0.2
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0.3	0	0	0.1

(Continued)

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 42 (Concluded)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Yellow monkey flower††,‡	Upper	25.8	37.0	2.6	0.6	17.1a
	Middle	20.6	11.8	0	0.2	8.3b
	Lower	1.8	1.8	0	0.1	1.1c
	Mean†	16.1a	16.9a	0.9b	1.5b	8.8
Unknown species**	Upper	4.4	0.8	1.4	0	1.7
	Middle	0.8	3.4	0	0	1.1
	Lower	17.0	0	0	0	4.3
	Mean†	7.4	1.4	0.5	0	2.2
Mean total stem density§	Upper	14.4	15.4	31.2	7.9	7.3a
	Middle	19.7	6.6	29.4	6.0	15.4a
	Lower	14.9	9.5	7.7	4.5	9.1b
	Mean†	16.3ab	10.5bc	22.8a	6.1c	13.9

** No significant differences in elevation or location at $P < 0.10$.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

§ Differences in locàtion (sites) significant at $P < 0.10$.

Table 43

Summary of Mean Stem Height Data (cm) for all Plant Species Sampled at the Miller Sands Wetland Habitat Development Site and Three Reference Areas During August 1980

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean*
Alsike clover**	Upper	57.9	0	0	0	57.9
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	57.9	0	0	0	57.9
American-three square**	Upper	0	0	57.2	0	57.2
	Middle	0	0	65.4	0	65.4
	Lower	0	0	86.6	0	86.6
	Mean†	0	0	62.2	0	62.2
Beggarticks**	Upper	22.8	38.8	0	49.0	31.7
	Middle	26.4	54.5	0	0	51.3
	Lower	21.7	0	0	0	21.7
	Mean†	23.1	48.4	0	49.0	39.3

(Continued)

* Means were calculated as the average of quadrat means from quadrats in which the listed plant species occurred.

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Birdsfoot-trefoil**	Upper	21.5	65.8	0	0	58.4
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	21.5	65.8	0	0	58.4
Buttercup pennywort**	Upper	7.0	0	0	0	7.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	7.0	0	0	0	7.0
Clammy hedge hyssop**	Upper	0	0	0	0	0
	Middle	0	0	0	0	0
	Lower	4.6	0	0	0	4.6
	Mean†	4.6	0	0	0	4.6
Common forget-me-not**	Upper	27.2	27.4	0	0	27.3
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	27.2	27.4	0	0	27.3

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Common spikerush††,‡	Upper	37.5	50.4	47.7	73.9	40.0b
	Middle	45.6	114.0	40.0	99.7	54.4a
	Lower	38.1	68.2	23.8	55.3	47.6Aab
	Mean†	39.6b	63.9a	32.8b	76.8a	45.9
Douglas aster††,‡	Upper	32.9	36.9	55.1	20.0	38.0b
	Middle	47.6	59.3	69.0	84.0	60.1a
	Lower	0	58.9	0	0	58.9a
	Mean†	37.8b	50.0ab	57.9Ab	62.7a	48.4
English plantain**	Upper	0	25.5	0	0	25.5
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	25.5	0	0	25.5
European beachgrass**	Upper	0	78.0	0	0	78.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	78.0	0	0	78.0

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Field horsetail**	Upper	0	44.0	0	0	44.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	44.0	0	0	44.0
Lilaeopsis‡‡	Upper	8.9		12.0		10.5
	Middle	10.8		11.5		11.2
	Lower	11.4	11.4	6.5	6.1	9.3
	Mean†	10.4	11.4	10.1	6.1	10.3
Lyngbye's sedge††,‡	Upper	49.0	82.4	69.3	114.7	88.7b
	Middle	66.6	110.0	84.2	125.9	102.4a
	Lower	0	113.5	51.0	105.8	88.8b
	Mean†	62.2B	103.8a	68.8b	116.2a	94.0
Moss**	Upper	5.0	0	0	0	5.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	5.0	0	0	0	5.0

(Continued)

** Insufficient data to analyze.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡‡ No significant differences in elevation or location at $P < 0.10$.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Mouse-ear chickweed**	Upper	0	21.7	0	0	21.7
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	21.7	0	0	21.7
Mudwort**	Upper	0	0	0	3.8	3.8
	Middle	0	0	3.0	5.5	4.3
	Lower	4.1	0	0	16.0	10.5
	Mean†	4.1	0	3.0	13.5	9.3
Nuttall's waterweed**	Upper	0	0	0	0	0
	Middle	0	0	0	3.0	3.0
	Lower	4.7	0	0	0	4.7
	Mean†	4.7	0	0	3.0	4.4
Pacific silverweed**	Upper	31.5	29.9	0	0	0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	30.4
	Mean†	31.5	29.9	0	0	30.4

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Panic grass**	Upper	0	66.5	0	0	66.5
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	66.5	0	0	66.5
Pointed rush††,‡	Upper	0	41.0	60.6	75.1	65.7B
	Middle	62.3	97.3	71.3	91.4	87.8A
	Lower	46.0	87.8	34.5	0	69.9B
	Mean†	50.1B	88.5A	59.1B	81.9A	74.5
Purple loosestrife	Upper	0	0	0	0	0
	Middle	0	0	0	0	0
	Lower	38.0	0	0	0	38.0
	Mean†	38.0	0	0	0	38.0
Quillwort**	Upper	0	0	0	0	0
	Middle	0	0	0	0	0
	Lower	0	0	0	21.5	21.5
	Mean†	0	0	0	21.5	21.5

(Continued)

** Insufficient data to analyze.
† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.
†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.
‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Red top**	Upper	0	40.0	0	0	40.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	40.0	0	0	40.0
Reed canarygrass**	Upper	42.0	83.7	0	42.2	55.9
	Middle	0	103.5	0	69.1	77.7
	Lower	33.0	0	0	18.0	25.5
	Mean†	40.2	88.7	0	51.6	57.7
Rushes**	Upper	15.0	0	0	0	15.0
	Middle	0	0	0	0	0
	Lower	31.1	0	0	0	31.1
	Mean†	25.7	0	0	0	25.7
Saltgrass**	Upper	0	0	0	28.1	28.1
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	0	0	28.1	28.1
Scouring rush**	Upper	29.0	0	0	0	29.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	29.0	0	0	0	29.0

