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Habitat development field investigations, Windmill Point marsh development site, James River, Virginia; Appendix D: Environmental impacts of marsh development with dredged material: Botany, soils, aquatic biology, and wildlife

Virginia Institute of Marine Science

TECHNICAL REPORT D-77-23

HABITAT DEVELOPMENT FIELD INVESTIGATIONS
WINDMILL POINT MARSH DEVELOPMENT SITE,
JAMES RIVER, VIRGINIA

APPENDIX D: ENVIRONMENTAL IMPACTS OF MARSH DEVELOPMENT WITH DREDGED MATERIAL: BOTANY, SOILS, AQUATIC BIOLOGY, AND WILDLIFE

by

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EXECUTIVE SUMMARY

The Windmill Point marsh development site is a 9.3-ha dredged material island located in the James River, 0.4 km west of Windmill Point, Prince George County, Virginia. The marsh site construction began in November 1974 and continued in conjunction with routine maintenance dredging through February 1975. The island, at the completion of construction, consisted of a sand dike forming a rectangular perimenter 152 x 396 m, occupying 1.2 ha above mean high water, confining an area about 5.7 ha of which 4.9 ha was intertidal substrate composed of dike and dredged material.

After construction, two breaches occurred on the south side. One breach was successfully repaired; the other repair did not hold and now functions as one of the main channels of tidal water exchange.

After grading in June and July 1975 to provide a smooth gradient from the uplands (emergent at mean high tide) to intertidal areas, the island was extensively seeded and sprigged with a number of plants. In September 1975, alternating bands were fertilized.

In summer 1976, a series of observations and measurements of benthic biota, fish, wildlife (principally birds), plants, and soils were initiated to describe changes that were taking place on the around the island, particularly with regard to biota. To better understand observations and measurements obtained from the experimental site, reference areas were selected from a nearby marsh and upland system at the mouth of Herring Creek, approximately 3.2 km upriver from the experimental site.

Much of the initial vegetation that was seeded or sprigged was destroyed within a year after construction, primarily by animal activity, most notably Canada geese, which ate seeds, foliage, and roots. The introduced plantings were very soon overshadowed by naturally invading species, particularly emergent arrowhead and pickerelweed.

Macrobenthos was qualitatively and quantitatively dominated by

tubificial oligochaetes and larval chironomid insects. The bivalve, Corbicula manilensis, was also very abundant. Oligochaetes of the genus Limnodrilus were the numerical and biomass dominants in most of the habitats.

Total density and biomass were highest in the low marsh and subtidal channels of the experimental site. Intermediate density and biomass were found in the higher marsh at both sites and in low marsh at the reference site. Lower values were found outside of the marshes on adjacent tidal flats and on subtidal bottoms used by the project. The differences were mainly due to differences in populations of oligochaetes.

The density and biomass of macrobenthos were highest in summer and lowest in winter. Species diversity was higher at the reference site than the experimental site due to both a greater number of species and less dominance by a few species at reference site stations.

Protection of tidal flat macrobenthos from predation by use of an exclosure cage resulted in a 3-fold increase in density and a 44-fold increase in biomass over surrounding areas indicating that predation by fish and birds plays a key role in benthic community structuring.

The permanent meiobenthos was comprised principally of nematodes, cladocerans, ostracods, and copepods. The density of meiobenthos was greatest in low marsh, subtidal channel, and tidal flat at the experimental site. Estimated biomass was greater at comparable reference sites principally because of greater density of crustaceans.

Secondary production estimates show that meiobenthos were nearly as important producers as macrobenthos in the reference site, but macrobenthos production was much greater in experimental sites.

Benthic organisms were a major part of the diet of the dominant fishes. Meiobenthic organisms, especially small crustaceans, were very important in this respect. Larger macrobenthic organisms such as oligochaetes were not numerically important food for the small fish that made up most of the sample. Overall crustaceans were the most abundant food, followed in decreasing order by insects, plant seeds, molluscs, and fish and fish eggs.

The reference site had significantly more fish species and a higher fish species diversity than the experimental site. No significant differences in numbers and biomass were, however, apparent between the two sites. The greater number of species and higher species diversity is attributed to a greater diversity of subhabitats (debris, branches, etc.) at the reference site.

In comparison with adjacent open bottom, the creation of the marsh has undoubtedly increased abundance and diversity of fish in the area. The marsh has resulted in more food and protection for many fish. The abundance of important forage species like the mummichog and spottail shiner was probably increased since they exhibit a strong dependence on littoral areas. Two species of some commercial and recreational importance, the channel catfish and the white perch, use the shoal areas adjacent to the island for nocturnal feeding.

The most important fish species in terms of abundance, biomass, and frequency of appearance, in decreasing order, were the spottail shiner, white perch, american eel, threadfin shad, mummichog, tidewater silverside, gizzard shad, channel catfish, silvery minnow, and spot. This corresponded to the general condition of the icthyofauna in this section of the James River.

The botanical studies indicated that plants were grouped into four major zones: an arrowhead-pickerelweed zone occupying the low, broad interior of the island; a beggar tick zone at higher levels of the marsh; a panic grass zone, the remnants of the plantings of beachgrass and switch grass which ran in an interrupted band around the island; and the only wooded area, a black willow zone consisting of black willow, cottonwood, and common alder on the eastern portion of the island. The remainder of the plant zones were heterogeneous mixtures of two or more species.

Floral inventories of the experimental area from 1974 through 1977 indicated that prior to dike construction about 55 species fairly evenly distributed between marsh and supratidal habitats occurred.

After construction, by July 1975, this number roughly doubled by natural invaders and the 6 species artificially introduced. The number of new species declined between July 1975 and September 1977, but the dike and original island developed a higher diversity than the marsh.

Species distribution and zonation appear to be primarily a function of elevation and the closely correlated tidal inundation, especially in intertidal areas. It appears that the arrowhead-pickerelweed and beggar tick zones are approaching climax or near-climax conditions in the marsh areas. In the higher areas of the original island and the dike, the increasing growth of trees with changing shade conditions will continue to exhibit changing species distribution.

In comparison with the reference marshes, insect damage was relatively light on the island. Muskrats were responsible for considerable localized damage, but once the mushrats moved on or were removed, the areas appeared to recover.

Severe winds in 1977 resulted in a sharp decrease in beggar tick heights, compared to 1976. Shore erosion, particularly on the west dike, was severe. By late 1977, only a narrow sand berm protected the interior marsh. The planted panic grass was undermined by wave action and wood plants such as willows were uprooted.

The experimental site supported a greater number of bird species than any of the reference sites. The greater number of birds at the experimental site was primarily due to gulls, terns and wading birds that were attracted to intertidal flat areas. Four species, the ring necked gull, red-winged blackbird, laughing gull and Canada goose comprised two-thirds of all the individuals at the experimental site.

Only the mallard, killdeer, red-winged blackbird and possibly the song sparrow nested on the island. Breeding could only be confirmed for the mallard and red-winged blackbird. Predation by fish crows and rice rats are considered to have a major impact on nest success of red-winged blackbirds.

Other than the rice rats, the only mammal to impact the island is the muskrat, which after birds, was the dominant wildlife on the island. By the end of the study period, there were 11 muskrat lodges on the island.

The Windmill Point experimental site is a habitat unique to the area, by virtue of its large tidal flats and basin, sand beach perimeter and openness relative to surrounding woodland communities. It functions as a bird motel, drawing migrants from many groups, especially those associated with intertidal environments.

Soil studies demonstrated extreme spatial heterogeneity of soil characteristics at the experimental site. The dike area was generally sand and sandy loam soils, while the interim dike and marsh areas were clay and silty loam. Marsh habitats at the experimental area were generally sandier than corresponding reference areas.

There was significant and positive correlation between % silt-clay, % volatiles, and organic carbon. Cation exchange capacity was related significantly to these measures. Reference site soils were generally higher in % volatiles, organic carbon, soil nitrogen, and cation exchange capacity. The soil measures generally related to plant growth and decomposition indicate that the soil system at the experimental site is still developing. Field observations also indicate that there is mixing of dike material with the marsh material which is influencing final soil characterization.

Changes in soil characteristics (particularly higher nitrogen and cation exchange capacity in the reference marsh) are thought to account for significantly higher pickerelweed height at the reference site during the 1976 growing season. With this exception, little causal soil-plant relationship was discernible from this study. Plant distribution appeared to be controlled more by physical environmental factors such as elevation and tidal inundation than differences in soil characteristics.

In summary, the Windmill Point marsh development project has resulted in creation of an area which has provided an excellent habitat for the bird and fish species in the area and has generally had a beneficial effect in terms of the local environment. There is, however, some concern that because of high erosion on the western side of the island, the island will erode away and the beneficial effect will be lost.

At this point in time, approximately three years after construction, the experimental site is still changing. Disregarding the threat of erosion for a moment, the interior of the island appears to have stabilized into arrowhead-pickerelweed and beggar tick dominated marshes. The more upland areas are in transition from essentially low open vegetation to the more typical wooded shore areas in that region of the James River. As this occurs and as the soils continue to mature with the addition of more organic material, the differences between the reference site and the experimental site should be reduced.

If the western side of the island does not withstand erosion, and the dike is breached through to the inner marsh, an entirely different community much more similar to surrounding open bottoms will likely result.

PREFACE

This appendix covers work completed under Contract DACW 39-76-C-0040 between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the Virginia Institute of Marine Science (VIMS) as part of the Dredged Material Research Program (DMRP). The DMRP is sponsored by the Office, Chief of Engineers, U. S. Army, and is being managed by the Environmental Effects Laboratory (EEL), (WES).

Field work for the projects discussed in this appendix was initiated in July 1976 and continued through August 1977.

Active interchange between WES personnel and VIMS personnel has occurred throughout the duration of this study, particularly with regard to the development of methodology with specific applicability to the James River experimental and reference sites. Particular notice should be made of the contributions of Jean Hunt in the area of Wildlife Studies, Ellis J. Clairain in the area of Nekton Studies, Robert T. Huffman in the area of Botanical Studies, and John D. Lunz in the area of Benthic Studies and overall program scope and integration.

Part II: Aquatic Biology--Benthos was prepared by Drs. Robert J. Diaz and Donald F. Boesch and J. L. Hauer, C. A. Stone, and K. Munson. The field work was aided by Paul Gapcynski, Nita Rigau, David Ludwig, Betsy Field, William Lunger, and Jack Gartner. Laboratory processing of samples was assisted by Paul Gapcynski, Nita Rigau, Betsy Field, and Priscilla Hinde. William Blystone helped with computer processing of data. Edward Murdy assisted in identification of insects. John Lunz of WES provided encouragement and advice and assisted in the collection of samples for metals analysis.

Part III: Aquatic Biology--Nekton was prepared by Mr. Robert K. Dias, Ms. Marion Hedgepeth, and Dr. John V. Merriner. Dr. Merriner supervised the research. Mr. Dias and Ms. Hedgepeth had the primary responsibility for field collections, data compilation and analysis, and preparation of this report. John Gourley, Hugh Brooks, and Jack Gartner assisted with all phases of the research. Edward Murdy assisted with identification of food organisms.

Part IV: Botanical Studies was prepared by Mr. Damon Doumlele and Dr. Gene Silberhorn. Dr. Robert T. Huffman and Mr. Jonathan Clark from WES provided technical assistance. Field assistance was given by A. Harris, Jr., M. S. Kowalski, W. M. Rizzo, J. Green, and R. Smith. Ms. Nancy Hudgins and Ms. Carole Knox typed the drafts of this section.

Part V: Wildlife Resources was prepared by Dr. Marvin Wass and Ms. Elizabeth Wilkins. Ms. Jean Hunt (WES) established the reference site and its included stations. Mr. John Gourley assisted by setting rodent traps on the island. Mr. Arthur Harris photographed a marsh hawk coursing the island in December 1976. Dr. John Pagals, Virginia Commonwealth University, Richmond, identified the rice rats. Ms. Shirley Sterling and Ms. Vanessa Forrest typed the drafts of this section.

Part VI: Soils Analysis was prepared by Dr. Richard Wetzel and Ms. Susan Powers. Dr. J. Scott Boyce (WES) provided invaluable technical assistance during this investigation. Don Hayward, Mark S. Kowalski, William M. Rizzo, and Linda Bowman provided field and technical aid. Ms. Nancy Hudgins and Ms. Carole Knox typed the drafts of this section.

Project coordination at VIMS was under the direction of Dr. Maurice P. Lynch. Report coordinator was Ms. Beverly Laird.

The authors' appreciation goes to Ruth Edwards, Annette Stubbs, Barbara Crewe, and Claudia Walthall for clerical assistance in the preparation of this appendix.

The Directors at WES during this study were COL G. H. Hilt, CE and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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PART I: INTRODUCTION

M. P. Lynch

1. The Windmill Point site, James River, Virginia (Figure 1) is one of the sites where technical information on the feasibility of using dredged material for the development of marsh habitats is being evaluated for the U. S. Army Corps of Engineers.

2. The Windmill Point marsh development site is a 9.3 ha dredged material disposal island located in the James River below Hopewell, Virginia, 0.4 km west of Windmill Point, Prince George County, Virginia. The island consists of a sand dike forming a rectangular perimeter of 152 by 396 m, occupying approximately 1.2 ha above mean high water. The dike confines an area of about 5.7 ha, consisting of an estimated 0.8 ha above mean high water and 4.9 ha of intertidal substrate composed of dike and dredged material.

3. The marsh development site construction began in November 1974 and continued in conjunction with routine maintenance dredging through February 1975. Prior to the 1974 disposal operations, the site existed as a small, about 0.7 ha, horseshoe-shaped island, which resulted from historically unconfined disposal of channel sediments dredged from the Windmill Point and Jordan Point navigation channels.

4. The dike was constructed from sand dredged from a borrow area approximately 2740 m west of the original island. Approximately 62,320 m^3 of sand went into the dike. During channel maintenance operations, approximately 166,680 m^3 of dredged material entered the disposal site at the northwest corner with effluent discharged at the southeast corner. An elevation gradient consequently developed from the high influent (NW) end to the low effluent (SE) end. Fines suspended in the effluent

slurry settled over and adjacent to the original island, causing an intertidal mud flat to develop at the eastern end of the original island.

5. After construction, two breaches occurred on the south side. One breach was successfully repaired. The other repair did not hold and that breach now functions as one of the main channels of tidal water exchange. The dike was graded in June and July 1975 to provide a smooth transition from the upland (emergent at mean high water) through the intertidal elevations.

6. Interior upland portions of the dike and the upland area within the dike were seeded with tall fescue (*Festuca elatior* var. *arundinacea*), orchard grass (*Dactylis glomerata*), and Ladina white clover (*Trifolium repens*). Exterior upland portions of the dike were seeded with a mixture of switch grass (*Panicum virgatum*) and coastal panic grass (*Panicum amarulum*). The intertidal zone on the exterior of the dikes was planted with a mixture of three-square bulrush (*Scirpus americanus*) and smooth cordgrass (*Spartina alterniflora*). Sprigs of water willow (*Justicia americana*) were planted along the upper intertidal zone along the west dike. On the original island and the disposal-created mud flat east of the dike, experimental blocks were established in which several species (big cordgrass, *Spartina cynosuroides*; smooth cordgrass; seacoast bulrush, *Scirpus robustus*; and arrow arum, *Peltandra virginica*) were sprigged. Additionally, in September 1975, intertidal and upland elevations of the dike were fertilized in a pattern of 45.7-m bands alternating with 15.2-m unfertilized areas.

7. Much of the planted vegetation, however, was destroyed within a year after construction by animal activity, most notably Canada geese, which ate seeds and foliage and dug into the sediments to feed on roots. As a result, almost all of the *Spartina* and *Scirpus* plantings on the exterior of the dikes, as well as the plantings on the unconfined dredged material, were destroyed. The upland plants were also grazed, but not as heavily. Artificial plantings were soon overshadowed by naturally invading species. By spring 1975, vegetation

on the pre-existing island which was destroyed or disturbed by construction and disposal operations had begun to regenerate. Additional species invaded the site by means of seed and vegetative propagules, which resulted in a total of some 72 species by July. The fall 1975, the most conspicuous naturally invading plants within the dike were arrowhead (Sagittaria latifolia) and pickerelweed (Pontederia cordata).

8. The selected reference site, composed of a natural marsh and upland areas at the mouth of Herring Creek, was located approximately 3.2 km upriver from the experimental site. The use of a reference site in conjunction with an experimental site (the Windmill Point site) enabled observations and/or measurements taken at the experimental site to be evaluated in terms of observations and/or measurements taken at a similar, natural site. Because of the lack of a reference site with the same exposure and sediment characteristics as the experimental site, the comparisons could at best be semiquantitative. Without the use of a reference site, however, trends or changes in measured or observed biota or characteristics at the experimental site could not be evaluated in terms of man-forced trends or changes.

9. For wildlife (primarily bird) studies, a section of vegetated gravel beach strand extending upriver from the mouth of Herring Creek was selected. This area (approximately 1 ha) was named the James River Berm reference site. It consists of a narrow, densely vegetated strand and an adjoining swamp dominated by a few large bald cypress (Taxodium distichium). More numerous and smaller ash trees (Fraxinus sp.) comprise the remainder and grow on fringing banks. Large trees on the berm proper include sycamore (Platanus occidentalis), tulip-tree (Liriodendron tulipifera), black gum (Nyssa sylvatica), sweet gum (Liquidambar styraciflua), and black walnut (Juglans nigra). Smaller trees and shrubs are the buckthorn (Rhamnus caroliniana), rose-of-sharon (Hibiscus syriacus), swamp dogwood (Cornus stricta), and common spice bush (Lindera benzoin). Ground cover is scarce in the open tidal swamp. On the berm, heavy growth of lianas largely preclude ground cover. In order of dominant cover, they are greenbriar (Smilax spp.), grapes (Vitis spp.), Virginia creeper (Parthenocissus quinquefolia),

trumpet vine (Campsis radicans), virgin's bower (Clematis virginia), and poison ivy (Rhus toxicodendron).

10. The research objectives of the studies discussed in this appendix were to:

- a. Document the growth and development process of both planted and naturally invading wetland vegetation.
- b. Relate the botanical growth and development process to varying chemical and physical properties of the experimental site.
- c. Relate faunal patterns of use to the physical characteristics of the dredged material and vascular plant community.
- d. Describe the changes in aquatic biota following the disposal of dredged material and site development.
- e. Document the concentration of selected metals in various plants and animals associated with the dredged material substrate.

11. The studies conducted by the Virginia Institute of Marine Science (VIMS) were grouped into five areas, Benthic Studies, Nekton Studies, Botanical Studies, Wildlife Studies (principally avifauna), and Soils Studies. The VIMS studies were complemented by geochemical and water quality studies conducted by Old Dominion University, topographic monitoring conducted by the Corps of Engineers, and pollutant mobilization studies (principally involving kepone) contracted by the U. S. Army Engineer Waterways Experiment Station (WES). The remainder of this appendix deals with these elements of the overall study conducted by VIMS.

12. The studies at the Windmill Point site are only part of the Dredged Material Research Program's (DMRP) Habitat Development Project (HDP). The overall HDP is testing and evaluating concepts of marsh development and land and water habitat development as environmentally beneficial disposal alternatives. The studies described in this appendix focus on a fresh water tidal marsh system. Other studies focus on different habitats. When taken as a whole, even though different techniques and study protocol had to be employed at different sites, the overall Habitat Development Program should provide strong

guidance as to the beneficial use of dredged material for habitat development and enhancement of wildlife resources.

PART II: AQUATIC BIOLOGY--BENTHOS

R. J. Diaz, D. F. Boesch, J. L. Hauer,
C. A. Stone, and K. Munson

Introduction

13. Benthic organisms are key secondary producers in marsh ecosystems. They serve in the principal pathway of energy from primary producers to carnivorous fishes and invertebrates and ultimately to wildlife in the marsh community. Benthic animals were also important constituents of the shallow water communities pre-existing in the area of the marsh-habitat development at Windmill Point (Diaz and Boesch 1977a). Thus, in the assessment of macrobenthic communities in the vicinity of the Windmill Point experimental site and the Herring Creek reference site, unique opportunities are presented to: (a) relate benthic organisms to the productivity and food chains of the marshes and (b) compare the benthos of shallow water and wetland habitats.

14. This portion of the post-construction ecological study attempts to describe the composition and structure of benthic communities in the various habitats represented at the experimental and reference sites, to compare the benthos of the experimental marsh with that of the pre-existing shoal flat and the reference marsh, and to relate the benthic invertebrate community to the food habits of fishes.

15. The primary focus of this study has been on the macrobenthos because it has been previously studied in the area and was presumed more important than smaller forms as food items of fishes. Preliminary results of food habit studies indicated that meiobenthic animals were important prey of some small fishes. Thus, additional exploratory research was conducted on the meiobenthos later in this study.

Materials and Methods

Sampling design

16. After visiting the sites and considering the statistical advantages of various sampling designs, a stratified random design was selected. The stratification of the marshes and surrounding bottoms assured that all tidal elevation and vegetation conditions received a certain minimum sampling effort. Random placement of sample positions within strata allowed application of statistical comparisons among strata. Seven strata at the experimental site and five strata at the reference site were defined as:

a. E1 - High intertidal marsh within the dike, including zones vegetated by *Typha*. This stratum fringed the inside of the dike with the most extensive area in the northeast corner of the site.

b. E2 - Low intertidal marsh within the dike, including most of the area within the dike. This stratum was vegetated by *Pontederia*, *Peltandra*, *Sagittaria*.

c. E3 - Low intertidal areas within the dike which were essentially nonvegetated, including small subtidal pools.

d. E4 - Subtidal areas within the marsh, including the moat which runs along the north and east sides of the dike and the pool at the northwest corner.

e. E5 - High intertidal mud flat outside of the dike along the east end of the site, including the experimental vegetation plots along the east perimeter.

f. E6 - Low intertidal mud flat outside of the dike along the east end of the site.

g. E7 - Low intertidal areas around the outside of the dike along the north, west, and south perimeters. This habitat is basically one of coarse sand and gravel.

h. R1 - High intertidal marsh at the reference site corresponding to E1.

i. R2 - Low intertidal marsh at the reference site corresponding to E2.

j. R3 - nonvegetated mud flat at the reference site corresponding to E3 and E6.

k. R4 - Subtidal creek bed at the reference site corresponding to E4.

1. R5 - Gravel and sand intertidal area near the reference site corresponding to E7.

17. Stratum E3 was dropped after July 1976 sampling because it was felt that there was insufficient separation between vegetated (E2) and nonvegetated low intertidal marsh within the dike. The strata are roughly delimited in Figures 2 and 3.

18. A 3-m square grid system was assumed over the experimental site, using as reference points the stake field placed around the perimeter of the marsh island at 30.5-m intervals by the Corps. The reference site was not grided, but was divided into small irregularly shaped areas, the boundaries of which followed the boundaries of the strata. Eight replicate samples of macrobenthos and sediments were taken in each stratum. The positions of the samples were the nodes of the 3-m grid at the experimental site and the delimited irregular areas in the reference site. These positions were determined by consulting a table of random numbers. Random sampling was conducted in July and November 1976 and January, April, and July 1977. Placements of replicates for each seasonal sampling period can be seen in Figures 4-13.

Treatment of samples

19. A 160-cm^2 rectangular corer was used to take samples of macrobenthos and sediments. Cores from July 1976 were 20 cm deep and were divided into two 10-cm-deep fractions in order to determine the utilization of deeper sediments by benthos. After removal of approximately 100 g of sediment with a 2.2-cm ID core tube for sediment analyses (from both top and bottom halves in July 1976), the remaining material was sieved through a 500-μm screen, relaxed with a 1 percent solution of propylene phenoxotol for a half hour, preserved with 5 to 10 percent buffered formalin, and stained with a vital stain (phloxine B). Later, the samples were microscopically examined and the animals present sorted into major taxonomic groups and placed in 70 percent ethanol for later identification and enumeration.

Meiobenthos

20. Meiobenthos samples were taken with 3.8-cm^2 core tubes to a depth of 5 cm and preserved with 5 percent formalin. After washing a few samples through a graded series of sieves from 500 to 63 µm, it was determined that the greatest number and diversity of animals was retained on a 125-µm sieve. Thus, the meiobenthos examined in this study consisted of those organisms that passed through a 500-µm sieve and were retained on a 125-µm sieve. Washed samples were examined with a dissecting microscope and all animals placed in 5 percent formalin for later identification and enumeration.

Sediment analyses

21. Percent sand, silt, and clay were determined by sieving and pipette analysis following procedures of Folk (1968), with the exception that 10 ml of 4 percent Alconox was added to disperse the samples and the samples were mildly shaken by hand and not blended. The silt and clay suspension of sediment samples with less than 10 percent silt and clay was filtered and not subsampled by pipette. Sediment descriptions refer to the Udden-Wentworth classification (Pettijohn 1957). The amount of detritus, or light elutriated material retained on a 63-µm screen including vermiculite, mica, plant roots, leaves, and stems, was expressed as a percent of the total dry weight of the sediment. Total solids and volatile solids concentrations were determined in accordance with procedures of Standard Methods (American Public Health Association 1971).

Biomass

22. Dry weight biomass was determined after drying at 80°C to constant weight. Biomass was determined for the bivalve *Corbicula manilensis*, oligochaetes, and chironomids. All other taxa were weighed as one group. *Corbicula* larger than 10 cm were removed from their shells for weighing, but small *Corbicula* weights include the shell after chemical decalcification.

Numerical methods

23. Species diversity was measured by the commonly used index of Shannon (H') (Pielou 1975), which expressed the information content per individual (base 2 logarithms). Species diversity, particularly as expressed by the Shannon measure, is widely used in impact assessments and may correlate well with environmental stress (Wilhm and Dorris 1968; Armstrong et al. 1971; Boesch 1972). More adverse and stressful environmental conditions often exhibit lower species diversity although this response is often not so simple (Jacobs 1975; Goodman 1975).

24. As considered above, species diversity is a composite of two components: species richness, the number of species in a community, and evenness, how the individuals are distributed among the species. Two measures of species richness were used: the number of species (s) per unit area (in this case 160 cm^2) or areal richness, and a measure of numerical richness standardized on the basis of the size of the sample in terms of numbers of individuals (N): $S-1/\log_e N$. Evenness was expressed as $J'=H'/\log_2 S$.

25. Numerical classification (Boesch 1977) was used to express the relationships of the species assemblages among habitats and over time. The Bray-Curtis (or Czekanowski) coefficient was used for both normal (collections) and inverse (species) classifications based on $\log_e (x+1)$ transformed data. The transformation was applied to dampen the otherwise overwhelming sensitivity of the index to heavily dominant species. The flexible sorting strategy was chosen to cluster collections and species because of its mathematical properties and proven usefulness in ecology (Boesch 1973; Clifford and Stephenson 1975). The cluster intensity coefficient β was set at -0.25, which effects moderately intense clustering. Details of these techniques may be found in Clifford and Stephenson (1975) and Boesch (1977).

Results

Sediment grain size

26. Sediments at the experimental site were generally sandier than those in the comparable habitats. At the reference site the only stratum with sandy sediments was the shore of the berm that separates Ducking Stool marsh from the James River (stratum R5). Sediments in the high marsh (R1) did show some sand in November and January, but it was patchy and limited to the area adjacent to the berm. (See Appendix A' for data, and Table 1 and Figure 14 for summary and descriptive statistics.)

27. The dike around the experimental marsh (E7) and shore of the berm (R5) were the sandiest strata, reflecting their unprotected locations where wind and tide energy prevent the accumulation of finer sediments. During periods of high water and storms, sand from these locations was transported into the high marsh areas of both sites. This was most apparent at the experimental site, an island which was exposed in all directions. The reference site was most exposed to storms with southerly winds. Sediments in the experimental high marsh (E1) had variable amounts of sand throughout the study but in July 1977 there was a significant ($\alpha<0.05$) increase in sand content over the other sampling periods. The dike around the marsh was, by then, breached regularly during normal high tides at three or four locations around its perimeter. These breaches accelerated the rate at which sand was transported into the marsh interior. Sediments in the subtidal areas within the dike (E4) were sandier than those in either the high (E1) or low (E2) marsh areas. This sand was transported into the marsh on flooding tide through the tidal inlet on the south side of the dike. This mechanism allowed the deposition of sand in the otherwise silty low marsh. In the course of the year of study, a large tidal flood delta consisting of silty-sand was formed extending from the tidal inlet 60 to 70 m into the interior of the habitat. Sand in portions of the experimental marsh away from the influence of the inlet

originated in the dredged material, and was concentrated by winnowing of fines during marsh construction, or was supplied by overwash of the sand dike.

28. Sediments on the mud flat at the east end of the experimental site (E5 and E6) were silty fine sand. The sand was supplied by the net downstream movement of river sand around Windmill Point. Through the course of the study, there was a trend toward increasing sand content on the mud flat. This may have resulted from the accretion of the flat due to the protection afforded by the island. Visual observation of the mud flat throughout the study indicated that it expanded greatly by July 1977 was over twice as large as it had been in July 1976. The paucity of sand in all habitats within the reference site indicates that the Ducking Stool marsh is a very protected habitat and a trap for fine sediments.

29. Silts and clays were virtually absent from the higher energy environments (E7 and R5). Sediments of the mud flat (E5 and E6 the only other area exposed to the James River, had the next lowest percentage of fines with an average range of 19 to 52 percent. Sediments in the lower mud flat (E6) were slightly siltier than those higher (E5), which are exposed to more wave energy. Sediments within the experimental marsh (E1, E2, E4) were all predominantly sandy-silt or clayey-silt. Sediments within the reference marsh (R1, R2, R3, R4) were silt or clayey-silt, except when sandy-silt patches near the berm (R1) were sampled in November and January. In general, sediments within the reference marsh were finer and had about three times as much clay as those in the experimental marsh.

30. The sediments at the experimental site were much more variable from season to season than those at the reference site. Within-stratum and between-strata variations were also much higher at the experimental site (Table 1). Sediments at the reference marsh were homogeneous fine sediments, reflecting the depositional environment which prevails there. Sediments at the experimental marsh were patchier and coarser, reflecting both the artificial depositional

events which created it and the ongoing erosional processes which seek to bring it to hydraulic equilibrium. During the period of study, there was a general trend toward greater concentrations of sand in the experimental marsh and adjacent flat, while the reference marsh remained continually muddy.

Detritus

31. The detritus content of the sediments, expressed as a percent of the total dry weight, was related to exposure, sediment grain size, and the presence of marsh plants. Generally, detritus was highest in sediments within the marshes (E1, E2, R1, R2) and the subtidal channel (E4, R4) where the dead plant material accumulated. Sediments of the high mud flat (E5), which had some marsh plants growing in it, had higher amounts of detritus than those of the nonvegetated lower flat (E6). Subtidal sediments in the reference marsh (E3) had slightly lower but more consistent amounts of detritus than those of the other reference strata, except the exposed sandy berm (R5) (Appendix A', Tables 1 and Figure 15).

32. The low experimental marsh (E2) was the only area to exhibit a seasonal pattern of detritus abundance, with highs in summer and lows in winter. Within-stratum and between-strata variations were greatest at the experimental site with the greatest amounts of detritus found in July 1976 (grand mean 21 percent), but low levels found in July 1977 (grand mean 7 percent). At the reference site, the grand mean was about 12 percent for all sampling seasons.

Total and volatile solids

33. Total solids concentration, an indication of water content of the sediments, was directly related to the amount of sand in the sediments. Highest total solids concentrations were found in sediments from strata in the James River (E5, E6, E7, R5) which had the most sand. In marsh sediments, total solids were lower, with values at the reference marsh slightly lower than those at the experimental marsh. Within-stratum and between-strata variations were similar at both sites (Figure 15).

34. Surface deposits (top 1 to 2 cm) were very watery and exhibited thixotropic properties when disturbed in the low marsh (E2, R2), subtidal areas within the marsh (E4, R4) and mud flat (E6, R3). The surface sediments in the high marsh (E1 R1) were very plastic and resembled waterlogged soil.

35. Volatile solids concentration, an estimate of organic matter in sediments, was, as with total solids concentration, directly related to the amount of sand in the sediment and also to the amount of detritus. Volatile solids concentrations were higher at the reference site than at the experimental site indicating the more depositional nature of the reference site sediments which have had many years to accumulate organic material from the marsh plants and allochthonous sources. The correlation between volatile solids and detritus content was significantly positive ($\alpha < 0.01$) for all seasons and ranged from 0.57 ($n = 33$) in January to 0.90 ($n = 37$) in April at the reference site and at the experimental site ranged from 0.70 ($n = 45$) in July 1976 to 0.60 ($n = 44$) in January. The within-stratum and between-strata variations were higher at the reference site than those at the experimental site (Figure 15).

Elevation and inundation

36. Detailed topographic data were available from the Corps of Engineers for the experimental site. This allowed determination of the elevation of each replicate sample (Table 2). However, the areal extent of the subtidal stratum (E4) was very small and did not appear clearly interpretable from the survey charts. Also, much of the low intertidal area around the dike (E7) was outside the survey limits. Thus, the elevations of samples from these two strata could not be quantitatively compared. Almost all replicates from stratum E7 were taken from approximately 0.25 m above Corps of Engineers low water. Subtidal areas (E4) were defined based on continuous inundation; thus, elevations in this stratum were lower than those in the low marsh (E2). However, the difference between the two strata could not be quantified.

37. Because the replicate samples were randomly placed within a

stratum, the average elevation of sampling sites within a stratum also varied somewhat from collection to collection. A more representative average elevation of each stratum was obtained by computing the mean elevation of all seasonal samples within the stratum. The average elevation of samples from the high marsh (E1) was 0.95 m; from the low marsh (E2), 0.73 m; from the high intertidal mud flat (E5), 0.64 m; and from the low intertidal mud flat (E6), 0.40 m. Replicates from the subtidal areas were probably 0.05 to 0.25 m lower than those from the low marsh. The Corps of Engineers also operated a tidal gage nearby on the mainland shore and was able to project these tidal data to estimate the percent of time and a given elevation interval was inundated. The average time that each stratum was inundated varied with season. For the first four sampling periods, the average percentages of time inundated were (tide data for July 1977 were not available):

	E1	E2	E3	E6
Jul 1976	38	62	72	97
Nov 1976	39	65	75	95
Jan 1977	14	39	50	80
Apr 1977	19	46	57	85

38. July 1976 estimates were based on tide data from 14 July 1976 to 31 August 1976. November estimates were based on the period from 1 September to 30 November. January estimates were based on the period from 1 December 1976 to 28 February 1977, however, the tide gage was frozen and inoperative for about 2/3 of January. April estimates are from 1 March to 29 March.

39. The seemingly slight change in elevation between the high (E1) and low marsh (E2) (0.21 m) was sufficient to cause almost a doubling in the percent of time that the low marsh was covered with water. The 0.25 m change in elevation between the high and low intertidal mud flats increased inundation time on the average by only 42 percent.

40. In winter, tides are generally lower and, depending on wind

conditions, elevations that are subtidal most of the time, can be exposed for several hours. This is reflected in the lower percent of time inundated for all strata in January.

Composition of macrobenthos

41. A complete list of taxa collected in macrobenthos samples is given in Table 3; the qualitative occurrence of each taxon by stratum and season is given in Appendix B', and complete abundance data are included in Appendix C'. The fauna was qualitatively and quantitatively dominated by tubificid oligochaetes and larval chironomid insects (Table 4). The oligochaetes were the most abundant animals at both experimental and reference sites. The insects were the most diverse, and they included many species which were relatively rare or seasonally abundant. The oligochaetes, on the other hand, comprised fewer species which tended to be ubiquitous and constant in occurrence.

42. Of the 75 species collected, 29 occurred in at least 6 percent of the samples in any collection period (Table 5). Eleven of these were oligochaetes and six were chironomids. Although seasonality of occurrence was apparent for some species, e.g. the bivalve *Corbicula manilensis* and the chironomids *Dicrotendipes nervosus* and *Tanypus* spp., most of the common species had a relatively consistent frequency of occurrence over the study period.

43. In terms of abundance, the oligochaetes outnumbered all other taxa by four to one, and the genus *Limnodrilus* accounted for over 80 percent of all of the oligochaetes. The molluscs were also dominated by one species, *Corbicula manilensis*, which accounted for 82 percent of all molluscs. The other major taxonomic group, Chironomidae, did not have one outstanding dominant genus. *Chironomus* and *Tanypus* were most abundant, but many other genera were close in abundance.

Habitation depth of macrobenthos

44. The top 10 cm of the 93 cores taken in July 1976 yielded 8440 individuals in 50 taxa. Partial analysis (35 of 93 core samples) of the bottom 10 cm of the cores found only 571 individuals in 18 taxa.

The individuals found in the 10- to 20-cm interval were:

Probable Contaminants		Potentially Deep Infauna	
Physa sp.	3	*Limnodrilus* spp.	263
Isotomidae	2	*Limnodrilus hoffmeisteri*	66
Gammarus fasciatus	2	*Limnodrilus cervix*	4
Tanypus sp.	3	*Ilyodrilus templetoni*	73
Dicrotendipes nervosus	3	*Branchiura sowerbyi*	47
Coelotanypus scapularis	1	*Peloscolex multisetosus*	78
Chironomus spp.	8	*Peloscolex freyi*	3
Cryptochironomus spp.	1	*Nais* spp.	3
Corbicula manilensis	8	Enchytraeidae	3

Nine of these 18 taxa represented by 31 individuals represented obvious contamination from the surface fauna since they are epifaunal or can live only near the sediment surface. It is also doubtful that many of the naids, enchytraeids, and smaller tubificids found in the lower 10 cm actually lived this deep. Only 57 of the 540 individuals that were potential deep infaunal species were large mature worms that burrow deeper than 10 cm. The 483 smaller worms were probably within the top 6 cm of the sediment. Handling and splitting the unconsolidated sediments in the field were the most likely causes of contamination. Thus, it appeared that at least 85 percent and probably a much higher proportion (as much as 97 percent) of the macrofauna lived in the top 10 cm of sediment. Based on this information, core samples during subsequent sampling periods were taken to a depth of 10 cm.

Abundance of macrobenthos

45. Densities of total macrobenthos are summarized by stratum and season in Table 6. Overall mean densities for each stratum are isted below in terms of numbers of individuals per m^2:

Stratum	Density (m^2)	Stratum	Density (m^2)
E1	2938	R1	3625
E2	8250	R2	4062
E4	6938	R4	1874
E5	2313	R3	2374
E6	2063		
E7	1000	R5	2186

Densities were generally greater within the marshes than on surrounding bottoms. In particular, the low marsh and subtidal bottoms within the experimental marsh were characterized by densities of macrobenthos much higher than those in adjacent habitats and in comparable habitats at the reference site. Densities in both high and low marsh were higher than those on unvegetated bottoms.

46. Examination of population density data for the most abundant species (Figures 16-20) indicates that, despite the obviously large variance, there were many significant differences between strata and seasons. These patterns essentially conform to those described above in terms of mean densities of total macrobenthos. For example, during most seasons the most abundant taxon, _Limnodrilus_ spp. (mainly immature _Limnodrilus hoffmeisteri_), had mean densities significantly higher in the low marsh and subtidal habitats within the experimental site (E2 and E4) than in habitats outside of the marsh. However, the pattern for mature _Limnodrilus hoffmeisteri_ was less clear cut. Other abundant oligochaetes, _Ilyodrilus templetoni_ and _Branchiura sowerbyi_, were also significantly ($\alpha < 0.05$) less abundant in habitats outside of the two marsh systems (E5, E6, E7, and R5). Only one abundant species, the bivalve _Corbicula manilensis_, showed significantly higher densities in these strata outside of the marshes ($\alpha < 0.05$).

47. The differences in total macrobenthos densities between comparable habitats at the reference and experimental sites and between seasons were mainly the result of differences in oligochaete population densities. Low marsh and subtidal habitats at the experimental site (E2, E4) had significantly denser populations of _Limnodrilus_ spp. and

Branchiura sowerbyi than at the reference site (R2, R4) during July and November 1976 and July 1977. On the other hand, differences during winter and spring were mostly nonsignificant and in several instances significantly higher densities of some oligochaetes taxa were found at the reference site during winter ($\alpha<0.05$).

Biomass of macrobenthos

48. Dry weight biomass data are presented in Appendix D' and are summarized in Table 7. Analysis of variance of the total dry weight biomass between sites, seasons, and strata indicated that biomass was higher at the experimental site ($\alpha<0.001$) and there were differences between strata ($\alpha<0.001$). However, there were no differences between the five seasons ($\alpha<0.05$). Variability between replicates caused by the occurrence of large individuals, mainly Corbicula and tabanid and tipulid insect larvae, tended to obscure any seasonal trends so that although there were reduced densities in the winter and spring there was no general reduction in biomass. Second-order (or two-way) interactions between sites and seasons and sites and strata were significant ($\alpha<0.001$), indicating that when considered separately there were differences at each site within strata and between seasons. Lowest biomass at the experimental site occurred in January, but at the reference site the highest biomass was found in January. This was due to the overwintering of large insect larvae at the reference site which were absent from the experimental site (see Appendix D' and Table 7). Other comparisons of the sites can be made from the mean seasonal biomass values (mg dry weight/160 cm^2):

	Jul '76	Nov	Jan	Apr	Jul '77
Experimental Site	27.7	29.8	14.8	40.0	55.3
Reference Site	8.6	20.0	33.0	17.6	20.8

Biomass was generally less spatially variable and less prone to seasonal fluctuations at the reference site than at the experimental site.

49. Higher biomass was generally found within the marshes

compared to bottoms outside of the marsh. At the experimental site, biomass in the low marsh (E2) and in subtidal areas within the marsh (E4) was much greater than outside of the dike (E5, E6, and E7). Similarly, biomass in the high and low marsh strata (R1, R2) at the reference site was higher than in nonvegetated bottoms at the site. Biomass was similar in comparable habitats between experimental and reference sites except for the low marsh. Average biomass at the experimental site was about three times that at the reference site, and in subtidal areas within the marshes (E4, R4) biomass was four times greater at the experimental site.

50. Oligochaetes were the most consistent contributors to biomass. They occurred in every stratum during every season and accounted for 46 percent of the total dry weight biomass (Figure 21, Table 7).

51. Attempts to correlate biomass of macrobenthos with sediment parameters were inconclusive. This was largely due to the high variance of biomass estimates. Oligochaete biomass was less variable than total biomass and was generally positively related to organic material (volatile solids) and negatively related to percent sand in sediments. However, because of the high variability correlations were seldom significant.