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Sea rocket**	Upper	0	0	0	0	0
	Middle	0	0	0	101.0	101.0
	Lower	0	0	0	0	0
	Mean†	0	0	0	101.0	101.0
Sedges**	Upper	0	0	0	0	0
	Middle	47.0	0	0	0	47.0
	Lower	0	79.1	0	3.7	14.5
	Mean†	47.0	79.1	0	3.7	18.5
Slender rush**	Upper	0	0	12.5	0	12.5
	Middle	0	0	0	0	0
	Lower	21.8	0	0	0	21.8
	Mean†	21.8	0	12.5	0	15.6
Slough sedge‡	Upper	40.9	58.0	0	0	43.0
	Middle	62.8	0	0	0	62.8
	Lower	47.3	0	0	0	
	Mean†	49.5	58.0	0	0	50.0

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Smartweeds**	Upper	15.9	27.7	0	0	25.4
	Middle	10.3	37.0	0	0	36.4
	Lower	0	0	0	0	0
	Mean†	13.1	33.6	0	0	30.5
Soft rush**	Upper	0	0	52.8	0	52.8
	Middle	43.0	0	0	0	43.0
	Lower	25.1	0	0	0	25.1
	Mean†	34.1	0	52.8	0	46.5
Softstem bulrush**	Upper	0	0	0	84.7	84.7
	Middle	0	0	0	106.5	106.5
	Lower	0	0	0	137.1	137.1
	Mean†	0	0	0	111.1	111.1
Suckling clover**	Upper	51.5	0	0	0	51.5
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	51.5	0	0	0	51.5
Spikerushes	Upper	39.0	59.3	0	0	49.2
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	39.0	59.3	0	0	49.2

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

Table 43 (Continued)

Species	Elev.	Site				
		Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Tall fescue**	Upper	0	49.6	0	0	49.6
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	49.6	0	0	49.6
Tapered rush	Upper	0	0	0	0	0
	Middle	43.8	0	0	0	43.8
	Lower	36.5	0	0	0	36.5
	Mean†	40.9	0	0	0	40.9
Thistle**	Upper	30.5	0	0	0	30.5
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	30.5	0	0	0	30.5
Tufted hairgrass††,‡	Upper	46.7	64.2	71.4	88.8	64.9
	Middle	69.3	91.1	64.8	87.4	77.0
	Lower	57.0	84.0	0	0	71.5
	Mean†	57.3C	75.9AB	68.7BC	88.0A	70.4

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Water cress**	Upper	11.0	0	0	0	11.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	11.0	0	0	0	11.0
Water foxtail‡‡	Upper	37.4	38.2	0	0	37.8
	Middle	35.0	55.1	0	0	42.5
	Lower	27.5	41.3	0	0	34.4
	Mean†	35.2	42.0	0	0	38.6
Water horehound	Upper	0	49.0	0	0	49.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	49.0	0	0	49.0
Water parsnip**	Upper	0	0	47.2	38.6	42.3
	Middle	163.0	38.5	0	53.7	58.6
	Lower	0	0	0	0	0
	Mean†	163.0	38.5	47.2	47.0	51.9

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

‡‡ No significant differences in elevation or location at $P < 0.10$.

Table 43 (Continued)

Species	Elev.	Site: Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Water plantain‡‡	Upper	9.0	0	0	0	9.0
	Middle	9.0	13.0	0	23.3	15.5
	Lower	13.1	11.1	0	9.1	11.1
	Mean†	11.1	11.7	0	13.2	12.0
Water purslane**	Upper	0	0	0	4.9	4.9
	Middle	7.7	0	0	5.0	7.7
	Lower	0	0	0	0	5.0
	Mean†	7.7	0	0	5.0	5.6
Water smartweed‡	Upper	16.9	28.1	15.0	0	19.2
	Middle	15.0	28.8	20.0	0	17.4
	Lower	18.5	21.9	0	0	19.6
	Mean†	17.0a	24.6a	17.5a	1	18.8
Watson's willow-herb§	Upper	0	0	0	41.0	0
	Middle	39.5	52.6	10.0	0	45.7
	Lower	26.3	38.3	0	0	34.2
	Mean†	28.1	43.7	10.0	41.0	37.9

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡‡ No significant differences in elevation or location at $P < 0.10$.

§ Differences in location (sites) significant at $P < 0.10$.

Table 43 (Continued)

Species	Elev.	Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
Willows**	Upper	68.0	0	0	0	68.0
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	68.0	0	0	0	68.0
Yellow flag**	Upper	0	55.3	0	0	55.3
	Middle	0	0	0	0	0
	Lower	0	0	0	0	0
	Mean†	0	55.3	0	0	55.3
Yellow monkey flower††,‡	Upper	23.4	30.2	28.8	30.5	28.3b
	Middle	28.4	45.4	0	27.7	35.0a
	Lower	8.8	30.6	0	6.3	18.0c
	Mean†	22.4b	34.6a	28.8ab	20.4b	28.0
Unknown species**	Upper	4.0	31.0	58.1	0	20.2
	Middle	43.0	42.2	0	0	42.8
	Lower	8.0	0	0	0	4.0
	Mean†	20.6	36.6	58.1	0	27.0

Site columns: Miller Sands, Cove Site, Harrington Pt., Snag Island (grouped under "Site").

(Continued)

** Insufficient data to analyze.

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 43 (Concluded)

Species	Elev.	Site				Mean
		Miller Sands	Cove Site	Harrington Pt.	Snag Island	
Total[††,‡]	Upper	29.7	47.0	50.3	72.9	45.6b
	Middle	40.4	66.1	49.9	83.5	58.8a
	Lower	24.0	64.6	30.6	40.6	39.5c
	Mean[†]	31.0d	56.5b	45.9c	67.4a	48.3

† The mean total for each site is based on 10 quadrats at each of three elevations for a total of 30 quadrats.

†† Differences in elevation significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

‡ Differences in location (sites) significant at $P < 0.05$. Letters indicate differences between means as determined by Duncan's Multiple Range Test.