Species diversity of macrobenthos

52. Data for H' species diversity, areal and numerical species richness, and evenness measures are fully listed in Appendix E' and are summarized in Table 6.

53. Analysis of variance of H' species diversity by site, stratum, and season indicated there was strong three-way interaction ($\alpha<0.004$) which made interpretation of main effects very difficult. Nonetheless, a comparison of means reveals some important trends among habitat strata and with season.

54. Species diversity at the experimental site tended to be high during the summer (July 1976 and 1977) and low in January and April. At the reference site, on the other hand, diversity was lowest in

summer and highest in winter. Diversity at the reference site was less affected by seasonality. Mean H' was higher at the reference site than in comparable habitats at the experimental site:

Stratum	H'	Stratum	H'
E1	1.04	R1	2.12
E2	1.56	R2	2.05
E4	1.71	R4	2.13
E5	1.42	R3	2.27
E6	1.53		
E7	1.32	R5	1.65

Within the sites there was no clear pattern of H' among the habitat strata.

55. There were no concordant changes in the evenness or species richness components of species diversity with season. Generally, evenness and richness declined in January at the experimental site, while evenness increased and richness decreased at the reference site. The greater H' values at the reference site were reflections of both higher evenness and greater areal and numerical species richness. The reference site had a qualitatively richer macrobenthic fauna than did the experimental site, although all species found exclusively at the reference site were rare and never abundant.

Numerical classification of macrobenthos

56. Because of the large number of replicate samples (451), the data were grouped by seasons and strata yielding 56 collections: the 11 habitat strata for 5 seasons (12 strata for July 1976). These 55 collections were subjected to numerical classificatory analyses to determine relationships of the communities among habitats, sites, and seasons.

57. The normal analysis, with all species included, separated the collections into five main groups (Table 8): 1) a large group made up of all the reference site collections except along the sandy shore (R5); 2) and 3) groups made up mainly of collections from the sandy

shore areas (E7 and R5); 4) a group of collections from the experimental site which had certain similarities to those from the reference site; and 5) a group composed mainly of collections from the experimental high and low marsh (E1 and E2). The classification of collections indicates that there were important differences in the composition of the macrobenthos at the experimental and reference sites, paralleling the differences in abundance and biomass described above.

58. Within the reference site there was no clear separation of collections among the strata, except the sandy shore (R5) which grouped with the comparable habitat at the experimental site (E7), or seasonal collections. This indicates a basic homogeneity of the community within the reference marsh. The two main groups of collections from the experimental site groups (4 and 5) were heterogeneous in their inclusion of a combination of strata and seasons. Only collections from the sand and gravel intertidal habitat (E7 and R5) were sufficiently distinct to form a separate group of collections from all five sampling periods.

59. The inverse analysis of species distribution patterns was performed on a reduced data set to eliminate effects of rare species which tend to group together only because they have rarity in common (Boesch 1977). Species which occurred in less than 9 percent of the 55 collections were not included. This left a total of 42 species and excluded 33 species.

60. Six species groups were separated in the inverse classification (Table 9). Species in group A were the numerically dominant species at both experimental and reference sites, they are also characteristic and dominant in the James River proper. Species group B was composed of species that were characteristic of the sandy habitats at the experimental site (E5, E6, E7) in July 1977. Group C species were generally characteristic of the sand and gravel intertidal habitats (E7 and R5). Group D included those species typical of the both sites excluding the sandy shores (E7 and R5). Group E and F

species were characteristic of the reference site.

61. There were groups of species that were typical of both the reference and experimental sites, reference site alone, and the high-energy environments (E7 and R5), but there was no group that was singularly characteristic of the experimental site. Group A, composed of dominant species, did contain 3 species, Branchiura sowerbyi, Limnodrilus cervix, and Tanypus spp., that were more frequent and abundant at the experimental site; however, commonness and abundance of these species at the experimental site caused them to cluster with the other dominant species.

Macrobenthos of the open James River

62. The macrobenthos of a reference station in the open James River near the reference site at a depth of approximately 1 m below low water was sampled throughout the period of study. This site was monitored during July to November 1976 as part of a study of the effects of open-water dredged material disposal (Diaz and Boesch 1977b). During subsequent sampling of the marsh habitats in January, April, and July 1977, core samples were also collected at this site (Table 10).

63. The assemblages of macrobenthos collected at this open-water site during 1976-1977 were essentially similar to those found during 1974-1975 in the Windmill Point area (Diaz and Boesch 1977a). The community was very similar in composition of dominant species to those found in the experimental and reference marsh habitats. The only exception was the dipteran larva Coelotanypus scapularis which was much more abundant in the open river than at the marsh sites. The density and biomass of macrobenthos at the open-water site were similar to those found on the muddy intertidal habitats of strata E5 and E6 at the experimental site; thus, they were generally lower than those found within the marsh habitats.

Effects of predator exclosure

64. An experiment was conducted ancillary to routine sampling in

order to determine the effects of predation by birds and fishes on the macrobenthos. Intensive utilization of intertidal habitats by shorebirds, gulls, and waterfowl had been observed, and it was further presumed that predation by fishes might also occur at high tide. A 0.25-m^2 cage frame covered with 6-mm galvanized wire mesh identical to those used by Virnstein (1977) was emplaced in the low intertidal flat (E6) in November 1976. Other cages placed in strata E4 and E5 were lost or destroyed. The enclosed bottom was sampled in July 1977. Data resulting from analyses of macrobenthos are included in Appendixes C' and D'.

65. One undesired result of caging in soft sediment habitats is that sediments may be artificially stablized and consequently become finer when enclosed by a cage structure (Virnstein 1977). Sediments within the cage in July 1977 were 49.8 percent sand, 31.0 percent silt, and 19.2 percent clay. Total solids content was 65.2 percent, and the concentration of volatile solids was 5.9 percent. The sand content fell below and the clay content and volatile solids concentration fell above the 95 percent confidence limits for the means for stratum E6 in July 1977 but were within the ranges observed for these parameters in this stratum.

66. The exclosure contained many more small Corbicula and large oligochaetes (mainly Branchiura) than the surrounding bottom. The total density of macrobenthos was over three times higher in the exclosure than on the unprotected flat, and the species richness and diversity were also elevated. However, perhaps the most dramatic effect was the great increase in biomass in the predator exclosure. Mean biomass within the cage was 1024 mg dry weight/160 cm^2, which was 44 times higher than the mean for the low intertidal mud flat (E6) in July 1977. This was due to the much larger size of animals in the exclosure. Mean weight of Corbicula was 34.84 mg/individual compared to 1.81 mg/individual and for oligochaetes was 1.74 mg/individual compared to 0.01 mg/individual for the mud flat (E6).

Composition and abundance of meiobenthos

67. Meiobenthos samples were collected along with the macrofaunal samples in July 1977 after analysis of fish food habits revealed that several species of fish were feeding on meiofauna. The single sampling period for meiobenthos obviously does not give an indication of seasonal fluctuation but was designed to provide an accurate representation of species densities and distribution patterns at both sites.

68. A total of 3748 individuals and 74 species was found in the 88 cores collected for meiobenthos (Table 11 and Appendix F'). These individuals and species represented both small individuals of macrofaunal species passing through a 500- m sieve (so-called temporary meiofauna) and true (permanent) meiofaunal species. Approximately 14 percent of the individuals representing 28 of the 74 species in the samples were small individuals of the macrofauna. All of these species were also taken in the samples collected for macrobenthos (Table 12).

69. Densities of permanent meiobenthos ranged from a mean of approximately 25 to 30/10 cm^2 in the sand-gravel habitats (E7 and R5) to nearly 200/10 cm^2 on the intertidal flat (E6). Densities within the marshes were approximately 100 to 150 individuals/10 cm^2. As with the macrobenthos, densities of meiobenthos were generally higher in the low marsh and subtidal bottoms within the experimental marsh (E2 and E4) than within the reference marsh (R2 and R4).

70. Nematodes were the most abundant meiofaunal animals, accounting for 54 percent of the individuals collected in the samples. Cladocerans (11 percent), oligochaetes (10 percent), copepods (9 percent), and ostracods (8 percent) were also abundant. Cladocerans were represented by the most species (15), followed by oligochaetes (13) insects and acarids (12), nematodes (11), and copepods (10). More species were found at the reference site than at the experimental site, particularly cladocerans for which 10 of the 15 species were only found at the reference site (Table 13).

71. Indices of species diversity of the meiobenthos are listed in Appendix G' and summarized in Table 14. These show a pattern very

similar to that for macrobenthos. H' diversity and species richness were higher within the marsh than in surrounding habitats and were generally higher in habitats at the reference site than in comparable habitats at the experimental site.

72. Normal classification of the combined collections within strata, using all species in the analysis, primarily separated collections from the experimental site from those of the reference site (i.e. the final fusion of the agglomeration combined experimental strata in one group and reference strata in another group). Within the experimental site cluster, collections from the sandy habitats (E6 and E7) were grouped together as were collections within the experimental site (E2, E4, and E5). Within the reference site cluster, the collection from the sandy habitat (R5) was separated, and collections from the vegetated areas (R1 and R2) were grouped together.

73. Inverse classification was applied to those species which occurred in at least two of the strata. The classification produced three groups of species primarily characteristic of the experimental site, three primarily characteristic of the reference site and one group common to both sites (Table 15). Species in groups A and B were characteristic of many collections from the experimental site and were also found in reference high and low marsh strata (R1 and R2). Group C species were typical of the intertidal mud flat (E6) and sandy shore (E7). Species in group D were characteristic of collections from strata R1, R2, and R5. Species in groups E and F were found in strata R3 and R4. Group G contained the more ubiquitous and abundant species.

Natural history of meiofauna

74. Copepods were found in all habitats of both sites, with the cyclopoid species greatly outnumbering the harpacticoids. Of the cyclopoid species, the only ones considered to be true benthic dwellers are *Paracyclops affinis* and *Paracyclops fimbriatus*, both of which are morphologically adapted to creeping among weeds or muddy bottoms. The remaining cyclopoid copepods were more-or-less free-swimming planktonic forms. However, these later forms were as prevalent throughout all

strata sampled as the creeping benthic-dwellers. The harpacticoid species encountered, mostly canthocamptids, are all considered to be adapted to benthic life in the muddy bottoms of lakes, seasonal ponds, and ditches. Copepods made up approximately 20 percent of the permanent meiofauna.

75. Cladocerans were found in all strata except the high marsh (E1), and the reason for their exclusion from this habitat is unknown at this time. The Sididae, Bosminidae, and Daphinidae were present only at the reference marsh although several of these taxa are well represented in the plankton of the limnetic James River (Burbidge 1974). The remaining species encountered were in the families Macrothricidae and Chydoridae, known to frequent shallow, weedy backwaters. Of these, Ilyocryptus is the best adapted to benthic life and was the most frequently encountered cladoceran. These species live in the sediment or creep around on vegetation, camouflaging themselves with mud and detritus attached to the carapace.

76. Ostracods were encountered in all strata except the sandy shore (E7). Darwinula stevensoni was found only at the reference site, where it was present in every stratum. Perhaps it has not yet colonized the island. Ostracods made up about 5 percent of the total individuals found at the experimental site and 20 percent of those at the reference site.

77. The nematode assemblage can best be described in terms of Wieser's (1953) classification by feeding type as indicated by their buccal morphology. Two feeding types were found at both sites. Species in type 1B, deposit feeders, which includes all of the Monohysteridae, were found to constitute the largest percentage of all nematodes encountered at the sites and occurred in all strata. Species of type 2B, predators and omnivores, including the Dorylaimidae and the genus Anatonchus, were found in all strata of the experimental site, but in fewer numbers than at the reference marsh. Predators/omnivores were absent from the coarse sand-gravel habitat (R5). The other genera found in this study were of indeterminate feeding type, but are

probably deposit feeders, and were relatively few in number. Nematodes made up from 60 to 90 percent of all meiofaunal individuals at the experimental site, and from 10 to 50 percent at the reference site.

78. Tardigrada were encountered most heavily in the high marsh strata of both sites. High concentration of these cryptobiotic animals is a reflection of their association with vegetation or detrital "litter" on the sediment surface in the high marsh.

Estimated biomass of meiobenthos

79. Biomass of meiobenthos was not directly measured but was estimated from abundance data by using stereotyped values for mass per individual for the various taxa. These values were obtained by determining the dry weight of a known number of representative individuals or in some cases from the literature. Since the mass per individual can vary widely, only crudely rounded conversion factors were used. The following values were used: Nematoda (1 μg/individual), Cladocera (7 μg/individual), Copepoda (5 μg/individual), and Ostracoda (10 μg/individual). These numbers tend to be somewhat higher than those most commonly presented in the literature (e.g. Gerlach 1971; Stripp 1969; Juario 1975; Ankar and Elmgren 1976), primarily because of the larger sieve size employed in this study (125 μm).

80. Estimates of mean biomass are presented in Table 16 for each stratum and for each taxon of the permanent meiofauna. Whereas nematodes were usually the numerical dominants, crustaceans usually dominated the biomass. Nematodes were important contributors to biomass in the marsh habitats at the experimental site (E1 and E2) and on the tidal flat at the experimental site (E5 and E6). Nematode biomass was lower at the reference site.

81. Crustaceans strongly dominated the biomass at the reference marsh, where crustacean biomass, and, thus, total meiofauna biomass was much larger than at the experimental site. Ostracods were most important in the high and low marsh (R1 and R2) and copepods and cladocerans in the low marsh and subtidal channels (R2 and R4).

82. The pattern of the meiobenthos biomass contrasted sharply

with that of the macrobenthos. Meiobenthos biomass was higher in the reference marsh strata while macrobenthos biomass was much higher in the experimental marsh strata, expecially during the summer when the meiobenthos samples were taken. Biomass of macrobenthos in July 1977 was higher than that estimated for meiobenthos in all habitat strata. Within the experimental marsh estimated biomass of meiobenthos was 5 to 10 percent of that for macrobenthos. However, at the reference marsh (R1, R2, R4), biomass of meiofauna was 32 to 80 percent of that of macrobenthos. This was due to the higher meiobenthos biomass and lower macrobenthos biomass at the reference marsh.

Discussion

Effectiveness of sampling design

83. The stratified random sampling scheme was selected because it seemed the most efficient design to sample the heterogeneous but identifiable habitats at the sites in a nearly unbiased manner. Strictly random sampling would have under-censused the limited but important habitats such as the high marsh and subtidal channels in the marsh. Furthermore, it would not have allowed comparison of comparable habitats between the sites which was a central aim of the study design. Systematic sampling might have better allowed mapping distributions and correlation with environmental variables; however, considerable small scale patchiness existed which would preclude meaningful mapping. The central aim of the study was not to delineate or classify benthic communities but to characterize the benthos of the perceived habitats. Fixed-station sampling would have made seasonal comparisons easier but would have not allowed extrapolation of conclusions to the entire sites.

84. The *a priori* division of the sites into habitat strata based on elevation, vegetation, and gross sediment type proved effective in that important differences in sediments and biota were demonstrated among the strata. However, variation of sedimentary and biotic

parameters within strata was often very great, and the differences between some strata were often small with respect to this variation. In addition to natural variability in the distribution of populations, this was due to the gradational rather than abrupt changes between some contiguous strata, e.g. the high and low intertidal mud flat (E5 and E6), and the mosaic of small-scale habitat conditions in others, e.g. in the marsh strata (E1, E2, R1, and R2).

85. Differences in the benthos of the habitat strata were best developed during both of the summer seasons (July 1976 and 1977). Between-habitat differences were less distinct in winter and spring when the benthos were less dense and more homogeneous. The gains in precision through stratification of the environment before random sampling as opposed to simple random sampling are only expected to be great when there are large differences in the mean and/or variance for the parameters measured (Ankar and Elmgren 1976). Because of the high within-stratum variance and because of the ubiquitous nature of the benthos in these habitats, these conditions were not ideal.

Benthos of marsh habitats

86. An important objective in the studies of benthos in this habitat development project is to compare the abundance, productivity, and resource value of the benthos in the marsh habitat development with that of the natural habitats it replaced. The site of the dredged material marsh island was a shallow bar upriver of a small island on the south shoal of the James River. The pre-existing island and bar were themselves products of dredged material disposal resulting from maintenance dredging of the navigation channel over the years. However, material had not been placed at the site for several years, and it was presumed that the bar was ecologically similar to other "natural" shoal habitats in the river.

87. Macrobenthos of the bar and surrounding bottoms was intensively sampled in November 1974, just prior to commencement of construction activities, by Diaz and Boesch (1977a). A 0.05-m^2 ponar grab was used rather than the corers used in this study; however the

treatment of samples, including sieving, sorting, and species determinations, was identical. For those stations on the portion of the bar claimed by the habitat construction, they reported a mean abundance of macrobenthos of 3964 individuals/m^2. On the lower portion of the intertidal area east of the island (E6), there was a mean density of 2875/m^2 in November 1976. However significantly higher mean densities ($\alpha<0.05$) of 5625/m^2 were found in the extensive low marsh at the experimental site (E2) during November 1976. Densities of macrobenthos in the marsh during the summer of 1976 and 1977 were much higher, such that the overall (all seasons) mean density was 8250/m^2 in the low marsh (E2) and 6938/m^2 in the subtidal channels in the marsh (E4). These were the only two habitat strata including those at the reference site which had significantly higher densities of total macrobenthos than were found on the pre-construction flat. Dry weight biomass data were not collected by Diaz and Boesch (1977a), but since the communities present both before and after development of the marsh were very similar in quantitative composition and size of individuals, it is expected that the patterns of macrobenthos biomass essentially parallel those of density.

88. Any of a number of factors may have been responsible for the greater abundance of macrobenthos in the marsh. Production by the vascular vegetation may have increased the food content of sediment deposits which provide the trophic support for most of the benthos. However, increases in the abundance of benthos in the summer preceded the input of this production to the sediments. Other increases of organic material may have been due indirectly to the emergent vegetation, which during the growing season may by a baffling effect cause increased sedimentation. Shading of the sediment by the dense summer foilage of broad leaved Pontederia, Peltandra, and Sagittaria may have allowed less extreme high temperatures to develop on the marsh sediment surface than on unvegetated tidal flats. Sediment stabilization by the plants may have enhanced the survival of infauna. Finally, the vegetation may have helped protect the benthos from

predation by fishes and birds much as the exclosure cage on the tidal flat caused increase abundance of macrobenthos. In this regard, it is interesting to note that one species favored by the exclosure experiment, the oligochaete *Branchiura sowerbyi*, was a common inhabitant of the marsh while it was usually rare on the unvegetated flat and it is in the open river.

89. The macrobenthos within the reference marsh did not exhibit total densities substantially greater than those known for shallow bottoms in the James River (Diaz and Boesch 1977a, 1977b). However, densities within the vegetated portions of the marsh (strata R1 and R2) were greater than on nonvegetated intertidal bottoms adjacent to the marsh. The very fine sediments which characterize the reference marsh may have been responsible for the lower densities of both macrobenthos and meiobenthos found there.

90. The macrobenthos of the tidal freshwater James River is dominated by a reasonably small number of eurytopic, and hence ubiquitous species (Diaz 1977; Diaz and Boesch 1977a). It is not surprising that the macrobenthos of the experimental and reference marshes was quantitatively very similar to that found widely in the open river. The dominant annelids, *Limnodrilus* spp. (immature), *Limnodrilus hoffmeisteri*, and *Ilyodrilus tempeltoni*, and the dominant mollusc *Corbicula manilensis* in the river were also dominants in the marshes. Certain common species in the open river such as the larval insects *Coelotanypus scapularis* and *Hexagenia mingo* and the oligochaete *Limnodrilus profundicola* were rarer in the marsh habitats. Conversely, several species commonly found in marsh habitats during this study were unknown or were very rare in the open river. Notable among these were several larval insects, *Chironomus* spp. and *Tanypus* spp. among the Chironomidae and tipulids, tabanids, and ceratopogonids.

91. The strong quantitative similarity in the benthic fauna of the experimental and reference marshes, the tidal flats, and the open James River contrasts with the considerable dissimilarity of the macrobenthos of planted and bare dredged material shoals, adjacent

creeks, and natural marshes reported by Cammen (1976a, 1976b). He studied two sandy sediment sites in North Carolina, one in a high salinity (35 ppt) regime and the other mesohaline (7 to 10 ppt), where *Spartina alterniflora* had been propagated on dredged material. Abundance of macrobenthos was much higher in the nonvegetated creeks than in the marsh at the high salinity site. Sediment trapping by the propagated plants raised the elevation of the sediment surface causing the development of large populations of larval insects which were rare at lower elevations. Thus, controlling the elevation of a dredged material marsh may be critical not only for optimizing the growing conditions of desirable marsh plants but also for the development of the desired benthos.

Comparison of experimental and reference marshes

92. The benthos of the experimental marsh at Windmill Point was different in several respects from that of the reference natural marsh on Herring Creek. These included differences in species composition, abundance, and biomass. There were a number of species of macrobenthos and meiobenthos which were found only at the reference marsh and a few found only at the experimental marsh. However, the dominant components of the macrobenthos and meiobenthos were common to both sites. There did exist some important differences in relative abundance of some important species. For example, the oligochaete *Peloscolex multisetosus* was consistently abundant at the reference marsh but not elsewhere. Several meiofaunal ostracods were also abundant only at the reference marsh.

93. Greater densities of macrobenthos in the low marsh and subtidal channels of the experimental site than in comparable habitats of the reference site were apparent in the summer. Although the cause of this is not obvious, it is possible that the very fine sediments found at the reference marsh created conditions more stressful for the benthos. Otherwise, it should be noted that important differences between the marshes existed in terms of vegetation, water drainage and

circulation, fishes, and avifauna.

Development of benthos following marsh construction

94. Over 1 year has passed from construction of the retaining dike, the placement of dredged material, and the colonization of the experimental site by marsh plants (spring 1975) when this study began. However, because of the opportunistic nature of the fauna, establishment of the existing benthic community in the experimental marsh occurred very rapidly, at least by the fall of 1975. Thixotropic dredged material discharged on a shoal on the northern side of the James River across from the experimental site in July 1976 was rapidly colonized by macrobenthos within weeks (Diaz and Boesch 1977b). By 4 months the community in this disposal area was very similar to that at an upriver control station.

95. The long-term fate of the benthos of the experimental marsh is uncertain and dependent not on further biological accommodation but on modification of the marsh habitat. Composition of the dredged material has apparently lowered the marsh somewhat since construction. With marsh development, however, conditions should be favorable for deposition of new sediments which should compensate for subsidence. More serious is the erosion of the protective sand dike surrounding the marsh. During the period of this study, the dike on the western and northern perimeters suffered substantial erosion, and there were several washovers and new inlets formed. Should a section of the dike be completely removed, the very fine sediment in the marsh would be susceptible to future erosion.

Production of benthos

96. Determination of secondary production by the benthos is a notoriously intractable problem. However, in order to understand potential trophic transfers from the benthos to fishes and wildlife, it is necessary to consider production rather than the static properties of standing stocks. The direct determination of production from the seasonal sampling of macrobenthos is not possible because of the lack

of, or difficulty in determining, age classes of most species and the very rapid growth and reproduction which takes place in these populations of opportunists.

97. An analysis is thus necessarily reduced to estimating rates of biomass turnover coupled with measuring the standing crop to develop crude estimates of production. Even then the turnover rates must vary widely among the macrobenthic and meiobenthic species found; published turnover rates are often not based on sound data. An attempt was made to use turnover rates for the various taxa which may not be absolutely accurate but which are believed to be realistic in a relative sense. Thus, between-habitat and between-taxon comparisons of estimated production rates can be made.

98. The standing crop values used in the production estimates for macrobenthos are the means of July 1976 and July 1977 biomass. These values represent seasonal maxima. Only July 1977 biomass data are available for meiobenthos and only permanent meiofauna were considered as meiobenthos producers. The production of those small macrofaunal individuals collected in meiobenthos samples is thought to be reflected in macrobenthos estimates.

99. The annual rate of biomass turnover is a function of the life cycle turnover rate, the ratio of a cohort's production to its standing crop, and the number of generations or cohorts per year (Gerlach 1971). Waters (1969) found from examinations of published data and from theoretical considerations that life cycle turnover rates for freshwater benthic invertebrates ranged from 2.5 to 5. All of the taxa which were important contributions to biomass must have several annual generations, except perhaps the molluscs. Large species generally tend to have a large life cycle turnover and a few annual generations, while small meiofuanal species generally have a smaller life cycle turnover and many annual generations. The high temperatures which are found in the tidal James River for 6 to 8 months of the year undoubtedly cause shorter generation time and more rapid turnover (Gerlach and Schrage 1971) than is suggested in most of the literature

which is based on studies in cold water lakes or boreal marine environments (Gerlach 1971; Johnson 1974). Thus, although the turnover rates used here are greater than the 2/year and 10/year commonly used for macrofauna and meiofauna turnover, respectively, they may well be below the real turnover rates.

100. Turnover rates of 10/year and 14/year were applied for oligochaetes and chironomids, respectively. These were based on the observations of Johnson (1974) who reported rates at least as high as these for warmer water environments in Lake Ontario. Annual turnover of Corbicula manilensis was estimated to be 3.5, based on the conservative assumption of a 3.5 life cycle turnover rate and one generation per year. For meiofauna the following assumptions were made:

Taxon	Life Cycle Turnover Rate	Generation/Year	Annual Turnover
Nematoda	2.5	8	20
Copepoda	4	4	16
Cladocera	5	3	15
Ostracoda	5	3	15
Other	3	4	12

101. These turnover rates were applied to summer biomass values to estimate production of macrofauna and meiofauna in the various habitats (Figure 22). These computations indicate that macrobenthos production at the experimental marsh was very much greater than at the reference marsh or on the unvegetated tidal flat. On the other hand, meiofaunal production was substantially greater at the reference marsh than in comparable experimental site habitats. In fact, the estimated production of meiobenthos at the reference marsh was nearly equal to the production of macrobenthos. Total production of benthos was highest in the low marsh and subtidal channels at the experimental site, and this was overwhelmingly attributable to high oligochaete production. At the reference marsh, oligochaetes were less productive, and meiofaunal crustaceans (ostracods, cladocerans and copepods) were

as productive as or more productive than the oligochaetes.

102. The consistency of this basic pattern in all three marsh habitats indicates that important differences existed in the biological structure of the communities between the experimental and reference marshes that were less obvious in considerations of the distribution and density of species of benthos. The potential of an interaction between macrofauna and meiofauna is suggested by these results. Although this could be a direct interaction, e.g. the sparser macrofauna of the reference marsh allowed larger meiofauna production, more likely it is a result of common factors acting on both components with different results. There may have been differences in sediment microhabitats between the two sites which are not adequately reflected in the measured sediment variables. Another important mechanism affecting community structure may be differences in the intensity of predation.

Relationship to fishes and wildlife

103. Parallel investigations of fishes and wildlife at the experimental site and the reference site demonstrate the key role of the benthos in trophic support of these living resources. Most of the fishes and many of the birds found at the sites fed exclusively or heavily on benthic prey.

104. The food habits of five fishes were examined (Part III), and meiobenthic Crustacea, larval chironomids, and juvenile Corbicula were the numerically most important prey items. The spottail shiner (Notropis hudsonis) was the only fish which fed heavily on Corbicula which comprised its major prey item at the experimental site. Meiobenthic crustaceans, mainly cyclopoid copepods and cladocerans, were more heavily preyed on by the spottail shiner at the reference site. The creek chubsucker (Erimyzon oblogus) was only taken at the reference site where it preyed almost exclusively on meiobenthic crustaceans, especially ostracods and cladocerans of the genus Alona. The channel catfish (Ictalurus punctatus) preyed mainly on chironomids and crustaceans. Cladocerans of the genus Sida and harpacticoid

copepods were particularly important prey items. Sida was notably rare in samples of meiobenthos and was probably associated with the marsh plants or associated periphyton rather than the sediment surface. The mummichog (*Fundulus heteroclitus*) fed heavily on ostracods, particularly *Physocrypta*, and copepods. Chironomids were important in the diet of specimens collected from the reference site. Juvenile white perch (*Morone americana*) had a diverse diet in which *Bosmina longirostris* (cladoceran) was particularly abundant. *Bosmina longirostris* is primarily a planktonic cladoceran which is also an important constituent of the food habits of pelagic feeding herrings in the James River (Burbidge 1974). Chironomids (especially at the reference site), other benthic cladocerans, ostracods, cyclopoids, and ceratopogonid insects were also well represented in white perch stomachs.

105. Perhaps the most striking feature of the food habits of these five fishes is the very important role of meiofaunal crustaceans in their diets. These faunal components comprise a relatively small portion of the biomass of the benthos, although as discussed above they can be important producers. Their apparently inordinant importance can be attributed to several factors: (a) the assessment of importance was based on numbers of individuals found in stomachs; thus, these small crustaceans may be less important in terms of biomass consumed; (b) the fish specimens analyzed were mostly small species or small individuals of larger species which can be expected to feed on meiofauna rather than macrofauna; and (c) these crustaceans are epibenthic and motile and thus may be more obvious and available prey (Macan 1977).

106. The oligochaetes which usually dominate the biomass of benthos were noticeably rare in the reported food items. However, they are without an exoskeleton or resistant integument and thus are very rapidly digested once consumed by a fish. Oligochaete setae were frequently present in fish stomachs; however, the importance of oligochaetes in the diets was very hard to quantify. Tubificids are long and thread-like worms which live in vertical burrows with their

anterior ends at the base of the burrow. Their thin posterior segments often project out of the burrow when covered by water to assist respiration. The oligochaetes can rapidly retract their posterior ends when disturbed as a natural escape response. In this way they may be able to avoid predation by these small fishes which do not forage deeply in the sediment.

107. It is difficult to assess the relative value of the benthos of the various habitats studied in trophic support of fishes. The reference marsh was more productive of the small crustaceans so important in the fish diets; however, the experimental marsh apparently supported more of the fishes. The high marsh was largely inaccessible to the fishes, but even though they could not be sampled in the low marsh proper, the fishes actively feed in this habitat when it is inundated. The subtidal channels within the marshes were particularly important habitats for the fishes. These channels and pools provided refuge at low tide and were particularly productive of small epibenthic crustaceans important to the fishes. The marsh habitats (including the associated channels and pools) provided protection and food resources not found on the exposed tidal flat. It thus appears that these habitats are beneficial to fish production.

108. The assessment of feeding behavior of birds included as part of the wildlife studies (Part V) indicated that over 20 species of birds which were observed feed largely on aquatic invertebrates. Semipalmated sandpipers (*Ereunetes pusillus*) and western sandpipers (*Ereunetes mauri*) foraged over the intertidal flats, particularly on the large flat to the east of the experimental marsh. These shorebirds were also found within the marsh during the winter when the vegetation was reduced. They feed by probing the sediments probably for oligochaetes and insect larvae. Within the marsh, common snipe (*Capella gallinago*) were found throughout the year, but in greatest abundance in spring. Snipe probably fed on moderately large prey such as the snail *Physa*, aquatic and terrestrial insects and, perhaps, oligochaetes. Pectoral sandpipers (*Erolia melanotos*) also foraged in

the marsh in early spring. Kildeer (Charadrius vociferus) were very common and were most often observed on the more exposed shorelines.

109. The degree of reliance of the wildlife resources on the benthos is difficult to quantify but appears to be considerable. Accounts of the specific feeding habits of the birds in this study are lacking, but there is ample documentation indicating the importance of benthic invertebrates in the diets of many shore and wasind birds (Holmes 1966; Recher 1966; Chamber and Milne 1975; Rofritz 1977). Conversely, it is difficult to assess the effects of bird predation on the benthos. The predator exclosure experiment conducted on the tidal flat at the experimental site, the habitat most intensely utilized by wading birds, suggests that these effects may indeed be considerable.

Summary

110. Marsh habitats at the experimental site of Windmill Point had generally sandier sediments than comparable habitats at the reference marsh at Herring Creek. The fine dredged material of the experimental marsh had become mixed with sand from the dike built to retain the dredged material. The reference marsh was more protected from waves and currents and had sediments totally comprised of silt and clay with higher organic content.

111. Because of astronomic and meteorological phenomena, tidal height and the degree of inundation of marsh habitats were greatest in the summer and fall and lowest in winter. This may cause more stressful conditions to marsh fauna in the winter and spring.

112. The macrobenthos was qualitatively and quantitatively dominated by tubificial oligochaetes and larval chironomid insects. The introduced bivalve Corbicula manilensis was also very abundant in some habitats. Oligochaetes of the genus Limnodrilus were the numerical and biomass dominants in most of the habitats.

113. The total density and biomass of macrobenthos were highest in the low marsh and subtidal channels of the experimental site.

Intermediate density and biomass were found in the higher marsh at both sites and in the low marsh at the reference site. Lower values were found outside of the marshes on adjacent tidal flats and on subtidal bottoms claimed by the habitat development project. These between-habitat differences were attributable mainly to differences in populations of oligochaetes.

114. The density and biomass of macrobenthos varied seasonally, with highest values in the summer and lowest in the winter. This is attributable to more stressful conditions in winter, the presence of plant cover in summer and life cycle patterns.

115. Species diversity of macrobenthos was higher at the reference site than in comparable habitats at the experimental site. This was due both to the greater richness (number of species) and greater evenness (less dominance by a few species) at the reference site habitats.

116. The experimental and reference marsh habitats were also separable on the basis of the species composition of the macrobenthos. The reference marsh had more unique species, but several widely distributed species were more common at the experimental marsh.

117. Protection of tidal flat macrobenthos from predation by means of an exclosure cage resulted in a 3-fold increase in density and a 44-fold increase in biomass over the surrounding habitat. This suggests that predation by fishes and birds played an important role in structuring the benthic community and that the production and resource value of the benthos would be underestimated by standing crop estimate.

118. Meiobenthos was sampled only during the summer of 1977 after analysis of fish food habits showed meiofauna to be important components. The permanent meiobenthos was comprised principally of nematodes, cladocerans, ostracods, and copepods. The density of meiobenthos was greatest in the low marsh, subtidal channel, and tidal flat at the experimental site. However, estimated biomass was greater in reference site habitats than in comparable experimental site habitats. This was due to the greater densities of crustaceans at the

reference site.

119 . Production estimates showed that in the reference marsh meiobenthos were nearly as important producers as macrobenthos, while macrobenthos production (principally by oligochaetes) was overwhelming in experimental marsh habitats. Although total production of benthos was much higher in experimental marsh habitats than in the reference marsh or on the open tidal flat, meiobenthos production was greater in reference marsh habitats.

120. The benthos of the habitats investigated provided critical support of fish and wildlife resources. Fishes fed largely on meiobenthic crustaceans and insect larvae. Oligochaetes which were so abundant were apparently not heavily preyed on, although, because of the rapid digestion of these soft-bodied forms, the analysis of stomach contents of the fishes probably underestimate their importance. Shorebirds which prey on benthic invertebrates were important components of the avifauna.

PART III: AQUATIC BIOLOGY--NEKTON

Robert Dias, John Merriner, Marion Hedgepeth

Introduction

121. The nekton subproject was to document the qualitative and quantitative changes in the nektonic community after habitat development, specifically (a) to relate patterns of animal use to the vascular plant community and the physical characteristics of the dredged material and (b) to describe the changes in aquatic biota following the disposal of dredged material and site development.

122. Previous studies on fishes of the tidal freshwater region of the James River are few, and detailed data on fishes inhabiting the marshes and shallows of this region are especially limited. Raney (1950) reviewed information on the freshwater fishes of the James River and noted that piedmont and coastal plain fishes had been little studied. The food habits and distribution of fishes from a lower piedmont tributary of the James River were studied by Flemer and Woolcott (1966). Jensen (1974), in an investigation of the environmental effects of thermal discharge from an electric generating plant, conducted fish studies in the tidal James River between Hopewell and Richmond, Virginia. Studies conducted by VIMS on the freshwater fishes of the James River have dealt primarily with anadromous species (Burbidge 1972; Hoagman et. al. 1973; Weaver 1975; and Loesch and Kriete 1976) but have provided information on the distribution and abundance of other species.

Methods and Materials

123. Quarterly sampling of nekton was conducted in October 1976 and February, April, and July 1977 (Appendix H'). Day (0700 to 1900 hours EST) and night (1900 to 0700 hours EST) samples were collected at the experimental and reference sites. Sampling stations (Figure 23)

and gear used were as follows:

a. Experimental site (Windmill Point):
- (E1) Marsh interior, 6 minnow traps.
- (E2) Mouth of dike breach, 1 fyke net.
- (E3) Mouth of culverts, 1 fyke net.
- (E4) Marsh exterior, 6 minnow traps.
- (E5) Marsh exterior, 3 beach seinings.

b. Reference site (Herring Creek):
- (R1) Marsh interior, 6 minnow traps.
- (R2) Marsh interior, 1 fyke net.
- (R3) Marsh exterior, 6 minnow traps.
- (R4) Marsh exterior, 3 beach seinings.

124. Fyke nets and baited minnow traps were set at the time of predicted high water and were retrieved after approximately 6 hours. The beach seine hauls were made when the ebb tidal velocity was maximum. Each seine haul was about 46 m long and was made parallel to the shore. Appendix I' contains descriptions of sampling gear. All specimens collected were preserved in the field in a 10% solution of buffered formalin with glycerin.

125. Day and night water samples were collected in duplicate concomitantly with nekton sampling from mid-depth at 4 locations at the experimental site and 3 locations at the reference site (Figure 23). Determinations of temperature (^{o}C), salinity (ppt), and dissolved oxygen (DO, mg/l) followed procedures of the Environmental Protection Agency (1974). A portable pH meter was used to determine pH, and a portable colorimeter was used to analyze turbidity (JTU's).

126. In the laboratory, the preserved specimens were identified to species, counted, measured for total length (mm), and weighed (g). In large collections, subsamples of 25 specimens per species were randomly selected for length and weight determinations. Nomenclature of fish species followed Bailey (1970) with one exception; the silvery minnow (*Hybognathus regius*) was considered a separate species from *Hybognathus nuchalis* as suggested by Pflieger (1971).

127. After preliminary compilation of the October catch data, 5 species (spottail shiner, *Notropis hudsonius*; creek chubsucker, *Erimyzon oblongus*; channel catfish, *Ictalurus punctatus*; mummichog,

Fundulus heteroclitus; and white perch, *Morone americana*) were selected for study of sex, condition of gonads, age, growth, and food habits. Abundance, biomass, frequency of occurrence, and trophic level of the species were used as selection criteria.

128. Channel catfish were aged by cross sections from the proximal portion of pectoral spines. The remaining species were aged by scales using methods in Lagler (1956). The formula of Poole (1961) was used for back-calculation of growth.

129. Stomachs and intestines from a maximum of 25 fish per species per collection were examined by the Borgeson (1963) method. A 25-mm segment of the anterior gastrointestine was used for the creek chubsucker which lacks a well formed stomach. One-ml subsamples of food contents from creek chubsucker intestines were examined with a Sedgwick-Rafter counting cell. Food organims were identified to the lowest taxonomic level possible. After identification of taxa, number of organisms and volume (when measurable) per taxon were determined for each fish size interval.

130. Volumes per taxon could seldom be determined with precision because of the preponderance of planktonic and meiobenthic organisms in the samples. These organisms, although numerically important, frequently occurred in trace volumes (less than 0.1 ml). We believe measurement errors were too large in volumetric determinations to yield meaningful data; therefore, number of organisms per taxon exclusively was used as a relative measure of importance of food items.

Results

Water quality analysis

131. Water temperature ranged from 3.0 to 32.7°C (Table 17) and exhibited an expected seasonal trend with lower temperatures encountered in February and higher temperatures in July. (A complete listing of nekton water quality data is given in Appendix J').

Between-site and within-site differences were slight. Day temperatures were higher than night, and ebb tide samples had a higher temperature than flood tide samples.

132. The total range in pH was from 6.8 to 8.7 (Table 17) with essentially no difference in mean pH between sampling sites, times, tides, or stations. The seasonal pH pattern differed for the 2 sites, suggesting a site-season interaction.

133. Salinity was relatively constant ranging from 0.07 ppt in April to 0.73 ppt in July (Table 17). No trends in mean salinity were evident between sampling sites, times, tides, or stations.

134. The total range in DO was 2.1 to 12.6 mg/l (Table 17). A seasonal pattern in DO related to temperature was apparent with February having the highest mean DO and July having the lowest. The reference site samples had a wider range and a higher mean DO than did those from the experimental site. Day samples had a higher mean DO than night samples, and samples from flood tide had a higher mean DO than those from ebb tide.

135. Turbidity ranged from 4 to 84 JTU's (Table 17). Water at the reference site had a higher mean turbidity than at the experimental site. Slight differences in mean turbidity were present between sampling times, tides, or stations within sites.

General trends in the nektonic community

136. The ichthyofauna of the tidal freshwater region of the James River is a moderately depauperate one with low diversity dominated by a few groups, especially cyprinids and clupeids.

137. Nekton sampling at both sites resulted in the capture of 6319 fish specimens which weighed over 144 kg and represented 15 families and 37 species (Tables 18 through 21). (A complete listing of nekton catch data is given in Appendix K'). Twelve species (N greater than 100 specimens) accounted for 88 percent of the specimens collected, and 14 species (biomass greater than 1 kg) accounted for 95 percent of the total biomass. Nine species were represented by 4 or fewer specimens.

138. More species were captured at the reference site than at the experimental site (Table 18). The species composition of the 2 sites was similar. Six species were unique to the reference site and 3 species were unique to the experimental site (Table 20). About 65 percent of the total specimens and 72 percent of the total biomass were collected at the experimental site.

139. July collections had the most species and specimens, and February had the least. A roughly equal biomass (40+ kg) was collected in October, April, and July, but February was much lower (2 kg).

140. More species, specimens, and biomass were collected at night than during the day (Table 18). More species and specimens were captured in the marsh exterior, but a larger biomass was collected in the marsh interior. Minnow traps captured the smallest number of species, specimens, and biomass. The beach seine caught the most species and specimens, and the largest biomass was obtained from fyke net samples.

141. The relative importance of the species was obtained by ranking species according to number of specimens, biomass, and frequency of appearance (the number of samples in which the species was present). Anderson et. al. (1977) used a similar method to determine relative importance. For each category the values were ordered, and the highest value was given a rank of 1, the second highest rank of 2, etc. The individual importance ranks were weighted equally and summed to give an overall species importance value (Table 22). The spottail shiner was first in relative importance, followed in decreasing order by the white perch, american eel (Anguilla rostrata), threadfin shad (Dorosoma petenense), mummichog, tidewater silverside (Menidia beryllina), gizzard shad (Dorosoma cepedianum), channel catfish, silvery minnow, and spot (Leiostomus xanthurus).

142. Species composition and relative abundance of species in the present study were similar to unpublished VIMS data, despite the large differences in sampling gear and effort (Table 23). Six species were numerically dominant in both data sets: threadfin shad, bay anchovy

(Anchoa mitchilli), spottail shiner, channel catfish, tidewater silverside, and white perch. Five of these species ranked in the top 10 most important species during the present study. Hoagman et. al. (1973), Jensen (1974), and Loesch and Kriete (1976) also presented nekton composition and abundance data which were quite similar.

Statistical analysis of catch data

143. Catch data were subjected to statistical analyses including analysis of covariance, correlation, and multiple regression (a) to determine the significance of spatial and temporal trends in the nektonic community and (b) to develop regression models which identify the major environmental factors of importance to community structure. Four dependent variables which reflect overall community structure were included in the analyses (number of species per sample, specimens, total biomass, and species diversity). Independent variables were water temperature, pH, salinity, DO, turbidity and dummy variables for site (reference vs. experimental), period (day vs. night), and station (marsh interior vs. exterior). Throughout these analyses the data were treated separately for the 3 gear types (seine, minnow trap, fyke net). Appendix L' gives a detailed discussion of these analyses. Only major findings are presented below.

144. The results of the statistical analyses were mixed. The pattern of response of the dependent variables to environmental factors differed among the 3 data sets. The effects of temperature, site and period were not consistent between the seine and minnow trap data. For example, temperature had a positive partial correlation with number of specimens for the seine data and a negative one for the minnow trap data. Also, number of species and species diversity were significantly higher at the reference site than at the experimental site based upon seine data, but the reverse was true for the minnow trap data. Number of specimens and total biomass were significantly higher at night for the seine data, whereas the converse held for the minnow trap data.

145. The different fishing efficiences and selectivities of the gear probably resulted in the different patterns of significance

observed for some of the independent variables. If forced to choose the one gear most useful for assessing the major trends of the data, the seine would be selected. Using the coefficient of multiple determination (R^2) as a criterion of goodness of fit, the R^2 values for regression equations developed for the seine data were highest in all but one case. The equations explained a high percentage (61 to 79%) of the total variance of the dependent variables. Minnow trap data were the least useful in analyzing trends with equations explaining less than 16 percent of the variation in the dependent variables. The high number of zero catches in the minnow traps and the lack of replication of the fyke nets resulted in less meaningful data sets for these gears. Jensen (1974) also found minnow traps to be ineffective gear for sampling the nektonic community.

146. pH and turbidity did show a consistent relationship with the dependent variables. pH was retained in many of the equations as a negatively significant independent variable. A higher catch and diversity is expected at a lower pH. Turbidity was a positively significant variable in several equations. Salinity and DO were retained as significant independent variables in few equations, and the pattern was not consistent for the 3 gears.

Comparison of nektonic and benthic community structures

147. Benthic organisms are important in the transfer of energy from primary producers to higher trophic levels, and they are a significant part of the diet of many fishes. Analysis of macrobenthic communities, therefore, should give clues to causes of fluctuations in the distribution and abundance of fish species.

148. Comparisons between nektonic and macrobenthic community structure were based upon number of species, number of specimens, species diversity, species evenness, and species richness (defined in Part II). For these comparisons, the nekton data were based on fyke net and beach seine samples; minnow trap data were deleted because of the high selectivity of this gear. Benthic data were from stations similar to those where nekton was collected (E4, E6, E7, R3, R4, and

R5; see Part II).

149. The most striking similarity between the nektonic and benthic communities was that both exhibited the same pattern when comparing the 2 sites (Table 24). For both communities a higher mean number of specimens were found at the experimental site, whereas the reference site had higher mean values for the other variables (number of species, species diversity, richness, and evenness). Samples of nekton and benthos from the experimental site had more specimens and a lower diversity than samples from the reference site.

150. The pattern of community structure of nekton and benthos was also similar in 3 seasons (Table 24). In both communities, the mean value of the 5 measures representing community structure were highest in summer (except for nekton where evenness was also high in spring), and intermediate values of these variables were found in fall and spring. In winter, however, the pattern was different between nekton and benthos. Nekton samples taken in winter had the lowest mean number of species, specimens, diversity, evenness, and richness, whereas benthic samples showed only small seasonal differences between fall, winter, and spring. Evidently, some factor other than the benthos has led to the low abundance and diversity of nekton during the winter.

151. Samples from different stations at both sites showed a different community structure when comparing nekton and benthos (Table 24). Nekton samples from the interior of the marshes of both sites had lower mean values of the community variables than did those from the exterior (except evenness which was about equal for the interior and exterior samples). On the other hand, benthic samples showed the reverse; the 5 variables were higher for benthic samples from the interior of marshes. These comparisons between marsh interior and exterior are confounded, however, since different types of gear were utilized to sample interior and exterior nekton stations.

Ecology of selected nekton species

152. Notropis hudsonius, spottail shiner. This species accounted for one-third (2094 specimens) of all specimens captured, ranked third in biomass (10.6 kg), and appeared in 34 percent of the nekton samples (91 out of a total of 264 samples). Almost three-fourths of the specimens were collected at the experimental site (Table 20). Over half of the specimens were collected in October and the remainder were about equally divided among the other 3 sample periods. Twice as many spottail shiner were collected at night as during the day and 80 percent were captured by beach seine. Additional information on the size, sex, gonads, and age of the spottail shiner is presented in Appendix M'.

153. The spottail shiner is abundant in all major Virginia tributaries of the Chesapeake Bay in fresh and brackish water (up to 10.7 ppt) and is captured both in mainstream and sluggish weedy necks, creeks, and swamps (Wass 1972). Although of no importance commercially, this species is important as a prey item for smallmouth bass, white bass, northern pike, and walleye (McCann 1959).

154. This species most commonly inhabits quiet, shallow water with a grassy bottom and rarely strays from the immediate shoreline (Hildebrand and Schroeder, 1928 and McCann 1959) but as summer progresses they move out of areas where heavier vegetation develops. In Missouri this species prefers a firm bottom of sand, gravel, and rubble and avoids strong currents (Pflieger 1975). The experimental site was characterized by coarser sediments (see Part II) and shallower water, than the reference site. Although plant stem density was not determined, the impression of both botanists and ichthyologists was that the reference site had the higher stem density during the growing season. Thus the experimental site was preferred by the spottail shiner because of its physical characteristics.

155. McCann (1959) also captured more spottail shiner at night than during the day either due to greater susceptibility to sampling gear or school movements into shallower water at night.

156. Molluscs, in particular the pelecypod Corbicula manilensis, were the dominant food of the spottail shiner and accounted for 27.3 percent of the total food organisms (Table 25). Crustaceans and plant material were next in importance, each representing about 25 percent of the total with cladocerans, ostracods, copepods, and plant seeds of arrowhead and panic grass as dominant groups. Insects represented about 20 percent of the total food organisms with chironomids and ceratopogonids in the majority. Fish eggs, especially those from Dorosoma sp. and Anchoa sp., were also present.

157. Molluscs and plant material were most important at the experimental site, whereas crustaceans and insects were dominant foods of the spottail shiner at the reference site (Table 25). Molluscs and fish eggs appeared in equal numbers in stomachs from the 2 sites. Plant material was more prevalent in stomachs from the experimental site, and crustaceans and insects were more abundant per stomach at the reference site.

158. Seasonal changes in the diet of the spottail shiner were evident (Table 25). During October molluscs, crustaceans, and plant seeds were the dominant foods. Crustaceans and insects were most important in February with other groups forming only a small portion of the total. Crustaceans were greatly reduced in importance during April and molluscs, insects and plant material accounted for over 90 percent of all food. Fish eggs were first found in spottail shiner stomachs in April. Crustaceans, insects and, to a lesser degree, molluscs were the dominant food in July.

159. Diurnal differences in food of the spottail shiner were noted (Table 25). Molluscs were the dominant food in day samples, and plant material was dominant in night samples. Molluscs, crustaceans, insects, and fish eggs from stomachs collected during the day had a higher average number per stomach than those at night; for plant material, the converse was true.

160. Several authors (Hildebrand and Schroeder 1928; Boesel 1938; McCann 1959; Smith and Kramer 1964; Pflieger 1975) have found the diet

of the spottail shiner to be very similar to that observed in the present study. This species can be considered omnivorous with its feeding habits determined largely by the availability of both planktonic and benthic food organisms. For example, macrobenthic samples showed the mollusc Corbicula manilensis to be more abundant at the experimental site, and this mollusc was also more important in the diet of specimens from the experimental site. Insects were a dominant food of this species from the reference site where the greater amount of emergent vegetation, overhanging tree limbs, and brush would be expected to yield a more abundant and diverse insect fauna. McCann (1959) compared spottail shiner food habits and found larval and adult insects dominated stomach samples at a station with large amounts of emergent vegetation, while a station with no emergent vegetation showed cladocerans as a more important prey.

161. Given the general availability of food organisms, size of the spottail shiner remains an important factor in determining the food eaten. Oligochaetes, were the most numerous macrobenthic organisms but were not eaten by the spottail shiner. This fish is probably too small to feed effectively upon oligochaetes. Our results parallel those of Smith and Kramer (1964) who reported oligochaetes and clams larger than 4 mm as abundant in benthic samples but absent from spottail shiner stomachs. They reported selection of larger organisms by larger fish. They found small crustaceans were most important in small fish, but in fish over 70 mm TL insects predominated. Smaller fish ate smaller crustaceans (Appendix N'), and specimens over 80 mm TL preferred the larger nonaquatic insects and were the major consumers of molluscs.

162. Erimyzon oblongus, creek chubsucker. This species was taken only at the reference site and ranked fourth in biomass (approximately 10 kg) even though only 26 specimens were captured. Most specimens were collected in October at night in the fyke net (Table 20). Additional data on the size, sex, gonads, and age of specimens of the creek chubsucker are presented in Appendix O'.

163. This freshwater species is a common inhabitant of all major Virginia tributaries of Chesapeake Bay and frequently occurs in sluggish streams and swamps (Wass 1972). Pflieger (1975) found it is an inhabitant of clear, quiet waters with thick growths of submergent vegetation and it commonly occurs in the deeper pools of small creeks (confirmed for a lower piedmont tributary of the James River by Flemer and Woolcott 1966). The absence of this species at the experimental site probably results from the lack of deep water.

164. Crustaceans accounted for 97.5 percent of the total food organisms of the creek chubsucker (Table 26 and Appendix N'). Ostracods (in particular Physocypria sp. and Candona sp.) represented over half of all food organisms encountered. Next in importance were cladocerans (25.5%) especially Alona sp. followed by copepods (19 percent).

165. Insects (chironomids) were found in small numbers (about 1% of the total) as were nematodes, molluscs, and other small invertebrates. Oligochaete setae and algae (mostly diatoms) were noted in all creek chubsucker stomachs.

166. Flemer and Woolcott (1966) reported similar feeding habits for this species and considered the prevalence of entomostracans and microscopic plants as an indication of omnivorous feeding. Pflieger (1975) suggested that the terminal mouth of this species indicated it was less a bottom feeder than many other suckers. Our data support this suggestion and indicate that this species feeds chiefly upon small planktonic and epibenthic invertebrates and algae that are common forms found on or near the bottom of weedy littoral areas.

167. Since the creek chubsucker was collected only at the reference site and mostly in October at night, further comparisons of feeding habits between sampling sites, seasons, and periods will not be made. With hindsight another species would have been a more suitable choice for detailed analysis of feeding habits. At the time of selection of the 5 nekton species (October) this species appeared to be a good choice.

168. Ictalurus punctatus, channel catfish. Seventy-eight channel catfish weighing 6.2 kg were captured. About 78 percent of these were collected at the reference site and 65 percent were collected in October. This species was most prevalent at night and in beach seine samples (Table 20). Additional information on the size, sex, gonads, and age of channel catfish is summarized in Appendix P'.

169. The channel catfish was introduced into Virginia and is now found in all major tributaries. A common inhabitant of mainstream waters from fresh to 15.1 ppt, this species is of minor commercial and sport importance (Wass 1972). In Missouri adults of this species are most frequently found in deep water or lie about obstructions during daylight, but at night they move onto riffles or into shallow water to feed (Pflieger 1975). Menzel (1945) discussed commercial fishing records of Virginia catfish fishermen which showed that more catfish entered pots at night. The prevalence of this species at night in shallow water during this study suggests a similar nocturnal feeding behavior.

170. Insects were the dominant food item found in channel catfish stomachs and accounted for 61 percent of all food organisms (Table 27 and Appendix N'). Chironomids were the major insect form found, especially Chironomus sp., Polypodilum sp., and Tanytarsus sp. The aquatic larvae of other dipterans were also present (tipulids, tabanids, syrphids, ceratopogonids). Nonaquatic insects and terrestrial spiders were found in small amounts.

171. Crustaceans were the next most important food and represented 24 percent of the total. The cladoceran Sida sp., which lives among the vegetation in lakes and streams, was the most abundant crustacean prey. Harpacticoid copepods and ostracods were also present.

172. Plant material consisting of berries, grasses, and arrowhead seeds represented 3 percent of the total food organisms and molluscs represented about 1 percent. Fish and fish eggs were also present but in smaller amounts.

173. Crustaceans were the dominant food in channel catfish stomachs from the experimental site (83%) but insects were dominant in those from the reference site (83%). Crustaceans were more prevalent in day stomach samples and insects were more prevalent in night samples.

174. The food habits of channel catfish have been investigated by Boesel (1938), Menzel (1945), Bailey and Harrison (1948), Darnell (1958), Perry (1969), Pflieger (1975), Lewis (1976), and Griswold and Tubb (1977). These studies and the present study are in agreement concerning the feeding habits of this species. The diet of small fish consists primarily of small aquatic insects and crustaceans. As size increases the fish becomes more omnivorous with the diet determined by local availability. In the present study specimens of this species over 200 mm TL fed chiefly on large insects, molluscs (Physa sp., Lymnaea sp., and Corbicula manilensis), and fish (threadfin shad and tidewater silverside). Bailey and Harrison (1948) also reported small catfish fed almost exclusively on insect larvae such as midges, mayflies, and caddisflies while large catfish (over 250 mm TL) fed on fish and large insects.

175. Production of catfish depends chiefly on favorable shelter conditions and an adequate food supply (Bailey and Harrison 1948). Areas with long straight stretches of stream of uniform depth and with a shifting sandy bottom are unfavorable catfish habitat. A diversity of environment is needed for maximum production with suitable shelter (deep pools, lagoons, backwaters, and obstructions such as stumps, submerged logs, drift jams, etc.). The presence of overhanging bushes and trees adds measurably to the supply of food, especially insects. These characteristics were typical of the reference site but not the experimental site. With the foregoing in mind, it is not surprising that over 3 times as many channel catfish were collected at the reference site than at the experimental site.

176. Fundulus heteroclitus, mummichog. One hundred ninety-two specimens of the mummichog weighing 0.6 kg were captured. This species ranked fourth in appearance (13 percent of the samples). A large

majority of the specimens were collected at the experimental site and most specimens were collected in April and during the day. Sixty percent of the specimens were captured by minnow traps in the marsh interior and about 34 percent were captured by beach seine (Table 20). Additional data on this species are summarized in Appendix Q'.

177. This estuarine species is abundant throughout the entire Chesapeake Bay region occurring from fresh to salt water (0 to 32 ppt), but is most often found in the mesohaline zone. Mummichogs are inhabitants of muddy marshes, channels and grass flats in summer and ascend streams to fresh water or burrow in silt in the winter (Wass 1972). The mummichog is an important forage fish and is also used extensively as bait by sport fishermen.

178. The main food items of the mummichog were crustaceans, especially ostracods (Physocypria sp.) and cyclopoid copepods, which represented about 65 percent of all food organisms (Table 28). Insects accounted for 16 percent of the food items; chief among these were dipterans and to a lesser degree homopterans. Fish eggs, panic grass seeds, gastropods, and arachnids were also present.

179. Insects were the dominant food in stomach samples in October and July, and crustaceans were dominant in April (Table 28). Fish eggs were present only in April and July stomach samples where they were the second most prevalent food item.

180. Stomachs from the experimental site contained a higher diversity of food items and crustaceans were the most prevalent prey. Insects were the most important food in samples from the reference site. Day stomach samples were dominated by crustaceans. Night samples had more fish eggs.

181. This species has omnivorous feeding behavior (Hildebrand and Schroeder 1928, Bigelow and Schroeder 1953). Within the limits imposed by its size the diet of this species, seems to be largely a function of local availability of food. The capture of most specimens in the marsh interior during the day with baited traps suggests increased feeding activity of this species during daylight.

182. Morone americana, white perch. This species ranked third in number of specimens and seventh in biomass collected (719 specimens; 7.7 kg). The white perch appeared in 14 percent of the samples. Eighty-three percent of the specimens were collected at the experimental site and 69 percent were collected in July. A large majority of the specimens were captured at night in beach seine samples (Table 20). Appendix R' presents additional data on this species.

183. This anadromous species is abundant in all major Virginia tributaries of Chesapeake Bay. In winter it is predominantly found in channels and during the remainder of the year it ranges from shallow to deep water (Wass 1972). This species is of minor commercial and sport importance.

184. Crustaceans represented almost 52 percent of all food organisms in stomachs of the white perch (Table 29). Cladocerans (especially Bosmina sp., Sida sp. and Leydigia sp.) were the dominant crustaceans; however, amphipods, ostracods (Physocypria sp. and Candona sp.), and copepods were also important foods.

185. Insects, accounted for about 41 percent of the food items and chironomids were the dominant insect type. The remaining food categories (molluscs, fish, and plant material) represented less than 10 percent of the total food organisms. Nematodes and oligochaetes were present in small numbers.

186. Crustaceans were more prevalent in stomach samples from the experimental site and in day samples. Insects were the most important food item at the reference site and in night samples, but the average number of insects per stomach was greater at the experimental site and in the day. Perch preferred insects when they were abundant but would readily switch to crustaceans as conditions changed.

187. White perch larger than 150 mm TL ate the mollusc Corbicula manilensis, ceratopoganid larvae, and fish. Those over 200 mm TL fed almost exclusively on fish (american eel, spottail shiner, and Fundulus sp.). Young-of-the-year fish primarily fed on small planktonic invertebrates and dipteran larvae. Hildebrand and Schroeder (1928) and

Reid (1972) have reported similar food habits for the white perch.

188. Webster (1943) observed the movement of young of this species into shoal areas at night and a return to deeper water during the day. We found evidence of a diurnal change in feeding behavior and felt cladocerans which formed the bulk of food from collections made just after sunset resulted from deep-water feeding prior to movement into shoal water. The appearance and position in the digestive tract of ants, scuds, mayfly nymphs, Sialis larvae, and Trichoptera adults as the night progressed were interpreted as evidence of littoral feeding. The volume of cladocerans eaten decreased after sunset and the volume of littoral organisms increased. These findings directly parallel the results of the present study. A large majority of our specimens were collected at night by seine.

189. Overall trends in feeding habits. Numerous taxa of food items were represented in the stomach samples of the 5 nekton species combined and individually by species (Table 30). All 5 species can be considered omnivorous.

190. Crustaceans (cladocerans, ostracods, and copepods) were the most prevalent food item and represented about 47 percent of the total food items for the combined data from all stomachs. Insects, were the next most important group (30.5%, mostly chironomids), followed by plant seeds (9.4%), molluscs (8.6%), and fish and fish eggs (1.9%). Other taxa represented in the samples included nematodes, rotifers, annelids, and arachnids.

191. Local availability of food appears to control the diet of these species. Size of individual fish was also important in determining prey. As fish size increased the diversity of food types and size of prey increased. Differences between sites and seasons in the feeding habits of the species can be explained by changes in prey abundance. For example, at the experimental site crustaceans were a consistently more important part of the diet of the nekton than were insects. At the reference site with its more abundant and diverse insect fauna insects increased in importance as food. Diurnal changes

in feeding habits were for some species and for channel catfish and white perch the change appeared to result from movement between deep and shallow water.

192. The relative importance of taxa in the benthic community differed from that of benthic organisms in the fish diets in 2 major ways. First, the absence of small crustaceans in macrobenthic samples was a result of sampling methodology so their true importance was not reflected in these data. Second, oligochaetes dominated the abundance of macrobenthic organisms (Table 31); Branchiura, Limnodrilus, Peloscolex, and Nais were numerically important in the macrobenthos but were represented by only a few specimens in stomachs of the creek chubsucker and the white perch. Reduced importance of oligochaetes in the observed diet of the nekton is probably the result of 2 factors: (a) most fish sampled were small and unable to feed upon the larger benthic organisms and (b) oligochaetes possess no exoskeleton and were rapidly digested. Aside from these differences the macrobenthic and food habits data were similar. Insects were the second most prevalent group in both the macrobenthos and nekton stomachs. A higher diversity of insects was found in the nekton stomachs than in the macrobenthos since many fish had fed upon terrestrial as well as aquatic insects.

193. Meiobenthic data from samples taken in July 1977 more closely resembled the data from fish stomachs than did the macrobenthic data. Small crustaceans (cladocerans, ostracods, and copepods) were numerically important in both meiobenthic and stomach samples. Chironomid insect larvae were prevalent in both meiobenthic and stomach samples; but other insects (especially hemipterans, homopterans, and hymenopterans) were not represented in the meiobenthos but were common in some fish stomachs.

194. In a few instances selection of particular crustaceans by the nekton was indicated. Ilyocryptus was the dominant cladoceran in the meiobenthos but was little utilized as foods by the nekton. Bosmina and Sida were important food of some fish species but were numerically reduced in meiobenthic samples. Bosmina may not have been a truly

selected food, since it is usually planktonic and its relative importance in stomachs may simply reflect its abundance in the water column.

Discussion and Conclusions

195. There were essentially no differences in water quality between the experimental and reference sites. Only DO had a noticeably higher mean value at the reference site than at the experimental site. Since DO was retained in only a few of the regression equations as a significant predictor of nekton abundance and diversity, we conclude that factors other than water quality were responsible for the observed differences in nekton between the 2 sampling sites. Other factors such as marsh area, kinds and amounts of plant cover, water depth, sediment characteristics, and exposure were probably important. However, the effects of these factors and their interactions are difficult to quantify in a way that is useful to a detailed statistical analysis.

196. Although the findings of the correlation and regression analyses were mixed, the results from the seine data indicate the utility of stepwise regression techniques in identifying factors important to community structure and developing equations with a predictive capability. For example activities which alter the temperature, pH or turbidity will significantly change the abundance and diversity of nekton. The magnitude of these effects can be estimated by the equations. As the above factors are quantified and incorporated into future regression models, the accuracy of these estimates should improve.

197. Examining the seine data, the reference site was found to have significantly more species and a higher species diversity than the experimental site. There were no significant differences in numbers and biomass between the 2 sites. The reference site seining station had attributes that may have led to high number of species and high species diversity. These included the presence of partly submerged

vegetation, relatively fine bottom sediments, proximity to deep water, and overhanging tree limbs, rocks, twigs and other debris in and around the sampling area. The experimental site seining station lacked vegetation, had coarser bottom sediments, and was clear of debris. The diversity of subhabitats at the reference site probably resulted in the higher diversity of nekton species at this site.

198. These observations suggest several ways in which the diversity of nekton species could be increased at the present and future artificial islands: (a) increase the stability of the dike to avoid the erosion and sanding over which is currently taking place, (b) increase the elevation of the dike and plant shrubs and trees around the island, (c) increase the internal depth of channels, and (d) offer an increased diversity of habitat by placing debris in and around the island.

199. With hindsight, it appears that the sampling design and methodology of this study could be improved in several ways. Before additional habitat evaluation studies of this nature are made, nekton gear development research should receive a high priority. The development of one kind of gear to effectively sample nekton from the various habitats encountered would be very beneficial. Lift nets or drop nets offer a possible solution, but they should be tested for reliability. Development of gear that is easier to replicate would allow more frequent sampling at about the same cost. With seasonal sampling the information derived from the analysis of age, growth, sex and gonads of selected species was of minimal value to project objectives. The value of the analysis of nekton feeding habits would have been increased if seasonal sampling of meiobenthos and terrestrial insects had been conducted coincident with fish sampling. Future studies should not overlook these important prey. Finally, the objectives of this project could not be fully met since pre-construction studies of nekton were not done. To quantify the changes after habitat development, preconstruction studies are required. The distribution and abundance of fish species cannot be

directly related to the vascular plant community. The different sampling characteristics of the gear and the mobility of species decreased the usefulness of nekton comparisons between vegetated and unvegetated areas.

200. Some general observations can be made despite our inability to quantify the changes which occurred after site development. Undoubtedly, the abundance and diversity of nekton in the area was increased by the creation of the Windmill Point marsh through provision of more living space, food, and protection to many nekton species. The abundance of important forage species like the spottail shiner and the mummichog was probably increased since they exihibit a high dependence upon littoral areas and rarely stray from the shoreline. The channel catfish and the white perch utilized the increased shoal areas for nocturnal feeding. In summary, we feel the Windmill Point marsh has benefited the area by providing additional habitat for the nekton and thereby increased their abundance and production.

Summary

201. Differences in water quality between the experimental and reference sites were slight. Dissolved oxygen had a higher mean value at the reference site; but water temperature, pH, salinity, and turbidity were essentially equal for the 2 sites.

202. Seasonal trends were evident in all water quality variables monitored. Mean water temperature and salinity were highest in July; pH and dissolved oxygen peaked in February; and turbidity was highest in April. February had the lowest mean temperature and turbidity; April had the lowest salinity; July had the lowest dissolved oxygen; and October had the lowest pH.

203. Mean water temperature and dissolved oxygen were higher in the day than at night. Day-night differences in the other water quality variables were not evident.

204. Water samples from ebb tide had a higher mean temperature and a lower mean dissolved oxygen than those from flood tide; pH, salinity, and turbidity showed little difference between ebb and flood tide.

205. Nekton sampling resulted in the capture of 6319 specimens weighing over 144 kg and representing 37 species of fish; relatively few species (about one-third of all species collected) accounted for most of the specimens and biomass collected.

206. The species compositon of nekton at both sites were similar. More species were captured at the reference site, but more specimens and a greater biomass were collected at the experimental site.

207. The smallest number of nektonic species, specimens, and biomass were collected in February; the largest number of species and specimens were collected in July; and the largest biomass was collected in April.

208. Night samples of nekton resulted in more species, specimens and biomass than day samples.

209. The smallest number of nekton species, specimens, and biomass were collected in minnow traps; the most species and specimens were captured in the beach seine; and the largest biomass was collected in fyke nets.

210. Overall, the 10 most important nektonic species (in terms of their abundance, biomass and frequency of appearance) in decreasing order were the spottail shiner, white perch, american eel, threadfin shad, mummichog, tidewater silverside, gizzard shad, channel catfish, silvery minnow, and spot.

211. The ichthyofauna of this area of the James River is a moderately depauperate one with a low diversity dominated by a few groups, especially cyprinids and clupeids.

212. The results of a statistical analysis of nekton catch data were mixed. The pattern of response of nekton to some environmental factors was not consistent for the 3 gear types.

213. The seine data set was found to be most useful for statistically assessing trends in the distribution, abundance and

diversity of nekton. Using the seine data, it was found that significantly more species had higher species diversity were at the reference site, and number of specimens and biomass did not differ significantly between the 2 sites.

214. The nektonic and benthic community structure exhibited a similar patter at the 2 sites. For both communities, samples from the experimental site had more specimens and a lower diversity than samples from the reference site.

215. It was concluded that the diversity of sub-habitats at the reference site resulted in the higher diversity of nekton species at that site. Methods suggested to increase the diversity of nekton at present and future experimental sites were stabilization of the dike to avoid erosion and sanding over of the marsh, elevation of the dike to allow the planting of shrubs and trees around the marsh, deepening of marsh channels, and addition of debris in and around the island to increase the habitat diversity.

216. The ecology of 5 nekton species was reviewed including the spatial and temporal trends in their distribution, abundance and feed habits. The spottail shiner, mummichog, and white perch were more abundant at the experimental site, and the creek chubsucker and channel catfish were more abundant at the reference site. The mummichog was more abundant in April; the white perch was more abundant in July; and the remaining 3 species were more abundant in October. All of these species except the mummichog were more prevalent in night samples than day samples; channel catfish and white perch appeared to move at night into shoal areas for feeding.

217. A high diversity of types of food was found in stomach samples from these 5 nekton species, and they can be considered omnivorous. The diet of these species appeared to be controlled primarily by the local availability and abundance of food. Size of fish was also important in determining prey. As size increased the diversity of food types increased. Typically, larger fish ate larger organisms.

218. Benthic organisms were a major part of the diet of the nekton species examined. The meiobenthic organisms, especially small crustaceans, were an important part of their diet. Larger macrobenthic organisms such as oligochaetes were not numerically important foods. Since most fish sampled were small; this was not considered unusual. Overall crustaceans were the most prevalent food, followed in decreasing order by insects, plant seeds, molluscs, and fish and fish eggs. Other taxa represented in stomach samples included nematodes, rotifers, annelids, and arachnids.

219. The following recommendations are made to improve the design and methodology of future studies: (a) develop a nekton sampling gear that efficiently samples both the interior and exterior of marshes, (b) sample meiobenthos and terrestrial insects coincident with fish sampling, and (c) conduct nekton studies in the area prior to site construction.

220. It was concluded that the Windmill Point marsh had benefited the area by providing additional habitat for the nekton.

PART IV. BOTANICAL STUDIES

Damon G. Doumlele and Gene M. Silberhorn

Introduction

221. The botanical aspect of the Windmill Point study was designed to evaluate the success or failure of planted and naturally invaded marsh and supratidal vegetation at the site and to correlate findings with soil parameters. Information on plant performance and distribution was obtained by both ground observations and aerial photography during the 1976 and 1977 growing seasons.

Methods

Sample collection

222. Nondestructive sampling. Plants were sampled by quadrats, the shape and size of which was a square with dimensions of 1 x 1 m. Various field layouts were tried during the 1976 and 1977 growing seasons. In 1976, 30 quadrats at the experimental site and 8 at the reference site, all located randomly without regard to vegetation types, were sampled. It was decided for 1977 to divide the island into plant zones and to sample within each zone in order to include all community types. Only those areas botanically similar to areas found at the experimental site (Figure 24) were sampled at the reference site (Figure 25). The number of nondestructive quadrats per zone at both sites was determined by a species-area curve (Cain 1938, Oosting 1956). The three largest and most homogeneous zones, arrowhead-pickerelweed beggar ticks (*Bidens laevis*), and panic grass (*Panicum* spp.), were sampled with 15 quadrats randomly located in each zone. At the reference site, two zones representing high and low marsh areas (Figure 25) were sampled. These two zones were chosen to correspond to the beggar ticks and arrowhead-pickerelweed zones at the experimental site; each of the two zones also contained 15 randomly located quadrats.

Because of spatial heterogeneity, three subzones per zone were sampled and are depicted in Figure 26. Subzones were located of the basis on an attempt to represent the entire zone both geographically and in terms of visual differences in plant characteristics.

223. The procedure for locating individual quadrats was as follows: Approximate boundaries of subzones were noted in the field. A central location was chosen as the starting point for random location of the five quadrats to be placed in the subzone. A number from 1 to 360 was drawn at random to give a compass heading; another number from 1 to 10 was drawn to give the number of paces to be taken in that direction. This established the location of the first quadrat which was used as the starting point for locating the second quadrat by the same procedure. The other three quadrats were located similarly, care being taken to ensure that all quadrats were well within the subzone boundaries. Because of the narrowness of subzones P1 and P2, the compass heading was not used and only the number of paces was drawn. The starting point was one end of the zone, and quadrats were located in a line down the center. Sampling consisted of placing a 1-m^2 frame at each quadrat location and estimating species cover (percent of ground covered per species) for all species growing within. Other observations such as natural invasion, signs of stress, disease, competition, animal use, and physical damage were also noted.

224. During the course of the study, 35-mm color slides taken from established photographic points were used to document visual changes in vegetation from month to month. One point was located in each major subzone or zone.

Species lists

225. From 1974 through 1977 several plant species lists for the experimental site were compiled. All species were collected, pressed, labeled, and listed in Tables 32 through 36. Nomenclature follows that of Radford et al. (1968), and sources for all determinations were Fernald (1950), Hitchcock (1950), and Gleason (1958).

Surveys and tidal data

226. Surveys of the experimental and reference sites conducted periodically by the U.S. Army Engineer District, Norfolk, and tidal data provided by WES were used where applicable in correlating plant parameters with elevation and tidal inundation.

Aerial photography and mapping

227. During 1976 several photographic overflights of the experimental and reference sites were made for the purpose of constructing vegetation maps. These maps (Figures 25 and 27) were prepared by WES and were used in assessing seasonal changes in plant distributions.

Results and Discussion

Zone descriptions

228. Figure 24 outlines the major plant communities present at the experimental site as of September 1977. Comparison with September 1976 (Figure 27) reveals generally little change in zonal boundaries. Changes did occur, however, in the vegetational content of some zones, notably in the vicinity of the pool at the northwest corner. In 1976 the area adjacent to the pool was dominated by two grasses, panic grass (Panicum dichotomiflorum) and barnyard grass (Echinochloa crusgalli). In the spring of 1977, jewelweed (Impatiens capensis) was very prevalent, but by September the area was heavily dominated by rice cutgrass (Leersia oryzoides) with smaller amounts of barnyard grass and common cattail. In the supratidal area at the northeast corner, changes mainly in zonal extent rather than composition took place. Although not yet dominated by black willow (Salix nigra), the area at the northeast corner labeled "Mixed Vegetation; 2,4,10" in Figure 24 contained many more willows than in 1976 and will most likely become dominated by this species in the next few years.

229. The following is a brief description of the major plant zones found to occur at the experimental and reference sites:

230\. Experimental site

a. Arrowhead-pickerelweed. This zone (Figure 28) occupied the lowest vegetated elevations of the site and was wholly confined to a broad area of the interior. At the lowest elevations arrowhead and pickerelweed almost equally codominated, but at higher elevations beggar ticks, barnyard grass, and rice cutgrass became more common. Isolated patches of wild rice (*Zizania aquatica*) and southern wild rice (*Zizaniopsis miliacea*) also occurred.

b. Beggar ticks. This zone (Figure 29) was found at higher elevations of the marsh and was dominated by beggar ticks but was much more diverse than the arrowhead-pickerelweed zone. Considerable amounts of barnyard grass, water smartweed (*Polygonum punctatum*), jewelweed, cattail, and water hemp (*Amaranthus cannabinus*) were well-distributed throughout the zone.

c. Panic grass. This was the only zone sampled which was artificially planted at the site (Figure 30). It was represented by an interrupted band that surrounded the island and was located on the dike and original island. Another stand was planted at the inner northeast portion of the island (Figure 24). The *Panicum* species present were *P. amarulum* (beachgrass) and *P. virgatum* (switchgrass), with the former being by far the more common. Since these two species commonly intermingled and were often difficult to distinguish, they are treated together in this report. Other species found in this zone included beggar ticks, pigweed (*Amaranthus* spp.), cocklebur (*Xanthium strumarium*), and jewelweed.

d. Black willow. Isolated stands of black willow, cottonwood (*Populus deltoides*), and common alder (*Alnus serrulata*) occurred on the eastern portion of the island and represented the only wooded areas of the site.

e. Other zones. The remainder of the plant zones are depicted in Figure 24 and consisted of heterogeneous mixtures of two or more species. Common species of these areas included Mexican tea (*Chenopodium ambrosioides*), bush clover (*Lespedeza cuneata*), umbrella sedge (*Cyperus strigosus*), wild sensitive plant (*Cassia nictitans*), gerardia (*Agalinis purpurea*), and evening primrose (*Oenothera biennis*).

231\. Reference site (sampled areas only)

a. Low marsh. Arrow arum dominated this zone (Figure 31), followed in order by pickerelweed, water smartweed, and wild rice. Water hemp and beggar ticks occurred sparingly.

b. High marsh. This diverse zone (Figure 32) generally can be characterized as an arrow arum-jewelweed-tearthumb association. Relative amounts of these species fluctuated greatly during the 1977 growing season (Table 39). Interestingly, beggar ticks was visibly dominant in 1976 but was a very minor species by August 1977 (Table 39).

Floral inventories

232. Results of floral inventories are given in Tables 32-37. Before dike construction, vegetation on the original island consisted of 55 plant species fairly evenly distributed between marsh and supratidal habitats (Table 32). Shortly after construction (July 1975) this number was roughly doubled by new invaders and six planted species. From July 1975 through September 1977, numbers of new species in both habitats declined, but the dike and original island developed a higher diversity than the marsh. This higher diversity was undoubtedly due to more plant competition as a result of decreased tidal inundation. Invading species in the dredged material were found mostly in the beggar ticks zone, which was a more suitable habitat than the lower arrowhead-pickerelweed zone. The low number of invading species in September 1977 possibly indicates an approach of climax or near-climax conditions, especially in the marsh. However, with the increased growth of trees (willows, cottonwoods, and sycamores) on the dike and originial island, species distribution there will undoubtedly continue to change with changing shade conditions.

Estimates of cover

233. Plant cover averages are listed in Tables 38 and 39. As seen from the tables, most of the dominant species of their respective zones reached their maximum cover in July or August. Beggar ticks in the beggar ticks zone and high marsh zone is an exception in that it peaked in June. The reason for this is most likely a severe windstorm that swept through the area in July, resulting in many broken stems and mortality of plants (Figure 33). In addition, the high marsh at the reference site was invaded by large numbers of grasshoppers and Japanese beetles, which visibly reduced the cover of most species by

devouring leaves (Figure 32). However, the beggar ticks at the experimental site recovered, as shown by the rising cover values in August. The beggar ticks at the reference site continued to decline to a negligible value by late August (Table 39). The reasons for the decline of beggar ticks in the high marsh are not clear, but perhaps the additional effect of insect damage was partly responsible. As beggar ticks in the high marsh decreased, halberd-leaved tearthumb (Polygonum arifolium), possibly due to increased availability of sunlight, dramatically increased until by August it and jewelweed dominated the zone.

234. Two other species, jewelweed and arrow arum, also reached peaks in June, but probably not as a result of subsequent wind damage. Jewelweed tends to be more robust and productive in shaded situations (Jervis 1969) and possibly declined as a result of decreased shading by beggar ticks. Arrow arum decreased in both the high and low marsh zones, but the cause of this decline is not known. Similar cover values for this species, as well as water smartweed, have been reported by Doumlele (1976) in a vegetationally similar freshwater marsh in Virginia.

Animal and environmental effects

235. As already mentioned, insects dramatically reduced the vegetation of the high marsh zone. Grasshoppers and Japanese beetles were also noted at the experimental site, but insect damage there was slight. The major plant damage inflicted by animals resulted from muskrat activity (see Part V: Wildlife Resources). Muskrats destroyed plants in many areas, whether for food or for lodge construction. Plants were destroyed by direct consumption of roots and/or shoots and by tunnels and runways dug by the animals. Several small areas were almost completely denuded (Figure 34) but during the year many were revegetated (Figure 35).

236. The effect of severe winds has already been mentioned. The effect on beggar ticks was much more deleterious, since visual comparisons of plant heights between 1976 and 1977 revealed a sharp

decrease in beggar ticks height, whereas arrowhead and pickerelweed were largely unaffected. Apparently, the flexibility of soft-stemmed plants such as arrowhead and pickerelweed contributed to their survival during the July 1977 windstorm, whereas the taller, rigid stems of such plants as beggar ticks and water hemp were broken (Figure 33).

237. Shore erosion probably presents the greatest threat to the future of the island. Erosion on the exposed west dike shifted that shoreline eastward to the point where, by late 1977, only a narrow sand berm protected the highly erodable interior marsh. The planted panic grass on that dike, though apparently a good soil retainer, was nevertheless undermined by wave action. Even woody plants such as willows were eventually uprooted. It is unlikely that vegetation alone will be able to stabilize this shoreline.

Elevational and tidal effects

238. Elevation ranges of areas sampled at the experimental site are shown graphically in Figure 36. The gradation from low elevations in the arrowhead zone to high elevations in the panic grass zone is readily apparent, although there is considerable overlap in the beggar ticks and panic grass.

239. Although it appears that elevation alone was an important factor in relation to species distribution, tidal inundation, a function of elevation, was more critical in the intertidal areas. That marsh plant species have differing tolerances to submergence is well-known, as demonstrated by the zonation patterns found in saltmarshes in response to elevational and inundational differences (Johnson and York 1915, Miller and Egler 1950, Kerwin and Pedigo 1971). This was apparently true at the experimental and reference sites, although zonal boundaries in these freshwater marshes were usually not as distinct. Thus, arrowhead and pickerelweed almost exclusively dominated the interior of the experimental site because of their tolerance of frequent flooding there. Similarly, pickerelweed and arrow arum dominated the lowest areas at the reference site. At slightly higher elevations, these three species were present, but their

cover was reduced (Tables 38 and 39), while other species such as beggar ticks increased in abundance as a result of their ability to withstand the reduced submergence.

Seasonal effects

240. Figure 27 depicts areal extents of zones for three months, May, July, and September 1976. The most obvious changes from May to September were the "invasion" of mudflats by arrowhead and pickerelweed and the subsequent "spread" of beggar ticks into these same areas. Upland areas remained stable, for the most part.

241. Although one is tempted to explain these changes as successional in nature, they are no more than stages of a normal seasonal cycle. Arrowhead and pickerelweed were present during the winter and early spring, but only as underground tubers and rhizomes and therefore were not visible from the air. By May the plants had sprouted but were immature; consequently, the area appeared as a mudflat with arrowhead and pickerelweed in small amounts. By July, however, the two species had more fully closed their canopies and thus had reduced the amount of nonvegetated "mudflat" area. Beggar ticks appeared to spread into the interior by September but, again, was probably present there in May and July, as well as the previous winter. Since seed dispersal of this species takes place in the fall, the seeds would have been well-distributed throughout the marsh by May of the following year. Any appearances of beggar ticks in the arrowhead zone later in the season would have to be explained by the fact that the seeds were there all along but, because of the greater tidal inundation, sprouted later than seeds at higher elevations.