Table 44

Summary of Mean Belowground or Root Biomass (g/m^2) Data from the Miller Sands Wetland Habitat Development Site and Three Nearby Reference Areas During August 1980

Depth, cm	Miller Sands	Cove Site	Harrington Pt.	Snag Island	Mean
0-5	375.3	859.7	859.5	456.7	579.4
5-10	117.5	536.1	878.0	362.7	431.9
10-15	70.2	244.3	575.4	322.8	304.1
15-20	51.3	136.3	439.2	306.8	248.2
20-25	26.7	137.8	244.7	178.8	142.7
Total	641.0	1914.2	2996.8	1627.8	1706.3

Table 45

Summary of Data Collected on Vegetation at the Miller Sands Wetland Habitat Development Site on 1 September 1982*

Species	Stem Density stems/m^2	Mean Stem Height, cm	Frequency of Occurrence, %	Mean No. Flowering stems/m^2
Beggarticks	12.0	15.7	75	0
Birdsfoot-trefoil	5.8	53.0	37.5	2.0
Common spikerush	0.2	60.0	12.5	0
Douglas aster	3.0	64.0	62.5	0
Flowering quillwort	1.0	5.0	12.5	0
Lilaeopsis	138.5**	9.7	100	0.2
Lyngbye's sedge	17.0	94.7	37.5	1.25
Pacific silverweed	1.2	13.4	25	0
Pointed rush	9.5	64.8	50	10.0
Reed canarygrass	1.25	106.2	25	0.8
Slough sedge	2.2	87.1	12.5	0
Smartweeds	5.0	13.6	75	0
Spring water starwort	0.5	19.0	12.5	0.2
Tapered rush	1.0	68.2	12.5	0.8
Tufted hairgrass	399.8**	130.9	100	55.0
Water foxtail	250.0**	40.7	75	0
Watson's willow-herb	3.8	67.2	87.5	0
Yellow monkey flower	10.5	55.3	100	0

Mean percent cover from the surface of the vegetation = 82.1%.

* Data are summarized from eight 0.5-m^2 quadrats with the intertidal zone.
** Based on estimated total for each quadrat.

Table 46

Comparison of Growth Trends Between 1977 and 1982 for European Beachgrass on the Miller Sands Habitat Development Site Sandpit*

Sample Identification	Mean No. Stems/Plant	Mean No. Seedheads/Plant
August 1977 sample of beachgrass planted January 1977	26.9	0.4
August 1977 sample of beachgrass planted May 1977	6.3	0.0
September 1982 random sample of beachgrass	87.5	6.9

* Transplants were originally planted in 1977 with 0.5- by 0.5-m spacing and fertilized with two applications of ammonium sulfate at the rate of 224 kg/ha.

Table 47

Percent Cover for 1980 and 1982 on the Upland Meadows at the Miller Sands Habitat Development Site

Species	Meadow I		Meadow II		Meadow III		All Sites Combined	
	1980	1982	1980	1982	1980	1982	1980	1982
Barren bromegrass			0.1				tr.*	
Canadian bluegrass					0.1		tr.	
Cat's ear		0.6	0.2	2.6	0.2	3.4	0.1	2.2
Cheat grass			0.2				0.1	
English plantain	2.8		6.6	2.0		2.2	3.1	1.4
Hop clover		0.2		3.6				1.3
Lichens			1.0	0.1	0.4		tr.	0.2
Moss	10.3	38.0	2.2	27.8	30.7	24.8	14.4	30.2
Mouse-ear chickweed	2.2		0.8				1.0	
Oregon bentgrass	2.3		1.6				1.3	
Pearly everlasting	0.2						0.1	
Rattail fescue		1.0		1.6				0.9
Red clover				0.6				0.2
Red fescue			4.2		13.4	42.8	5.9	14.3
Red top	3.1	4.2		37.4			1.0	13.9
Reed canarygrass			7.5	1.6	0.9	5.0	2.8	2.2
Ryegrass			0.4					0.1
Scouring rush	8.3	15.2	11.8	13.4	7.7	13.2	9.3	13.9
Sheep sorrel	1.9		0.4				0.8	
Sleepy catchfly	0.2				0.1		0.1	
Stream lupine	4.6	1.4	7.3	4.0	0.1		4.0	1.8
Suckling clover	0.3	1.8	0.8	0.2			0.4	0.7
Tall fescue	19.8	27.6			0.4	0.6	6.7	9.4
Vetches					0.1		tr.	
Western wheatgrass	2.0						0.7	
White clover	0.8						0.3	
TOTAL	58.8	90.0	45.1	94.9	54.1	92.0	52.1	92.7

* tr. = >0.1%.

Table 48

Plant Species Observed at the Miller Sands Habitat Development Site and Associated Reference Areas, 1 September 1982

Plant Species in Miller Sands Wetland Quadrats

Beggarticks
Birdsfoot-trefoil
Common spikerush
Douglas aster
Flowering quillwort
Lilaeopsis
Lyngbye's sedge
Pacific silverweed
Pointed rush
Reed canarygrass
Slough sedge
Smartweed
Spring water starwort
Tapered rush
Tufted hairgrass
Water foxtail
Watson's willow-herb
Yellow monkey flower

Species Observed on the Wetland Habitat Development Site but Which Did Not Occur in Sampled Quadrats

Alsike clover
Common forget-me-not
English plantain
Purple loosestrife
Water horehound
Water parsnip
Willows
Yellow flag

Table 49

Number of Benthic Invertebrates by Elevation from the Miller Sands Wetland Habitat Development Site and Three Reference Areas

August 1980*

Taxon	Miller Sands (Experimental)			Cove Site (Natural)			Snag Island (Natural)			Harrington Point (Natural)		
	U**	M	L	U	M	L	U	M	L	U	M	L
Oligochaetes												
Lumbriculidae	534	147	33	1183	226	208	31	31		32	23	
Tubificidae	31		135	8	51	468	1953	2896	2350	4067	1323	531
Enchytraeidae	190		33	396	494	144	333	210	2			
Naididae									6			
Polychaetes												
Nereidae												2
Leeches												
Helobdella stagnalis											2	4
Dyna spp.				1	9	4	1	20		13	15	11
Isopods												
Asellidae		1										
Amphipods												
Corophium salmonis			2	1		1			1			
Anisogammarus confervicolus			2		3	11	26	7		29	18	30
Bivalves												
Corbicula fluminea	1	2	16			7	18	71	18	62	18	13
Sphaerididae				5	240	91	43	74	13	18	1	
Gastropods												
Planoribidae			8		2	4			1	4		
Lymnaeidae	39	19	104	47	19	13	7	9		7	5	
Hydrobiidae												35
Physa sp.						3		1				
Insects												
Libelluidae							2		2			
Chironomidae			68	2	21	44	46	108	80	12	12	11

(Continued)

* Abundances are total of six replicates for an area of 0.3 m^2.
** U = upper elevation, M = middle elevation, L = lower elevation.