Soil-plant relationships

242. Table 40 summarizes the soils and dominant plant community relationships. Elevation above mean low water obviously played a major role in determining species composition and distribution at both the experimental and reference sites. Soil chemical properties (i.e. nutrient availability, CEC, etc.) probably more influenced within-zone variability and comparative aspects of species performance than overall

plant distribution. Soil type resulted from both physical and biological influences. Because of the relatively young nature of the experimental marsh system, being dominated by physical influences, it can be expected to change in time. Just as elevation probably governed overall plant distribution, soil type determined to a large extent many of the measured soil properties (see Part VI: Soil Analysis). The more subtle interactions between elevation, soil type, and soil chemical properties determined species composition within a zone. Competitive interactions, given the same physical and chemical properties of the soil substrate, determined dominance. Initial plant invasion of the habitat development site cannot be related specifically to soil properties except in the broadest terms, since invasion was the result of stochastic processes. Species replacement and distribution changes occurred between the 1976 and 1977 growing seasons, suggesting that the habitat development site is tending toward a more climactic condition. Soil properties can be expected to follow the same trend as the system becomes more ecologically mature and to more directly influence species composition and distribution within similar physical zones. Without further field and experimentally oriented study, these changes cannot be predicted or their controls determined.

Summary and Conclusions

243. Botanical data were collected through the use of quadrats from July through September 1976 and from June through August 1977 at the experimental and reference sites. Data consisted of species cover and environmental effects and were collected from five distinct plant arrowhead-pickerelweed, beggar ticks, and panic grass at the experimental site, and the high and low marsh at the reference site.

244. Periodic floral inventories conducted at the experimental site revealed a large number of naturally invading plant species shortly after dike construction in 1975, but by late 1977 numbers of invading species had decreased. The greatest diversity and change in

species composition took place on the dike and original island as a result of more plant competition from less frequent tidal inundation.

245. Maximum plant development at the experimental site appeared to take place in July and August as opposed to June for the reference site. Numerous factors may be responsible for this difference, including differences in soil cation exchange capacity and soil nitrogen (see Part VI: Soil Analysis) as well as species differences.

246. Wind, insects, and muskrats may have combined to produce atypical results, especially in the beggar ticks communities at both sites.

247. Panic grass, beggar ticks, arrowhead-pickerelweed (combined), and arrow arum were clear-cut dominants of the panic grass, beggar ticks, arrowhead-pickerelweed, and low marsh zones, respectively, throughout the summer. The high marsh zone, however, changed from an arrow arum-beggar ticks to an arrow arum-beggar ticks-jewelweed to a jewelweed-tearthumb zone late in the summer, probably as a result of beggar ticks destruction by winds.

248. Species distribution and zonation was found to be a function of elevation and tidal inundation, especially in the intertidal areas. The ability of a species to withstand submergence was a major factor in determining its location at the sites.

249. Apparent successional changes in plant cover as detected from aerial photographs were actually stages of a normal seasonal cycle. Successional changes are occurring, as evidenced by changes in willow distribution at the northeast corner, but accurate assessments can be made only through long-term studies.

PART V: WILDLIFE RESOURCES

Marvin Wass and Elizabeth Wilkins

Introduction

250. This part of the study was intended to evaluate the Windmill Point Marsh Development site as a marsh habitat attractive to avifauna and other wildlife. The objectives were to census bi-monthly at the experimental and reference sites in the months of July 1976 through August 1977.

Methods

Field methods

251. Censuses of the experimental and reference sites were scheduled twice monthly over a 14-month period from 1 July 1976 to 30 August 1977. Extreme weather in the winter months precluded regular censusing, but a total of 37 censuses was made at the experimental site and 18 at the James River Berm over the 14-month period. The reference site was established in January 1977, and 13 censuses were made over an 8-month period. A preliminary census was made at the experimental site on 18 May 1976.

252. At the experimental site and James River Berm, counts were made by walking slowly through the census areas, recording all birds seen or heard during that time. The 2 observers worked together on most occasions, in order that more birds could be flushed and counted. The duration of each count was determined by the time required to walk the areas, averaging from about 1.5-2 hours for the experimental site, 1-1.5 hours each for the Berm and reference site.

253. At the Herring Creek reference site, 6 observation stations were established (Figure 37), and birds were counted during a 10-minute period at each station. Birds seen between stations were recorded as miscellaneous, but were later combined with station observations for

analysis, as very few birds were seen while observers were stationary. Birds nearby, but outside the 2.9-ha study area, were not included in the analysis and were treated as miscellaneous, as was done for the experimental site and James River Berm. While camping at the experimental site, species that were seen only after the census were recorded, but were considered miscellaneous and were not included in analysis or census data.

254. Censuses were made without respect to time of day, as it was not feasible to census the 3 areas at a consistent hour over the entire period. For the experimental site, tide level probably played as important a role in influencing species and number of individuals seen as hour of day.

255. Nest searches were conducted at all 3 sites in season, and active nests were tagged and mapped (Figures 39 and 40). Nest contents were followed as closely as possible, given the inadequacy of bi-monthly observations for this purpose. Supporting vegetation was also recorded.

256. For all censuses, binoculars and a spotting telescope were used to identify and count birds present.

257. In addition to bird censuses, other wildlife was also observed. Muskrats (Ondatra zibethicus) were located and mapped (Figure 38), and toward the end of the study 20 household mouse traps were set to confirm the presence of small rodents on the island.

Statistical methods

258. Species diversity was measured for each observation date by the Shannon index (Pielou 1975), given by:

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i$$

where s = number of species in a sample (census) and p_i = proportion of the i^{th} species in the sample. To assess the contribution to the species diversity of numbers of species (species richness) and the distribution of individuals among component species (evenness), the following formulae were used:

Evenness (J') = $H'/\log_2^s$ (Pielou 1975)

Species Richness (SR) = (S-1)/LnN (Margalef 1958)

Community parameters were averaged by season, using these dates (Anderson 1972):

Late Spring	-	Apr 16 through Jun 1
Early Summer	-	Jun 2 through Jul 15
Late Summer	-	Jul 16 through Sep 1
Fall	-	Sep 2 through Nov 1
Winter	-	Nov 2 through Mar 1
Early Spring	-	Mar 2 through Apr 15

259. In addition to species diversity, a foraging diversity (Tomoff 1974) was calculated for each census at each site, using the above formula for H' with s = number of ecologic feeding categories (food items) and p_i = proportion of 1) species_i to total species in the census, and 2) individuals_i to total individuals in the census.

260. Resemblance between the experimental site and the reference site was measured by Dice's similarity coefficient, especially where the number of positive attributes is variable (Boesch 1977). The Dice coefficient is given by:

$$\frac{2a}{2a + b + c}$$

where a number of joint presences (of species), b = number of species exclusive to entity B (experimental site), and c = number of species exclusive to entity C (reference site).

261. Relative abundance was calculated for species and individuals in 3 major feeding categories at the experimental site. The data was plotted by seasonal means to show changes in abundance due to migration and food availability.

Results

General Characteristics

262. At the experimental site, a total of 10,316 birds were counted during the study period: 3575 were counted in 13 censuses in 1976, and 6741 in 24 censuses in 1977. The mean number of birds per census was 275.0 in 1976 and somewhat higher in 1977, at 280.9. At the reference site, 577 birds were counted in 12 censuses, with a mean of 48.1 per census. Eighteen censuses of the James River Berm produced 553 birds, with a mean of 30.7 birds per census.

263. Bird density varied seasonally, according to food availability and migration patterns (Tables 41 through 43). At the experimental site, birds per hectare ranged from a low of 7.53 in the early summer of 1976, to a high of 69.62 in the early spring of 1977. This high value resulted from large numbers of ring-billed gulls resting on the mud flat at low tide. Fall densities were also high at the island, with Canada geese (Branta canadensis) and red-winged blackbirds (Agelaius phoenicius) dominant. The decline in density in early summer, followed by an increase in late summer, was a trend which was also observed in the second year of censusing (Figure 41).

264. At the reference marsh, densities were lower, determined almost entirely by the numbers of seed-eating fringillids and red-winged blackbirds. Values were highest in winter (mean 36.17 birds per hectare) and lowest in late spring and early summer (7.08 and 5.20 respectively), when seed availability was low and spring migration had subsided.

265. At the James River Berm, avian density was also highest in winter (not including the unusual counts of common grackles (Quiscalus quiscula) and red-winged blackbirds on 30 August 1977), with a mean of 26.77 birds per hectare. Again, the seed-eaters, in this case white-throated sparrows and cardinals, were in abundance. The lows for this study area were in the early summer of 1976 and in the late summer for both years (again disregarding the outstanding blackbird and

grackle count). The wooded berm, unlike the other sites, is essentially unaffected by the local presence of migrant shorebirds and swallows, and by the influx of red-winged blackbirds, which boosted late summer densities in other areas.

Community structure parameters

266. The number of species at the experimental site averaged 14.6 per census for the entire study, and peaked during migration in late spring 1977, with a mean of 19.4 species per census (Table 44). The lowest numbers of species were recorded in the early summer of 1977, with a mean of 10.8 species per census. The number of breeding species was low, although some species which bred in the general area obviously used the island for foraging or loafing. The number of winter resident species per hectare was quite high, compared with values for other types of habitats in the Virginia-Maryland area (Table 45).

267. Shannon diversity was also highest in the late spring of 1977 at the experimental site, averaging 3.54 bits/individual (Figure 42), as were evenness (0.84) and species richness (3.83). Lows for H' and evenness were in fall 1976, when large flocks of red-winged blackbirds and Canada geese were present on the island.

268. At the reference site, evenness values were comparable, but species richness and H' were generally lower (Table 46). Diversity was highest in winter and early spring, with mean H' of 2.08 and 2.12 respectively, and lowest in late summer. Low diversity at this site resulted from consistently low numbers of species per census, averaging 6.4 for the study.

269. The James River Berm was also characterized by low numbers of species but evenness was almost always high (overall mean, 0.84). Most species were represented by one individual for a given census, which is typical in woodland habitats. H' was highest in early summer (3.46 bits/individual) and lowest (excluding blackbird and grackle counts on 30 August 1977) in early spring when 2 fringillid species comprised 83 per cent of birds censused on that date, thus lowering evenness (Table 47).

Foraging patterns

270. The most important food items for bird species at the experimental site were fish, ground seed, and tidal invertebrates (Table 48), although 12 feeding categories were recognized and included in calculation of foraging diversity: 1) warm prey and carrion, 2) plant and animal, 3) fish, 4) tidal invertebrates, 5) air insects, 6) foliage insects, 7) bole and twig insects, 8) ground insects, 9) leaves, roots, aquatic seed, 10) tree seed, 11) ground seed, and 12) nectar (Table 49).

271. Piscivores, mostly gulls, terns and herons, were almost always present on the island in substantial numbers, averaging 107.6 individuals per census for the 37 censuses. While the gulls and terns were rarely observed feeding, they certainly benefited from the expansive mud flats for resting. The herons were seen fishing both in the interior marsh (at high tide) and on the perimeter. Belted kingfishers (Megaceryle alcyon) and common mergansers (Mergus merganser) also fished in the interior channel. Numbers of piscivore species remained fairly constant seasonally but abundance was low in the fall (Figure 43).

272. Shorebirds feeding on tidal invertebrates fluctuated seasonally in abundance and numbers of species, with migration peaks in the spring of 1977 and late summer of both years. Numbers of shorebirds were always greatest during low tides, with pectoral sandpipers (Calidris melanotus) and common snipes (Capella gallinago) concentrated in the interior marsh, and killdeer (Charadrius vociferus), and western and semipalmated sandpipers (Calidris mauri and C. pusillus) on the exterior beaches and mudflat. The snipes and pectoral sandpipers favored the softer substrate in the interior, as both species feed by deep probing. Numbers of shorebirds never exceeded 100 for one census and averaged only 28.0 per census. However, they formed a diverse group, averaging 21.1% of total species per census. Since most of these species breed and winter to the far north and south respectively, abundance was lowest during these

seasons.

273. Ground-seed eaters included red-winged blackbirds, fringillids, and doves. Again, relative abundance of species did not vary widely by season, except for a slight peak in fall. On the other hand, numerical abundance did show temporal correlation associated with seed availability, with greatest numbers in fall and winter, and lowest in early spring.

274. Waterfowl, eating leaves, roots and aquatic seeds, were also an important group at the island. The most abundant species in that assemblage was the Canada goose, which was largely responsible for an overall mean of 43.6 individuals per census--15.6 higher than the mean for the shorebirds. However, numbers of waterfowl species were usually low, ranging from 1-4 per census, whereas the shorebirds ranged from 1-9 species per census.

275. Of the remaining foraging categories, aerial and ground insectivores (swallows and wrens respectively) were seasonally important; and the other groups were represented by single or few observations for a given census.

Foraging diversity

276. Foraging diversity (Table 50) for species at the experimental site peaked in fall (2.48) when species were fairly evenly distributed among an average of 6.6 feeding categories per census. For individuals, foraging diversity (FD) was highest in late spring of 1977 (Figure 44), corresponding to a similar peak in H' diversity. At this time, no foraging group was significantly dominant, and the standard deviation between seasonal abundance means for the 3 major groups was only 5.6 individuals, compared with 30.8 between means for the 37 censuses.

277. At the reference site, FD was lower for both species and individuals, with the highest value in early summer 1977 at 2.25, when on 24 June, 6 species were counted from 5 feeding groups. The lowest values for foraging diversity were in fall and winter when seed-eaters dominated both species and individuals. FD was also low for

individuals in late summer as a result of red-winged blackbird and swallow abundances.

278. The James River Berm was comparable to the experimental site in grand mean foraging diversity, but both species and individuals were most diverse with respect to feeding in early summer 1976 (2.52 and 2.45 respectively). Lows were also in early summer of the next year, but these values for both years are based on 1 census only and are probably not good indicators of seasonality. Of diversities obtained from more than one census, the mean for late spring 1977 was highest (2.48), as was true for the experimental site. Foraging diversity for individuals was highest at this site, as individuals were most evenly distributed among species and feeding groups.

Nesting

279. The red-winged blackbird and the mallard (*Anas platyrynchos*) were the only species at the experimental site for which breeding was established. However, killdeer exhibited feigning behavior in 1976, and the long-billed marsh wren (*Cistothorus palustris*) constructed a nest in broad-leaved cattails (*Typha latifolia*) in 1977 but did not lay eggs. The song sparrow (*Melospiza melodia*) may have nested in both years, as at least 2 singing males were present throughout the spring and early summer. Nests of this species were not found.

280. The red-winged blackbird, the most common nesting species in tidal marshes of the Chesapeake Bay (Meanley and Webb 1963), nested at the site in both years. However, in 1976, only 4 nests were found, in either beggar's ticks (*Bidens laevis*) or cattail (*Typha* spp.). In 1977, 34 nests were found, concentrated mostly in willows (*Salix nigra*) and alders (*Alnus serrulata*) in the northeast corner. Other plant species were used to a lesser extent (Figure 45). Much of the beggar's ticks were damaged by heavy winds in July 1977, which may account for the fact that only one nest was found in that vegetation. Otherwise, it is likely that the red-wings would have renested in *Bidens*, as the breeding season for the species typically lasts from late April through mid-August.

281. Red-winged blackbird nest density was high at the experimental site, with 310 per hectare in the willow-alder zone (Table 51). Red-wing nest density for the whole census area was also high, at 5.15 nests per hectare, compared with 3.25 per hectare at the High Island, Texas disposal site (Contract Report D-77-2, 1977).

282. Nesting success for this abundant species was obviously low (Figure 39), although it was difficult to follow the nests from construction through fledging of young. Only 11 per cent of the nests observed produced fledglings, compared with 46 per cent success for a tidal fresh water marsh on the Pautuxent River in Maryland (Meanley and Webb 1963). At the High Island Site, success was lower; only 1 of the 41 nests hatched. The investigators cited heavy parasitism by brown-headed cowbirds (Molothrus ater) as the major factor in nest failure. No cowbirds were seen at the experimental site, leaving egg-eaters, such as fish crows and grackles, as likely predators. Egg shell remains were found in many of the unsuccessful nests. Rice rats (Oryzomys palustris) may also have been responsible for destruction of eggs and nests.

283. Mallards also nested at the experimental site. A nest was found on 18 May 1977 in a low intertidal site at the southwest corner of the island. Although the nest and 9 eggs were frequently inundated at high tide, the hen sat on the nest for about 50 days (normal incubation period is 27-28 days), by which time the nest was collapsing and the eggs were putrefied. During that time a second hen produced a brood of at least 10 from an unseen nest. We later observed 7 juveniles in flight at the island, probably from the same brood.

284. At the reference site, red-winged blackbirds nested more successfully (Figure 40). All nests were in buttonbush (Cephalanthus occidentalis), and nest density was lower than in the willows and alders at the experimental site. The eastern kingbird (Tyrannus tyrannus), indigo bunting (Passerina cyanea), and orchard oriole (Icterus spurius) may have nested within a hectare of the site, as territorial males were observed.

285. A white-eyed vireo's nest with 4 young was the only evidence of breeding at the James River Berm. It was in a sweetshrub (Lindera benzoin) limb fork about 1 meter off the ground and overhanging the Peltandra marsh border.

Comparison between sites

286. The census areas were quite different in vegetation and topography, resulting in low similarities between avifauna of the 3 sites, as measured by Dice's similarity coefficient (Pielou 1975). The lowest overall similarity between 2 sites was between the experimental site and the James River Berm (0.22), followed by the experimental and the reference site (0.38), and 0.45 between the reference site and the James River Berm (Table 52).

287. Resemblance between the experimental site and reference site was greatest in early spring 1977 (0.37) and winter (0.31). Six species were shared in winter and 9 in early spring (Table 53). Late spring similarity was very low, with only the red-winged blackbird in common.

288. Foraging similarity was also calculated for the experimental and reference sites (Table 54). Again resemblance was greatest in the early spring, when species from 5 out of 9 foraging categories were shared. It was lowest in late summer, when only 4 of a total of 11 groups were shared.

Other wildlife

289. Unidentified insect larvae were fed to young red-winged blackbirds in 1976 and 1977. Other insects were also present at the experimental site, notably several butterfly species: monarch (Danaus plexippus), American copper (Lycaena phleas), imported cabbage worm (Pieris rapae), and several swallowtails (Papilio spp.) were most abundant. Swarming midges (Chironomidae) attracted swallows in both years. Although a near plague of grasshoppers (Locustidae) occurred at the reference marsh in 1977, few were seen at the experimental site. Tiger beetles (Cicindela sp.) were observed at the island in 1976 but not in 1977. Two nests of a wasp (Polistes fuscatus) were found in

black willows in 1977.

290. Amphibians were also observed at the experimental site. Small toads (Bufo woodhousei) were seen on several occasions and at least 2 distinct amphibian calls were heard in spring 1977. A bullfrog's (Rana catesbeana) egg mass and a dead adult were found at the reference site in 1977.

291. Reptiles seen were a red-bellied turtle (Chrysemus rubriventris) at the experimental site, and a 1.5 meter black rat snake (Elaphe obsoleta obsoleta) at the James River Berm.

292. Muskrats dominated wildlife, other than avifauna, at the experimental site. The remains of 3 young were found in the severe winter of 1976-77, probably left by an avian predator. Two more were found dead later in 1977. In the absence of trapping, predation could occur only in winter when marsh hawks hunted over the island.

293. Muskrat lodges were found in the fall of 1976, and continued to increase in number throughout the study, totalling 11 (Figure 38). In addition to lodges, numerous runs and cleared feeding pads indicated a substantial population. Damage to willows at the up-river end of the island was considerable, as bark was stripped from the lower third of almost every tree.

294. By contrast, only 1 muskrat dwelling was found at the reference site. Beavers (Castor canadensis) were present, as was evidenced by extensive girdling of ash trees.

295. Most perplexing was the discovery in the spring of 1977 of rice rats on the island. As 9 were trapped in one evening, it is likely that they had been present for some time. Furthermore, rodent scat was found in several red-winged blackbird nests, and on one occasion a small mammal was observed exiting a nest which had previously held 2 eggs. It is probable, therefore, that rice rats contributed to nest failure of the red-winged blackbird and possibly the long-billed marsh wren at the experimental site.

Discussion

296. The avifauna at the experimental site is characterized by marked seasonal fluctuation in species composition and population density, associated with local nomadism, as well as long range seasonal migration. For species which are permanent residents in the area, seasonal movement is associated with requirements for food or nesting.

297. Of the 85 species observed at the island, 30 are year-round local residents; whereas only 6 species were seen in all seasons at the site. Of the 36 species observed at the experimental site which breed locally, only the mallard, killdeer, red-winged blackbird, and possibly the song sparrow, nested at the experimental site. Two more species, the bald eagle (Haliaeetus leucocephalus) and the osprey (Pandion haliaetus), would breed in the area if certain pesticides allowed reproduction. Furthermore, at the present successional stage of the island, birds which might nest there would not include more than 10 species, although taller trees could allow some woodland species to nest.

298. Densities of fringillids and gregarious red-winged blackbirds responded to high seed availability in late summer and fall, but were limited by the 0.10 ha of suitable nesting habitat in the breeding season. High densities of ring-billed gulls, on the other hand, were related to flocking preceding departure for breeding grounds in the northern United States and Canada. Along both the Pacific and Atlantic coasts, large areas of mud flats and beach serve as courtship "arenas" for the species, and mating usually occurs prior to arrival at the breeding site (Bent 1947). Laughing gulls replaced ring-billed gulls in the summer months.

299. Avifaunal diversity also varied seasonally. Dense aggregations of dominant species such as red-winged blackbirds, Canada geese, and ring-billed gulls resulted in low diversities. In the absence of such overwhelming dominants, shorebirds of 12 species contributed to high diversities during the spring migration of 1977.

300. Of the intertidal habitats available at the island, including the interior marsh, beach perimeter and the mud flat, the latter supported the largest number of shorebird species. The mud flat would have a greater variety of micro-habitats for foraging than would the diked perimeter, which is mostly coarse sand and gravel (see Part II). Few of these species obtain food by deep probing, thus the soft substrate in the interior marsh did not attract many species, although snipes and pectoral sandpipers were there in large numbers.

301. With respect to shorebirds, the study supported the finding by Burger et al. 1977, that species composition and abundance are associated with tide level, rather than diel time. Although inundation data are not yet available, greatest numbers of shorebirds were seen when a large position of the mud flat was exposed, and few, or no, species remained in the high intertidal zones when the flat was covered.

302. A major factor in the dissimilarity between study areas is the presence of mud flats at the experimental site, whereas suitable intertidal habitat is scarce at the reference marsh and James River Berm. Thus gulls and migrant shorebirds were rarely observed there, which lowered similarity by quantitative as well as qualitative differences in species composition. Other factors affecting resemblance include size of study area, height above tide levels, vegetation, and disparities in census effort between sites.

303. Red-winged blackbird nest success at the island was low, and was apparently affected severely by the presence of rice rats on the island, either from predation on eggs or chicks, or by occupation of nest. Fish crows are documented egg-eaters, and may also have affected nest success.

304. In addition to rice rats, other wildlife has colonized the disposal site. If the muskrat population continues to increase, damage to substrate stabilizing vegetation may be severe. It is recommended that composition of the rodent population be further enumerated and monitored.

Summary

305. Of the 3 sites censused, the experimental site supported the greatest number of species. Large numbers of gulls and terns were attracted to the mud flat. Migrating ring-billed gulls were replaced by post-breeding laughing gulls in summer. Most interesting were the 24 species of shorebirds and rails encountered. Only 1 of that assemblage, the common snipe, was seen at the reference marsh.

306. Four species comprised two-thirds of all the individuals at the island: the ring-billed gull, red-winged blackbird, laughing gull, and Canada goose. The dense flocking of these species is related both to local seasonal movements and to spring and fall migration. While such large numbers lowered diversity, numbers of species remained high through most of the study.

307. Breeding species were few, in spite of the fact that many species known to nest in the area were seen at the experimental site. Predation by fish crows or rice rats may be the factors limiting nest success of at least 1 species, the red-winged blackbird, but further investigations during the breeding season are needed. Mallards nesting on the island reared 1 successful brood.

308. In summary, the Windmill Point experimental site is a habitat unique to the area, by virtue of its large tidal flats and basin, sand beach perimeter and openness relative to surrounding woodland communities bordering the upper tidal James River. It functions as an avian motel, drawing migrants from many groups, especially those associated with intertidal environments. Nevertheless, unless successional stages leading to arboreal growth follow, the experimental site seems unlikely to persist for more than a decade. Hopefully, future islands constructed from dredged material will be designed for reasonable longevity to serve as refuges for migrating avifauna and other wildlife.

PART VI: SOILS ANALYSIS

R. Wetzel and S. Powers

Introduction

309. Soils studies at the Presquile National Wildlife Refuge, the Windmill Point habitat development site, and Ducking Stool Marsh, on the James River, Virginia, were conducted in the autumn of 1976 to supplement concurrent studies of the natural vascular plant flora of these tidal freshwater marshes (see Part IV: Botanical Studies). The overall objective of this study was to provide quantitative soils data for the various plant sampling zones. These soils data include analyses for various physical, chemical, and biological parameters in an effort to further our knowledge of artificial marsh habitat development using dredged material.

310. Three independent field sampling programs were carried out during the period October 1976 to June 1977. The first program for soils sampling from the three marsh systems in October 1976 was for heavy metal and organochlorine soils analyses. The results of these analyses are the subject of another technical report to WES. The second field sampling program in November 1976 was for soils sampling specifically at the experimental site, Windmill Point (WP), and the reference site, Ducking Stool Marsh (DS). The results of the various soils analyses for the second field sampling program are presented in this report. A third field sampling program was carried out in June 1977, and some of the analyses not obtained during the second effort are reported.

Materials and Methods

Field sampling

311. Soil sampling stations at the experimental and reference

marshes were chosen to correspond to various vegetation zones in 1976. Nine areas were sampled at Windmill Point and two at Ducking Stool. Because of changes in plant sampling design between 1976 and 1977 growing seasons (see Part IV: Botanical Studies), the soil sampling stations are not paired by specific location but are representative of general soil conditions within the various vegetation zones. Ten replicate cores were taken randomly from each plant sampling zone at the experimental (WP) and reference (DS) sites during the second field program (November 1976) and processed for the various soil measures reported herein. Except for presentation of the field descriptions of the October sampling program, only the results of the November sampling program at the experimental and reference sites are given in this report. Table 55 gives a description of each of the sampling areas, and Figures 46 and 47 map the soil sampling areas for WP and DS respectively.

312. Soil sampling in each of the areas consisted of hand coring using acid-cleaned, acrylic 5- by 50-cm (ID by length) core tubes. The replicate core samples were described as to general physical characteristics (e.g. soil texture, lithology, odor, color, etc.) on sampling, capped with plastic air-tight closures, and stored on ice in a specially constructed core box for transport to the VIMS laboratory located at Gloucester Point, Virginia. The time interval from first coring to arrival at the laboratory was usually 6 to 8 hours. General sampling conditions for each field day were kept as part of the field record.

Sample processing

313. Core samples were returned to the laboratory and immediately processed for sample storage and analysis of soil pH, water content, and volatile and total solids. Processing consisted of extruding the core sample into a half section of a larger plastic coring tube and sectioning the core at 15- and 30-cm depths. For many of the hand-taken cores, 30-cm or greater core lengths were not obtained, especially for the interior areas of the experimental site.

For the replicate core samples, the top 15-cm and >15 -cm sections were used for compositing into top and bottom samples. The top (0 to 15-cm) and bottom (15<X<30-cm) sections of each core from a single sampling area were combined in a plastic bag and thoroughly mixed by hand, making a single composite soil sample for each coring area. The top and bottom sections were then divided into four composite subsamples according to the following scheme:

a. Subsample 1. Approximately 1000 g dry weight (DW) was placed in plastic bags and immediately frozen for the analyses reported herein.

b. Subsample 2. Approximately 500 g DW was placed in acid-washed, distilled-water-rinsed glass jars and air-dried at laboratory temperature (25 to 27°C). These samples were later capped and shelf-stored for WES.

c. Subsample 3. Approximately 500 g DW was placed in acid-washed distilled-water-rinsed glass jars and capped with parafilm-lined caps. The jars were completely filled to exclude air and stored refrigerated at 4°C for WES.

d. Subsample 4. Approximately equal weights of the top and bottom composite samples were mixed (combined weight of approximately 500 g DW) and stored in acid-washed, distilled-water-rinsed glass jars. The jars were capped with aluminum-foil-lined caps and stored frozen (-20°C) for WES.

Subsample 1 was used for the analyses reported herein. Subsamples 2-4 were for later analysis by contractual arrangement through WES.

Methods of analysis

314. The following soil parameters were measured for each of the experimental and reference composite soil samples and are grouped according to the analysis(es).

315. pH/Eh, water content, volatile solids, total solids and organic content. Eh measures were made in situ using a Pt-Ag/AgCl redox electrode couple and a digital microvolt-ohm meter following the methods of Schindler and Konich (1971). The electrode couple was standardized against a saturated di-chromate solution (Eh(mV) = 837 @ 18°C; pH = 2.0; rH = 33) and compared with a Pt-Hg/HgCl (Calomel) redox

couple (Effenberger 1967; Kaluch 1954). Meter readings were corrected by the addition of 200 mV to the recorded value (relative to the standard hydrogen electrode). Cores for in situ Eh measurement were specially constructed from 5- by 50-cm (ID by length) acrylic core tubes having 5-mm (3/16-in) holes alternately drilled at a 45° angle and spaced at 1 cm intervals over the length of the core. The holes were then sealed with silicon rubber cement forming a septum to allow insertion of the electrodes.

316. Triplicate soil pH determinations were made using a 1:1 (w/v) soil saturation with distilled water mixture immediately after compositing the core samples. Approximately 20 g (wet weight) was tared into 100-ml glass beakers, and 20 ml of distilled water was added. The soil was dispersed using a glass rod and stirred at approximately 5-minute intervals for 30 minutes. The soil suspensions were then allowed to stand for an additional hour and pH determined using a Fisher Model 12 pH/mV meter and combination pH probe (Fisher Scientific Company, Pittsburgh, Pennsylvania). Reported pH values are at ambient laboratory temperature (22°C). In situ measures for pH were planned, but lack of field compatible equipment necessitated the method chosen.

317. Water content, concentration of volatile and total solids, and organic matter content were determined in triplicate on 15- to 30-g wet weight (WW) subsamples of the composited samples. Subsamples were taken immediately after compositing the core samples and placed in precombusted (4 hours @ 550°C), tared aluminum weighing pans. For water content, the subsamples were dried in a forced draft oven at 100°C to a constant weight. Percent water content was calculated on a dry weight (DW) basis as

$$\%\ \text{moisture DW} = \frac{WW - DW}{DW} \times 100$$

318. Total solids and volatile solids, were determined for

each subsample by combusting the dried samples at 550°C for 4 hours, returning the ignited samples to the oven, and the ash or combusted sample weights (AW) determined the following day. Using the known dry weight (DW) and ash weights (AW), volatile solids (VS), and total solids (TS) and organic matter content (OM) were calculated as

$$\% \text{ VS} = \frac{\text{DW} - \text{AW}}{\text{DW}} \times 100$$

$$\% \text{ TS} = 100 - \% \text{ VS}$$

319. Salinity. Soil salinity was determined using the methods suggested by Black et al. (1965). Soil subsamples were dried at 60°C in a forced draft oven, sieved through a 2.0-mm standard screen to remove larger particles and debris, and approximately 20 g DW tared into 250-ml Erlenmeyer flasks. Distilled and deionized water (200 ml) was added to the flasks, and the soil samples were dispersed by shaking and allowed to stand, covered, overnight. The flask contents were then filtered through 0.22-μ membrane filters (Millipore Corp., Bedford, Massachusetts), and the conductivity of the filtrate was measured using a Beckman RS 7B Salinometer (Beckman Instruments, Inc., Irvine, California). Conductivity was converted to salinity using prepared standard solutions and soil salinity calculated and reported as g/100g DW of soil.

320. Particle size analysis. The particle size analyses for the composited soil samples were determined on oven-dried samples (60°C) by a combination wet-dry sieving and sedimentation analysis with pipette sampling (Black et al. 1965).

321. Organic carbon. Organic carbon was determined as the readily oxidizable fraction using the Walkley-Black method (Black et al. 1965). Total organic carbon is only estimated, perhaps grossly, by this analytical method for water logged marsh soils. Cross comparisons of sampling areas, particularly those that differ in either plant

associations or general physical characteristics, should therefore be made with caution and knowledge of this introduced and unknown analytical bias. The method was standardized using glucose and reported as percent organic carbon (dry weight basis).

322. Nitrogen. The following forms of nitrogen were determined for the soil samples: Kjeldahl N (TKN); nitrate N (NO_3^-); nitrite N (NO_2^-) and ammonia N (NH_4^+-N). Generally, the methods outlined by Black et al. (1965) were followed. Total Kjeldahl nitrogen (organic N + NH_4^+) was determined using standard methods as reported in Black et al. (1965) for macrodeterminations. NH_4^+, NO_3^-, and NO_2^-- nitrogen species were determined by soil extraction using 2 N KCl with continuous shaking for 1 hour using a wrist action shaker. Extractant volume to soil weight (DW) ratios ranged from 2.5 to 3.0 for sandy soils and 5 to 10 for fine-grained, silty soils. The extracted samples were gravity filtered using Whatman No. 40 paper into 100-ml acid-washed flasks and the soil washed with 2- by 10-ml aliquots of 2 N KCl. Final volume was adjusted to 50 ml using 2 N KCl.

323. Concentrations of the three nitrogen species in the KCl filtrates were determined using colorimetric methods. NH_4^+ was determined using phenol-hypochlorite as described by Solorzano (1969). After reduction to nitrite using a copper-cadmium column, nitrate and nitrite were determined by a diazotization reaction (Strickland and Parsons, 1968). Six randomly chosen subsamples were analyzed for nitrite, and for all trials nitrite was below detection. No further nitrite determinations were made. All samples were read using a Spectronic 20 (Beckman Instruments, Inc., Irvine, California) with a 10-mm light path. Standards for sample calculation and column calibration were made up in 2 N KCl. NH_4Cl, KNO_3, and $NaNO_2$ were used for standardization.

324. Phosphorus. Soil phosphorus was determined as extractable phosphorus using oxalate (Owens et al. 1977). Oven-dried samples (approximately 1 g DW) were placed in acid-washed flasks and 20 ml of the oxalate extracting solution added. The samples were extracted for

2 hours with continuous agitation using a wrist action shaker and then gravity filtered using Whatman No. 40 paper into acid-washed flasks. The filtrates were adjusted to volume and PO_4^{-3} determined colorimetrically using the single reagent method of Murphy and Riley (1962). Standards were run following the same procedure using KH_2PO_4 instead of soil.

325. Potassium. Potassium was determined by acetate extraction following the procedures of Black et al. (1965). The extraction procedure coincides with the methods of Toth and Ott (1970) for the determination of cation exchange status (CES) using 1N neutral ammonium acetate solution. Following extraction and collection of the acetate leachates as suggested by Toth and Ott (1970), the filtrates were analyzed for potassium by flame atomic absorption.

326. Sulfides. Attempts were made to analyze for total, acid volatile sulfides in the soil samples. A methodology was devised following the work of Goldhaber (1974). Approximately 20 g DW of soil was weighed into tared, 125-ml flasks. The samples were covered with 50 ml distilled water (pH 8.0), stoppered, and attached to the N_2 purging system on a wrist action shaker. The flasks were purged for 5 minutes with N_2 to remove gaseous sulfur contamination. Each flask was attached to a sulfide trap consisting of 10 ml of 0.5 M $AgNO_3$. Following purging of the system, 10 ml of 6.0 N H_2SO_4 was injected into the sample flasks to volatilize the sulfides, and purging, with sample agitation, was continued for 30 minutes. The silver sulfide precipitate was collected following the acid treatment by vacuum filtration onto tared, membrane filters. Acid volatile sulfides were calculated using dry weights of the filtered precipitates.

327. Cation exchange capacity and CES (exchangeable bases). Cation exchange capacity (CEC) and CES were determined as discussed in Black et al. (1965), and with slight modification, the methods of Toth and Ott (1970) were followed. For the data presented in this report, approximately 10 to 15 g (WW) of freshly thawed soil sample was weighed into 50-ml, acid-washed Erlenmeyer flasks and covered immediately with

20 ml 1N neutral NH_4OAc. The flasks were placed on a wrist action shaker and agitated for 16 hours. Experiments conducted prior to experimental and reference sites soils analyses indicated that the extremely short (30-minute) equilibration time suggested by Toth and Ott (1970) was inadequate for soil samples collected from the marsh interior at the experimental site and stations at the reference site. This is probably related to the high organic content and silty nature of these marsh samples. Resolution of equilibration time with mild agitation was done using time series experiments on replicated soil samples. Equilibration times of 1, 2, 6, 12, and 24 hours were chosen for the experiment and the results presented below:

Equilibration Time (hr.)	Blank* (meq NH^4)	Experimental (meq/100 g DW)	$\bar{X}$ (meq/100 g DW)	Range	Coefficient of Variation (%)
1	0.437	44.40	56.36	23.92	30.0
		68.32			
2	0.790	54.52	60.94	12.81	14.9
		67.35			
6	0.518	62.60	59.43	6.34	7.5
		56.26			
12	0.378	55.36	59.97	9.22	10.8
		64.58			
24	0.278	54.58	55.09	2.88	3.5
		55.60			

* Mean of two determinations

The samples for the experiment were taken from the Ducking Stool-Pickerel Weed plant sampling site and represent a soil of high organic matter content, nutrients, and exchange capacity relative to the other sampling areas. The results of the experiment suggest that equilibration times should be longer than proposed by Toth and Ott (1978) for marsh soils; the authors chose 16 hours for the current work as a compromise in terms of sample processing (i.e., morning preparations, afternoon equilibration, and sample analysis the following morning) and efficiency of operation. Following a more thorough study resolving equilibration times for various soil and sediment types, the authors feel that the chosen time can be significantly reduced. Sample size to volume ratios for the various leachates and sample washings were exactly as reported by Toth and Ott (1970). Centrifugation was substituted for the suggested filtration step for collecting the various leachates as a means of reducing contamination for the NH_4^+ determination and to reduce sample processing time especially with the silty marsh soils.

328. For the CEC determination, NH_4^+ (the exchanged cation) in the 10% NaCl leachates was determined by the colorimetric method of Solorzano (1969). NH_4^+Cl standards in 10% NaCl were used for standardization.

329. ECS was determined by the procedures given in Toth and Ott (1970). Because of apparent Fe contamination in the CEC determinations, ECS was run on a separate set of soil subsamples. The exchangeable cations Fe, Mn, Zn, Cu, Ni, Na, K, Ca, and Mg were determined by flame atomic absorption.

330. The above methods were used for analysis of the November 1976 sampling program. Because of harsh field conditions during the period of sample collection, field Eh measures were not obtained, and, for some sampling stations, less than 100 g of material was available for all the analyses of soil >15 cm in depth due to poor core penetration and sample retention, expecially for bottom samples from stations 2, 7, and 8 (interior stations at the experimental site). As a result, the analyses of bottom samples 2, 7, and 8 are incomplete for ECS and some nitrogen species. For all analyses, the composite core samples were kept frozen (-20°C) until analysis.

331. A third field sampling program was carried out (June 1977) employing the same methods as before and in situ analyses reported for pH and Eh profiles and nutrient analyses for specific samples that are not

reported for November. Other analyses for this sampling program will be completed as time permits. All sample handling and analytical techniques were as discussed.

Results and Discussion

332. Tables 55 and 56 give field descriptions and general characteristics of the soil sampling stations for the October and November 1976 sampling programs, respectively. The stations were chosen to coincide with the 1976 vascular plant sampling areas. The areas were heterogeneous in terms of both biological (plant) characteristics, origin of substrate (dredged material, dike construction, and mixtures), physical influences (exposure and tidal inundation), and, as reported here, the soil parameters investigated for this study. Soil textural classes ranged from sand to silty clays.

333. Stations WP3, 4, and 9 at the experimental site were sand soils and dominated by mixed grasses and small trees (willow). WP1 was a sandy loam soil and also vegetationally dominated by mixed grasses (Panicum sp.). WP1 was probably a mixed soil of both dredged material and dike origin. WP3, 4, and 9 soils were of dike construction origin. No comparable sites existed at the reference site marsh. These stations represented the highest elevations at the experimental marsh (range: + 4.4 to + 6.5 feet above mean low water). Table 57 summarizes soil particle size data.

334. Stations WP5 and WP6 were interior dike sampling areas and dominated by the Typha-Bidens plant association and are classed as silty loam and sandy clay loams respectively. The vegetation zone formed a more or less continuous border around the island interior between the regularly flooded lower marsh elevations dominated by the Sagittaria-Pontederia association and the dike itself. The soil was of dredge material origin and contained a higher percentage silt-clay fraction than the dike areas. The two stations differed, however, in particulate size fractionation in the top 15 cm with WP5, located along

the southern dike and farther from the direct influence of the discharge or spillway used during island construction, having a higher silt-clay fraction (76.81%) than WP6, located along the northern dike and nearer the original spillway, having a silt-clay fraction of 38.62% (see Table 57). It is suspected from field observations that some mixing of dike construction and dredged materials took place in these areas due to either aeolian or water transport. WP5 in particular showed a significantly higher gravel content (53.88%) in the >15 cm soil sample and indicated the extreme heterogeneity of the soil substrate and possible intrusion of diked material below the surface layers in this vegetation zone.

335. Stations WP2 and WP7, and WP8 were all interior marsh stations and characterize the lower intertidal, vegetated and non-vegetated areas respectively. WP2 and WP7 were dominated by the Sagittaria-Pontederia plant association with a silty loam soil. WP8 was a non-vegetated, lower intertidal soil sampling site near the breach in the southern dike and was a loam soil.

336. The soils of these areas were predominately silt-clays (67 to 84%) in the top 15 cm with silt-sized materials being the major fraction. The vegetated sites were similar in nearly all respects. WP8 was similar for most measures except a somewhat lower silt content than the other stations (see Table 57). There was also evidence of dike materials being transported into this area (WP8); however, the areas of mixing were obvious and were avoided during sampling for the present study.

337. Two areas at the reference site were selected as references for the Sagittaria-Pontederia and Typha-Bidens study sites at Windmill Point. The Ducking Stool Peltandra-Pontederia site (DSPW) had a silty clay soil. The Ducking Stool Typha-Bidens area (DSTy) was also a silty clay soil but contained a higher sand fraction than DSPW and was higher in elevation. Direct comparison of DSTy with WP4 and WP5 soils was not possible due to the extreme heterogeneity of the WP sites.

338. Physical analyses, other than particle size for the soils, are presented in Table 58. Soil pH was near neutral for all stations

except WP9 which was more acidic. No explanation can be offered for this difference. Soil salinity was variable and low, generally reflecting river salinities reported for the James River in the region of the experimental site. Percent moisture, volatile solids, and organic carbon generally correlate directly with the % silt-clay fraction; i.e., increases in % silt-clay fraction generally correspond to increase in % moisture, volatiles, and organic carbon (Figure 48). No apparent correlation was evident between soil pH (in water) and these parameters.

339. Correlation between % volatiles, as a measure of organic matter content, and soil organic carbon was not as good as one might expect. These data are presented in Figure 49 with the 0.4, 0.5, and 0.6 isopleths for % organic carbon: % volatiles ratios drawn. Data points falling above the 0.4 to 0.6 envelope would indicate the organic carbon method used underestimated total organic carbon. Points below the envelope generally indicate contamination and more than likely weighing errors associated with the % volatiles determination. It is clear in the figure that many of these data fall above the envelope, particularly the >15-cm soil samples (solid circles). Because the Walkley-Black technique measures only the easily oxidizable organic matter fraction, this result was anticipated. The more refractory organic matter constituents would be expected in the lower soil layers. These refractile components may, however, contribute significantly to such other soil measures as CEC and extractable nutrients.

340. Total organic nitrogen, measured as Kjeldahl nitrogen (TON + NH_4^+), the extractable inorganic nitrogen species NO_3^-, and NH_4^+, phosphorus and potassium soil concentrations are presented in Table 59. As mentioned, nitrite was below detectable limits. Organic nitrogen accounts for greater than 90% of total soil nitrogen at all stations followed by NH_4^+ and NO_3^-. Phosphorus and potassium followed the same general trends as nitrogen with the sand soils low (WP3, 4, and 9), sandy loam soils intermediate (WP1 and 6), and the silty loam soils and silty clays progressively higher (WP2, 5, 7, 8, and the reference marsh sites). These nutrient data follow the same general trend established by the

particle size analyses and the physical parameters reported before.

341. Since the study did not include seasonal soils data or above-below ground plant tissue analyses for C, N, P, and K, no detailed comparison for plant-nutrient relationships are possible. It appears that comparable plant sampling areas at the experimental and reference sites were similar although soil nitrogen tended to be lower and extractable phosphorus higher for the interior marsh stations at the experimental site. No statistical degree of confidence can be ascribed to the measured differences, however. These stations (WP2, 5, 6, and 7) also were lower in both % volatiles and organic carbon, indicating that the soil system was still developing at the experimental site.

342. CEC and CES determinations are presented in Table 60. The values fall in the higher range reported by Toth and Ott (1970) for various bay and riverine sediments. The reference marsh soils exhibited the highest reported values (DSPW and DSTy surface samples). The trends were similar to those previously discussed and follow the soil textural classes with sand soils, low progressing to the highest values associated with the silty clay soils of the reference marsh. The sand soils appear high relative to the other classes. No causal explanation can be offered other than re-emphasizing that even within this soil class there was extreme heterogeneity among samples. The CEC values correlate closely with the silt-clay soil fraction and organic matter soil content (% volatiles). Figure 50 illustrates the simple linear correlation and suggests that 70 to 80% of soil CEC can be attributed to organic matter (presumably the major part of the silt-clay fraction). Toth and Ott (1970) report that 80% of CEC for bay and riverine sediment is due to the organic matter content. It is interesting to note, however, that other factors must also be included for a complete understanding. DSTy soil samples did not fall within the bounds projected by the regression analyses. These soils are marked with an asterisk (Figure 50B) and were not included in the data set for regression calculation. It is speculated that soil pH, minerology, and the chemical nature of the organic matter contributes to the unexplained variation.

343. Exchangeable bases or CES (Toth and Ott 1970) of the soils were highly variable. No consistent pattern in terms of absolute quantity of exchangeable cation (by species) was apparent. All values appear low, particularly Fe and Mn. We have not been able to account for this. The exchangeable H as presented in the Table is therefore probably in error since it was based on the difference between CEC and the sum of exchangeable cations. An alternative explanation is that the sample handling procedure oxidized the soils sufficiently to reduce the metals to trace levels. A general pattern, however, was consistent for all samples with Ca, Na, and Mg being the predominate exchangeable cation and K, Fe, and Mn lower and for some soils below detectable limits. The qualitative exchange status of each cation is presented in Table 61. Only the top (0- to 15-cm) samples are included since four bottom samples stations lacked enough material for determination.

344. Exchangeable Zn, Cu, and Ni determinations are presented in Table 62. These data, as well as the values for Fe given in the previous table, are suspect. Perhac (1974) claims that NH_4OAc is not effective in removing (leaching) metals from sediment. During analysis, a 5- to 10-fold variation was often encountered in replicate soil samples. Even on samples with good replication, the concentrations were at or very near detection limits. It can only be concluded that either exchangeable Zn, Cu, and Ni were present at very low concentrations at the soil sampling stations or the finding of Perhac (1974) that the methodology suggested for these analyses is inappropriate must be supported.

345. Table 63 presents the field data obtained from the third soil sampling program. These data suggest that the soils were in general not highly reduced which may in part explain the low exchangeable Fe and Mn values as these would be present in the oxidized state and not measured as part of CES. WP3 was the only station that indicated significant reduction potential at depth. These data agree with the general findings of Adams and Darby (1976).

Summary

346. The soils studies carried out during the present investigation were designed to complement concurrent studies of the vascular plant flora of the experimental and reference marshes. Few comparative data exist in the literature for the agronomic measures reported here for waterlogged, tidal-freshwater marsh soils and the associated vascular plant flora that make up the major marsh areas; i.e., Sagittaria-Pontederia-Peltandra associations. The experimental design followed does not lend itself to the identification and explanation of causal plant-soil relationships. The comparisons are descriptive of general soil conditions within various vegetational zones for one point in time. The results do suggest areas where more detailed study would be fruitful for the purposes of the Dredged Material Research Program at WES. This summary is therefore restricted to comparisons between the various zones and suggest possible explanations for the observed plant community characteristics and soil parameters. The following conclusions are drawn from the data reported.

347. The soil measures reported demonstrate the extreme spatial heterogeneity of soil characteristics at the experimental site. General groupings, based on soil textural classes would be the sand and sandy loam soils (WP1, 3, 4, and 9), the clay and silty loam soils (WP6, 2, 5, and 7), and the loam and silty clay soils (WP8, DSPW, and DSTy). These areas generally correspond to the dike, interior dike, and lower elevations of the marshes at Windmill Point and Ducking Stool respectively. These areas grade elevationally from the supratidal dike areas to the low intertidal areas having mean inundation periods of 30 to 40 percent. The zones differ in plant community structure probably as the result of both elevation and soil characteristics. As mentioned, WP1 demonstrated characteristics intermediate between the other dike areas and the Typha-Bidens zone. This in all likelihood reflects the mixed nature of the substrate. WP5 and WP6 were also dissimilar in many respects (i.e. particle size fractionation, organic matter content,

nutrients). This is probably due to original particle size fractionation and distribution occurring during island construction.

348. For nearly all measures, there was a significant and positive correlation between % silt-clay, % volatiles, and organic carbon. CEC relates significantly to these measures and supports the conclusions of Toth and Ott (1970) and Boyd (1970). These measures also followed the general elevation gradient relative to mean low water and soil texture classes.

349. The physical and chemical analyses of soils indicated that reference site soils were higher with regard to % volatiles, organic carbon, soil nitrogen, and CEC. In particular, differences in CEC and soil nitrogen between reference and experimental site soils may account for the observed significant difference in Pontederia plant height between these sites for the 1976 growing season. Differences in plant height and productivity due to different nutrient regimes have been reported for a variety of marsh ecosystems (e.g., Wetzel et al. 1977; Chalmers et al. 1976).

350. The data, particularly those soil measures generally related to plant growth and decomposition (e.g. organic matter content, available nutrients, and soil measures attributable to organic content such as CEC), suggest that the soil system at the experimental site is still developing.

351. Various methods were found inappropriate. Methods modified after the work of Goldhaber (1974) for sulfide analysis were not quantitative and generally displayed high variability. Repeated attempts to standardize the method were not successful considering the reported low levels of sulfides present (Adams and Darby 1976). Bremner and Bundy (1974) have reported and cite the influences of organo-sulfur compounds on soil nitrogen determinations and soil nitrification. It would seem appropriate that an adequate sulfur methodology be devised for future study particularly if such studies include nutrient dynamic aspects. A second method which indicated extreme variability was analysis of exchangeable metals (Fe, Mn, Zn, Cu, Ni) employing acetate for soils

extraction. Perhac (1974) has reported on the inadequacies of acetate leaching, and Harris (Personal Communication, Richard Harris, VIMS, Gloucester Point, Virginia) confirms his findings and general conclusions. Because the analysis methodologies are outside the authors' areas of experience, they can offer no suggestion. Comparison of exchangeable metals (by the methods suggested) and total soils metal analyses would suggest that if the acetate leaching methods are appropriate for determining exchangeable metal species, the soils metals at the experimental site are not readily available for plant incorporation.

PART VII: SUMMARY AND OVERVIEW

M. P. Lynch

352. The Windmill Point marsh-development project succeeded in constructing an island-marsh habitat that was attractive to plants and animals indigenous to the local region. Although the feasibility of constructing successful fresh water tidal marshes was demonstrated, not all the original goals were achieved.

353. With minor exceptions, the seeded or sprigged species did not last beyond the first growing season, and no effect of the alternate treatment of areas with fertilizer was apparent.

354. The western end of the island was severely eroded. By the end of the study, only a short section of the original dike remained to protect the interior marsh. Two breaches occurred before completion of the project. One of these was successfully plugged. The other breach, on the south side of the island, now functions as one of the main channels of tidal water exchange.

355. The use of a reference marsh and adjacent uplands for comparison with the experimental island marsh was only partially successful, principally because no marshes in the open exposed position of the experimental site could be located. Sufficient similarity was obtainable, however, to demonstrate success of the experimental marsh.

356. The principal difference between the experimental site and the reference site, other than exposure, was the significantly higher concentration of soil constituents at the reference site, such as % volatiles, organic carbon, soil nitrogen, and cation exchange capacity, which are related to accumulation and breakdown of plant detritus. Higher soil nitrogen at the reference site may have been the cause for the significantly higher height of the pickerelweed in this area in 1976.

357. Water quality, with the exception of a higher dissolved oxygen at the reference site, did not differ between the two areas.

358. Soil studies indicated extreme spatial heterogeneity of soil

characteristics at the experimental site. The dike, interior dike, and lower marsh elevations were sand and sandy loam soil, clay and silty loam soils, and loam and silty clay soils respectively. At the reference site, loam and silty clay soils were found.

359. For nearly all areas, there was a significant and positive correlation between % silt-clay, % volatiles, and organic carbon. These characteristics also followed a general elevation gradient that reflects the periods of inundation as did the soil types with higher values in the lower marsh loam and silty clays and lower values in the higher sand and sandy loam soils.

360. The soil measures generally related to plant growth and decomposition, such as organic constituents, indicate the soil system at the experimental site is still developing. Field observations at the experimental site also indicate there is mixing of dike material with marsh material which is influencing final soil characterizations.

361. With the exception of the higher nitrogen and cation exchange capacity previously mentioned that is thought to account for significantly higher pickerelweed at the reference site during the 1976 growing season, no causal soil-plant relationship was discernible from this study. Plant distribution and zonation appeared to be controlled more by physical environmental factors such as elevation and tidal inundation than differences in soil characteristics.

362. Floral inventories of the experimental site from 1974 through 1977 indicated that prior to dike construction, about 55 species were fairly distributed between marsh and supratidal habitats. After construction, by July 1975 this number was roughly doubled by natural invaders plus the six introduced species. Between July 1975 and September 1977, the number of invading species had decreased.

363. The botanical studies indicated that plants were grouped into four major zones: an arrowhead-pickerelweed zone occupying the low, broad interior of the island; a beggar tick zone at higher levels of the marsh; a panic grass zone, the remnants of the plantings of beachgrass and switch grass which ran in an interrupted band around the

island; and the only wooded area, a black willow zone consisting of black willow, cottonwood, and common alder on the eastern portion of the island. The remainder of the plant zones were heterogeneous mixtures of two or more species.

364. Maximum plant development at the experimental site appeared to take place in July and August as opposed to June for the reference site. No specific reason for this difference was identified.

365. Apparent successional changes in plant cover as detected from aerial photographs were actually stages of a normal seasonal cycle. Successional changes are occurring, as evidenced by changes in willow distribution at the northeast corner, but accurate assessments can be made only through long-term studies.

366. It appears that the arrowhead-pickerelweed and beggar tick zones are approaching climax or near-climax conditions in the experimental marsh areas. In the higher areas of the original island and the dike, the increasing growth of trees with changing shade conditions will continue to exhibit changing species distribution.

367. During 1977, insects dramatically reduced the vegetation of the reference site. Grasshoppers and Japanese beetles were also noted at the experimental site, but insect damage there was slight. The major plant damage inflicted by animals at the experimental site resulted from muskrat activity. Muskrats destroyed plants in many areas, whether for food or for lodge construction. Plants were destroyed by direct consumption of roots and/or shoots and by tunnels and runways dug by the animals. Several small areas were almost completely denuded, but during the year many were revegetated.

368. An effect of severe winds was observed. The effect on beggar ticks was very deleterious, since visual comparisons of plant heights between 1976 and 1977 revealed a sharp decrease in beggar ticks height, whereas arrowhead and pickerelweed were largely unaffected. Apparently, the flexibility of soft-stemmed plants such as arrowhead and pickerelweed contributed to their survival during the July 1977

windstorm, whereas the taller, rigid stems of such plants as beggar ticks and water hemp were broken.

369. Erosion greatly impacted the vegetation on the western end of the island. The planted panic grass on the dike, although apparently a good soil retainer, was undermined by wave action. Even woody plants such as willows were eventually uprooted.

370. The Windmill Point experimental site provides, by virtue of its openness relative to surrounding woodland communities, sand beach perimeter, large tidal flat, and basin, a combination of habitats unique to the upper tidal James River. The most obvious result of this combination of habitats is the large number of birds recorded at the experimental site compared to the reference site. The island-marsh appears to act as an avian motel drawing migrants from many groups, especially those associated with intertidal environments.

371. The greater number of birds at the experimental site was primarily due to gulls, terns, and wading birds that were attracted to the intertidal flat areas. Four species, the ring-necked gull, red-winged blackbird, laughing gull, and Canada goose, comprised two-thirds of all the individuals at the experimental site. At both the berm and marsh reference sites, the red-winged blackbird and seed eaters, either fringillids, sparrows, or cardinals, made up the greater part of the population.

372. Bird density at the experimental site was highest in early spring and fall and lowest in early summer. This was principally due to migrants, particularly gulls and geese.

373. Only the mallard, killdeer, red-winged blackbird, and possibly the song sparrow nested on the island. Breeding could only be confirmed for the mallard and red-winged blackbird. Predation by fish crows and rice rats are considered to have a major impact on nest success of red-winged blackbirds.

374. The most important food items for bird species at the experimental site were fish, ground seed, and tidal invertebrates. Waterfowl, eating leaves, roots, and aquatic seeds, were also an

important group at the island. Canada geese were the most important birds in this category and are considered responsible for elimination of some of the planted species.

375. Muskrats dominated the wildlife other than birds. By the end of the study, 11 muskrat lodges were located on the island. Numerous runs and cleared feeding pads indicated a substantial population. Considerable damage to willows was caused by the muskrats. The only other mammal noted was the rice rat.

376. Benthic organisms are key secondary producers in both marsh ecosystems and in the shallow water ecosystems that pre-existed at the experimental site before island-marsh construction. Initially, only macrobenthos was sampled, but after preliminary analysis of fish food habits, meiobenthos was examined.

377. Production estimates showed that in the reference marsh meiobenthos were nearly as important producers as macrobenthos, while macrobenthos production (principally by oligochaetes) was overwhelming in experimental marsh habitats. Although total production of benthos was much higher in experimental marsh habitats than in the reference marsh or on the open tidal flat, meiobenthos production was greater in reference marsh habitats.

378. Macrobenthos was qualitatively and quantitatively dominated by tubificial oligochaetes and larval chironomid insects. The bivalve, *Corbicula manilensis*, was also very abundant. Oligochaetes of the genus *Limnodrilus* were the numerical and biomass dominants in most of the habitats.

379. Total density and biomass were highest in the low marsh and subtidal channels of the experimnental site. Intermediate density and biomass were found in the higher marsh at both sites and in low marsh at the reference site. Lower values were found outside of the marshes on adjacent tidal flats and on subtidal bottoms used by the project. The differences were mainly due to differences in populations of oligochaetes.

380. The density and biomass of macrobenthos were highest in

summer and lowest in winter. Species diversity was higher at the reference site than the experimental site due to both a greater number of species and less dominance by a few species at reference site stations.

381. Protection of tidal flat macrobenthos from predation by use of an exclosure cage resulted in a 3-fold increase in density and a 44-fold increase in biomass over surrounding areas indicating that predation by fish and birds plays a key role in benthic community structuring.

382. The permanent meiobenthos was comprised principally of nematodes, cladocerans, ostracods, and copepods. The density of meiobenthos was greatest in low marsh, subtidal channel, and tidal flat at the experimental site. Estimated biomass was greater at comparable reference sites principally because of greater density of crustaceans.

383. Benthic organisms were a major part of the diet of the dominant fishes. Meiobenthic organisms, especially small crustaceans, were very important in this respect. Larger macrobenthic organisms such as oligochaetes were not numerically important food for the small fish that made up most of the sample. Overall crustaceans were the most abundant food, followed in decreasing order by insects, plant seeds, molluscs, and fish and fish eggs.

384. The reference site had significantly more fish species and a higher fish species diversity than the experimental site. No significant differences in numbers and biomass were, however, apparent between the two sites. The greater number of species and higher species diversity is attributed to a greater diversity of subhabitats (debris, branches, etc.) at the reference site.

385. In comparison with adjacent open bottom, the creation of the marsh has undoubtedly increased abundance and diversity of fish in the area. The marsh has resulted in more food and protection for many fish. The abundance of important forage species like the mummichog and spottail shiner was probably increased since they exhibit a strong dependence on littoral areas. Two species of some commercial and

recreational importance, the channel catfish and the white perch, use the shoal areas adjacent to the island for nocturnal feeding.

386. The most important fish species in terms of abundance, biomass, and frequency of appearance, in decreasing order, were the spottail shiner, white perch, american eel, threadfin shad, mummichog, tidewater silverside, gizzard shad, channel catfish, silvery minnow, and spot. This corresponded to the general condition of the icthyofauna in this section of the James River.

387. Although this series of studies has demonstrated that tidal fresh water island-marsh habitats can be constructed and attract local species, certain questions still remain. By comparison with data from similar reference site habitats, it is obvious that the island-marsh system is still evolving towards the more typical marsh system with adjacent woodlands. If the rapidly eroding western end of the island becomes stabilized and the internal marsh protected from erosion, it will be interesting to note whether the soils in the marsh system continue to increase in those characteristics associated with decaying plant material such as organic carbon, nitrogen, % volatiles, and cation exchange capacity, or whether the admixture of sand blowing or washing over the dikes at high water will be sufficient to retain the more sandy characteristics at the experimental site.

388. The openness, including lack of substantial trees is considered to contribute to the large number of bird species at the experimental site as contrasted to the reference site. It would be interesting to monitor the bird populations as the larger plant species, particularly on the higher ground develop and enable the invasion of new plant species suited to wooded habitats.

389. If the western end of the island is breached, the response of the interior marsh to higher energy river water would provide an interesting case study to evaluate permanence of artificially created habitats.

390. With respect to enhancement of wildlife resources, the Windmill Point project has been beneficial to the region through the

present. A greater diversity and/or biomass of benthic biota, birds, fish, and plants is found at the experimental site than in surrounding shallow water communities. The experimental site also compares favorably with reference sites in terms of wildlife resources and productivity.

391. It is strongly recommended that monitoring continue at the Windmill Point experimental site until the plant communities at the island become similar to those on adjacent shores or the island succumbs to erosion. Such data should prove of great value in predicting the success of future island marsh systems created to obtain a benefit from dredge material.

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Table 1

Percentage Composition of Sediment Constituents (Values are Means ($\bar{X}$), Standard Deviations (SD) for Each Stratum)

Date	Stratum*	Sand $\bar{X}$	Sand SD	Silt $\bar{X}$	Silt SD	Clay $\bar{X}$	Clay SD	Detritus $\bar{X}$	Detritus SD	Total Solids $\bar{X}$	Total Solids SD	Volatile Solids $\bar{X}$	Volatile Solids SD
July 1976	R1	0.0	0.0	72.03	9.41	27.92	9.41	23.42	3.11	23.95	4.47	30.27	11.12
	R2	0.0	0.0	79.76	3.82	20.21	3.84	14.83	6.57	30.88	4.33	17.57	1.67
	R3	0.0	0.0	79.57	10.73	22.00	17.84	13.32	5.15	34.83	8.42	20.31	15.21
	R4	0.0	0.0	85.83	6.33	14.14	5.99	11.61	3.60	31.51	7.02	17.54	9.52
	R5	99.71	0.28	**0.27	0.29	0.0	0.0	0.0	0.0	86.06	5.94	1.66	2.08
	E1	13.61	33.34	69.88	30.78	16.49	13.85	23.29	31.98	47.02	8.11	13.54	4.66
	E2	12.44	30.47	73.63	26.28	14.67	5.04	16.51	9.31	45.12	5.30	13.40	4.31
	E3	0.0	0.0	87.61	7.15	13.64	7.58	25.31	7.85	43.85	3.48	13.53	2.45
	E4	28.67	34.08	57.29	32.13	2.18	8.84	11.71	13.79	18.74	12.96	11.86	9.89
	E5	67.86	24.76	29.63	23.66	2.47	1.80	0.26	0.59	61.35	26.15	2.98	2.44
	E6	48.41	29.97	45.49	23.82	6.08	6.61	4.97	11.12	68.80	7.29	6.57	4.11
	E7	99.04	1.23	**0.93	1.20	--	--	0.0	0.0	65.20	40.36	1.21	1.31
November 1976	R1	17.41	28.48	67.48	24.10	15.09	12.73	22.40	19.91	38.13	9.75	17.38	7.40
	R2	0.0	0.0	83.53	5.42	16.44	5.41	14.23	3.02	27.61	8.93	17.40	3.14
	R3	0.0	0.0	89.35	4.44	10.61	4.44	11.00	3.95	32.20	16.51	13.80	3.77
	R4	0.0	0.0	88.35	2.55	11.61	2.55	13.65	7.84	31.60	10.73	16.52	6.34
	R5	99.58	0.68	**0.20	0.33	0.20	0.33	0.0	0.0	85.43	4.13	0.40	0.21
	E1	23.10	24.38	67.89	21.73	8.98	4.67	12.68	10.32	43.27	8.91	15.57	2.97
	E2	23.07	12.09	67.71	19.63	4.83	0.38	11.02	10.11	47.53	5.90	11.36	1.72
	E4	35.70	27.12	59.48	25.52	4.79	1.78	4.61	5.57	51.73	11.97	10.63	5.58
	E5	67.65	12.81	29.04	12.48	3.28	1.62	1.46	2.89	66.08	6.68	4.61	3.05
	E6	27.59	9.74	68.70	9.32	4.52	0.43	2.67	1.61	51.09	6.63	7.90	1.8[illegible]
	E7	93.98	12.78	5.18	11.72	0.61	1.11	0.0	0.0	80.91	4.05	7.37	3.[illegible]
January 1977	R1	8.19	20.50	17.33	17.33	18.57	8.23	21.49	7.60	32.37	13.17	21.28	7.9[illegible]
	R2	0.34	0.64	82.22	8.00	17.42	8.11	16.93	6.82	31.85	11.56	22.07	15.58
	R3	0.0	0.0	89.48	4.91	10.50	4.91	11.04	5.26	30.70	0.0	13.71	0.0
	R4	0.0	0.0	84.70	5.64	15.05	5.63	15.12	10.49	29.21	9.81	16.66	5.22
	R5	98.84	0.56	**0.57	0.28	---	---	0.0	0.0	87.61	1.31	0.58	0.07

(Continued)

Table 1 (Concluded)

Date	Stratum*	Sand		Silt		Clay		Detritus		Total Solids		Volatile Solids	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
January 1977 (Continued)	E1	13.07	7.39	71.00	9.48	15.91	4.06	11.76	3.10	48.86	6.36	11.87	1.38
	E2	8.01	4.27	81.51	6.69	10.48	5.73	10.91	5.02	49.10	8.00	11.12	2.24
	E4	43.09	28.10	50.48	24.79	6.40	4.35	6.70	4.93	57.57	12.34	8.80	3.11
	E5	70.93	24.51	25.36	24.40	3.67	1.92	3.16	5.93	73.01	8.77	3.25	2.97
	E6	51.09	14.72	42.79	14.38	6.09	0.96	10.22	6.83	71.91	6.35	6.35	4.07
	E7	99.59	0.46	**0.22	0.23	--	--	0.0	0.0	89.88	2.61	0.75	0.72
April 1977	R1	0.0	0.0	68.52	23.25	31.11	22.29	22.70	8.80	24.93	4.06	25.60	6.48
	R2	0.0	0.0	77.80	11.05	22.19	11.05	13.29	3.03	21.19	5.81	14.94	3.42
	R3	0.0	0.0	83.71	6.59	13.57	7.83	12.62	5.98	33.36	16.14	15.70	6.11
	R4	0.0	0.0	83.38	9.45	16.60	9.45	14.01	9.95	26.96	3.18	18.11	7.48
	R5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.30	4.00	0.42	0.26
	E1	14.61	17.70	47.48	12.02	37.87	14.15	8.56	3.64	51.10	8.15	13.82	4.28
	E2	6.24	9.21	82.18	9.00	11.58	2.65	12.57	3.33	50.71	6.59	11.88	2.21
	E4	18.93	28.30	69.16	24.90	11.89	3.97	25.63	12.91	43.65	5.19	11.04	3.08
	E5	81.59	18.46	14.98	18.17	3.41	0.80	0.07	0.20	75.99	5.65	2.39	1.88
	E6	52.50	22.22	40.97	19.96	7.14	4.35	0.0	0.0	66.94	6.76	5.97	2.75
	E7	99.44	1.59	0.22	0.63	0.34	0.95	0.0	0.0	82.53	12.9	1.08	0.71
July 1977	R1	0.0	0.0	76.79	6.49	23.19	6.49	14.20	1.52	33.00	13.93	16.32	4.84
	R2	0.0	0.0	74.74	4.00	25.22	3.97	20.51	3.96	23.10	4.47	16.86	2.38
	R3	0.0	0.0	79.03	3.15	20.94	3.17	11.90	5.49	29.30	2.61	14.09	1.14
	R4	0.0	0.0	82.51	7.47	17.48	7.46	15.63	6.22	24.86	5.56	16.51	8.41
	R5	92.79	13.37	5.49	10.27	1.71	3.22	0.0	0.0	54.69	20.11	2.18	2.50
	E1	50.55	43.38	40.31	38.15	9.12	9.53	8.46	13.93	45.66	3.01	10.12	0.85
	E2	0.0	0.0	90.51	1.49	9.47	1.49	23.01	5.55	58.05	16.56	9.19	6.17
	E4	54.90	24.27	36.86	20.30	8.21	4.44	7.53	9.75	57.24	10.16	8.08	3.40
	E5	79.59	16.56	15.09	15.56	5.22	1.14	0.0	0.0	74.16	8.01	2.40	2.46
	E6	74.48	16.00	18.86	14.72	6.66	2.42	0.66	0.80	70.45	11.52	3.13	2.01
	E7	96.83	6.05	**2.14	5.09	1.57	3.63	0.0	0.0	77.02	11.95	0.71	0.64

Parameter columns: Sand, Silt, Clay, Detritus, Total Solids, Volatile Solids.

*Stratum: R=Reference: 1=high marsh; 2=low marsh; 3=mud flat; 4=subtidal; 5=sandy shore
E=Experimental: 1-high marsh; 2=low marsh; 3=low marsh; 4=subtidal; 5=high mudflat; 6=low mud flat; 7=sand dike.

**Indicates values for silt and clay constituents

Table 2

Elevation of Macrobenthic Sampling Stations at Experimental Site. Data Are Based on Corps of Engineers Low Water in Feet

Stratum	Elevation (low water, ft.)				
	Jul 1976	Nov 1976	Jan 1977	Apr 1977	Jul 1977
E1-1	3.3	3.2	2.6	3.3	2.6
2	3.3	3.1	3.5	1.8	2.6
3	3.0	3.3	3.5	3.6	3.5
4	3.2	3.2	2.6	3.7	3.0
5	3.1	3.3	3.1	3.7	3.6
6	3.8	3.7	2.7	2.5	3.2
7	2.4	3.7	3.0	2.7	2.7
8	3.2	3.0	3.0	2.5	3.3
$\bar{X}$	3.2	3.3	3.0	2.9	3.1
SD	0.4	0.2	0.4	0.7	0.4
E2-1	2.5	2.4	2.3	2.2	2.2
2	3.0	2.1	2.5	2.2	2.6
3	2.8	2.8	2.6	2.1	2.2
4	2.4	2.3	2.2	2.6	2.3
5	2.4	3.0	2.6	2.2	2.0
6	2.6	2.5	2.1	1.9	2.3
7	2.5	2.5	1.9	1.7	2.3
8	2.2	2.4	2.1	2.7	2.4
$\bar{X}$	2.6	2.5	2.4	2.2	2.3
SD	0.4	0.3	0.2	0.3	0.2
E5-1	2.0	2.6	3.4	3.1	2.0
2	0.5	1.9	1.9	2.0	1.7
3	2.2	3.4	1.6	3.3	2.8
4	1.5	3.3	1.8	1.9	2.0
5	1.8	0.8	2.7	2.1	1.8

(Continued)

Table 2 (Concluded)

Stratum	Jul 1976	Nov 1976	Jan 1977	Apr 1977	Jul 1977
6	2.9	2.0	1.2	3.1	1.3
7	1.6	3.3	1.9	1.9	1.0
8	0.2	3.1	0.6	1.6	2.7
$\overline{X}$	1.6	2.6	1.9	2.4	1.9
SD	0.9	0.9	0.8	0.7	0.6
E6-1	1.1	1.5	1.4	1.3	1.5
2	1.1	1.3	1.7	1.7	1.5
3	1.6	1.4	1.8	1.4	1.6
4	1.7	1.4	1.6	1.8	1.6
5	1.5	0.5	1.4	1.2	1.4
6	1.6	0.3	1.1	1.0	1.5
7	1.5	1.4	1.6	0.9	1.0
8	0.9	0.6	0.6	0.9	1.6
$\overline{X}$	1.4	1.0	1.4	1.3	1.5
SD	0.3	0.5	0.4	0.4	0.2

Table 3

Taxa Collected in Macrobenthos Samples

Phylum: Platyhelminthes		
Class: Turbellaria		
	Family:	Plagiostomidae
		Hydrolimax grisea Haldeman
	Family:	Planaridae
		Cura foremanii (Girard)
Phylum: Nemertea		
		Prostoma rubrum (Leidy)
Phylum: Mollusca		
Class: Pelecypoda		
	Family:	Corbiculidae
		Corbicula manilensis (Phillippi)
	Family:	Sphaeriidae
		Sphaerium transversum (Say)
		Pisidium sp.
	Family:	Unionidae
		Elliptio complanata Lightfoot
Class: Gastropoda		
	Family:	Physidae
		Physa sp.
	Family:	Lymnaeidae
		Lymnaea stagnalis (Linnaeus)
	Family:	Planorbidae
		Gyraulus sp.
	Family:	Ancylidae
		Ferrissia sp.
	Family:	Pomatiopsidae
		Pomatiopsis sp.

Table 3 (Continued)

Phylum: Annelida		
Class: Polychaeta		
	Family:	Sabellidae
		Manyunkia speciosa Leidy
Class: Oligochaeta		
	Family:	Tubificidae
		Tubifex sp.
		Aulodrilus pigueti Kowalewski
		Branchiura sowerbyi Beddard
		Ilyodrilus templetoni (Southern)
		Limnodrilus spp.
		Limnodrilus cervix Brinkhurst
		Limnodrilus hoffmeisteri Claparede
		Limnodrilus udekemianus Verrill
		Limnodrilus profundicola Smith
		Peloscolex multisetosus Brinkhurst
		Peloscolex freyi Brinkhurst
	Family:	Naidiae
		Chaetogaster sp.
		Nais spp.
		Dero digitata (Muller)
		Stylaria lacustris (Linnaeus)
	Family:	Enchytraeidae
		Enchytraeid spp.
	Family:	Lumberliculidae
		Lumberliculid sp.
Class: Hirudinea		
	Family:	Piscicolidae
		Helobdella elongata (Castle)
		Helobdella stagnalis (Linnaeus)
		Helobdella puntatalineata Moore
		Batracobdella phalera Graf

Table 3 (Continued)

Phylum: Arthropoda			
Class: Arachnida			
	Spiders		
Class: Crustacea			
	Order: Isopoda		
		Family:	Asellidae
			Asellus sp.
	Order: Amphipoda		
		Family:	Gammaridae
			Gammarus fasciatus Say
		Family:	Hyalellidae
			Hyalella azteca (Saussure)
Class: Insecta			
	Order: Collembola		
		Family:	Isotomidae
			Isotomid sp.
		Family:	Smynthuridae
			Smynthurid sp.
	Order: Ephemeroptena		
		Family:	Ephemeridae
			Hexagenia mingo Walsh
		Family:	Baetidae
			Caenis sp.
			Ephemerella sp. Traver
	Order: Odonata		
	Suborder: Zygoptera		
		Zygopteran sp.	
	Order: Tricoptera		
		Tricopteran spp.	
	Order: Hemiptera		
		Family:	*Trichocorixa* sp.
	Order: Diptera		
		Family:	Tipulidae

Table 3 (Continued)

	Helius sp.
	Tipula sp.
Family:	Culcidae
	Chaoborus punctipennis (Say)
Family:	Tabanidae
	Chrysops sp.
	Anacimas sp.
Family:	Chironomidae
	Chironomid sp. 3
	Chironomid sp. 4
	Chironomid sp. 6
	Ablabesmyia sp. E
	Chironomus spp.
	Coelotanypus scapularis (Loew)
	Cryptochironomus spp.
	Dicrotendipes nervosus (Staeg.)
	Glyptotendipes sp.
	Harnischia sp.
	Polypedilum spp.
	Procladius bellus (Loew)
	Pseudochironomus sp.
	Stictochironomus devinctus (Say)
	Cryptocladopelma sp.
	Tanypus spp.
	Tanytarsus sp.
	Trichocladius sp.
	Lauterborniella sp.
	Cricotopus sp.
Family:	Ceratopogonidae
	Palpomyia sp.
Family:	Dolichopodidae
	Argyra sp.
	Hydrophorus sp.

Table 3 (Concluded)

Order: Coleoptera		
	Family:	Chrysomelidae
		<u>Donacia</u> sp.

Table 4

Qualitation and Composition of the Macrobenthos by Higher Taxon

Taxonomic Group	Jul '76	Nov '76	Jan '77	Apr '77	Jul '77	Total
	Percent of Species					
Platyhelminthes	2.12	3.8	2.8	0.0	0.0	2.6
Nemertea	0.0	1.9	0.0	2.9	0.0	1.3
Mollusca	12.8	13.5	13.8	5.8	13.7	11.7
Bivalvia	6.4	5.8	8.3	2.9	7.8	5.2
Gastropoda	6.4	7.7	5.5	2.9	5.8	6.5
Annelida	25.5	36.5	33.3	41.1	33.3	28.6
Oligochaeta	23.4	26.9	27.8	38.2	27.4	22.1
Polychaeta	0.0	1.9	0.0	0.0	0.0	1.3
Hirudinea	2.1	7.7	5.5	2.9	5.8	5.2
Arthropoda	59.6	44.2	50.0	50.0	51.0	55.8
Insecta	46.80	34.6	38.8	42.85	43.1	50.6
Chironomidae	29.7	21.2	30.5	28.57	29.7	27.3
	Percent of Individuals					
Platyhelminthes	0.0*	0.8	0.2	0.0	0.0	0.1
Nemertea	0.0	0.1	0.0	0.4	0.0	0.1
Mollusca	3.6	13.4	1.3	1.3	5.5	4.9
Bivalvia	3.4	12.0	1.2	1.3	5.0	4.5
Gastropoda	0.2	1.4	0.1	0.0*	0.5	0.4
Annelida	80.9	74.1	70.5	86.7	73.3	77.6
Oligochaeta	80.8	73.2	69.0	86.7	72.7	77.1
Polychaeta	0.0	0.0*	0.0	0.0	0.0	0.0*
Hirudinea	0.1	0.9	1.5	0.0	0.6	0.5
Arthropoda	15.5	11.6	28.1	11.6	21.2	17.2
Insecta	15.4	10.2	25.6	11.4	21.0	16.6
Chironomidae	15.0	7.6	24.0	9.9	19.6	15.3

* Less than 0.03 percent

Table 5

Frequency of Occurrence of Major Species of Macrobenthos by Season

Species	Percent				
	Jul 1976	Nov 1976	Jan 1977	Apr 1977	Jul 1977
Turbellaria					
Hydrolimax grisea	1	3	7	0	0
Bivalvia					
Corbicula manilensis(sm)	46	55	12	28	51
Corbicula manilensis(lg)	6	3	2	1	1
Gastropoda					
Physa sp.	9	6	1	1	9
Oligochaeta					
Tubifex sp.	8	23	2	2	0
Branchiura sowerbyi	33	31	31	18	23
Ilyodrilus templetoni	44	33	22	28	45
Limnodrilus spp.	95	92	83	76	88
Limnodrilus hoffmeisteri	70	52	30	63	64
Limnodrilus cervix	35	23	3	12	18
Peloscolex multisetosus	15	17	27	20	18
Peloscolex freyi	9	3	0	9	7
Nais sp.	16	9	0	24	8
Enchytraeidae	5	5	17	15	0
Lumberliculidae	0	6	1	2	0
Hirudinea					
Helobdella elongata	6	15	9	0	13
Helobdella stagnalis	0	7	9	1	3
Isopoda					
Asellus sp.	1	6	5	1	2
Amphipoda					
Gammarus fasciatus	2	3	9	3	2

(continued)

Table 5 (Concluded)

Species	Percent Jul 1976	Nov 1976	Jan 1977	Apr 1977	Jul 1977
Insecta					
Trichocorixa sp.	3	7	1	0	5
Chironomidae					
Chironomus sp.	48	36	31	34	38
Coelotanypus scapularis	20	26	22	4	36
Cryptochironomus spp.	16	18	22	13	23
Dicrotendipes nervosus	13	0	2	2	27
Glyptotendipes sp.	0	3	6	0	2
Polypedilum sp.	8	5	1	6	38
Procladius bellus	8	11	1	0	18
Tanypus spp.	41	8	19	6	44
Ceratopogonidae					
Palpomyia sp.	8	6	2	1	9
Total Number of Samples	93	88	87	87	88

Table 6

Descriptive Statistics for Community Structure Parameters of Macrobenthos by Stratrum and Sampling Period 160 cm^2 Cores

Stratum	Date	Number of Individuals		Number of Species		Diversity (H')		Evenness (J')		Richness (SR)	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
E1	July	63	73	4.4	2.0	1.21	0.63	0.52	0.94	0.85	0.38
	November	40	40	4.6	1.7	1.51	0.31	0.74	0.07	1.11	0.27
	January	9	11	2.2	1.8	0.80	0.90	0.44	0.48	0.67	0.64
	April	51	40	2.7	1.3	0.54	0.43	0.37	0.28	0.49	0.29
	July	94	217	4.1	3.3	1.15	0.86	0.54	0.37	0.54	0.69
E2-3	July	267	250	7.6	1.7	1.68	0.35	0.56	0.11	1.25	0.31
	November	90	32	7.2	1.2	1.59	0.22	0.57	0.08	1.36	0.29
	January	27	14	3.1	0.3	1.35	0.16	0.83	0.08	0.69	0.13
	April	54	37	3.6	1.5	1.33	0.21	0.78	0.13	0.74	0.47
	July	221	75	7.4	2.2	1.83	0.32	0.65	0.04	1.20	0.42
E4	July	125	51	5.9	1.5	1.61	0.53	0.58	0.19	1.22	0.25
	November	68	31	6.6	1.7	1.62	0.51	0.60	0.16	1.33	0.42
	January	36	46	4.0	2.2	1.37	0.52	0.78	0.13	0.94	0.37
	April	165	104	6.5	1.5	2.01	0.23	0.76	0.07	1.14	0.36
	July	160	44	7.6	1.8	1.90	0.30	0.66	0.10	1.31	0.34

(Continued)

Table 6 (Continued)

Stratrum	Date	Number of Individuals X̄	Number of Individuals SD	Number of Species X̄	Number of Species SD	Diversity (H') X̄	Diversity (H') SD	Evenness (J') X̄	Evenness (J') SD	Richness (SR) X̄	Richness (SR) SD
E5	July	63	52	7.0	2.4	2.00	0.75	0.72	0.21	1.53	0.48
	November	54	13	5.1	2.0	1.45	0.43	0.67	0.17	1.05	0.53
	January	6	10	0.9	1.1	0.30	0.58	0.24	0.44	0.12	0.25
	April	12	7	2.9	1.0	1.11	0.64	0.69	0.34	0.80	0.52
	July	48	37	7.0	1.7	2.23	0.38	0.80	0.12	1.62	0.32
E6	July	74	25	7.9	1.9	2.12	0.42	0.72	0.07	1.63	0.48
	November	46	13	5.1	1.4	1.57	0.31	0.70	0.11	1.08	0.35
	January	7	8	3.0	4.2	0.74	0.68	0.57	0.47	0.63	0.62
	April	7	10	3.9	2.1	1.11	0.99	0.43	0.46	0.94	0.90
	July	32	12	6.3	1.6	2.09	0.45	0.80	0.07	1.59	0.55
E7	July	7	6	6.6	2.8	1.31	0.65	0.81	0.33	1.16	0.54
	November	32	17	2.2	0.9	0.45	0.42	0.36	0.31	0.41	0.32
	January	4	4	4.0	0.1	1.75	0.73	0.62	0.44	0.40	0.59
	April	7	12	2.7	1.5	1.00	0.74	0.79	0.11	0.72	0.53
	July	30	22	5.6	1.7	2.10	0.29	0.86	0.05	1.43	0.24