Table 49 (Concluded)

Taxon	Miller Sands (Experimental)			Cove Site (Natural)			Snag Island (Natural)			Harrington Point (Natural)		
	U	M	L	U	M	L	U	M	L	U	M	L
Insects (Continued)												
Ceratopongidae			3									
Tabanidae	1	2										
Tipulidae	7	3	26	20	70	66	4	9		10	14	
Dolichodidae	11	11	59	20	40	38	2	11	1	12	8	
Psychodidae		2	13	6	9		4	1				
Psychodidae?			1						1			
Muscidae									1			
Carabidae	2		1	10	1	1						1
Chrysomelidae				5			18	9		279	48	8

Table 50

Average Percent Fines (Sediment Finer than 63 μm) and Volatile Solids at the Miller Sands Wetland Aquatic Habitat Development Site and Reference Areas in August 1980

	Percent Fines			Percent Volatile Solids		
Habitat	U	M	L	U	M	L
Miller Sands (experimental)	6	7	12	1.4	0.9	1.4
Cove Site (natural)	7	26	32	1.3	3.1	3.2
Snag Island (natural)	61	56	38	4.5	4.3	2.8
Harrington Pt. (natural)	21	15	13	2.7	1.8	1.8

Table 51

Selected Miller Sands Benthic Invertebrate Data for August 1980

Summarized Over All Elevations

Taxon	Location			
	Miller Sands (Experimental)	Cove Site (Natural)	Snag Island (Natural)	Harrington Pt. (Natural)
Oligochaetes	1226*	3538	8679	6640
Leeches	0	16	23	50
Corophium salmonis	2	2	1	0
Anisogammarus conifervicolus	2	16	37	86
Corbicula fluminea	21	8	119	103
Sphaerids	0	373	144	21
Gastropods	244	98	20	57
Chironomids	76	74	260	39
Tipulids	40	173	14	27
Dolichodids	90	109	16	22
Crysomelids	0	6	30	372

* Individuals per square metre.

Table 52

Wildlife Observed at Miller Sands Habitat Development Site and at Associated Reference Areas on 1 September 1982

Miller Sands	
Bald eagle	Savannah sparrow
Barn swallow	Song sparrow
Black-bellied plover	Tree swallow
Blackcapped chickadee	Unidentified sandpipers
California gull	Western (Pacific) flycatcher
Canada goose	Western gull
Caspian tern	Western sandpiper
Cedar waxwing	Western wood pewee
Common crow	White-crowned sparrow
Double-crested cormorant	Willow flycatcher
Glaucous-winged gull	Wimbrel
Glaucous-winged/Western gull hybrids	Yellow warbler
Herring gull	Columbia white-tailed deer
Killdeer	Meadow vole
Least sandpiper	Muskrat
Mallard	Norway rat
Osprey	Nutria
Ring-billed gull	Shrew
Robin	White-footed mouse
Sabine's gull	

Snag Island	Harrington Point
American widgeon	Common crow
Black-bellied plover	Glaucous-winged gull
Brandt's cormorant	Glaucous-winged/Western gull hybrids
California gull	Great blue heron
Double-crested cormorant	Western gull
Glaucous-winged gull	
Glaucous-winged/Western gull hybrids	
Great blue heron	
Least sandpiper	
Western gull	
Western sandpiper	

APPENDIX A:
ALPHABETIZED LISTING OF PLANTS AND WILDLIFE APPEARING IN THE TEXT

Plants

Common Name	Scientific Name
Alder	*Alnus* sp.
Alsike clover	*Trifolium hybridum*
American beachgrass	*Ammophila breviligulata*
American elm	*Ulmus americanus*
American germander	*Teucrium canadense*
American searocket	*Cakile edentula*
American three-square	*Scirpus americanus*
Annual glasswort	*Salicornia biglovii*
Annual saltmarsh aster	*Aster subulatus*
Apple	*Malus pumila*
Arrow arum	*Peltandra virginica*
Arrowheads	*Sagittaria* spp.
Arrow-leaved tearthumb	*Polygonum sagittatum*
Asiatic bittersweet	*Celastrus orbiculatus*
Asparagus	*Asparagus officinale*
Asters	*Aster* spp.
Bagpod	*Sesbania vesicaria*
Bahia grass	*Paspalum notatum*
Bald cypress	*Taxodium distichum*
Barberry	*Berberis* sp.
Barley	*Hordeum vulgare*
Barnyard grass	*Echniochloa crusgalli*
Barren bromegrass	*Bromus sterilis*
Bayberry	*Myrica pensylvanica*
Beach morning glory	*Ipomoea stolonifera*
Beach panic grass	*Panicum amarulum*
Beach-tea	*Croton punctatus*
Beardgrass	*Andropogon* sp.
Beggarticks	*Bidens* sp.
Bermuda grass	*Cynodon dactylon*
Big cordgrass	*Spartina cynosuroides*

Big smartweed	*Polygonum pennsylvanicum*
Bindweeds	*Convolvulus* spp.
Birdsfoot-trefoil	*Lotus corniculatus*
Bitter panic grass	*Panicum amarum*
Black cherry	*Prunus serotina*
Black cottonwood	*Populus trichocarpa*
Black gum	*Nyssa sylvatica*
Black locust	*Robinia pseudo-acacia*
Black needlerush	*Juncus roemerianus*
Black oak	*Quercus velutina*
Black swallowwort	*Cynanchum nigrum*
Black willow	*Salix nigra*
Blazing star	*Liatris* sp.
Blue curls	*Trichostema dichotomum*
Bluegrass	*Poa* sp.
Bluestem grass	*Andropogon perangustatus*
Boneset	*Eupatorium perfoliatum*
Box elder	*Acer negundo*
Bracken fern	*Pteridium aquilinum*
Broadleaf arrowhead	*Sagittaria latifolia*
Broadleaf cattail	*Typha latifolia*
Brome grass	*Bromus* sp.
Broom sedge	*Andropogon virginicus*
Bull thistle	*Cirsium vulgare*
Bull tongue	*Sagittaria lancifolia*
Bur cucumber	*Sicyos angulatus*
Bur reed	*Sparganium* sp.
Bushy beardgrass	*Andropogon glomeratus*
Buttercup pennywort	*Hydrocotyle ranunculoides*
Buttonbush	*Cephalanthus occidentalis*
Cabbage palm	*Sabal palmetto*
Camphorweed	*Heterotheca subaxillaris*
Camphorweed fleabane	*Pluchea camphorata*
Canadian bluegrass	*Poa compressa*
Catalpa	*Catalpa speciosa*
Cat's ear	*Hypochaeris radicata*