(Continued)

Table 6 (Continued)

Stratum	Date	Number of Individuals $\bar{X}$	SD	Number of Species $\bar{X}$	SD	Diversity (H') $\bar{X}$	SD	Evenness (J') $\bar{X}$	SD	Richness (SR) $\bar{X}$	SD
R1	July	54	45	6.6	2.8	1.85	0.71	0.70	0.12	1.46	0.64
	November	41	40	7.2	2.4	2.02	0.46	0.73	0.14	1.84	0.44
	January	45	29	9.0	2.7	2.45	0.38	0.79	0.07	2.19	0.51
	April	56	57	5.8	2.0	2.00	0.50	0.84	0.11	1.37	0.47
	July	93	57	10.3	4.5	2.30	0.55	0.72	0.08	2.08	0.72
R2	July	56	52	7.1	2.8	1.72	0.33	0.66	0.13	1.51	0.52
	November	40	21	7.1	2.4	2.13	0.63	0.78	0.11	1.73	0.61
	January	122	71	7.5	1.9	2.12	0.18	0.75	0.09	1.41	0.38
	April	49	30	7.1	2.2	2.05	0.38	0.74	0.05	1.63	0.44
	July	60	34	8.8	2.0	2.22	0.24	0.73	0.13	2.01	0.22
R3	July	23	10	5.1	2.2	2.22	2.26	0.59	0.27	1.27	0.63
	November	20	6	6.5	1.2	2.31	0.33	0.86	0.05	1.78	0.32
	January	42	13	8.0	1.3	2.52	0.40	0.84	0.09	1.90	0.40
	April	38	40	4.9	1.7	1.82	0.48	0.82	0.11	1.28	0.48
	July	65	31	9.6	2.0	2.48	0.48	0.77	0.14	2.18	0.37

(Continued)

Table 6 (Concluded)

Stratum	Date	Number of Individuals $\bar{X}$	Number of Individuals SD	Number of Species $\bar{X}$	Number of Species SD	Diversity (H') $\bar{X}$	Diversity (H') SD	Evenness (J') $\bar{X}$	Evenness (J') SD	Richness (SR) $\bar{X}$	Richness (SR) SD
R4	July	19	15	4.3	2.3	1.48	0.90	0.88	--	1.11	0.65
	November	21	13	6.5	1.7	2.21	0.25	0.83	0.06	1.89	0.40
	January	64	53	9.8	3.2	2.41	0.48	0.76	0.17	2.20	0.50
	April	19	11	5.8	2.3	2.02	0.62	0.82	0.08	1.66	0.55
	July	27	11	8.0	2.0	2.52	0.37	0.85	0.05	2.15	0.53
R5	July	40	18	5.4	1.1	1.69	0.51	0.69	0.15	1.29	0.37
	November	44	34	4.1	1.5	1.30	0.75	0.61	0.28	1.22	0.85
	January	17	10	5.0	2.4	1.58	0.90	0.67	0.31	1.37	0.76
	April	45	37	3.4	1.5	1.20	0.63	0.48	0.26	0.64	0.37
	July	28	17	7.6	1.8	2.48	0.40	0.86	0.09	2.10	0.54
Cage	July '77	135	56	9.3	2.1	2.40	0.34	0.75	0.03	1.78	0.26

Table 7

Mean and Standard Deviation of Dry Weight Biomass (mg/160 cm^2)
for Oligochaetes and Total Macrobenthos
by Stratum and Sampling Period

		Oligochaetes		Total	
Stratum	Date	$\overline{X}$	SD	$\overline{X}$	SD
E1	July	15.43	22.01	21.02	20.46
	November	15.72	17.09	22.20	17.80
	January	6.50	10.79	7.31	11.55
	April	5.07	10.43	5.51	10.35
	July	17.74	46.87	26.07	50.15
	Average	12.09	33.44	16.41	22.06
E2-3	July	25.36	30.40	29.18	30.98
	November	44.36	22.48	50.21	21.58
	January	53.78	34.45	47.10	37.13
	April	57.62	82.76	64.88	78.96
	July	61.49	30.67	81.39	28.72
	Average	48.52	40.15	54.55	39.47
E4	July	14.95	12.66	78.38	177.38
	November	21.97	7.28	40.27	27.60
	January	21.56	46.28	27.54	47.99
	April	92.29	69.87	144.44	97.26
	July	78.99	65.10	96.19	62.46
	Average	45.95	40.35	77.36	82.54
E5	July	4.49	2.76	8.94	5.34
	November	8.18	5.03	11.03	4.53
	January	1.39	2.91	0.0	0.0
	April	4.82	8.87	13.17	14.13
	July	2.84	5.67	10.01	6.39
	Average	4.34	5.05	8.63	6.08

(Continued)

Table 7 (Continued)

Stratum	Date	Oligochaetes $\overline{X}$	Oligochaetes SD	Total $\overline{X}$	Total SD
E6	July	7.71	5.86	11.05	5.58
	November	10.82	6.41	16.66	11.11
	January	3.27	4.15	3.80	4.13
	April	5.34	17.33	10.15	17.26
	July	0.37	0.60	23.34	28.85
	Average	5.50	6.87	13.00	13.39
E7	July	0.31	0.32	17.74	44.86
	November	1.86	3.01	38.34	24.24
	January	1.13	1.31	1.72	2.30
	April	11.07	1.25	1.97	2.37
	July	0.45	0.37	48.70	58.22
	Average	2.96	1.25	21.69	26.40
R1	July	12.79	8.18	13.51	8.13
	November	27.11	32.26	50.49	70.20
	January	26.85	56.37	28.50	39.19
	April	21.97	36.92	39.60	44.54
	July	12.19	12.37	27.70	20.03
	Average	20.18	29.22	31.96	36.42
R2	July	4.69	3.07	5.27	3.35
	November	13.36	10.15	18.28	9.67
	January	26.41	28.63	52.06	31.44
	April	11.97	8.11	14.54	8.67
	July	9.92	6.28	20.62	30.37
	Average	13.27	11.25	22.15	16.70

Table 7 (Concluded)

		Oligochaetes		Total	
Stratum	Date	$\overline{X}$	SD	$\overline{X}$	SD
R3	July	4.77	2.33	5.60	1.97
	November	5.36	5.49	16.40	31.20
	January	4.93	2.79	27.62	11.10
	April	9.60	9.03	10.60	8.69
	July	8.56	4.76	17.14	11.20
	Average	6.64	4.88	15.47	12.83
R4	July	5.07	2.42	3.70	5.85
	November	4.73	7.97	7.81	9.31
	January	4.04	3.91	49.16	48.32
	April	5.13	1.84	21.58	47.92
	July	8.00	6.94	9.56	7.67
	Average	5.39	5.10	18.36	23.81
R5	July	2.01	1.77	14.69	22.21
	November	3.33	3.65	7.14	6.05
	January	4.00	5.49	7.88	6.48
	April	1.78	1.78	1.90	1.87
	July	3.43	5.98	28.82	61.37
	Average	2.91	3.73	12.09	19.60

Table 8

Group Produced from Numerical Classification of Macrobenthos Samples Pooled by Stratum and Season

Site Group	Stratum	Season
Group 1	R1	Jul 1976
	R1	Nov
	R1	Jan
	R1	Apr
	R1	Jul 1977
	R2	Jul 1976
	R2	Nov
	R2	Jan
	R2	Apr
	R2	Jul 1977
	R3	Jul 1976
	R3	Nov
	R3	Jan
	R3	Apr
	R3	Jul 1977
	R4	Jul 1976
	R4	Nov
	R4	Jan
	R4	Apr
	R4	Jul 1977
	R5	Jul 1977
Group 2	E5	Apr
	E6	Apr
	R5	Jul 1976
	R5	Nov
	R5	Jan
	E7	Jul 1976
	E7	Nov
Group 2 (Cont'd)	E7	Jan
	E7	Apr
Group 3	E2	Jul 1977
	E7	Jul 1977
	E6	Jul 1977
Group 4	E2	Jul 1976
	E2	Jul 1977
	E4	Jul 1976
	E4	Nov
	E4	Apr
	E5	Jul 1976
	E5	Nov
	E6	Jul 1976
	E6	Nov
	E3	Jul 1976
Group 5	E1	Jul 1976
	E1	Nov
	E1	Jan
	E1	Apr
	E1	Jul 1977
	E4	Jan
	E2	Nov
	E2	Jan
	E2	Apr
	E5	Jan
	E6	Jan
	R5	Apr

Table 9

Groups Produced from Numerical Classification of Macrobenthos Species

Group A	Group D (Continued)
Limnodrilus spp. (O)	Limnodrilus profundicola (O)
Limnodrilus hoffmeisteri (O)	Trichocorixa sp. (I)
Limnodrilus cervix (O)	Palpomyia sp. (I)
Ilyodrilus templetoni (O)	Physa sp. (G)
Branchiura sowerbyi (O)	Lumberliculidae (O)
Chironomus spp. (C)	Pisidium sp. (B)
Tanypus spp. (C)	Spiders
Corbicula manilensis (sm) (B)	

Group B	Group E
Polypedilum sp. (C)	Asellus sp. (Is)
Dicrotendipes nervosus (C)	Helobdella stagnalis (H)
Pseudochironomus sp. (C)	Hyalella azteca (A)
Tanytarsus sp. (C)	Hydrolimax grisea (T)
Caenis sp. (I)	
Dero digitata (O)	
Corbicula manilensis (lg) (B)	

Group C	Group F
Donacia sp. (I)	Coelotanypus scapularis (C)
Glyptotendipes sp. (C)	Cryptochironomus (C)
Stictochironomus sp. (C)	Chironomid sp. 3 (C)
	Nais spp. (O)
Group D	Procladius bellus (C)
Enchytraeidae (O)	Peloscolex multisetosus (O)
Hydrophorus sp. (I)	Helobdella elongata (H)
Peloscolex freyi (O)	Gammarus fasciatus (A)
	Tubifex spp. (O)

Key: O - Oligochaete; C - Chironomid; I - Insect; Is - Isopod; B - Bivalve; G - Gastropod; A - Amphipod; H - Hirudinean

Table 10

Macrobenthos Collected at a Subtidal James River Control Site

Species	January 1977 Replicate 1	2	3	4	Total	April 1977 Replicate 1	2	3	4	Total	July 1977
Limnodrilus	26	32	15	23	96	26	29	36	37	128	29
Limnodrilus hoffmeisteri			3	1	4	1	1	3		5	3
Ilyodrilus templetoni	10	5	2	3	20	2	2	2	4	10	15
Peloscolex freyi						7	10	8	2	27	
Nais spp.			2		2		1			1	
Chironomus spp.	10	1	8	5	24	1	1	3	2	7	1
Cryptochironomus sp.		1			1	2		1	1	4	1
Pseudochironomus							2			2	
Tanypus sp.	1	1		1	3						
Coelotanypus scapularis	17	13	12	17	59	2	7	1	1	11	8
Procladius bellus						3	2	1		6	
Harnischia sp.							1			1	
Ablabesmyia sp. E							1			1	
Chaoborus punctipennis								1		1	
Corbicula manilensis		1			1	27	14	6	6	53	

Table 11

Taxa Collected in Meiobenthos Samples

Phylum: Aschelminthes

- **Class:** Nematoda
  - Nematode sp. 10
  - Nematode sp. 11
  - **Order:** Monohysteridae
    - **Family:** Monohysteridae
      - *Monohystera* sp.
      - *Monohystrella* sp. 1
      - *Monohystrella* sp. 2
  - **Order:** Dorylaimida
    - **Family:** Dorylaimidae
      - *Dorylaimus* sp.
      - *Amphidorylaimus* sp.
      - *Thornenema* sp.
    - **Family:** Mononchidae
      - *Anatonchus* sp.
    - **Family:** Bathyodontidae
      - *Alaimus* sp.
  - **Order:** Araeolaimida
    - **Family:** Plectidae
      - *Paraplectonema* sp.

Phylum: Tardigrada

- **Class:** Eutardigrada
  - **Family:** Macrobiotidae
    - *Macrobiotus richtersii* J. Murray
    - *Macrobiotus dispar* J. Murray
    - *Macrobiotus furcatus* Ehrenberg
    - *Macrobiotus hufelandii* S. Schultze
    - *Hypsibius* sp.
- **Class:** Heterotardigrada

Table 11 (Continued)

Family:	Scutechiniscidae
	Echiniscus sp.
Phylum: Annelida	
Class: Oligochaeta	
Family:	Tubificidae
	Tubifex sp.
	Aulodrilus pigueti Kowalewski
	Branchiura sowerbyi Beddard
	Ilyodrilus templetoni Southern
	Limnodrilus spp.
	Limnodrilus cervix Brinkhurst
	Limnodrilus hoffmesteri Claparede
	Peloscolex multisetosus Brinkhurst
Family:	Naidiae
	Nais spp.
	Dero digitata Muller
	Stylaria lacustris Linnaeus
Family:	Enchytraeidae
	Enchytraeid sp.
Phylum: Arthropoda	
Class: Crustacea	
Order: Cladocera	
Family:	Sididae
	Sida crystallina O.F. Muller
	Latona setifera O.F. Muller
	Diaphanosoma sp.
Family:	Daphiniidae
	Moina micrura Kurz
Family:	Bosminidae
	Bosmina longirostris O.F. Muller
Family:	Macrothricidae
	Ilyocryptus spp.
	Diaphanosoma agilis Fischer

Table 11 (Continued)

	Family:	Chydoridae
		Kurzia latissima Kurz
		Leydigia leydigi Leydia
		Leydigia acanthocercoides Fischer
		Alona costata Sars
		Alona affinis Leydig
		Alona quadrangularis O.F. Muller
		Pleuroxus denticulatus Birge
		Chydorus sphaericus O.F. Muller
Subclass: Copepoda		
Suborder: Cyclopoida		
	Family:	Cyclopidae
		Eucyclops agilis Koch
		Paracyclops affinis Sars
		Paracyclops fimbriatus Fischer
		Macrocyclops fuscus Jurine
		Halicyclops magniceps Lilljeborg
		Mesocyclops edax S.A. Forbes
	Family:	Canthocamptidae
		Canthocamptus staphlinoides Pearse
		Canthocamptus robertcokeri M.S. Wilson
		Canthocamptus sp.
		Moraria sp.
Subclass: Ostracoda		
	Family:	Cypridae
		Physocypria sp.
		Cypridopsis sp.
		Candona sp.
	Family:	Darwinulidae
		Darwinula stevensoni Brady and Robertson
Class: Acari		
Class: Insecta		
Order: Diptera		

Table 11 (Concluded)

	Family:	Ceratopogonidae
		Palpomyia sp.
	Family:	Chironomidae
		Chironomus sp.
		Cryptochironomus sp.
		Pseudochironomus sp.
		Stictochironomus sp.
		Tanypus spp.
		Coelotanypus sp.
		Harnischia sp.
		Polypedilum sp.
		Procladius sp.
Phylum: Mollusca		
Class: Pelecypoda		
	Family:	Corbiculidae
		Corbicula manilensis Phillippi
	Family:	Sphaeriidae
		Pisidium sp.
Class: Gastropoda		
	Family:	Physidae
		Physa sp.

Table 12

Number of Individuals and Species of Macrofauna and Meiofauna Found in the 8 Cores (30 cm^2) from Each Stratum Collected for Meiobenthos

	Macrofauna		Meiofauna	
Stratum	Species	Individuals	Species	Individuals
E1	14	67	15	294
E2	8	118	11	462
E4	10	90	19	325
E5	9	42	15	582
E6	6	15	16	301
E7	4	11	10	90
R1	12	88	20	332
R2	10	25	19	269
R3	11	40	14	232
R4	10	34	19	244
R5	3	10	15	77

Table 13

Occurrence of Species in Meiobenthos Samples, July 1977

	Stratum										
	Experimental						Reference				
Species	E1	E2	E4	E5	E6	E7	R1	R2	R3	R4	R5
Limnodrilus spp.	X	X	X	X	X	X	X		X	X	X
Limnodrilus hoffmeisteri	X	X	X	X		X					
Limnodrilus cervix		X		X							
Limnodrilus profundicola				X							
Dero digitata							X	X		X	
Nais spp.	X	X	X		X	X	X	X	X	X	
Peloscolex multisetosus							X	X			
Ilyodrilus templetoni	X	X	X	X			X	X	X		
Tubifex spp.	X										
Enchyraeidae	X										
Branchiura sowerbyi	X	X	X								
Aulodrilus pigueti									X		
Stylaria lacustris							X				
Corbicula manilensis		X		X	X		X	X	X	X	
Physa sp.	X										
Pisidium sp.							X				
Palpomyia sp.	X		X						X	X	
Chironomus spp.			X	X	X		X	X	X	X	
Pseudochironomus sp.				X							
Stictochironomus sp.			X							X	
Cryptochironomus sp.	X							X			
Polypedilum sp.				X	X	X			X		
Procladius bellus									X	X	X
Tanypus sp.	X	X	X				X	X	X	X	
Coelotanypus scapularis	X		X				X	X	X	X	X
Harnischia sp.	X										
Acari							X	X			

(Continued)

Table 13 (Continued)

	Stratum										
	Experimental						Reference				
Species	E1	E2	E4	E5	E6	E7	R1	R2	R3	R4	R5
Eucyclops agilis		X	X	X	X	X	X	X	X	X	X
Paracyclops affinis		X	X	X					X	X	
Paracyclops fimbriatus					X	X	X	X			X
Macrocyclops fuscus					X					X	
Mesocyclops edax							X				
Halicyclops magniceps											X
Canthocamptus staphlinoides	X		X	X	X	X	X	X		X	
Canthocamptus robertcokeri				X							
Canthocamptus sp. 2			X								
Moraria sp.						X					
Monohystrella sp. 1	X	X	X	X	X	X	X	X	X	X	X
Monohystrella sp. 2	X				X	X	X	X			
Monohystera sp.	X		X						X		
Dorylaimus sp.	X	X	X	X	X	X					
Amphidorylaimus sp.	X	X	X	X	X	X	X	X			
Thornenema sp.	X	X	X	X	X	X	X		X	X	
Paraplectonema sp.					X					X	X
Alaimus sp.					X			X	X	X	X
Anatonchus sp.	X		X	X			X	X			
Nematode sp. 10							X		X		X
Nematode sp. 11	X										
Ilyocryptus spp.		X	X	X	X		X	X	X	X	X
Alona affinis		X	X	X	X					X	X
Alona costata			X	X	X	X					X
Alona quadrangularis									X	X	
Leydigia leydigi									X	X	
Leydigia acanthoceroides										X	
Moina branchiata										X	X
Latona setifera										X	

(Continued)

Table 13 (Concluded)

	Stratum										
	Experimental						Reference				
Species	E1	E2	E4	E5	E6	E7	R1	R2	R3	R4	R5
Diaphanosoma sp.								X			
Pleuroxus denticulatus								X			
Sida crystallina								X			
Bosmina longirostris								X	X	X	
Kurzia latissima							X				
Chydorus sphaericus							X				
Macrothrix sp.			X	X				X	X		
Physocypria sp.	X	X	X	X	X		X	X	X	X	X
Candona sp.	X	X	X				X	X		X	X
Cypridopsis sp.		X					X				X
Darwinula stevensoni							X	X	X	X	X
Macrobiotus richtersii	X		X	X			X	X			
Macrobiotus dispar	X							X			
Macrobiotus furcatus							X				
Macrobiotus hufelandii	X				X						
Hypsibius sp.	X		X								
Echiniscus sp.							X				

Table 14

Density and Diversity Statistics for Collection of Meiobenthos

Stratum		Number of Individuals ($3.8\ cm^2$)	Number of Species	Species Diversity (H')	Evenness (J')	Species Richness (SR)
E1	$\bar{X}$	45	8.3	2.22	0.62	2.45
	SD	35	2.1	0.61	0.23	0.53
E2	$\bar{X}$	72	9.1	2.13	0.61	2.04
	SD	39	2.3	0.43	0.17	0.31
E4	$\bar{X}$	51	10.3	2.76	0.84	2.40
	SD	23	2.3	0.37	0.19	0.47
E5	$\bar{X}$	78	9.8	2.04	0.60	2.14
	SD	62	3.6	0.26	0.15	0.55
E6	$\bar{X}$	39	7.3	1.73	0.45	1.84
	SD	18	1.9	0.42	0.12	0.55
E7	$\bar{X}$	12	4.5	1.77	0.36	1.50
	SD	11	2.0	0.42	0.17	0.35
R1	$\bar{X}$	52	11.0	2.82	0.87	2.58
	SD	27	4.1	0.42	0.26	0.73
R2	$\bar{X}$	36	8.7	2.29	0.53	2.14
	SD	25	4.1	0.70	0.39	0.99
R3	$\bar{X}$	34	10.1	2.72	0.67	2.62
	SD	10	1.1	0.27	0.27	0.23
R4	$\bar{X}$	34	9.8	2.72	0.67	2.55
	SD	21	3.7	0.29	0.27	0.70
R5	$\bar{X}$	10	4.7	1.72	0.40	1.53
	SD	9	2.7	1.11	0.29	0.98

Table 15

Groups Produced by Numerical Classification of Species of Meiobenthos

Group A	Group E
Anatonchus spp. (N)	Palpomyia sp. (I)
Macrobiotus richtersii (T)	Cryptochironomus fulvus (C)
Ilyodrilus templetoni (O)	Leydigia leydigi (Cl)
Tanypus spp. (C)	Bosmina longirostris (Cl)
Group B	**Group F**
Monohystera spp. (N)	Alaimus spp. (N)
Dorylaimus spp. (N)	Procladius sp. (C)
Limnodrilus hoffmeisteri (O)	Paracyclops affinis (Cp)
Branchiura sowerbyi (O)	Alona affinis (Cl)
	Chironomus spp. (C)
Group C	Diaphanosoma agilis (Cl)
Alona costata (Cl)	Nais spp. (O)
Polypedilum sp. (C)	Coelotanypus spp. (C)
Canthocamptus staphlinoides (Cp)	
Corbicula manilensis (B)	**Group G**
Paracyclops fimbriatus (Cp)	Eucyclops agilis (Cp)
	Ilyocryptus spp. (Cl)
Group D	Physocypria spp. (Cp)
Darwinula stevensoni (Os)	Thornenema sp. (N)
Nematode sp. 10 (N)	Limnodrilus spp. (O)
Candona spp. (Os)	Amphidorylaimus spp. (N)
Monohystrella sp. 2 (N)	Monohystrella sp. 1 (N)

Key: N - Nematoda; O - Oligochaete; C - Chironomidae; I - Insecta exc. Chironomidae; Cp - Copepoda; Os - Ostracoda; Cl - Cladocera; T - Tardigrada

Table 16

Estimated Dry Weight Biomass of Permanent Meiobenthos by Stratum for July 1977

Stratum	Dry Weight Biomass (mg/m^2)					
	Nematoda	Copepoda	Cladocera	Ostracoda	Other	Total
E1	70.1	1.6	0	55.9	48.0	175.6
E2	133.2	19.7	66.8	52.6	0	272.3
E4	59.9	108.6	78.3	75.7	12.5	335.0
E5	165.1	24.7	142.8	3.3	1.3	337.2
E6	91.8	13.2	25.3	6.6	0.7	137.6
E7	26.0	14.8	4.6	0	0	45.4
R1	40.8	98.7	23.0	381.6	14.5	558.6
R2	43.8	9.9	124.3	240.1	2.6	420.7
R3	24.0	97.0	191.1	55.9	0	368.0
R4	7.6	148.0	271.7	42.8	0	470.1
R5	9.2	26.3	36.8	55.9	0	128.2

Table 17

Summary Statistics of Water Quality Variables

	Temperature, °C					pH					Salinity, ppt					Dissolved Oxygen, mg/l					Turbidity, JTU's				
	$\bar{X}$	SD	N	X_{min}	X_{max}	$\bar{X}$	SD	N	X_{min}	X_{max}	$\bar{X}$	SD	N	X_{min}	X_{max}	$\bar{X}$	SD	N	X_{min}	X_{max}	$\bar{X}$	SD	N	X_{min}	X_{max}
Windmill Point	16.4	8.896	128	3.4	32.0	7.5	0.324	128	6.8	8.3	0.129	0.053	128	0.071	0.480	7.8	1.319	128	4.8	10.3	34.6	17.533	128	4	84
October	14.3	0.474	32	14.0	15.3	7.4	0.076	32	7.2	7.5	0.106	0.026	32	0.082	0.195	7.7	0.511	32	7.0	9.6	43.9	7.649	32	16	54
February	4.9	1.110	32	3.4	9.1	7.9	0.109	32	7.7	8.2	0.132	0.016	32	0.118	0.182	9.3	0.488	32	8.0	10.2	15.7	13.692	32	4	49
April	16.7	1.871	32	15.0	25.2	7.4	0.417	32	6.8	8.3	0.095	0.071	32	0.071	0.480	8.0	0.884	32	6.0	10.3	46.6	11.782	32	30	84
July	29.5	1.167	32	27.5	32.0	7.5	0.210	32	7.1	8.1	0.182	0.031	32	0.160	0.340	6.1	0.687	32	4.8	7.3	32.3	16.139	32	4	77
Herring Creek	16.1	8.464	90	3.0	32.7	7.6	0.372	90	7.0	8.7	0.114	0.079	90	0.066	0.731	8.5	2.135	90	2.1	12.6	39.6	17.808	90	8	84
October	13.7	0.602	24	12.5	14.5	7.3	0.118	24	7.1	7.5	0.117	0.131	24	0.075	0.731	8.8	1.239	24	6.4	10.7	50.3	12.110	24	32	73
February	6.1	2.033	24	3.0	9.5	7.6	0.227	24	7.2	8.0	0.115	0.047	24	0.096	0.331	10.6	1.205	24	8.5	12.6	20.4	6.903	24	8	30
April	18.3	3.563	24	14.4	26.8	7.9	0.284	24	7.4	8.3	0.082	0.048	24	0.066	0.308	8.1	0.692	24	6.5	9.2	51.4	6.213	24	42	64
July	29.6	1.504	18	27.9	32.7	7.5	0.504	18	7.0	8.7	0.153	0.008	18	0.140	0.170	5.8	2.238	18	2.1	9.8	35.1	21.101	18	8	84
October	14.0	0.624	56	12.5	15.3	7.3	0.099	56	7.1	7.5	0.110	0.087	56	0.075	0.731	8.2	1.057	56	6.4	10.7	46.6	10.226	56	16	73
February	5.4	1.668	56	3.0	9.5	7.8	0.228	56	7.2	8.2	0.124	0.034	56	0.096	0.331	9.8	1.070	56	8.5	12.6	17.7	11.456	56	4	49
April	17.4	2.824	56	14.4	26.8	7.6	0.445	56	6.8	8.3	0.089	0.062	56	0.066	0.480	8.1	0.800	56	6.0	10.3	48.7	10.006	56	30	84
July	29.6	1.284	50	27.5	32.7	7.5	0.341	50	7.0	8.7	0.171	0.029	50	0.140	0.340	6.0	1.434	50	2.1	9.8	33.3	17.918	50	4	84
Day	17.3	8.999	112	4.7	32.7	7.5	0.340	112	6.8	8.7	0.130	0.033	112	0.066	0.731	8.4	1.677	112	4.3	12.6	36.3	19.230	112	4	84
Night	15.1	8.267	106	3.0	30.0	7.6	0.351	106	6.8	8.3	0.115	0.037	106	0.068	0.200	7.7	1.732	106	2.1	10.3	37.0	16.118	106	4	84
Max Flood	15.6	8.298	106	4.3	30.0	7.6	0.334	106	6.8	8.3	0.124	0.074	106	0.066	0.731	8.4	1.399	106	5.3	12.3	36.9	18.411	106	4	84
Max Ebb	16.9	9.059	112	3.0	32.7	7.5	0.353	112	6.8	8.7	0.121	0.056	112	0.066	0.480	7.8	1.967	112	2.1	12.6	36.4	17.232	112	4	84
Station 1	16.2	9.132	32	3.4	31.0	7.5	0.270	32	7.0	7.9	0.143	0.082	32	0.073	0.480	7.9	1.352	32	5.4	9.8	35.1	16.231	32	4	[illegible]
Station 2	16.9	8.958	32	4.0	32.0	7.5	0.382	32	6.8	8.3	0.123	0.037	32	0.071	0.200	7.7	1.460	32	4.8	10.2	38.1	14.620	32	4	61
Station 3	16.2	9.070	32	4.2	31.0	7.6	0.327	32	6.8	8.2	0.124	0.038	32	0.073	0.190	7.8	1.300	32	5.3	10.3	35.2	21.314	32	4	84
Station 4	16.2	8.827	32	4.4	31.0	7.5	0.319	32	6.9	8.1	0.124	0.039	32	0.073	0.182	7.9	1.209	32	5.2	9.9	30.0	16.422	32	4	51
Station 5	16.2	8.745	30	3.0	31.0	7.5	0.297	30	7.0	8.1	0.123	0.118	[illegible]	[illegible]	0.731	8.3	2.308	30	[illegible]	12.3	38.5	[illegible]	30	12	73
Station 6	16.2	8.539	30	3.2	30.5	7.5	0.391	30	7.1	8.3	0.100	[illegible]	[illegible]	[illegible]	0.160	8.2	2.534	30	[illegible]	12.6	39.2	[illegible]	30	8	68
Station 7	15.9	8.393	30	4.7	32.7	7.7	0.408	30	7.1	8.7	0.120	0.063	30	0.068	0.331	8.9	1.355	30	5.2	11.7	40.7	19.509	30	8	84
Overall	16.3	8.702	218	3.0	32.7	7.5	0.345	218	6.8	8.7	0.123	0.065	218	0.066	0.731	8.1	1.735	218	2.1	12.6	36.7	17.776	218	4	84

Table 18

Total Number of Species, Specimens, and Biomass Collected

	Number of Species	Number of Specimens	Biomass (kg)
Grand Total	37	6319	144.1
October	25	2261	43.1
February	12	315	2.0
April	27	1034	49.7
July	33	2709	49.3
Windmill Point	31	4137	103.1
Herring Creek	34	2182	41.0
Day	33	2407	64.9
Night	35	3912	79.2
Marsh Interior	20	722	97.1
Interior Minnow Traps	5	165	0.7
Gut Fyke Net	20	566	93.7
Culvert Fyke Net	7	41	2.7
Marsh Exterior	35	5547	47.1
Exterior Minnow Traps	6	231	1.5
Seine	35	5316	45.6

Table 19

List of Families and Species with Total Number of Specimens and Biomass Collected

	Specimens	Biomass (g)
1. ANGUILLIDAE (freshwater eels)		
Anguilla rostrata, american eel	71	7,905.0
2. CLUPEIDAE (herrings)		
Alosa aestivalis, blueback herring	49	48.8
Alosa pseudoharengus, alewife	18	706.3
Brevoortia tyrannus, atlantic menhaden	135	908.2
Dorosoma cepedianum, gizzard shad	186	5,973.9
Dorosoma petenense, threadfin shad	532	1,228.6
3. ENGRAULIDAE (anchovies)		
Anchoa mitchilli, bay anchovy	117	91.7
4. UMBRIDAE (mudminnows)		
Umbra pygmaea, eastern mudminnow	1	3.2
5. CYPRINIDAE (minnows and carps)		
Cyprinus carpio, carp	27	57,800.0
Hybognathus regius, silvery minnow	112	938.1
Nocomis raneyi, bull chub	2	12.0
Notemigonus crysoleucas, golden shiner	57	1,303.1
Notropis analostanus, satinfin shiner	86	219.3
Notropis bifrenatus, bridle shiner	15	18.0
Notropis hudsonius, spottail shiner	2,094	10,616.7
6. CATOSTOMIDAE (suckers)		
Carpiodes cyprinus, quillback	4	19.9
Erimyzon oblongus, creek chubsucker	26	9,952.6
7. ICTALURIDAE (freshwater catfishes)		
Ictalurus catus, white catfish	2	146.5
Ictalurus nebulosus, brown bullhead	52	11,614.0
Ictalurus punctatus, channel catfish	78	6,226.7
Noturus gyrinus, tadpole madtom	2	6.4
8. CYPRINODONTIDAE (killifishes)		
Fundulus diaphanus, banded killifish	103	221.2
Fundulus heteroclitus, mummichog	192	605.1
9. ATHERINIDAE (silversides)		
Membras martinica, rough silverside	17	81.6
Menidia beryllina, tidewater silverside	282	433.5
10. PERCICHTHYIDAE (temperate basses)		
Morone americana, white perch	719	7,749.4
Morone saxatilis, striped bass	136	166.3
11. CENTRARCHIDAE (sunfishes)		
Lepomis gibbosus, pumpkinseed	51	1,193.5
Lepomis macrochirus, bluegill	43	1,496.4
Micropterus salmoides, largemouth bass	2	751.5
Pomoxis nigromaculatus, black crappie	37	8,584.1
12. PERCIDAE (perches)		
Etheostoma olmstedi, tessellated darter	89	194.5
Perca flavescens, yellow perch	4	297.2
13. SCIAENIDAE (drums)		
Leiostomus xanthurus, spot	942	6,489.7
Micropogon undulatus, atlantic croaker	2	1.0
14. BOTHIDAE (lefteye flounders)		
Paralichthys lethostigma, southern flounder	1	31.1
15. SOLEIDAE (soles)		
Trinectes maculatus, hogchoker	33	61.5
GRAND TOTAL	6,319	144,095.5

Table 20

Species and Number of Specimens Collected

Species	Total	Location: Windmill Point	Location: Herring Creek	Month: October	Month: February	Month: April	Month: July	Period: Day	Period: Night	Gear: Interior Minnow Trap	Gear: Gut Fyke Net	Gear: Culvert Fyke Net	Gear: Exterior Minnow Trap	Gear: Beach Seine
Anguilla rostrata	71	44	27	16	1	32	22	16	55	3	11	2	6	49
Alosa aestivalis	49	9	40	2		1	46	5	44					49
Alosa pseudoharengus	18	1	17			3	15	1	17					18
Brevoortia tyrannus	135	3	132				135	44	91					135
Dorosoma cepedianum	186	177	9	173		9	4	172	14		174	4		8
Dorosoma petenense	532	177	355	390		1	141	495	37		47			485
Anchoa mitchilli	117	36	81	30		86	1	90	27					117
Umbra pygmaea	1		1		1				1					1
Cyprinus carpio	27	26	1	5		14	8	18	9		19	1		7
Hybognathus regius	112	63	49	32	16	9	55	69	43		1			111
Nocomis raneyi	2	1	1			2		1	1					2
Notemigonus crysoleucas	57	4	53	6		30	21	19	38		5			52
Notropis analostanus	86	19	67	30	10	25	21	49	38					86
Notropis bifrenatus	15	3	12		1	3	11	5	10				1	14
Notropis hudsonius	2,094	1,544	550	1,188	199	380	327	714	1,380	42	152	21	211	1,668
Carpiodes cyprinus	4		4			4		1	3					4
Erimyzon oblongus	26		26	22		1	3	3	23		25			1
Ictalurus catus	2		2				2		2		2			
Ictalurus nebulosus	52	38	14	17	1	3	31	8	44	1	41	4		6
Ictalurus punctatus	78	17	61	51		5	22	22	56		6	1	2	69
Noturus gyrinus	2		2	1			1		2					2
Fundulus diaphanus	103	26	77	14	70	4	15	24	79	3	3			97
Fundulus heteroclitus	192	177	15	44	3	134	11	155	37	116	3	8		65
Membras martinica	17	17					17	17						17
Menidia beryllina	282	135	147	144	3	20	115	152	130		4			278
Morone americana	719	597	122	40		186	493	125	594		9			710
Morone saxatilis	136	9	127	2			134	81	55					136
Lepomis gibbosus	51	15	36	17		28	6	18	33		2			49
Lepomis macrochirus	43	4	39	18	3	5	17	13	25		23		10	10
Micropterus salmoides	2	1	1			1	1	1	1		1			1
Pomoxis nigromaculatus	37		37	4		26	7	12	25		37			
Etheostoma olmstedi	89	51	38	9	7	19	54	47	42				1	88
Perca flavescens	4	2	2			3	1	1	3		1			3
Leiostomus xanthurus	942	931	11				942	1	941					942
Micropogon undulatus	2	2		2					2					2
Paralichthys lethostigma	1	1					1	1						1
Trinectes maculatus	33	7	26	4			29	23	10					33
Total Specimens	6,319	4,137	2,182	2,261	315	1,034	2,709	2,407	3,912	165	566	41	231	5,316
Total Species	37	31	34	25	12	27	33	33	35	5	20	7	6	35

Table 21

Species and Biomass (g) Collected

Species	Total	Location: Windmill Point	Location: Herring Creek	Month: October	Month: February	Month: April	Month: July	Period: Day	Period: Night	Gear: Interior Minnow Trap	Gear: Out Fyke Net	Gear: Culvert Fyke Net	Gear: Exterior Minnow Trap	Gear: Beach Seine
Anguilla rostrata	7,905.0	5,799.9	2,105.1	3,305.2	244.3	2,524.8	1,830.7	1,051.7	6,853.3	80.7	3,192.5	329.0	328.5	3,974.3
Alosa aestivalis	48.8	12.4	36.4	3.5		1.9	43.4	6.4	42.4					48.8
Alosa pseudoharengus	706.3	3.8	702.5			653.0	53.3	248.0	458.3					706.3
Brevoortia tyrannus	908.2	12.0	896.2				908.2	340.2	568.0					908.2
Dorosoma cepedianum	5,973.9	4,194.3	1,779.6	905.8		4,083.0	985.1	2,175.0	3,798.9		5,664.4	271.7		37.8
Dorosoma petenense	1,228.6	318.8	909.8	568.9		6.1	653.6	1,069.2	159.4		105.5			1,123.1
Anchoa mitchilli	91.7	30.3	61.4	19.8		70.1	1.8	69.1	22.6					91.7
Umbra pygmaea	3.2		3.2		3.2				3.2					3.2
Cyprinus carpio	57,800.0	57,318.0	482.0	16,298.0		23,730.0	17,772.0	43,148.0	14,652.0		48,528.0	1,250.0		8,022.0
Hybognathus regius	938.1	556.9	381.2	366.6	201.1	87.6	282.8	457.5	480.6		15.8			922.3
Nocomis raneyi	12.0	7.2	4.8			12.0		7.2	4.8					12.0
Notemigonus crysoleucas	1,303.1	126.2	1,176.9	81.6		931.0	290.5	303.1	1,000.0		68.6			1,234.5
Notropis analostanus	219.3	26.4	192.9	54.4	15.0	76.9	73.0	118.3	101.0					219.3
Notropis bifrenatus	18.0	3.7	14.3		0.7	3.0	14.3	5.2	12.8				1.2	16.8
Notropis hudsonius	10,616.7	8,106.8	2,510.0	6,169.9	1,132.0	2,373.2	941.7	3,488.2	7,128.6	228.8	890.5	101.2	1,139.5	8,256.8
Carpiodes cyprinus	19.9		19.9			19.9		3.4	16.5					19.9
Erimyzon oblongus	9,952.6		9,952.6	8,420.8		254.7	1,277.1	1,237.9	8,714.7		9,697.9			254.7
Ictalurus catus	146.5		146.5				146.5		146.5		146.5			
Ictalurus nebulosus	11,614.0	9,230.3	2,383.7	1,716.0	219.2	694.9	8,983.9	1,317.0	10,297.0	4.3	10,843.9	274.1		491.7
Ictalurus punctatus	6,226.7	3,502.7	2,724.0	1,739.7		2,972.1	1,514.9	1,630.8	4,595.9		2,746.8	385.0	7.1	3,087.8
Noturus gyrinus	6.4		6.4	1.7			4.7		6.4					6.4
Fundulus diaphanus	221.2	61.4	159.8	34.3	136.0	13.7	37.2	46.5	174.7	6.8	8.3			206.1
Fundulus heteroclitus	605.1	571.8	33.3	109.0	6.8	452.1	37.2	507.0	98.1	377.4	13.9	42.3		171.5
Membras martinica	81.6	81.6					81.6	81.6						81.6
Menidia beryllina	433.5	185.5	248.0	240.2	3.9	36.8	152.6	223.3	210.2		6.8			426.7
Morone americana	7,749.4	5,460.2	2,289.2	1,235.8		4,389.9	2,123.7	2,108.9	5,640.5		767.6			6,981.8
Morone saxatilis	166.3	10.4	155.9	9.7			156.6	99.9	66.4					166.3
Lepomis gibbosus	1,193.5	274.3	919.2	355.9		666.3	155.4	338.0	855.5		44.2			1,149.3
Lepomis macrochirus	1,496.4	73.0	1,423.4	503.7	3.3	139.9	695.0	676.0	820.4		1,375.9		3.2	117.3
Micropterus salmoides	751.5	700.0	51.5			51.5	700.0	700.0	51.5		700.0			51.5
Pomoxis nigromaculatus	8,584.1		8,584.1	864.6		5,279.5	2,440.0	3,222.5	5,361.6		8,584.1			
Etheostoma olmstedi	194.5	73.8	120.7	29.8	26.9	76.2	61.6	120.7	73.8				4.1	190.4
Perca flavescens	297.2	23.2	274.0			37.2	260.0	15.2	282.0		260.0			37.2
Leiostomus xanthurus	6,489.7	6,264.2	225.5				6,489.7	3.3	6,486.4					6,489.7
Micropogon undulatus	1.0	1.0		1.0					1.0					1.0
Paralichthys lethostigma	31.1	31.1					31.1	31.1						31.1
Trinectes maculatus	61.5	13.8	47.7	2.4			59.1	44.0	17.5					61.5

Table 22

Importance Ranking of Species

Species	Specimens Rank	Biomass Rank	Appearance Rank	Sum of Ranks	Overall Importance Rank
Anguilla rostrata	16	6	2	24	3
Alosa aestivalis	20	30	21.5	71.5	26
Alosa pseudoharengus	26	18	24.5	68.5	24
Brevoortia tyrannus	9	16	23	48	19
Dorosoma cepedianum	7	10	17	34	7.5
Dorosoma petenense	4	13	12	29	4.5
Anchoa mitchilli	10	27	14.5	51.5	20
Umbra pygmaea	36.5	36	35.5	108	37
Cyprinus carpio	24	1	21.5	46.5	18
Hybognathus regius	11	15	8.5	34.5	9.5
Nocomis raneyi	33	34	31	98	33
Notemigonus crysoleucas	17	12	14.5	43.5	14
Notropis analostanus	14	23	6	43	13
Notropis bifrenatus	28	33	19	80	28
Notropis hudsonius	1	3	1	5	1
Carpiodes cyprinus	29.5	32	31	92.5	31
Erimyzon oblongus	25	4	26.5	55.5	23
Ictalurus catus	33	26	35.5	94.5	32
Ictalurus nebulosus	18	2	16	36	11
Ictalurus punctatus	15	9	10	34	7.5
Noturus gyrinus	33	35	31	99	34
Fundulus diaphanus	12	22	8.5	42.5	12
Fundulus heteroclitus	6	19	4	29	4.5
Membras martinica	27	28	31	86	30
Menidia beryllina	5	20	5	30	6
Morone americana	3	7	3	13	2
Morone saxatilis	8	25	19	52	21
Lepomis gibbosus	19	14	11	44	15.5

(continued)

Table 22 (Concluded)

Species	Specimens Rank	Biomass Rank	Appearance Rank	Sum of Ranks	Overall Importance Rank
Lepomis macrochirus	21	11	13	45	17
Micropterus salmoides	33	17	31	81	29
Pomoxis nigromaculatus	22	5	26.5	53.5	22
Etheostoma olmstedi	13	24	7	44	15.5
Perca flavescens	29.5	21	28	78.5	27
Leiostomus xanthurus	2	8	24.5	34.5	9.5
Micropogon undulatus	33	37	35.5	105.5	36
Paralichthys lethostigma	36.5	31	35.5	103	35
Trinectes maculatus	23	29	19	71	25

Table 23

Species and Number of Specimens Collected in the Vicinity of the Study Area

Species	Present Study: Windmill Point	Present Study: Herring Creek	VIMS Fall Surveys (Trawl), River Miles [illegible]: 1976	River Miles: 1975	River Miles: 1974	Herring Creek: 1976	Herring Creek: 1975	VIMS Summer Survey (Seine) River Miles 50 to 60: 1974
Elops saurus								24
Anguilla rostrata	44	27		37				20
Alosa aestivalis	9	40	497	103,993	4,695		3,097	3
Alosa pseudoharengus	1	17		70	135		2	12
Alosa sapidissima				19	136			1
Brevoortia tyrannus	3	132	18	9	4	1		5
Dorosoma cepedianum	177	9	4	10	7	1	1	25
Dorosoma petenense	177	355	5,201	79	1,307	5	5	295
Anchoa mitchilli	36	81	10,537	2	899	6		50
Umbra pygmaea		1						
Cyprinus carpio	26	1						3
Hybognathus regius	63	49		20			2	29
Nocomis raneyi	1	1					1	13
Notemigonus crysoleucas	4	53	1		4		2	292
Notropis analostanus	19	67		1	1			336
Notropis hudsonius	1,544	550	21	23	1,135		26	2,942
Notropis bifrenatus	3	12						36
Carpiodes cyprinus		4						13
Erimyzon oblongus		26						3
Hypentelium nigricans								1
Moxostoma macrolepidotum								4
Ictalurus catus		2		131	5			1
Ictalurus nebulosus	38	14		35				2
Ictalurus punctatus	17	61		203	1			410
Noturus gyrinus		2						
Fundulus diaphanus	26	77						383
Fundulus heteroclitus	177	15						1
Membras martinica	17							
Menidia beryllina	135	147	15	22	2		2	114
Menidia menidia					1			
Morone americana	597	122	7	6	1			66
Morone saxatilis	9	127	3	2				
Lepomis auritus								2
Lepomis gibbosus	15	36		1				86
Lepomis macrochirus	4	39						45
Micropterus dolomieui								1
Micropterus salmoides	1	1						
Pomoxis nigromaculatus		37						
Perca flavescens	2	2						9
Etheostoma olmstedi	51	38		3				34
Leiostomus xanthurus	931	11	2					
Micropogon undulatus	2							
Paralichthys lethostigma	1							
Trinectes maculatus	7	26						
Total Specimens	4,137	2,182	16,306	104,657	8,303	13	3,138	5,261
Total Species	31	34	11	19	15	4	9	33

Note: Data sources, present study and Virginia Institute of Marine Science fall and summer surveys.

Table 24

Comparison of Nektonic and Benthic Community Structure by Season, Site, and Station

	Nekton								Benthos							
	Season				Site		Station		Season				Site		Station	
	Fall	Winter	Spring	Summer	Windmill Point	Herring Creek	Marsh Interior	Marsh Exterior	Fall	Winter	Spring	Summer	Windmill Point	Herring Creek	Marsh Interior	Marsh Exterior
Species	8.20	2.40	8.50	11.20	6.60	8.60	4.20	8.70	5.20	5.30	4.30	7.50	4.50	6.60	6.80	4.90
Specimens	124.70	18.20	56.40	167.90	117.10	66.50	35.10	110.70	40.10	28.40	47.40	53.20	48.70	35.90	68.40	29.[illegible]
Species Diversity	1.30	0.60	1.48	1.60	1.03	1.45	0.92	1.35	1.58	1.55	1.50	2.26	1.38	2.07	2.01	1.58
Species Evenness	0.65	0.52	0.72	0.71	0.57	0.73	0.67	0.64	0.66	0.68	0.66	0.80	0.63	0.76	0.76	0.67
Species Richness	1.64	0.70	1.96	2.24	1.34	1.94	1.23	1.77	1.28	1.27	1.05	1.79	1.00	1.70	1.58	1.23

Note: Data are mean values for each category. Nekton data based upon fyke net and beach seine samples; benthic data from stations E4, E6, E7, R3, R4, and R5. See Part II: Aquatic Biology--Benthos.

Table 25

Summary Data of Feeding Habits Analysis of *Notropis hudsonius*

Major Food Category	Overall Number	Overall Number per Stomach	Overall Percent Total	October Number	October Number per Stomach	October Percent Total	February Number	February Number per Stomach	February Percent Total	April Number	April Number per Stomach	April Percent Total	July Number	July Number per Stomach	July Percent Total
Mollusca	1300	1.268	27.3	717	1.545	29.3	22	0.244	4.9	526	2.447	32.8	35	0.137	13.6
Crustacea	1177	1.148	24.8	761	1.640	31.1	290	3.222	64.7	30	0.140	1.9	96	0.375	37.2
Insecta	946	0.923	19.9	191	0.412	7.8	109	1.211	24.3	546	2.540	34.1	100	0.391	38.8
Fish Eggs	76	0.074	1.6	0	0	0	0	0	0	75	0.349	4.7	1	0.004	0.4
Plant Material	1166	1.138	24.5	764	1.647	31.2	5	0.056	1.1	381	1.772	23.8	16	0.062	6.2
Other	90	0.088	1.9	14	0.030	0.6	22	0.244	4.9	44	0.205	2.7	10	0.039	3.9
Total	4755	4.639	100.0	2447	5.274	100.0	448	4.978	99.9	1602	7.451	100.0	258	1.008	100.1
Number of Stomachs Examined		1025			464			90			215			256	

(Continued)

Table 25 (Concluded)

Major Food Category	Location						Period					
	Windmill Point			Herring Creek			Day			Night		
	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	800	1.297	35.9	500	1.225	19.8	800	1.653	31.1	500	0.924	22.9
Crustacea	329	0.533	14.8	848	2.078	33.6	677	1.399	26.3	500	0.924	22.9
Insecta	210	0.340	9.4	736	1.804	29.1	651	1.345	25.3	295	0.545	13.5
Fish Eggs	37	0.060	1.7	39	0.096	1.5	59	0.122	2.3	17	0.031	0.8
Plant Material	818	1.326	36.7	348	0.853	13.8	349	0.721	13.6	817	1.510	37.4
Other	34	0.055	1.5	56	0.137	2.2	35	0.072	1.4	55	0.102	2.5
Total	2228	3.611	100.0	2527	6.194	100.0	2571	5.312	100.0	2184	4.037	100.0
Number of Stomachs Examined		617			408			484			541	

Table 26

Summary Data of Feeding Habits Analysis of *Erimyzon oblongus*

Major Food Category	Overall			Month: October			February			April			July		
	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Cladocera	613	23.58	25.50	521	23.68	31.65	0	-	-	5	5.00	6.41	87	29.00	12.79
Ostracoda	1282	49.31	53.33	702	31.91	42.65	0	-	-	20	20.00	25.64	560	186.67	82.35
Copepoda	449	17.27	18.68	395	17.95	24.00	0	-	-	37	37.00	47.44	17	5.67	2.50
Insecta	22	.85	.92	15	.68	.91	0	-	-	7	7.00	8.97	0	-	-
Other	38	1.46	1.58	13	.59	.79	0	-	-	9	9.00	11.54	16	5.33	2.35
Total	2404	92.47	100.01	1646	74.81	100.00	-	-	-	78	78.00	100.00	680	226.67	99.99
Number of Stomachs Examined		26			22			0			1			3	

Table 27

Summary Data of Feeding Habits Analysis of *Ictalurus punctatus*

Major Food Category	Overall			October			February			April			July		
	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	27	.34	1.14	3	.06	.32	0	-	-	0	-	-	24	1.09	1.86
Crustacea	573	7.25	24.27	7	.13	.76	0	-	-	0	-	-	566	25.73	43.98
Insecta	1442	18.25	61.07	778	15.00	84.47	0	-	-	29	5.80	.19	635	28.86	49.34
Fish	11	.14	.46	11	.21	1.19	0	-	-	0	-	-	0	-	-
Plant Material	70	.89	3.00	20	.38	2.17	0	-	-	0	-	-	50	2.27	3.88
Other	238	3.01	10.08	102	1.96	11.07	0	-	-	124	24.80	.81	12	.54	.93
Total	2361	29.88	100.02	921	17.71	99.98	0	-	-	153	30.60	100.00	1287	58.50	99.99
Number of Stomachs Examined		79			52			0			5			22	

(Continued)

Table 27 (Concluded)

Major Food Category	Location						Period					
	Windmill Point			Herring Creek			Day			Night		
	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	21	1.24	3.11	6	.10	.35	19	.83	1.77	8	.14	.62
Crustacea	562	33.06	83.26	11	.18	.65	565	24.56	52.56	8	.14	.62
Insecta	38	2.24	5.63	1404	22.64	83.27	403	17.52	37.49	1039	18.55	80.79
Fish	0	-	-	11	.18	.65	8	.35	.74	3	.05	.23
Plant Material	52	3.06	7.70	18	.29	1.07	64	2.78	5.95	6	.11	.46
Other	2	.12	.30	236	3.81	14.00	16	.70	1.49	222	3.96	17.26
Total	675	39.70	100.0	1686	27.19	99.99	1075	46.74	100.0	1286	22.96	99.99
Number of Stomachs Examined		17			62			23			56	

Table 28

Summary Data of Feeding Habits Analysis of *Fundulus heteroclitus*

Major Food Category	Overall			October			February			April			July		
	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	20	.14	3.47	12	.27	26.09	0	-	-	0	-	-	8	.73	8.99
Crustacea	374	2.56	64.82	3	.07	6.52	3	1.00	60	366	4.16	83.75	2	.18	2.25
Insecta	95	.65	16.46	21	.48	45.65	2	.67	40	10	.11	2.29	62	5.64	69.66
Fish Eggs	76	.52	13.17	0	-	-	0	-	-	61	.69	13.96	15	1.36	16.85
Plant Material	5	.03	.87	4	.09	8.70	0	-	-	0	-	-	1	.09	1.12
Other	7	.05	1.21	6	.14	13.04	0	-	-	0	-	-	1	.09	1.12
Total	577	3.95	100.00	46	1.05	100.00	5	1.67	100	437	4.96	100.00	89	8.09	99.99
Number of Stomachs Examined		146			44			3			88			11	

(Continued)

Table 28 (Concluded)

Major Food Category	Location						Period					
	Windmill Point			Herring Creek			Day			Night		
	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	20	.15	4.50	0	-	-	11	.10	2.34	9	.25	8.49
Crustacea	340	2.56	76.58	34	2.62	25.56	337	3.06	71.55	37	1.03	34.91
Insecta	28	.21	6.31	67	5.15	50.38	76	.69	16.14	19	.53	17.92
Fish Eggs	44	.33	9.91	32	2.46	24.06	36	.33	7.64	40	1.11	37.74
Plant Material	5	.04	1.13	0	-	-	5	.05	1.06	0	-	-
Other	7	.05	1.58	0	-	-	6	.05	1.27	1	.03	.94
Total	444	3.34	100.01	133	10.23	100.0	471	4.28	100.0	106	2.94	100.0
Number of Stomachs Examined		133			13			110			36	

Table 29

Summary Data of Feeding Habits Analysis of *Morone americana*

	Month														
	Overall			October			February			April			July		
Major Food Category	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	9	.03	.16	0	-	-	0	-	-	8	.06	.59	1	.01	.02
Crustacea	2895	8.75	51.81	45	1.12	20.74	0	-	-	435	3.51	32.32	2415	14.46	60.00
Insecta	2283	6.90	40.86	144	3.60	66.36	0	-	-	547	4.41	40.64	1592	9.53	39.55
Fish	129	.39	2.31	15	.38	6.91	0	-	-	103	.83	7.65	11	.07	.27
Plant Material	240	.73	4.29	0	-	-	0	-	-	239	1.93	17.76	1	.01	.02
Other	32	.10	.57	13	.32	5.99	0	-	-	14	.113	1.04	5	.03	.12
Total	5588	16.88	100.00	217	5.42	100.0	0	-	-	1346	10.85	100.0	4025	24.11	99.98
Number of Stomachs Examined		331			40			0			124			167	

(Continued)

Table 29 (Concluded)

	Location						Period					
	Windmill Point			Herring Creek			Day			Night		
Category	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total	Number	Number per Stomach	Percent Total
Mollusca	4	.02	.09	5	.04	.50	1	.01	.02	8	.04	.57
Crustacea	2730	12.88	59.53	165	1.39	16.47	2516	20.46	60.01	379	1.82	27.09
Insecta	1526	7.20	33.28	757	6.36	75.55	1591	12.94	37.98	692	3.33	49.46
Fish	103	.49	2.25	26	.22	2.59	39	.32	.93	90	.43	6.43
Plant Material	210	.99	4.58	30	.25	2.99	24	.20	.57	216	1.04	15.44
Other	13	.06	.28	19	.16	1.90	18	.15	.43	14	.07	1.00
Total	4586	21.63	100.01	1002	8.42	100.0	4189	34.06	99.94	1399	6.73	99.99
Number of Stomachs Examined		212			119			123			208	

Table 30

Taxa and Number of Organisms from Stomachs of Selected Nekton Species

Taxon	A	B	C	D	E	Total
Nematoda	5	12	94		5	116
Rotatoria			1			1
Pelecypoda	189				3	192
Corbicula manilensis	1101	6	22	1	6	1136
Pisidium sp.	2					2
Gastropoda	8					8
Physa sp.			1	19		20
Lymnaea sp.			4			4
Gyraulus sp.		2				2
Annelida		1				1
Oligochaeta						
Branchiura sowerbyi					1	1
Limnodrilus spp.		8			8	16
Nais spp.		1				1
Peloscolex multisetosus		1				1
Diplopoda			3			3
Arachnida	13	3	4			20
Thomisidae			1	1		2
Misumenops sp.				1		1
Callilepis sp.				1		1
Nopsides sp.				1		1
Araneida				2		2
Labidognatha			1			1
Agelena sp.			1			1
Pirata sp.			1			1
Lycosidae			1			1
Pardosa sp.			1			1

Note: A = *Notropis hudsonius*, B = *Erimyzon oblongus*, C = *Ictalurus punctatus*, D = *Fundulus heteroclitus*, E = *Morone americana*

(Continued)

Table 30 (Continued)

Taxon	A	B	C	D	E	Total
Oonopidae			1			1
Opilionidae			5			5
Acarina	9	2			3	14
Ixodidae				1		1
Arrenurus sp.	1					1
Euphthircaridae	1					1
Crustacea	80				4	84
Amphipoda		2	1		5	8
Gammarus fasciatus	1		4		7	12
Cladocera	145	160	1		387	693
Chydorus sp.					3	3
Alona sp.	18	428			4	450
Bosmina sp.	86	17		2	1588	1693
Leydigia sp.	32				45	77
Ilyocryptus sp.	8	5	1			14
Sida sp.	1		555		373	929
Daphnia sp.		2			1	3
Euryalona occidentalis		1				1
Ostracoda		25			1	26
Physocypria sp.	88	566	4	307	160	1125
Candona sp.	86	691	1	5	85	868
Copepoda	171	152			11	334
Cyclopoida	441	130	2	48	189	810
(Nauplius)		1				1
Calanoida				1	12	13
Harpacticoida	20	166		11	17	214
Decapoda			1		3	4
Insecta	113			1	44	158
Collembola			1			1
Thysanura						
Lepismatidae	2				1	3

(Continued)

Table 30 (Continued)

Taxon	A	B	C	D	E	Total
Ephemeroptera	1				1	2
Ephemeridae	4				2	6
Hexagenia sp.					5	5
Heptageniidae	1					1
Leptophlebiidae						
Paraleptophlebia sp.					2	2
Baetidae						
Ephemerella sp.			1		5	6
Odonata	1					1
Orthoptera			1			1
Tettigoniidae	1					1
Psocoptera						
Psocidae	2				7	9
Hemiptera	2		6		2	10
Corixidae					4	4
Trichocorixa sp.					8	8
Sigara sp.					1	1
Hesperocorixa sp.					1	1
Mesoveliidae						
Mesovelia mulsanti	3			1		4
Miridae	1					1
Pentatomidae			2			2
Homoptera	7		6			13
Membracidae	1		9	1		11
Cicadellidae	1		7			8
Cercopidae			1			1
Delphacidae	6		3	5		14
Psyllidae	1		9			10
Flatidae						
Anorminis sp.	1					1
Coleoptera	4		2	1		7

(Continued)

Table 30 (Continued)

Taxon	A	B	C	D	E	Total
Carabidae	1		4	1		6
Dytiscidae	1			1		2
Copelatus sp.			1			1
Hydrophilus undulatus			1			1
Polyphaga			1			1
Staphylinidae	1		1			2
Heteroceridae			2			2
Chilocorus stigma			4			4
Chrysomelidae	2		5			7
Crytocephalus sp.			1			1
Tricoptera			5			5
Hydroptilidae			1			1
Lepidoptera			1			1
Frenatae			1			1
Pyralidae			1			1
Diptera	17		4	1		22
Nematocera					1	1
Tachinidae				1		1
Tipulidae	34		12	6	29	81
Culicidae					8	8
Tabanidae			1	2		3
Chrysops sp.			2			2
Syrphidae			1			1
Muscidae			1	1		2
Cecidomyiidae				1		1
Chironomidae	344	15	772	1	1504	2636
Chironomus sp.	109		106	2	97	314
Cryptochironomus sp.	16		16		55	87
Dicrotendipes sp.	2				1	3
Glyptotendipes sp.	2		3		1	6
Harnischia sp.					6	6
Polypedilum spp.	105	5	59		163	332

(Continued)

Table 30 (Continued)

Taxon	A	B	C	D	E	Total
Procladius sp.	6		3		3	12
Tanytarsus sp.	20	1	343		43	407
Cricotopus sp.	1		1		4	6
Ceratopogonidae	2		3		1	6
Palpomyia sp.	76	1	11		249	337
Stilobezzia sp.					5	5
Johannsenenomyia sp.			1			1
Schizophora				1		1
Acalyptratae				1		1
Hymenoptera	18		13	2	1	34
Apocrita	2		1	60	19	82
Proctotrupidae	2					2
Ichneumonidae			1			1
Chalcididae	2		4	5		11
Trigonalidae			1			1
Formicidae	30				1	31
Myrmicinae	1		1			2
Vespidae			1			1
Zethinae			1			1
Apidae			1			1
Apis mellifera			1			1
Unidentifiable Insect Egg			1			1
Pisces			2		17	19
Anguillidae						
Anguilla rostrata					1	1
Clupeidae						
Dorosoma petenense			7			7
Dorosoma sp. (eggs)	28				56	84
Alosa aestivalis (eggs)					23	23
Alosa sp. (eggs)	2				19	21
Alosa sp.					1	1

(Continued)

Table 30 (Concluded)

Taxon	A	B	C	D	E	Total
Cyprinodontidae				1		1
Fundulus heteroclitus (egg)			124	11		135
Fundulus sp.					6	6
Atherinidae						
Menidia beryllina			2			2
Menidia beryllina (eggs)			1			1
Menidia sp. (eggs)	1					1
Percichthyidae						
Morone americana (eggs)			1		3	4
Engraulidae						
Anchoa sp. (eggs)	45					45
Cyprinidae						
Notropis hudsonius					1	1
Notropis sp.					2	2
Pisces eggs (unidentifiable)				64	15	79
Amphibia			1			1
Plant Seeds						
Alismataceae						
Sagittaria latifolia	707		51			758
Poaceae						
Panicum amarulum	43			5		48
Unidentifiable seeds and berrier	401		19		240	660
Unidentifiable plant material	15					15
Unidentifiable eggs	61					61
Total Number of Organisms	4755	2404	2361	577	5588	15,685
Total Number of Stomachs Examined	1025	26	79	146	331	1,607

[illegible]

[illegible]

[illegible]

Taxa	Windmill Point Fall	Winter	Spring	Summer	Total	Herring Creek Fall	Winter	Spring	Summer	Total
Phylum: Platyhelminthes										
Class: Turbellaria										
Hydrolimax grisea (Haldeman)							2			2
Cura foremanii (Girand)						1				1
Phylum: Nemertea										
Prostoma rubrum (Leidy)								17		17
Phylum: Mollusca										
Class: Pelecypoda										
Family: Corbiculidae	1				1	1				1
Corbicula manilensis (Phillippi)	307	2	6	138	453	59	23	29	33	144
Family: Sphaeriidae										
Sphaerium transversum (Say)							7		4	11
Pisidium sp.									3	3
Class: Gastropoda										
Physa sp.	1			3	4					
Lymnaea sp.									1	1
Ferrissia sp.						1			12	13
Class: Oligochaeta										
Tubifex sp.	1		3		4	271	1	1		273
Aulodrilus pigueti (Kowaleoski)						4			87	91
Branchiura sowerbyi (Beddard)	81	46	97	242	466		10		2	12
Ilyodrilus templetoni (Southern)	25	7	57	39	128	14	25	51	58	148
Limnodrilus spp.	642	141	403	724	1910	145	235	308	318	1006
Limnodrilus cervix (Brinkhurst)	50	10	157	49	266					
Limnodrilus hoffmeisteri (Claparede)	54	152	325	70	601	43	52	139	87	321
Limnodrilus udekemianus (Verrill)						1				1
Limnodrilus profundicola (Smith)								2		2
Peloscolex multisetosus (Brinkhurst)	2		2		4	5	47	12	8	72
Peloscolex freyi (Brinkhurst)	2			1	3			23	1	24
Family: Naidae	5				5	2				2
Nais spp.			22	2	24			18	1	19
Dero digitata (Muller)								5	10	15
Stylaria lacustris (Linnaeus)						2			1	3
Family: Enchytraeidae		2	2	2	6	1	5	151		157
Family: Lumberliculidae						5		1		6
Class: Hirudinea										
Helobdella elongata (Castle)						5	15		10	30
Helobdella stagnalis (Linnaeus)							3			3
Batracobdella phalera (Graf)						1				1
Class: Crustacea										
Order: Isopoda										
Asellus sp.						1	2			3
Order: Amphipoda										
Gammarus fasciatus (Say)						10	41	3	3	57
Class: Insecta										
Order: Ephemeroptera										
Hexagenia mingo (Walsh)						2	2			4
Caenis sp.			1		1	1	3	1	9	14
Order: Hemiptera										
Trichocorixa sp.	2				2	2				2
Order: Coleoptera							7	3		10
Family: Chrysomelidae								3		3
Order: Diptera										
Family: Dolichopodidae		5			5					
Family: Culicidae										
Chaoborus punctipennis (Say)						1				1
Family: Chironomidae										
Chironomid sp. 3								1		1
Chironomid sp. 6		1			1					
Ablabesmyia sp. (E. Roback)			1		1	2				2
Chironomus spp.	13	1	356	180	550	47	326	8	27	408
Coelotanypus scapularis (Loew)	33			32	65	28	43	5	40	116
Cryptochironomus spp.	2	1	2	7	12	10	38	3	36	87
Dicrotendipes nervosus				37	37		7		49	56
Glyptotendipes sp.		1			1	2	4		1	7
Harnischia sp.									6	6
Polypedilum spp.			3	133	136	2	1	1	22	26
Procladius bellus (Loew)				2	2	12		1	160	173
Pseudochironomus sp.			23	12	35	1	3	2	8	14
Stictochironomus devinctus (Say)				1	1		5			5
Cryptocladopelma sp.									4	4
Tanypus spp.	11		16	104	131	2	67	2	6	77
Pentaneurd sp.		2			2					
Tanytarsus sp.									11	11
Cricotopus sp.				1	1	1				1
Family: Ceratopogonidae										
Palpomyia sp.		1		1	2			1	1	2
TOTAL	1232	372	1476	1780	4860	685	974	791	1020	3470

Table 32

Floral Inventory of Experimental Site Taken December 1974

Scientific Name	Common Name
Marsh Community	
Amaranthus cannabinus (L.) J. D. Sauer	Water Hemp
Aneilema keisak Hassk.	
Aster subulatus Michx.	Saltmarsh Aster
Boehmeria cylindrica (L.) Sw.	False Nettle
Carex spp.	Sedge
Cephalanthus occidentalis L.	Buttonbush
Echinochloa crusgalli (L.) Beauv.	Barnyard Grass
Hibiscus moscheutos L.	Swamp Rose Mallow
Impatiens capensis Meerb.	Jewelweed
Juncus spp.	Rush
Justicia americana (L.) Vahl	Water Willow
Ludwigia decurrens Walt.	Primrose Willow
Ludwigia palustris (L.) Ell.	Water Purslane
Ludwigia uruguayensis (Lam.) Hara	Primrose Willow
Peltandra virginica (L.) Kunth	Arrow Arum
Polygonum punctatum Ell.	Water Smartweed
Polygonum sagittatum L.	Arrow-leaved Tearthumb
Pontederia cordata L.	Pickerelweed
Rorippa islandica (Oeder) Borbás	Yellow Cress
Rumex verticillatus L.	Water Dock
Sagittaria falcata Pursh	Arrowhead
Scirpus americanus Pers.	Threesquare
Scirpus cyperinus (L.) Kunth	Woolgrass
Scirpus validus Vahl	Soft-stem Bulrush
Typha angustifolia L.	Narrow-leaved Cattail
Typha latifolia L.	Common Cattail
Vernonia noveboracensis (L.) Michx.	Ironweed

(Continued)

Table 32 (Concluded)

Scientific Name	Common Name
Upland Community	
Agalinis purpurea (L.) Penn.	Gerardia
Alnus serrulata (Ait.) Willd.	Common Alder
Apios americana Medic.	Groundnut
Aster dumosus L.	Aster
Aster puniceus L.	Aster
Aster vimineus Lam.	Aster
Cassia nictitans L.	Wild Sensitive Plant
Celtis occidentalis L.	Hackberry
Chenopodium ambrosioides L.	Mexican Tea
Clematis virginiana L.	Virgin's Bower
Cornus amomum Mill.	Dogwood
Cynanchum laeve (Michx.) Pers.	Sandvine
Cyperus esculentus L.	Nut Grass
Cyperus strigosus L.	Umbrella Sedge
Eupatorium capillifolium (Lam.) Small	Dog Fennel
Fraxinus americana L.	White Ash
Lespedeza cuneata (Dumont) G. Don	Bush Clover
Mikania scandens (L.) Willd.	Climbing Hempweed
Panicum virgatum L.	Switchgrass
Polygonum lapathifolium L.	Dock-leaved Smartweed
Populus deltoides Marsh.	Cottonwood
Robinia pseudo-acacia L.	Black Locust
Rumex crispus L.	Yellow Dock
Rumex obtusifolius L.	Bitter Dock
Salix nigra L.	Black Willow
Solanum carolinense L.	Horse Nettle
Taxodium distichum (L.) Richard	Bald Cypress
Xanthium strumarium L.	Cocklebur

Table 33

Floral Inventory of Experimental Site Taken July 1975: New Species Only

Scientific Name	Common Name
Dredged Material	
Alisma subcordatum Raf.	Water Plantain
Ammannia coccinea Rottb.	Scarlet Ammannia
Echinochloa crus-pavonis (H.B.K.) Schult.	
Eleocharis obtusa (Willd.) Schultes	Spikerush
Eragrostis hypnoides (Lam.) BSP.	Love Grass
Erianthus sp.	Plume Grass
Galium trifidum L.	Bedstraw
Gratiola virginiana L.	Hedge Hyssop
Hypericum mutilum L.	St. John's-wort
Hypericum sp.	St. John's-wort
Juncus acuminatus Michx.	Rush
Juncus tenuis Willd.	Path Rush
Leersia oryzoides (L.) Sw.	Rice Cutgrass
Lindernia dubia (L.) Penn.	False Pimpernel
Mimulus ringens L.	Monkey Flower
Panicum dichotomiflorum Michx.	Panic Grass
Paspalum dissectum L.	
Paspalum fluitans (Ell.) Kunth	
Paspalum sp.	
Pilea pumila (L.) Gray	Clearweed
Rotala ramosior (L.) Koehne	Toothcup
Sagittaria sp.	Arrowhead
Dike and Original Island	
Acalypha rhomboidea Raf.	Three-seeded Mercury
Acer rubrum L.	Red Maple
Alopecurus carolinianus Walt.	Foxtail Grass
Amaranthus hybridus L.	Amaranth
Amaranthus spinosus L.	Thorny Amaranth
Artemisia annua L.	Wormwood

(Continued)

Table 33 (Concluded)

Scientific Name	Common Name
Bidens aristosa (Michx.) Britt.	Beggar Ticks
Bidens frondosa L.	Beggar Ticks
**Dactylis glomerata* L.	Orchard Grass
Datura stramonium L.	Jimson Weed
Digitaria sanguinalis (L.) Scop.	Crabgrass
Eclipta alba (L.) Hassk.	Yerba-de-Tago
Eleusine indica (L.) Gaertn.	Goosegrass
**Festuca elatior* L.	Fescue
Fimbristylis spp.	
Helenium autumnale L.	Sneezeweed
Liriodendron tulipifera L.	Tulip Tree
Lolium sp.	Rye Grass
Mollugo verticillata L.	Carpetweed
Oenothera sp.	Evening Primrose
Oxalis sp.	Wood Sorrel
**Panicum amarulum* Hitchc. & Chase	Beachgrass
Phytolacca americana L.	Poke
Planera aquatica Walt. ex J.F. Gmel.	Planer-tree
Platanus occidentalis L.	Sycamore
Potentilla norvegica L.	Cinquefoil
Ranunculus sp.	Buttercup
Rumex conglomeratus Murr.	Clustered Dock
Salix spp.	Willow
Solanum americanum Mill.	Nightshade
Solidago altissima L.	Goldenrod
**Spartina alterniflora* Loisel.	Smooth Cordgrass
**Spartina cynosuroides* (L.) Roth.	Big Cordgrass
**Trifolium repens* L.	White Clover
Veronica anagallis-aquatica L.	Water Speedwell
Viola sp.	Violet
Zea mays L.	Corn

*Species artificially planted.

Table 34

Floral Inventory of Experimental Site Taken July-November 1976:

New Species Only

Scientific Name	Common Name
Dredged Material	
Aeschynomene virginica (L.) BSP.	Sensitive-joint Vetch
Bidens laevis (L.) BSP.	Beggar Ticks
Carex frankii Kunth	Sedge
Carex tribuloides Wahlenb.	Sedge
Cuscuta campestris Yuncker	Dodder
Echinochloa walteri (Pursh) Nash	Walter's Millet
Galium tinctorium L.	Bedstraw
Juncus effusus L.	Soft Rush
Kosteletskya virginica (L.) Presl	Seashore Mallow
Polygonum arifolium L.	Halberd-leaved Tearthumb
Sagittaria latifolia Willd.	Arrowhead
Strophostyles helvola (L.) Ell.	Wild Bean
Dike and Original Island	
Andropogon virginicus L.	Broom Sedge
Aster simplex Willd.	Aster
Bidens cernua L.	Beggar Ticks
Chenopodium album L.	Lamb's Quarters
Craetaegus sp.	Hawthorn
Cyperus erythrorhizos Muhl.	Umbrella Sedge
Diodia virginiana L.	Buttonweed
Eragrostis refracta (Muhl.) Scribn.	Love Grass
Erechtites hieracifolia (L.) Raf.	Fireweed
Erigeron canadensis L.	Horseweed
Eupatorium serotinum Michx.	Thoroughwort
Euphorbia maculata L.	Eyebane
Fragaria virginiana Duchesne	Strawberry
Gnaphalium obtusifolium L.	Catfoot

(Continued)

Table 34 (Concluded)

Scientific Name	Common Name
Humulus japonicus Sieb. & Zucc.	Japanese Hops
Lycopus americanus Muhl. ex Bart.	Bugleweed
Lycopus virginicus L.	Bugleweed
Oenothera biennis L.	Evening Primrose
Penthorum sedoides L.	Ditch Stonecrop
Polygonum cespitosum Blume	Tufted Smartweed
Polygonum pensylvanicum L.	Pinkweed
Ranunculus repens L.	Creeping Buttercup
Rosa palustris Marsh.	Swamp Rose
Sacciolepis striata (L.) Nash	
Saponaria officinalis L.	Soapwort
Scirpus atrovirens Willd.	Bulrush
Scutellaria lateriflora L.	Mad-dog Skullcap
Setaria viridis (L.) Beauv.	Bristly Foxtail
Sicyos angulatus L.	Bur Cucumber
Solidago sempervirens L.	Seaside Goldenrod
Ulmus americana L.	American Elm
Ulmus rubra Muhl.	Slippery Elm

Table 35

Inventory of Experimental Site Taken May-June 1977:

New Species Only

Scientific Name	Common Name
Dredged Material	
Carex albolutescens Schw.	Sedge
Carex crinita Lam.	Sedge
Carex lurida Wahlenb.	Sedge
Carex scoparia Schkuhr	Sedge
Carex stipata Muhl.	Sedge
Carex vulpinoidea Michx.	Sedge
Circuta maculata L.	Water Hemlock
Galium obtusum Bigel.	Bedstraw
Iris pseudacorus L.	Yellow Iris
Panicum spretum Schultes	Panic Grass
Ptilimnium capillaceum (Michx.) Raf.	Mock Bishop-weed
Scirpus fluviatilis (Torr.) Gray	River Bulrush
Sium suave Walt.	Water Parsnip
Zizaniopsis miliacea (Michx.) Döll & Aschers.	Southern Wild Rice
Dike and Original Island	
Ambrosia artemisiifolia L.	Common Ragweed
Asclepias syriaca L.	Milkweed
Baccharis halimifolia L.	Groundsel Tree
Calystegia sepium (L.) R. Brown	Bindweed
Erigeron annuus (L.) Pers.	Daisy Fleabane
Festuca octoflora Walt.	Fescue
Festuca ovina L.	Fescue
Gnaphalium purpureum L.	Purple Cudweed
Helianthus annuus L.	Common Sunflower
Hypochoeris radicata L.	Cat's-ear
Lactuca canadensis L.	Lettuce
Lactuca scariola L.	Prickly Lettuce
Lepidium virginicum L.	Pepperwort

(Continued)

Table 35 (Concluded)

Scientific Name	Common Name
Oenothera laciniata Hill	Sow Thistle
Pyrrhopappus carolinianus (Walt.) DC.	False Dandelion
Ranunculus sceleratus L.	Cursed Crowfoot
Scutellaria integrifolia L.	Skullcap
Sonchus asper (L.) Hill	Sow Thistle
Specularia perfoliata (L.) A. DC.	Venus' Looking-glass
Taraxacum officinale Weber	Common Dandelion
Trifolium campestre Schreb.	Low Hop Clover
Trifolium pratense L.	Red Clover
Verbena urticifolia L.	Vervain

Table 36

Floral Inventory of Experimental Site Taken July-September 1977: New Species Only

Scientific Name	Common Name
Dredged Material	
Bidens coronata (L.) Britt.	Beggar Ticks
Eleocharis fallax Weath.	Spikerush
Lobelia cardinalis L.	Cardinal Flower
Panicum agrostoides Spreng.	Panic Grass
Zizania aquatica L.	Wild Rice
Dike and Original Island	
Arthraxon hispidus (Thunb.) Makino	
Bidens polylepis Blake	Beggar Ticks
Carduus discolor (Muhl. ex Willd.) Nutt.	Thistle
Cenchrus longispinus (Hack.) Fern.	Sandbur
Commelina communis L.	Dayflower
Cyperus iria L.	Umbrella Sedge
Digitaria ischaemum (Schreb.) Schreb. ex. Muhl.	Smooth Crabgrass
Epilobium coloratum Biehler	Willow-herb
Eupatorium maculatum L.	Joe-pye-weed
Fimbristylis autumnalis (L.) R. & S.	
Hibiscus militaris Cav.	Halberd-leaved Rose Mallow
Ipomoea lacunosa L.	Morning Glory
Leptochloa uninervia (Presl) Hitchc. & Chase	Sprangletop
Lippia nodiflora (L.) Michx.	Fog-fruit
Sedum ternatum Michx.	Stonecrop
Solidago tenuifolia Pursh	Goldenrod
Vitis vulpina L.	Winter Grape

Table 37

Summary of Floral Inventories of Experimental Site Taken December 1974 to September 1977

Habitat	Increase in Species over Previous Inventory: Dec 1974	Jul 1975	Jul-Nov 1976	May-Jun 1977	Jul-Sep 1977	Total
Marsh or Dredged Material	27	22	12	14	5	80
Upland Dike and Original Island	28	*37	32	23	17	137
Total	55	59	44	37	22	217

*Includes six planted species.

Table 38

Mean Percent Cover for Plant Species Sampled at the Experimental Site, June-August 1977

Species	Mean Percent Cover								
	Arrowhead Zone			Beggar Ticks Zone			Panic Grass Zone		
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug
Beggar Ticks	8.53	1.20	7.67	67.53	45.33	55.80	0.07	0.33	0.67
Arrowhead	32.33	37.47	27.00	---	0.00	2.00	0.00	0.00	0.00
Panic Grass	0.00*	0.00	0.00	0.00	2.00	0.00	36.53	64.07	59.53
Pickerelweed	2.60	37.20	55.67	0.00	0.00	0.00	0.00	0.00	0.00
Jewelweed	0.00	0.00	0.00	25.73	0.80	2.80	0.60	0.27	---
Barnyard Grass	2.67	1.33	1.87	0.53	7.00	6.73	0.00	0.00	0.00
Rice Cutgrass	0.07	---	0.73	1.13	3.33	1.73	0.00	0.00	0.00
Water Smartweed	0.00	0.00	0.00	0.00	0.67	3.80	0.00	0.00	0.00
Water Hemp	0.00	0.00	0.00	---	5.00	2.60	0.00	0.00	0.00
Others	---**	---	---	0.27	0.73	3.33	2.67	2.13	7.93

* Negligible value.
** Species not sampled.

Table 39

Mean Percent Cover for Plant Species Sampled at the Reference Site, June-August 1977

Species	Mean Percent Cover					
	Low Marsh			High Marsh		
	Jun	Jul	Aug	Jun	Jul	Aug
Arrow Arum	50.40	39.00	23.33	45.00	23.88	2.53
Water Smartweed	0.13	6.07	4.27	0.00	0.00	0.07
Pickerelweed	6.13	13.47	5.87	2.07	0.00	0.20
Tearthumb	0.00*	0.00	0.00	0.67	2.50	10.93
Beggar Ticks	0.00	0.80	0.33	8.20	2.12	0.07
Water Hemp	0.00	0.67	1.00	0.07	0.25	0.13
Jewelweed	0.00	---**	1.53	36.33	15.38	12.67
Lizard's Tail	0.00	0.00	0.00	1.00	5.62	1.20
Others	2.73	2.40	0.53	0.07	---	2.80

* Negligible value.
** Species not sampled.

Table 40

Soils-Plant Relationships

Soil Type	Station*	Vegetation	Elevation** (cm)	% Silt/Clay	CEC (meq·100gDW^{-1})	NH_4^+ (µg·gDW^{-1})	PO_4^{-3}	Volatile Solids % DW
Sand	WP9	Willow/grasses	198	5.95	17.0	1.32	96.9	0.3
Sand	WP3	Panic grass	146	3.79	14.4	1.31	47.5	0.3
Sand	WP4	Mexican tea	137	3.34	16.0	1.98	47.5	0.3
Sandy loam	WP1	Mixed grasses	134	25.90	21.0	7.26	253.0	2.5
Sandy clay loam	WP6	Beggar ticks	134	38.62	30.5	24.30	741.0	3.3
Silty loam	WP2	Arrowhead-pickerelweed	107	84.14	43.2	74.5	1250.0	7.9
Silty loam	WP7	Arrowhead-pickerelweed	101	80.46	41.4	82.6	1075.0	9.9
Silty loam	WP5	Beggar ticks	98	76.81	33.9	16.8	790.0	7.5
Loam	WP8	Unvegetated mudflat	91	67.27	47.7	122.0	1210.0	10.2
Silty clay	DSPW	Arrow-arum	--	86.18	67.3	86.2	536.0	13.7
Silty clay	DSTy	Beggar ticks	--	77.11	64.5	16.2	928.0	20.9

* Soil sampling stations (see Part VI: Soils Analysis).
** Elevation above mean low water.