Cattails	*Typha* spp.
Centipede grass	*Eremochloa ophiuroides*
Cheat grass	*Bromus tectorum*
Chufa	*Cyperus esculentus*
Clammy hedge hyssop	*Gratiola neglecta*
Climbing hempweed	*Mikania scandens*
Clovers	*Trifolium* spp.
Club moss	*Lycopodium* sp.
Coarse nutsedge	*Cyperus odoratus*
Coarse rush	*Juncus biflorus*
Coastal panic grass	*Panicum* sp.
Cocklebur	*Xanthium sturmarium*
Common alder	*Alnus serrulata*
Common burdock	*Arctium minus*
Common elder	*Sambucus canadensis*
Common forget-me-not	*Myosotis scorpioides*
Common greenbrier	*Smilax bona-nox*
Common mullein	*Verbascum thapsis*
Common plantain	*Plantago virginica*
Common ragweed	*Ambrosia artemisiifolia*
Common reed	*Phragmites australis*
Common spikerush	*Eleocharis palustris*
Common three-square	*Scirpus americanus*
Common velvetgrass	*Holcus lanatus*
Cowpea	*Vigna* sp.
Crabgrass	*Digitaria sanguinalis*
Croton	*Croton punctatus*
Curly-leaf dock	*Rumex crispus*
Cypress bulrush	*Scirpus cyperinus*
Dallis grass	*Paspalum dilatatum*
Dandelion	*Taraxacum officinale*
Dayflower	*Commelina* sp.
Deer pea	*Vigna luteola*
Deer-tongue grass	*Panicum clandestinum*
Densely-flowered smartweed	*Polygonum densiflorum*
Dodder	*Cuscuta* sp.

Dog fennel	*Eupatorium capillifolium*
Douglas fir	*Pseudotsuga menziesii*
Douglas aster	*Aster subspictus*
Downy chess	*Bromus secalinus*
Dropseed grass	*Sporobolus* sp.
Drummond sesbania	*Sesbania drummondii*
Dwarf dandelion	*Krigia virginica*
Eastern cottonwood	*Populus deltoides*
Eastern red cedar	*Juniperus virginiana*
Elderberry	*Sambricus callicarpa*
English plantain	*Plantago lanceolata*
European beachgrass	*Ammophila arenaria*
Evening primrose	*Oenothera biennis*
Everlasting	*Gnaphalium* sp.
Fall panic grass	*Panicum dichotomiflorum*
False indigo-bush	*Amorpha fruticosa*
False nettle	*Boehmeria cylindrica*
Fescue	*Festuca* spp.
Field horsetail	*Equisetum arvense*
Field mint	*Mentha arvensis*
Fimbristylis	*Fimbristylis castanea*
Fleabanes	*Erigeron* spp.
Flowering quillwort	*Lilaea scilloides*
Flowering spiderwort	*Tradescantia* sp.
Forget-me-not	*Myosotis* sp.
Foxtail grass	*Setaria* sp.
Frankenia	*Frankenia grandifolia*
Giant cutgrass	*Zizaniopsis miliacea*
Glassworts	*Salicornia* spp.
Globe nutsedge	*Cyperus globosus*
Goldenrods	*Solidago* spp.
Goose grass	*Eleusine indica*
Grapes	*Vitis* spp.
Green ash	*Fraxinus pennsylvanica*
Greenbrier	*Smilax* sp.
Groundnut	*Apios americana*

Ground pine	*Lycopodium obscurum*
Groundsel	*Baccharis pilularis*
Groundsel tree	*Baccharis halimifolia*
Gulf cordgrass	*Spartina spartinae*
Gulf croton	*Croton* sp.
Gumweed	*Grindelia squarrosa*
Hairy vetch	*Vicia villosa*
Halberd-leaved tearthumb	*Polyganum arifolium*
Hawthorn	*Crataegus* sp.
Hedge mustard	*Sisymbrium officinale*
Hedge bindweed	*Convulvulus sepium*
Hop clover	*Trifolium agrarium*
Horse nettle	*Solanum carolinense*
Horsetail fleabane	*Erigeron canadensis*
Ice plant	*Mesembryanthemum nodiflorum*
Indian blanket	*Gaillardia pulchella*
Indian hemp	*Apocynum cannabinum*
Ironweed	*Vernonia noveboracensis*
Ivy-leaved morning glory	*Ipomoea hederacea*
Jaumea	*Jaumea carnosa*
Jewelweed	*Impatiens capensis*
Ladina white clover	*Trifolium repens ladina*
Lambsquarters	*Chenopodium album*
Late flowering thoroughwort	*Eupatorium serotinum*
Lead plant	*Amorpha herbacea*
Leafy beggarticks	*Bidens frondosa*
Lemon beebalm	*Monarda citriodora*
Lichens	
Lilaeopsis	*Lilaeposis occidentalis*
Live oak	*Quercus virginiana*
Lobelia	*Lobelia* sp.
Loblolly pine	*Pinus taeda*
Longleaf pine	*Pinus palustris*
Long-spined sandspur	*Cenchrus longispinus*
Lyngbye's sedge	*Carex lyngbeyii*
Mannagrass	*Glyceria striata*

Marestail fleabane	*Erigeron canadensis*
Maritime pinweed	*Lechea maritima*
Marsh dayflower	*Commelina communis*
Marsh boltonia	*Boltonia asteroides*
Marsh elder	*Iva frutescens*
Marsh fleabane	*Pluchea* sp.
Marsh loosestrife	*Lythrum lineare*
Marsh marigold	*Caltha asarifolia*
Marsh pepper	*Polygonum hydropiper*
Marsh rose mallow	*Hibiscus moscheutos*
Marsh yellow cress	*Rorippa islandica*
Mild water pepper	*Polygonum hydropiperoides*
Mistletoe	*Phorandendron serotinum*
Mock bishop's weed	*Ptillimnium capillaceum*
Morning glory	*Ipomoea* sp.
Mosses	
Mouse-ear chickweed	*Cerastium vulgatum*
Mudwort	*Limosella aquatica*
Narrowleaf cattail	*Typha angustifolia*
New Zealand spinach	*Tetragonia expansa*
Nightshade	*Solanum sisymbriifolium*
Nodding beggarticks	*Bidens cernua*
Nodding smartweed	*Polygonum lapathifolium*
Northern blackberry	*Rubus* sp.
Northern catalpa	*Catalpa* sp.
Northern dewberry	*Rubus flagellaris*
Northern red oak	*Quercus rubra*
Nutsedges	*Cyperus* spp.
Nuttall's waterweed	*Elodea nuttallii*
Ogeechee plum	*Nyssa ogeche*
Onion	*Allium* sp.
Orach	*Atriplex semibaccata*
Orchard grass	*Dactylis glomerata*
Oregon bentgrass	*Agrostis oregonsis*
Overcup oak	*Quercus lyrata*
Pacific cordgrass	*Spartina foliosa*

Pacific glasswort	*Salicornia pacifica*
Pacific nine-bark	*Physocarpus capitatus*
Pacific silverweed	*Potentilla pacifica*
Panic grasses	*Panicum* spp.
Pearly everlasting	*Anaphalis margaritacea*
Pennywort	*Hydrocotyle* sp.
Pepperbush	*Clethra alnifolia*
Peppergrass	*Lepidium virginicum*
Peppervine	*Amepolopis arborea*
Perennial foxtail grass	*Setaria geniculata*
Perennial glasswort	*Salicornia virginica*
Perennial pea	*Lathyrus latifolius*
Perennial ryegrass	*Lolium perenne*
Perennial saltmarsh aster	*Aster tenuifolius*
Philadelphia daisy fleabane	*Erigeron philadelphicus*
Pickleweed	*Salicornia rubra*
Pickerelweed	*Pontederia cordata*
Pigeongrass foxtail	*Setaria glauca*
Pigweed	*Amaranthus* sp.
Pilewort	*Erechtites hieracifolia*
Plantain	*Plantago* sp.
Pointed rush	*Juncus oxymeris*
Poison ivy	*Rhus radicans*
Pokeweed	*Phytolacca americana*
Poor-joe	*Diodia teres*
Prickly pear cactus	*Opuntia* sp.
Pumpkin ash	*Fraxinus tomentosa*
Purple loosestrife	*Lythrum salicaria*
Pussytoes	*Antennaria* sp.
Quillwort	*Isoetes* sp.
Rabbits-foot clover	*Trifolium arvense*
Rabbitfoot grass	*Polypogon monspeliensis*
Ragwort	*Senecio* sp.
Rattail fescue	*Festuca myuros*
Red alder	*Alnus rubra*
Red clover	*Trifolium pratense*

Red fescue	*Festuca rubra*
Red maple	*Acer rubrum*
Redosier dogwood	*Cornus stolonifera*
Red rattlebox	*Sesbania punicea*
Red top	*Agrostis alba*
Reed canarygrass	*Phalaris arundinacea*
Rice cutgrass	*Leersia* oryzoides
River bulrush	*Scirpus fluvitialis*
River birch	*Betula nigra*
Roseate orach	*Atriplex rosea*
Rose mallow	*Hibiscus* spp.
Royal fern	*Osmunda regalis*
Rush	*Juncus* sp.
Ryegrass	*Lolium multiflorum*
Saltbush	*Atriplex* sp.
Saltgrass	*Distichlis spicata*
Salt cedar	*Tamarix gallica*
Saltflat grass	*Monanthochloe littoralis*
Saltmarsh bulrush	*Scirpus robustus*
Saltmarsh cattail	*Typha domingensis*
Saltmarsh fleabane	*Pluchea purpurascens*
Saltmarsh morning glory	*Ipomoea sagittata*
Saltmarsh sand spurry	*Spergularia marina*
Saltmeadow cordgrass	*Spartina patens*
Saltwort	*Batis maritima*
Sand grass	*Triplasis purpurea*
Sand pine	*Pinus clausa*
Sandspur	*Cenchrus pauciflorus*
Sand spurry	*Spergularis platensis*
Sassafras	*Sassafras albidum*
Saw grass	*Cladium jamaicensis*
Scotch broom	*Cytisus scoparius*
Scouring rush	*Equisetum hyemale*
Sea lavender	*Limonium carolinianum*
Sea oats	*Uniola paniculata*
Sea oxeye	*Borrichia frutescens*

Sea purslane	*Sesuvium portulacastrum*
Sea rocket	*Cakile fusiformis*
Seashore dropseed	*Sporobolus virginicus*
Seashore mallow	*Kosteletzkya virginica*
Seaside goldenrod	*Solidago sempervirens*
Sea watch	*Angelica lucida*
Sedge	*Carex* spp.
Sensitive fern	*Onoclea sensibilis*
Sericea lespedeza	*Lespedeza cuneata*
Sesbania	*Sesbania exaltata*
Sheep sorrel	*Rumex acetosella*
Shortleaf pine	*Pinus echinata*
Sicklepod	*Cassia obtusifolia*
Silver maple	*Acer saccharinum*
Sitka spruce	*Picea sitchensis*
Six weeks fescue	*Festuca octoflora*
Skunk cabbage	*Symplocarpus foetidus*
Sleepy catchfly	*Silene antirrhina*
Slender rush	*Juncus tenuis*
Slough grass	*Spartina pectinata*
Slough sedge	*Carex obnupta*
Small white morning glory	*Ipomoea lacunosa*
Smartweed	*Polygonum* sp.
Smooth beggarticks	*Bidens laevis*
Smooth cordgrass	*Spartina alterniflora*
Smooth sumac	*Rhus glabra*
Sneezeweed	*Helenium autumnale*
Soft camphorweed	*Heterotheca pilosa*
Soft rush	*Juncus effusus*
Softstem bulrush	*Scirpus validus*
Southern dewberry	*Rubus trivialis*
Southern hackberry	*Celtus laevigata*
Southern wild rice	*Zizaneopsis miliacea*
Spiderwort	*Tradescentia virginiana*
Spikerushes	*Eleocharis* spp.
Spiny sandspur	*Cenchrus echinatus*

Spring water starwort	*Callitriche verna*
Spurge	*Euphorbia dentata*
Staghorn sumac	*Rhus typhina*
Stream lupine	*Lupinus rivulus*
St. Augustine grass	*Stenotaphrum secundatum*
St. John's wort	*Hypericum* sp.
Suckling clover	*Trifolium dubium*
Swamp dock	*Rumex verticillatus*
Swamp dogwood	*Cornus amomum*
Swamp milkweed	*Asclepias incarnata*
Swamp rose	*Rosa palustris*
Switchgrass	*Panicum virgatum*
Sycamore	*Platanus occidentalis*
Tall fescue	*Festuca elatior*
Tall wheatgrass	*Agropyron elongatum*
Tansy	*Tanacetum vulgare*
Tapered rush	*Juncus acuminatus*
Thistle	*Cirsium* sp.
Thorny amaranth	*Amaranthus spinosus*
Timothy	*Phleum pratense*
Tree-of-heaven	*Ailanthus altissima*
Trumpet creeper	*Campsis radicans*
Tufted hairgrass	*Deschampsia caespitosa*
Tulip poplar	*Liriodendron tulipifera*
Vetches	*Vicia* spp.
Water cress	*Rorippa nasturtium-aquaticum*
Water foxtail	*Alopecurus geniculatus*
Water hemlock	*Cicuta maculata*
Water hemp	*Amaranthus cannabinis*
Water hemp	*Acnida cannabina*
Water horehound	*Lycopus americanus*
Water hyssop	*Bacopa monnieri*
Water hyacinth	*Eichhornia crassipes*
Water parsnip	*Sium sauve*
Water pennywort	*Hydrocotyle bonariensis*
Water plantain	*Alisma plantago-aquatica*

Water purslane	*Ludwigia palustris*
Water smartweed	*Polygonum punctatum*
Water willow	*Justicia americana*
Watson's willow-herb	*Epilobium watsonii*
Wax myrtle	*Myrica cerifera*
Western wheatgrass	*Agropyron* sp.
White clover	*Trifolium repens*
White Dutch clover	*Trifolium repens*
White mulberry	*Morus alba*
White thoroughwort	*Eupatorium album*
Wild bean	*Strophostyles umbellata*
Wild lettuce	*Lactuca canadensis*
Wild onion	*Allium canadense*
Wild peppergrass	*Lepidium* sp.
Wild rice	*Zizania aquatica*
Wild rye	*Elymus virginicus*
Willows	*Salix* spp.
Winged sumac	*Rhus copallina*
Winterfat	*Eurotia lanata*
Wisteria	*Wisteria* sp.
Woodbine	*Parthenocissus quinquefolia*
Wood nettle	*Laportea canadensis*
Woolly croton	*Croton capitata*
Yarrow	*Achillea millefolium*
Yaupon	*Ilex vomitoria*
Yellow flag	*Iris pseudacorus*
Yellow monkey flower	*Mimulus guttatus*
Yerba	*Eclipta alba*
Yucca	*Yucca treculeana*

Wildlife and Aquatic Biota

Common Name	Scientific Name
Alder flycatcher	*Empidonax alnorum*
Alewife	*Alosa pseudoharengus*
Alligator	*Alligator mississipiensis*
American goldfinch	*Spinus tristis*
American oystercatcher	*Haematopus palliatus*
American robin	*Turdus migratorius*
American shad	*Alosa americanus*
American widgeon	*Anas americana*
Amphipods	*Amphipoda*
Anchovies	*Anchoa* spp.
Ants	*Formicidae*
Armadillo	*Pasypus novemicinctus*
Asiatic clam	*Corbicula fluminea*
Atlantic croaker	*Micropogon undulatus*
Avocet	*Recurvirostra americana*
Bald eagle	*Haliaeetus leucophalus*
Barnacle larvae	*Lepas* spp.
Banded watersnake	*Natrix fasciata pictiventris*
Barn swallow	*Hirundo rustica*
Beaver	*Myrocastor canadensis*
Beetles (tiger)	Cicindelidae
Belted kingfisher	*Megaceryle alcyon*
Black-bellied plover	*Squatarola squatarola*
Blackcapped chickadee	*Parus atricapillus*
Black-crowned night heron	*Nycticorax nycticorax*
Black-necked stilt	*Himantopus mexicanus*
Black racer	*Coluber constrictor*
Black skimmer	*Rynchops niger*
Black vulture	*Coragyps atratus*
Blueback herring	*Alosa aestivalis*
Blue crab	*Callinectes sapidus*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue-wing teal	*Anas discors*

Boat-tailed grackle	*Cassidix mexicanus*
Bobwhite quail	*Colinus virginianus*
Brant's cormorant	*Phalacrocorax penicillatus*
Brewer's blackbird	*Euphagus cyanocephalus*
Brine flies	Ephydridae
Brownheaded cowbird	*Molothrus ater*
Brown pelican	*Pelecanus occidentalis*
California gull	*Larus Californicus*
Canada goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Cardinal	*Richmondena cardinalis*
Carp	*Cyprinus carpio*
Caspian tern	*Sterna caspia*
Catbird	*Dumtella carolinensis*
Cedar waxwing	*Bombycilla cedrorum*
Channel catfish	*Ictalurus catus*
Chinook salmon	*Onchorhynchus tshaivytscha*
Clapper rail	*Rallus longirostris*
Cliff swallow	*Petrochelidon pyrrhonota*
Coho salmon	*Onchorhynchus kisutch*
Columbia white-tailed deer	*Odecoileus virginiana columbiana*
Common crow	*Corvus brachyrhynchos*
Common gallinule	*Gallinula chloropus*
Common grackle	*Quiscalus quiscala*
Common tern	*Sterna hirundo*
Common yellowthroat	*Geothlypis trichas*
Copepods	*Copepoda*
Cotton rat	*Sigmadon hispidus*
Crappie	*Pomoxis* spp.
Diamondback terrapin	*Malaclemys terrapin centrata*
Dog	*Canis familiaris*
Double-crested cormorant	*Phalacrocorax auritus*
Dunlin	*Erolia alpina*
Eastern cottontail rabbit	*Sylvilagus virginiana*
Eastern meadowlark	*Sturnella magna*
Eastern mole	*Scalopus aquaticus*

Fiddler crab	*Uca pugnax*
Fire ants	*Solenopsis saevissima richteri*
Fish crow	*Corvus ossifragus*
Flounder	*Paralichthys albigutta*
Forster's tern	*Sterna forsterii*
Fox sparrow	*Passerella iliaca*
Gastropods	*Gastropoda*
Glaucous-winged gull	*Larus glaucescens*
Goat	*Capra hircus*
Grasshopper	*Locustinae*
Grass shrimps	*Palaemonetes* spp.
Great black-backed gull	*Larus marinus*
Great blue heron	*Ardea herodias*
Great crested flycatcher	*Myiachus crinitus*
Great egret	*Casmerodius albus*
Great-tailed grackle	*Quiscalus mexicanus*
Green heron	*Butorides virescens*
Gulf menhaden	*Brevoortia patromus*
Gulls	*Larus* spp.
Hairy woodpecker	*Dendrocopos villosus*
Harbor seal	*Phoca vitulina*
Hermit crabs	*Paguroidae*
Herring gull	*Larus argentatus*
Horned lark	*Eremophila alpestris*
House mouse	*Mus musculus*
Isopods	*Isopoda*
Kestrel	*Falco sparvesius*
Killdeer	*Charadrius vociferus*
King rail	*Rallus elegans*
Land snails	
Largemouth bass	*Micropeterus salmoides*
Laughing gull	*Larus atricilla*
Least sandpiper	*Erolia minutilla*
Least tern	*Sterna albifrons*
Leech	*Piscicolidae*
Lesser scaup	*Aythya affinis*

Lesser yellowlegs	*Totanus falvipes*
Little blue heron	*Florida coerulea*
Long-billed curlew	*Numenius americanus*
Long-billed dowitcher	*Limnodromus scoplopercus*
Long-billed marsh wren	*Cistothorus palustris*
Louisiana heron	*Hydranassa tricolor*
Mallard	*Anas platyrhynchos*
Marbled godwit	*Limosa fedoa*
Marine worms	*Diopatra* spp.
Marsh hawk	*Circus cyaneus*
Marsh rice rat	*Oryzomys palustris*
Marsh wren	*Cistothorus palustris*
Meadow jumping mouse	*Zapus hudsonius*
Meadow vole	*Microtus pennsylvanicus*
Mockingbird	*Mimus polyglottos*
Mourning dove	*Zenaida macroura*
Mullets	*Mugil* spp.
Muskrat	*Ondatra zibethicus*
Mute swan	*Cygnus olor*
Northern phalarope	*Lobipes labatus*
Norway rat	*Rattus norvegicus*
Nutria	*Myocastor coypus*
Osprey	*Pandion haliaetus*
Oyster	*Crassostea virginica*
Pacific lamprey	*Entosphenus tridentatus*
Peamouth	*Mylocheilus caurinus*
Peregrine falcon	*Falco peregrinus*
Periwinkle	
Polychaetes	*Polychaeta*
Purple martin	*Progna subis*
Raccoon	*Procyon lotor*
Red-bellied woodpecker	*Centurus carolinus*
Redfish	*Sebastes marinus*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelauis phoeniceus*
Ring-billed gull	*Larus delawarensis*

Ring-necked duck	*Aythya collaris*
Ring-necked pheasant	*Phasianus colchicus*
River otter	*Lutra canadensis*
Robin	*Turdus migratorius*
Rough-winged swallow	*Stelgidopteryx ruficollis*
Royal tern	*Sterna maximus*
Ruddy turnstone	*Arenaria interpres*
Sabine's gull	*Xema sabini*
Saltmarsh song sparrow	*Melospiza melodia*
Sanderling	*Crocethia alba*
Sandpipers	*Calidris* spp.
Sandwich tern	*Sterna sandvicensis*
Savannah sparrow	*Passerculus sandwichensis*
Scissor-tailed flycatcher	*Muscivora forficata*
Sea lion	*Zalophus californianus*
Seaside sparrow	*Ammospiza maritima*
Sea trout	*Cynoscion nebulosus*
Semi-palmated plover	*Charadrius semipalmatus*
Sheepshead	*Archosargus probatocephalus*
Short-tailed shrew	*Blarina brevicauda*
Shrews	*Blarina* spp.
Smelt	Osmeridae
Snow goose	*Chen caerulescens*
Snowy egret	*Leucophoyx thula*
Snowy plover	*Charadrius alexandrinus*
Sockeye salmon	*Onchorhynchus nerka*
Song sparrow	*Melospiza melodia*
Spider mite	Order Acarina
Spotted sandpiper	*Actitis macularis*
Starry flounder	*Platichthys stellatus*
Striped bass	*Morone saxatilis*
Sturgeon	*Acipenser* sp.
Sunfishes	*Lepomis* spp.
Swallows	*Hirundo* spp.
Swamp rabbit	*Sylvilagus aquaticus*
Terns	*Sterna* spp.

Threespine stickleback	*Gasterosteus aculeatus*
Tiger beetles	Cicindalidae
Tree sparrow	*Spizella arborea*
Tree swallow	*Iridoprocne bicolor*
Trowbridge shrew	*Sorex trowbridgii*
Townsend's vole	*Microtus townsendii*
Trout	*Salmo* spp.
Vagrant shrew	*Sorex vagrans*
Vesper sparrow	*Pooecetes gramineus*
Western flycatcher	*Empidonax difficilis*
Western gull	*Larus occidentalis*
Western meadowlark	*Sturnella neglecta*
Western sandpiper	*Ereunetes mauri*
Western wood-pewee	*Contopus sordidulus*
White-crowned sparrow	*Zonotrichia leucophrys*
White-footed mouse	*Peromyscus leucopus*
White mullet	*Mugil curema*
White perch	*Morone americanus*
White pelican	*Pelecanus erthrorynchos*
White shrimp	*Penaeus setiferus*
White-tailed deer	*Odocoileus virginiana*
Whitings	*Urophycis* spp.
Willet	*Catoptrophorus semipalmatus*
Willow flycatcher	*Empidonax traillii*
Wilson's plover	*Characrius wilsonia*
Wimbrel	*Numerius phaeopus*
Wood duck	*Aix sponsa*
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-crowned night heron	*Nyctanassa violacea*
Yellow warbler	*Dendroica petechia*