Table 41

Mean Density of Bird Species at the Windmill Point Experimental Site

	Birds per hectare								
	1976				1977				
Common Name	Late Spring (1)*	Early Summer (2)	Late Summer (3)	Fall (6)	Winter (2)	Early Spring (7)	Late Spring (5)	Early Summer (5)	Late Summer (6)
Double-crested cormorant							0.55		
Great blue heron	0.15	0.08	0.10	0.13	0.23	0.06	0.03	0.06	0.03
Green heron			0.05					0.15	0.15
Great egret			0.05			0.02			
Snowy egret							0.09		0.03
Black-crowned night heron				0.25	0.23	0.06			
Yellow-crowned night heron									0.03
Whistling swan					0.08				
Canada goose				23.7	2.88	7.74			
Snow goose				0.10					
Mallard	0.30	0.15	0.30	1.49	0.83	0.49	1.12	0.39	0.91
Black duck		0.08	0.20						0.15
Pintail					0.45				
Blue-winged teal				0.08		0.17			0.18
American wigeon							0.12		
Wood duck						0.02			

*Number of censuses

(Continued)

Table 41 (Continued)

Common Name	Birds per hectare								
	1976				1977				
	Late Spring (1)	Early Summer (2)	Late Summer (3)	Fall (6)	Winter (2)	Early Spring (7)	Late Spring (5)	Early Summer (5)	Late Summer (6)
Lesser scaup				0.03					
Common merganser							0.15		
Turkey vulture						0.02			0.18
Sharp-shinned hawk				0.08					
Red-tailed hawk				0.03					
Bald eagle			0.05	0.03			0.18	0.06	0.05
Osprey			0.05				0.03	0.06	0.03
Marsh hawk				0.05	0.08				
King rail				0.03		0.02		0.03	
Virginia rail					0.15		0.03		
Sora				0.73					
American coot				1.01	0.30	0.04			
Semipalmated plover	0.15		0.15	0.03			0.82		0.10
Killdeer	0.15	1.21	1.06	1.69		0.13		0.09	2.06
Black-bellied plover	1.67			0.03			0.18		0.18
Upland sandpiper									0.03
Ruddy turnstone							0.03		
Common snipe				0.25	0.91	3.38	0.15		

(Continued)

Table 41 (Continued)

Common Name	1976 Late Spring (1)	1976 Early Summer (2)	1976 Late Summer (3)	1976 Fall (6)	1977 Winter (2)	1977 Early Spring (7)	1977 Late Spring (5)	1977 Early Summer (5)	1977 Late Summer (6)
	Birds per hectare								
Spotted sandpiper		0.08	0.20	0.03			0.15	0.03	0.23
Greater yellowlegs		0.08					0.27		0.03
Lesser yellowlegs					0.08	0.30	0.27		0.08
Wilson's phalarope									0.03
Pectoral sandpiper						2.21	0.18		1.03
Red knot									0.03
Baird's sandpiper			0.05						
Dunlin							0.21		
Short-billed dowitcher									0.10
Least sandpiper									
Semipalmated sandpiper	0.91	0.15	2.17	0.18			1.18		0.28
Western sandpiper			1.11				1.15	0.03	4.51
Sanderling							0.06		0.03
Great black-backed gull				0.03	0.23	0.02			
Ring-billed gull	1.82	0.08	0.05	0.05	17.13	42.73	1.70	0.03	0.08
Herring gull					0.98	0.65	0.51		
Laughing gull	2.12	1.74	20.9	1.84	0.15	0.04	1.21	5.88	8.76
Bonaparte's gull	2.12					0.02			
Caspian tern		0.38	1.46	1.41		1.35	0.21	0.42	0.28

(Continued)

Table 41 (Continued)

Common Name	Birds per hectare								
	1976					1977			
	Late Spring (1)	Early Summer (2)	Late Summer (3)	Fall (6)	Winter (2)	Early Spring (7)	Late Spring (5)	Early Summer (5)	Late Summer (6)
Common tern		0.08					0.70		0.13
Forster's tern								0.06	0.03
Black skimmer			0.15						0.03
Rock dove									0.05
Mourning dove	0.30	0.23	0.25	0.28			0.12	0.09	0.43
Chimney swift							0.03		
Ruby-throated hummingbird			0.05						0.03
Belted kingfisher			0.05	0.05	0.08				
Common flicker				0.13			0.03	0.03	
Downy woodpecker							0.03		
Eastern kingbird			0.05						
Tree swallow				0.25		0.17	2.03	0.03	0.40
Rough-winged swallow							0.12		0.05
Bank swallow		0.23	0.15				0.06		6.38
Barn swallow	0.30	0.76	0.15	0.08		0.15	0.33	0.48	0.48
Purple martin		0.30					0.03	0.30	
Common crow		0.08	0.05			0.06	0.12	0.03	
Fish crow	0.30		1.81	0.05		0.24	0.45	0.42	0.78
Long-billed marsh wren				0.23	0.99	0.35	0.18	0.03	

(Continued)

Table 41 (Concluded)

Common Name	Birds per hectare								
	1976				1977				
	Late Spring (1)	Early Summer (2)	Late Summer (3)	Fall (6)	Winter (2)	Early Spring (7)	Late Spring (5)	Early Summer (5)	Late Summer (6)
Ruby-crowned kinglet				0.03					
Starling							0.03		
Yellow-rumped warbler				0.03					
Common yellowthroat				0.15					
Red-winged blackbird	0.15	1.67	13.89	18.65	1.67	3.79	3.27	3.15	24.51
Common grackle				0.03		0.65	1.21		0.03
American goldfinch			0.10	0.08	0.76				0.05
Savannah sparrow				0.45		0.11	0.12		
Sharp-tailed sparrow				0.08					
Field sparrow				0.05					
White-throated sparrow						0.04			
Swamp sparrow				1.99	7.05	3.70	0.15		
Song sparrow		0.15	0.20	2.52	5.38	0.89	0.64	0.24	0.04
Snow bunting				0.05					
Total	10.44	7.53	44.85	58.46	40.64	69.62	20.23	12.09	53.36

Table 42

Mean Density of Bird Species at the Herring Creek Reference Site

Common Name	Birds per hectare 1977 Winter (3)*	Early Spring (3)	Late Spring (2)	Early Summer (1)	Late Summer (3)
Great egret					0.11
Green heron				0.35	0.11
Black duck		0.23			
Wood duck			0.35		0.23
Common merganser		0.11			
Turkey vulture		0.11			
Marsh hawk	0.11				
Merlin		0.11			
Bobwhite	0.46				
Common snipe		0.11			
Ring-billed gull		0.11			
Yellow-billed cuckoo				0.69	0.46
Belted kingfisher		0.11			
Common flicker		0.11			
Red-bellied woodpecker			0.17		
Downy woodpecker	0.11				
Eastern kingbird			0.86	0.35	0.11
Unidentified flycatcher					0.11
Barn swallow					2.88
Bank swallow					2.88
Fish crow		0.23			
Common crow		0.11			
Carolina chickadee	0.11				
Long-billed marsh wren	0.11				

*Number of censuses

(Continued)

Table 42 (Concluded)

Common Name	Birds per hectare 1977 Winter (3)	Early Spring (3)	Late Spring (2)	Early Summer (1)	Late Summer (3)
American robin	0.11				
Brown thrasher		0.11			
Common yellowthroat			0.17		0.11
Red-winged blackbird	3.45	0.46	4.32	3.11	8.07
Common grackle				0.35	
Orchard oriole				0.35	
Indigo bunting			0.69		0.23
American goldfinch	2.19	0.11			
Cardinal	0.46	0.46	0.52		
Purple finch	0.23				
White-throated sparrow	14.07	1.26			
Swamp sparrow	9.11	2.42			
Song sparrow	5.65	2.31			
Total	36.17	8.47	7.08	5.20	15.30

Table 43

Mean Density of Birds at the James River Berm Site

	Birds per hectare							
	1976			1977				
Common Name	Early Summer (1)*	Late Summer (2)	Fall (5)	Winter (2)	Early Spring (2)	Late Spring (2)	Early Summer (1)	Late Summer (3)
Red-shouldered hawk				0.51				
Bobwhite				0.51	0.51			
American woodcock								0.34
Yellow-billed cuckoo						0.51	1.03	0.34
Barred owl		0.51	0.21					
Ruby-throated hummingbird			0.41			0.51		0.69
Common flicker			2.68	1.55				
Pileated woodpecker				0.51			2.06	0.34
Red-bellied woodpecker			0.41			0.51		
Yellow-bellied sapsucker			0.41	1.03				
Downy woodpecker		0.51		0.51			1.03	
Blue jay			3.30					
Fish crow	1.03	0.51	1.03			1.03		0.34
Carolina chickadee	3.09	1.03	1.65	2.57	1.03	1.03	2.06	0.34
Tufted titmouse		0.51		2.06		0.51	2.06	0.34
Winter wren			0.21					

*Number of censuses

(Continued)

Table 43 (Continued)

Common Name	Birds per hectare: 1976 Early Summer (1)	1976 Late Summer (2)	1976 Fall (5)	1977 Winter (2)	1977 Early Spring (2)	1977 Late Spring (2)	1977 Early Summer (1)	1977 Late Summer (3)
Carolina wren		0.51	2.47	1.03	1.03	1.03	1.03	1.71
Mockingbird				0.51				
Brown thrasher			0.82		0.51			
American robin			0.21					
Blue-gray gnatcatcher			0.21		0.51			
Ruby-crowned kinglet			0.21	0.51				
White-eyed vireo	1.03				0.51		3.09	2.75
Red-eyed vireo		0.51	0.21			0.51	1.03	0.69
Black-and-white warbler						0.51		
Yellow-rumped warbler			1.65					
Prothonotary warbler		0.51	0.21			0.51	1.03	
Northern parula							1.03	
Yellow-throated warbler							1.03	
Louisiana waterthrush			0.62					
Common yellowthroat			1.24					0.34
Kentucky warbler			0.21					
American redstart			0.21					
Red-winged blackbird	2.06		0.21			1.03		15.46

(Continued)

Table 43 (Concluded)

Common Name	1976 Early Summer (1)	1976 Late Summer (2)	1976 Fall (5)	1977 Winter (2)	1977 Early Spring (2)	1977 Late Spring (2)	1977 Early Summer (1)	1977 Late Summer (3)
	Birds per hectare							
Common grackle								72.16
Indigo bunting	1.03					2.06	2.06	0.34
Cardinal	1.03	1.03	1.65	7.22	4.12	2.06	5.15	1.72
Purple finch				1.03				
American goldfinch		0.51	0.21					
White-throated sparrow			2.47	4.64	10.31			
Swamp sparrow				1.55				
Song sparrow			0.41	1.03				
Total	9.27	6.14	23.53	26.77	18.53	11.81	23.69	97.90

Table 44

Community Structure Parameters, Windmill Point Experimental Site

Season/ Date	No. of Species	No. of Individuals	Diversity (H')	Evenness (J')	Species Richness
Late Spring					
5/18/76	12	68	2.98	0.83	2.61
Early Summer					
7/07/76	15	47	3.34	0.85	3.63
7/14/76	10	52	2.56	0.77	2.27
$\overline{X}$	12.5	49.5	2.95	0.81	2.95
Late Summer					
7/29/76	17	307	1.96	0.48	2.79
7/30/76	9	254	2.36	0.75	1.44
8/13/76	18	329	1.71	0.41	2.93
$\overline{X}$	14.7	296.7	2.01	0.54	2.39
Fall					
9/09/76	12	342	2.25	0.63	1.88
9/29/76	15	148	1.32	0.34	2.80
10/06/76	14	166	1.85	0.48	2.54
10/13/76	21	247	2.32	0.53	3.63
10/28/76	16	288	2.37	0.59	2.65
10/29/76	22	1126	1.52	0.34	2.99
$\overline{X}$	16.7	386.0	1.93	0.48	2.75
Winter					
11/16/76	21	201	3.46	0.79	3.77
2/11/77	13	348	1.87	0.50	2.05
$\overline{X}$	17.0	250.0	2.66	0.64	2.91
Early Spring					
3/03/77	10	238	1.38	0.42	1.64
3/29/77	8	172	2.39	0.80	1.35
3/29/77	12	1451	0.31	0.09	1.51
3/30/77	18	435	2.99	0.72	2.79

(Continued)

Table 44 (Concluded)

Season/ Date	No. of Species	No. of Individuals	Diversity (H')	Evenness (J')	Species Richness
4/13/77	12	62	2.91	0.81	2.66
4/13/77	12	419	2.05	0.57	1.82
4/14/77	15	453	2.57	0.67	2.12
$\overline{X}$	12.0	462.8	2.01	0.58	1.99
Late Spring					
4/27/77	22	147	3.70	0.83	4.21
4/28/77	28	172	4.05	0.84	5.24
5/19/77	17	108	3.54	0.87	3.41
5/20/77	15	177	3.31	0.85	2.70
5/26/77	15	56	3.11	0.81	3.24
$\overline{X}$	19.4	132.0	3.54	0.84	3.83
Early Summer					
6/02/77	12	216	1.44	0.40	2.04
6/16/77	6	54	1.69	0.66	1.25
6/23/77	11	41	2.62	0.76	2.69
6/27/77	13	43	2.76	0.74	3.19
7/11/77	12	46	2.96	0.83	2.87
$\overline{X}$	10.8	80.0	2.29	0.68	2.41
Late Summer					
7/26/77	13	92	2.50	0.68	2.65
7/26/77	24	886	1.63	0.36	3.38
7/27/77	12	426	1.60	0.45	1.82
8/10/77	18	250	3.09	0.74	3.07
8/29/77	17	249	2.75	0.67	2.89
8/30/77	14	199	2.36	0.62	2.45
$\overline{X}$	16.3	350.7	2.32	0.59	2.71
Grand Mean	14.6	230.6	2.52	0.68	2.73
SD	2.92	153.6	0.55	0.13	0.51

Table 45

Number of Winter Resident Bird Species at Windmill Point Experimental Site, Compared with Other Virginia-Maryland Census Areas*

Habitat	Location	Birds per hectare
Windmill Point Disposal Site	Prince George Co., Va.	3.79
Lagoon	Arlington Co., Va.	0.72
Mixed wooded habitat	Montgomery Co., Md.	0.93
Abandoned field	Prince George Co., Md.	3.28
Upland oak-hickory hardwood forest	Fairfax Co., Va.	1.91
Coastal disturbed floodplain	Gloucester Co., Va.	5.80

*Censuses are from American Birds, 29th Winter Bird-Population Study.

Table 46

Community Structure Parameters, Herring Creek Reference Site

Season/ Date	No. of Species	No. of Individuals	Diversity (H')	Evenness (J')	Species Richness
Winter					
1/13/77	9	74	2.22	0.70	1.86
1/25/77	8	170	2.10	0.70	1.36
2/23/77	5	70	1.91	0.82	0.94
$\overline{X}$	7.3	104.7	2.08	0.74	1.39
Early Spring					
3/03/77	14	43	2.89	0.76	3.46
3/30/77	7	22	2.48	0.88	1.94
4/14/77	3	9	0.99	0.31	0.62
$\overline{X}$	8.0	24.7	2.12	0.65	2.01
Late Spring					
5/20/77	7	27	2.08	0.74	1.82
5/27/77	4	14	1.29	0.64	1.13
$\overline{X}$	5.5	20.5	1.68	0.69	1.47
Early Summer					
6/24/77	6	15	1.87	0.72	1.85
Late Summer					
7/27/77	4	25	0.87	0.43	0.93
8/10/77	9	66	2.06	0.65	1.91
8/30/77	3	42	0.32	0.20	0.53
$\overline{X}$	5.3	44.3	1.08	0.43	1.12
Grand Mean	6.4	41.8	1.77	0.65	1.57
SD	1.18	32.9	0.42	0.12	0.36

Table 47

Community Structure Parameters, James River Berm

Season/ Date	Species	Individuals	Diversity (H')	Evenness (J')	Species Richness
Early Summer					
7/14/76	6	9	2.42	0.93	2.27
Late Summer					
7/30/76	7	8	2.74	0.97	2.88
8/19/76	4	4	1.99	1.00	2.16
$\overline{X}$	5.5	6.0	2.36	0.98	2.52
Fall					
9/09/76	8	19	2.71	0.91	2.37
9/29/76	8	9	2.95	0.93	3.19
10/06/76	16	36	3.33	0.83	4.18
10/14/76	7	19	2.71	0.97	2.03
10/29/76	13	29	3.00	0.81	3.56
$\overline{X}$	10.4	22.4	2.94	0.89	3.07
Winter					
1/25/77	15	30	3.57	0.91	4.11
2/23/77	6	22	1.81	0.70	1.61
$\overline{X}$	10.5	19.2	2.69	0.81	2.86
Early Spring					
3/30/77	6	29	1.66	0.64	1.48
4/14/77	5	7	2.23	0.96	2.05
$\overline{X}$	5.5	18.0	1.94	0.80	1.76
Late Spring					
5/20/77	7	8	2.15	0.72	2.85
5/27/77	9	15	3.05	0.96	2.95
$\overline{X}$	8.0	11.5	2.60	0.80	2.90

(Continued)

Table 47 (Concluded)

Season/ Date	No. of Species	No. of Individuals	Diversity (H')	Evenness (J')	Species Richness
Early Summer					
6/24/77	13	23	3.46	0.93	3.82
Late Summer					
7/27/77	9	15	2.74	0.86	2.95
8/10/77	5	8	2.15	0.93	1.92
8/30/77	7	263	0.92	0.32	1.26
$\overline{X}$	7.0	95.3	1.94	0.70	2.04
Grand Mean	8.6	27.9	2.56	0.84	2.71
SD	2.8	30.3	0.54	0.09	0.68

Table 48

Relative Abundance of Birds in Three Major Feeding Categories at the Experimental Site

	Feeding Category											
	Fish				Tidal Invertebrates				Ground Seed			
	Individuals		Species		Individuals		Species		Individuals		Species	
Date	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
5/18/76	42	61.8	4	33.3	19	27.9	4	33.3	3	4.4	2	16.7
7/07/76	8	17.0	5	33.3	5	10.6	1	6.7	19	4.04	4	20.0
7/14/76	23	44.2	2	20.0	15	28.8	4	40.0	9	17.3	2	20.0
7/29/76	163	53.1	6	35.2	9	2.9	2	11.8	126	41.0	4	23.5
7/30/76	95	37.4	2	22.2	67	26.4	5	55.5	92	36.2	2	22.3
8/13/76	233	68.5	7	38.9	18	5.3	4	22.2	68	20.7	3	16.7
9/09/76	101	29.5	3	25.0	74	21.6	4	33.3	166	48.5	4	33.3
9/29/76	12	8.2	6	40.0	1	0.7	1	6.7	131	89.1	5	33.3
10/06/76	3	1.8	2	14.3	2	1.2	2	14.3	123	74.1	4	28.6
10/13/76	19	7.7	4	19.0	2	0.8	1	4.8	176	71.3	5	23.8
10/28/76	5	1.7	3	18.7	5	1.7	2	12.5	166	57.6	4	25.0
10/29/76	12	1.1	5	22.7	5	0.4	2	9.1	193	17.1	6	27.3
11/16/76	11	5.5	5	23.8	24	11.9	5	23.8	117	58.2	4	19.0
2/11/77	240	68.9	4	30.8	4	1.1	2	15.4	74	21.3	3	23.1
3/03/77	6	2.5	3	30.0	10	4.3	1	11.1	39	16.4	3	30.0
3/29/77	72	41.9	2	25.0	34	19.8	1	12.5	53	30.8	3	37.5
3/29/77	1408	97.0	4	33.3	5	0.3	3	25.0	--	--	-	--
3/30/77	134	30.8	4	22.2	90	20.7	4	22.2	163	37.4	3	16.7
4/13/77	8	11.2	2	16.7	18	29.0	2	16.7	31	50.0	5	41.7

(Continued)

Table 48 (Concluded)

	Feeding Category											
	Fish				Tidal Invertebrates				Ground Seed			
	Individuals		Species		Individuals		Species		Individuals		Species	
Date	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
4/13/77	278	66.3	5	41.7	82	19.6	3	25.0	50	11.9	1	8.3
4/14/77	189	41.7	6	40.0	40	8.8	2	13.3	63	13.9	4	26.7
4/27/77	39	26.5	4	18.2	19	12.9	8	36.3	12	8.2	3	13.7
4/28/77	77	44.8	11	39.3	17	9.9	6	21.4	28	16.3	5	17.8
5/19/77	34	31.5	5	29.4	35	27.8	7	41.1	27	25.0	2	11.8
5/20/77	27	15.2	5	33.3	88	49.7	5	33.3	44	24.8	3	20.0
5/26/77	16	28.1	5	33.3	1	1.8	1	6.7	21	37.5	2	13.3
6/02/77	173	80.1	5	41.7	3	1.4	2	16.7	32	14.8	2	16.7
6/16/77	29	55.5	2	50.0	--	--	-	--	19	35.2	1	16.7
6/23/77	13	31.7	5	45.4	--	--	-	--	20	48.8	2	18.1
6/27/77	9	20.9	5	38.4	1	2.3	1	7.7	26	60.5	3	23.1
7/11/77	11	23.9	4	33.3	2	4.3	2	16.7	18	39.1	2	16.7
7/26/77	56	69.9	5	38.5	14	15.2	3	23.1	13	14.1	2	15.4
7/26/77	36	4.1	7	29.2	78	8.8	9	37.5	604	68.2	3	12.5
7/27/77	12	2.8	4	3.3	93	21.8	3	25.0	273	64.1	2	16.7
8/10/77	69	34.0	6	33.3	58	23.2	4	22.2	38	15.2	3	16.7
8/29/77	106	42.6	3	17.6	56	22.3	7	41.2	48	18.3	4	17.6
8/30/77	114	57.3	2	14.3	46	23.1	5	35.7	22	11.1	3	21.4
Total 39	83	1257.2	--	1114.6	1035	467.8	-	779.8	3107	1222.4	-	761.7
Mean 107	6	34.0	4.4	30.1	28.0	12.64	3.19	21.1	84.0	30.3	3.05	20.6

Table 49

Feeding Categories and Associated Birds at Experimental, Reference, and Berm Sites

Feeding Type	Common Name
Warm Prey and Carrion	Turkey vulture
	Black vulture
	Sharp-shinned hawk
	Red-tailed hawk
	Red-shouldered hawk
	Merlin
	Marsh hawk
	Barred owl
	Great horned owl
Plant and Animal	Lesser scaup
	Sora
	Common flicker
	Red-bellied woodpecker
	Yellow-bellied sapsucker
	Mockingbird
	Brown thrasher
	Common crow
	American robin
	Starling
	Yellow-rumped warbler
	Common grackle
	Rufous-sided towhee
Fish	Double-crested cormorant
	Great blue heron
	Green heron
	Great egret
	Snowy egret
	Louisiana heron
	Black-crowned night heron
	Yellow-crowned night heron
	Common merganser
	Bald eagle
	Osprey
	Great black-backed gull
	Ring-billed gull
	Herring gull
	Laughing gull
	Bonaparte's gull
	Least tern
	Common tern
	Forster's tern

(Continued)

Table 49 (Continued)

Feeding Type	Common Name
Fish (Continued)	Caspian tern
	Black skimmer
	Belted kingfisher
	Fish crow
Tidal Invertebrates	Horned grebe
	Bufflehead
	King rail
	Virginia rail
	Semipalmated plover
	Killdeer
	Black-bellied plover
	Ruddy turnstone
	American woodcock
	Common snipe
	Upland sandpiper
	Spotted sandpiper
	Greater yellowlegs
	Lesser yellowlegs
	Red knot
	Pectoral sandpiper
	Baird's sandpiper
	Least sandpiper
	Dunlin
	Short-billed dowitcher
	Semipalmated sandpiper
	Western sandpiper
	Sanderling
	Wilson's phalarope
Air Insects	Chimney swift
	Eastern kingbird
	Empidonax flycatcher
	Eastern wood pewee
	Eastern phoebe
	Barn swallow
	Tree swallow
	Bank swallow
	Rough-winged swallow
	Purple martin
	Blue-gray gnatcatcher
Foliage Insects	Yellow-billed cuckoo
	White-eyed vireo
	Red-eyed vireo
	Prothonotary warbler
	Northern parula
	Yellow warbler

(Continued)

Table 49 (Concluded)

Feeding Type	Common Name
Foliage Insects (Continued)	Yellow-throated warbler
	American redstart
	Orchard oriole
Bole and Twig Insects	Pileated woodpecker
	Downy woodpecker
	Carolina chickadee
	Tufted titmouse
	Ruby-crowned kinglet
	Black and white warbler
Ground Insects	Winter wren
	Carolina wren
	Long-billed marsh wren
	Louisiana waterthrush
	Kentucky warbler
	Common yellowthroat
Leaves, Roots, and Seeds	Whistling swan
	Canada goose
	Snow goose
	Mallard
	Black duck
	Pintail
	Blue-winged teal
	American wigeon
	Wood duck
	Redhead
	Canvasback
	American coot
Tree Seed	Blue jay
	Indigo bunting
	Purple finch
	Cardinal
	American goldfinch
Ground Seed	Bobwhite
	Rock dove
	Mourning dove
	Red-winged blackbird
	Savannah sparrow
	Sharp-tailed sparrow
	Field sparrow
	White-throated sparrow
	Swamp sparrow
	Song sparrow
	Snow bunting
Nectar	Ruby-throated hummingbird

Table 50

Foraging Diversity at Experimental Site, Reference Site, and James River Berm

Site: Season*	Number of censuses	Mean foraging diversity (species) $p_i = \frac{spp_i}{total\ spp}$	SD**	Mean foraging diversity (indiv.) $p_i = \frac{indiv_i}{total\ indiv.}$	SD
Experimental Site:					
1976 1	1	2.08	--	1.44	--
2	2	2.14	0.31	2.00	0.25
3	3	2.06	0.56	1.40	0.16
4	6	2.48	0.40	1.19	0.33
5	2	2.36	0.23	1.56	0.46
1977 6	7	2.03	0.48	1.42	0.62
1	5	2.27	0.25	2.13	0.24
2	5	2.18	0.19	1.58	0.48
3	6	2.14	0.13	1.73	0.32
	$\overline{X}$	2.19		1.61	
Reference Site:					
1976 5	3	1.56	0.73	0.54	0.34
6	3	1.66	0.66	0.92	0.37
1977 1	2	2.12	0.88	1.60	0.64
2	1	2.25	--	1.69	--
3	3	2.00	0.42	0.79	0.43
	$\overline{X}$	1.92		1.11	
James River Berm Site:					
1976 2	1	2.52	--	2.45	--
3	2	1.91	0.11	1.95	0.06
4	5	2.20	0.25	1.99	0.22
5	2	1.94	0.60	1.83	0.43
1977 6	2	2.25	0.46	1.75	0.13
1	2	2.48	0.34	2.35	0.28
2	1	1.74	--	1.77	--
3	3	2.35	0.13	1.72	0.74
	$\overline{X}$	2.17		1.97	

*Season: 1=late spring; 2=early summer; 3=late summer; 4=fall; 5=winter; 6=early spring

**SD=standard deviation

Table 51

Windmill Point Experimental Site and Herring Creek Reference Site

1977 Bird Nest Densities

Site*	Species	No. Nests	Vegetation Zone	Area (ha.)	Density within Vegetation Zone (per ha.)
Exp	Red-winged blackbird	31	*Salix-Alnus*	0.10	310.00
Exp	Red-winged blackbird	2	*Bidens-Typha*	2.18	0.91
Exp	Long-billed marsh wren	2	*Bidens-Typha*	2.18	0.91
Exp	Mallard	2	*Bidens-Typha*	2.18	0.91
Exp	Red-winged blackbird	1	*Panicum amarulum*	0.50	2.00
Ref	Red-winged blackbird	11	*Cephalanthus*	0.14	18.50
Ref	Long-billed marsh wren	1	*Cephalanthus*	0.14	1.14

*Exp - Experimental; Ref - Reference

Table 52

Cumulative Similarity between Avifauna at the Experimental and Reference Sites, and the James River Berm*

Sites Compared	Number of Species Shared	Dice's Similarity Coefficient
Experimental-Reference	24	0.22
Experimental-James River Berm	14	0.38
James River Berm-Reference	16	0.45

*Comparisons made only from latest date of establishment of either site as a study area.

Table 53

Seasonal Similarity between Avifauna at the Experimental and Reference Sites, 1977

Season	Number of Species at Experimental Site Only	Number of Species at Reference Site Only	Number of Species Shared	Dice's Similarity Coefficient
Winter	18	7	6	0.32
Early Spring	22	8	9	0.37
Late Spring	44	6	1	0.04
Early Summer	21	4	2	0.14
Late Summer	38	9	4	0.15

Table 54

Seasonal Foraging Similarity between Avifauna at Experimental and Reference Sites, 1977

Season	Feeding Categories at Experimental Site Only	Feeding Categories at Reference Site Only	Categories Shared	Dice's Similarity Coefficient
Winter	3	2	4	0.61
Early Spring	2	2	5	0.71
Late Spring	3	2	5	0.67
Early Summer	4	1	4	0.61
Late Summer	4	3	4	0.53

Table 55

Description of Soil Sampling Stations; November 1976

Station*	Location**	Description
WP1	150,400	Mixed grasses; *Panicum* spp. predominates; adjacent to spillway used during island construction; supratidal sand soil
WP2	300,200	*Sagittaria* (Arrowhead) and *Pontederia* (Pickerelweed) dominant vegetation; regularly inundated, water logged soils; dredged material origin; silty loam soil
WP3	500,500	*Panicum* spp., dominant vegetation; soil originating from dike construction; supratidal sand soil
WP4	525,000	*Chenopodium* spp., *Amarantha* dominant vegetation; soil originating from dike construction; supratidal sand soil
WP5	6000,050	*Typha-Bidens* dominates vegetation; sand strata at 15 cm; upper soil fine silt and clay; dredged material origin; some evidence of dike material intrusion; silty loam soil in top layer
WP6	675,500	Similar to WP5; sandy clay loam soil
WP7	925,350	Similar to WP2; silty loam soil
WP8	1000,050	Interior mudflat; dredged material origin with areas of mixing with dike construction materials; loam soil outside areas of mixing
WP9	1300,300	Mixed grasses and willows predominate vegetation; soil of dike construction origin; site of original dredge island; sand soil

(continued)

Table 55 (concluded)

Station	Location**	Description
DSPW†	(see Figure G-37)	Peltandra (Arrow arum) with some Pontederia (Pickerelweed) dominant vegetation; intertidal soils of predominately silts and clays; silty clay soil
DSTy††	(see Figure G-37)	Similar to DSPW except Typha-Bidens plant association; higher elevation; silty clay soil

* WP = Windmill Point (experimental site): DS = Ducking Stool Marsh (reference site)

** Coordinates read in the x, y, plane and correspond to the scales marked on Figure 46

† PW = Pickerelweed

†† Ty = Typha-Bidens

Table 56

Core Descriptions for the Heavy Metal and Organochlorine Sampling Program; October 1976

Station*	Core length** $\bar{X}$ (cm)	Description
1. WP-Mud Flat	24.5 (23.8-25.2)	heterogeneous soil; in places, predominately gravel; others silty-clay; dark gray, no obvious odor
2. WP-PW	24.8 (21.0-28.5)	dark gray-green; silty-clay with plant fragments throughout; no obvious odor
3. WP-Ty	23.0 (20.6-25.0)	similar to WP-PW
4. DS-Mud Flat	30.0 (26.5-33.0)	dark gray to black; silty-clay; H_2S odor obvious; some leaves and large plant fragments present
5. DS-PW	28.1 (26.0-30.0)	similar to DS-Mud Flat
6. PNWR-Mud Flat	24.8 (20.2-29.0)	dark gray to black; silty-clay; highly reduced in places; large detrital-plant fragments
7. PNWR-PW	25.5 (20.5-33.2)	similar to PNWR-Mud Flat; more detrital material
8. PNWR-Ty	14.7 (12.8-16.4)	same as above

* Legend; WP = Windmill Point (experimental site)
DS = Ducking Stool Marsh (reference site)
PNWR = Presquile National Wildlife Refuge
PW = Pickerel Weed
Ty = *Typha-Bidens*

** Nos. in parenthesis indicate the Range; N = 5

Table 57

Soils Particle Size Analyses; November 1976

	% in class					
Station*	Gravel (>2mm)	Sand (2-0.062 mm)	Sand/gravel (>0.062 mm)	Silt (4-8)	Clay (<8)	Silt/Clay (4-<8)
WP1-Top	1.40	72.70	74.10	17.03	8.87	25.90
Bottom	8.71	46.79	55.68	30.51	13.84	44.35
WP2-Top	1.25	14.62	15.86	65.48	18.66	84.14
Bottom	0.00	18.48	18.48	55.05	26.48	81.53
WP3-Top	22.73	71.69	94.42	1.41	2.38	3.79
Bottom	17.22	73.46	90.69	3.33	5.98	9.31
WP4-Top	22.00	74.67	96.66	0.39	2.95	3.34
Bottom	5.60	79.77	85.37	0.51	14.12	14.63
WP5-Top	1.12	22.07	23.19	55.94	20.87	76.81
Bottom	53.88	11.50	65.38	22.58	12.04	34.62
WP6-Top	16.32	45.05	61.37	22.84	15.78	38.62
Bottom	1.52	25.88	27.40	59.14	13.46	72.60
WP7-Top	0.67	18.88	19.54	61.62	18.84	80.46
Bottom	1.00	10.34	11.34	37.04	51.62	88.66
WP8-Top	3.79	28.93	32.73	44.06	23.21	67.27
Bottom	0.00	15.54	15.54	43.15	41.31	84.46
WP9-Top	2.43	91.61	94.05	1.11	4.84	5.95
Bottom	16.22	78.50	94.72	1.35	3.93	5.28
DSPW-Top	0.55	13.27	13.82	38.88	47.30	86.18
Bottom	0.00	5.46	5.46	45.31	49.23	94.54
DSTy-Top	1.29	21.60	22.89	45.66	31.45	77.11
Bottom	1.60	27.25	28.85	32.87	38.28	71.15

* See Table 55 for station description.

Table 58

Soils Physical Measures; November 1976

Station*	pH**	Moisture** (%DW)	Salinity† (g/100g DW)	Volatiles† (%DW)	Carbon† (%DW)
WP1-Top	7.02	31.02	0.159	2.5	0.64
Bottom	7.23	44.91	0.208	4.3	1.22
WP2-Top	6.90	112.35	0.548	7.9	4.42
Bottom	6.82	95.68	0.740	8.5	--
WP3-Top	7.35	7.02	0.310	0.3	0.07
Bottom	7.30	12.91	0.300	0.2	0.09
WP4-Top	7.20	8.32	0.312	0.3	0.08
Bottom	7.45	8.80	0.332	0.2	0.04
WP5-Top	6.77	75.32	0.282	7.5	3.17
Bottom	6.78	78.19	0.484	7.5	1.81
WP6-Top	6.96	59.21	0.371	3.3	2.35
Bottom	7.19	71.62	0.944	5.2	1.98
WP7-Top	7.18	110.84	0.444	9.9	4.24
Bottom	7.22	104.49	1.024	10.3	--
WP8-Top	7.27	115.99	0.243	10.2	5.81
Bottom	7.27	102.42	0.362	9.2	--
WP9-Top	5.73	5.61	0.145	0.3	0.10
Bottom	5.83	6.96	0.124	0.4	0.05
DSPW-Top	7.00	185.60	0.084	13.7	6.07
Bottom	6.78	98.80	0.094	9.6	2.34
DSTy-Top	6.02	264.37	0.100	20.9	7.55
Bottom	6.10	217.46	0.265	21.0	24.14

* See Table 55 for station description.
** mean of three replicates.
† mean of two replicates.

Table 59

Soils Total Nitrogen and Exchangeable Nutrients; November 1976 (all values as $\mu g \times g^{-1}$ DW)

Station*	TKN	NO_3^-	NH_4^+	TON**	TN†	P	K
WP1-Top	1326.	0.154	7.26	1319.	1326.	253.	8.08
Bottom	1203.	---††	10.05	1193.	(1203.)	---	24.2
WP2-Top	2360.	0.315	74.5	2286.	2360.	1250.	20.6
Bottom	1690.	0.140	92.6	1598.	1690.	1286.	---
WP3-Top	46.2	0.079	1.31	44.9	46.3	47.5	13.3
Bottom	48.9	0.452	0.67	48.2	49.4	47.5	11.2
WP4-Top	83.2	0.413	1.98	81.2	83.6	47.5	9.20
Bottom	19.9	0.219	0.59	19.3	20.1	43.8	5.15
WP5-Top	2080.	---	16.8	2062.	(2080.)	790.	60.0
Bottom	1486.	---	15.8	1470.	(1486.)	---	26.3
WP6-Top	1580.	0.157	24.3	1556.	1580.	741.	29.8
Bottom	1530.	---	25.0	1505.	(1530.)	1246.	---
WP7-Top	1730.	---	82.6	1647.	(1730.)	1075.	80.8
Bottom	3080.	0.112	278.	2802.	3080.	1328.	0.0
WP8-Top	2579.	5.275	122.	2457.	2584.	1209.5	68.5
Bottom	2252.	0.112	277.	1975.	2252.	1472.1	---
WP9-Top	112.	0.980	1.32	111.	113.	96.9	38.0
Bottom	99.5	0.51	0.60	98.9	99.6	---	37.4
DSPW-Top	3252.	0.728	86.2	3171.	3258.	536.	60.5
Bottom	1709.	0.175	89.2	1620.	1709.	353.	21.6
DSTy-Top	7580.	1.071	16.2	7564.	7581.	928.	220.
Bottom	5710.	0.141	10.2	5700.	5710.	584.	93.0

* See Table 55 for station description.

** TON = (TKN - NH_4^+); Total Organic Nitrogen

† TN = (TKN + NO_3^-) Total Nitrogen; ( ) = NO_3^- not included for calculation

†† No entry (---) indicates sample exhausted by time of analysis

Table 60

Soils Cation Exchange Capacity (CEC) and Cation Exchange Status (CES); November 1976 (All values as meq x 100 gDW^{-1})

Station*	CEC	Fe	Mn	Na	K	Ca	Mg	H**
WP1-Top	21.0	0.090	0.042	0.11	0.021	0.271	0.024	20.7
Bottom	22.3	0.053	0.250	0.18	0.062	0.816	0.207	20.7
WP2-Top	43.2	0.087	0.268	1.06	0.053	0.085	0.300	41.3
Bottom	30.32	0.058	0.199	---†	---	---	---	---
WP3-Top	14.4	0.070	0.019	0.37	0.034	0.276	0.093	13.5
Bottom	12.5	0.004	n.d.††	0.28	0.029	0.189	0.068	11.9
WP4-Top	16.0	0.014	n.d.	1.59	0.024	0.216	0.029	14.1
Bottom	9.0	0.010	n.d.	n.d.	0.008	0.252	0.017	8.7
WP5-Top	33.9	n.d.	n.d.	0.82	0.151	2.06	0.590	30.3
Bottom	32.1	n.d.	0.147	1.57	0.067	n.d.	0.202	30.1
WP6-Top	30.5	n.d.	n.d.	0.94	0.076	0.077	0.155	29.3
Bottom	37.5	0.042	n.d.	---	---	---	---	---
WP7-Top	41.4	0.021	0.038	0.32	0.207	3.48	1.37	35.9
Bottom	94.79	0.560	0.645	---	---	---	---	---
WP8-Top	47.7	0.093	0.037	1.45	0.175	0.533	0.503	44.9
Bottom	44.74	n.d.	n.d.	---	---	---	---	---
WP9-Top	17.0	0.010	0.016	0.79	0.097	0.642	0.319	15.1
Bottom	18.6	0.110	0.032	0.51	0.048	0.123	0.081	17.8
DSPW-Top	67.3	n.d.	n.d.	1.17	0.155	2.66	0.634	62.7
Bottom	54.1	0.164	0.022	0.90	0.055	2.185	0.215	50.6
DSTy-Top	64.5	0.119	0.080	1.94	0.562	7.35	1.72	52.7
Bottom	39.6	0.045	n.d.	n.d.	0.238	4.93	1.26	39.3

*See Table 55 for station descriptions.

**H = exchangeable hydrogen = CEC-(Fe + Mn + Na + K + Ca + Mg) (See Toth and Ott 1970).

† No entry indicates sample exhausted by time of analysis.

†† n.d. = below detection limits.

Table 61

Qualitative Comparison of Cation Exchange Status for Soils (0 to 15 cm)

Station*	Description	CES** (meq/100g DW)
WP1	Dike	Ca > Na > Fe > Mg > Mn > K
WP3	Dike	Na ≥ Ca > Mg > Fe > K > Mn
WP4	Dike	Na ≥ Ca > Mg > K > Fe
WP9	Dike	Na ≥ Ca > Mg > K > Mn > Fe
WP5	*Typha-Bidens*	Ca > Na ≥ Mg > K
WP6	*Typha-Bidens*	Na ≥ Ca > Mg > K
WP2	Pickerelweed	Ca > Mg ≥ Na > K > Mn > Fe
WP7	Pickerelweed	Ca > Mg > Na ≥ K > Mn > Fe
WP8	Pickerelweed (non-vegetated)	Ca ≥ Na > Mg > K > Fe > Mn
DSPW	Pickerelweed	Ca > Na > Mg > K > Fe > Mn
DSTy	*Typha-Bidens*	Ca > Mg > K > Fe

* See Table 55 for station descriptions.
** If a cation species is omitted = below detection limits.

Table 62

Soils, Exchangeable Zn, Cu, and Ni; November 1976

(All values as meq x 100 gDW^{-1})

Station*		Zn	Cu	Ni
WP1 -	Top	n.d.**	0.0003	n.d.
	Bottom	n.d.	0.0003	n.d.
WP2 -	Top	n.d.	0.0007	0.0004
	Bottom	n.d.	n.d.	0.0012
WP3 -	Top	0.044	0.002	n.d.
	Bottom	0.006	0.0001	0.0001
WP4 -	Top	0.001	n.d.	0.0001
	Bottom	n.d.	0.0001	n.d.
WP5 -	Top	n.d.	0.0006	0.0005
	Bottom	0.002	0.0002	n.d.
WP6 -	Top	0.002	n.d.	n.d.
	Bottom	0.001	0.0008	n.d.
WP7 -	Top	n.d.	n.d.	0.0002
	Bottom	n.d.	0.0007	0.0005
WP8 -	Top	n.d.	n.d.	0.0003
	Bottom	0.009	n.d.	0.0003
WP9 -	Top	0.001	n.d.	0.0007
	Bottom	0.002	0.0001	0.0011
DSPW -	Top	0.288	0.0006	n.d.
	Bottom	0.006	0.0004	n.d.
DSTy -	Top	0.021	0.0003	0.0021
	Bottom	0.006	0.0004	0.0006

* See Table 55 for station descriptions.
**n.d. = below detection limits.

Table 63

eH and pH data for June 1977 Sampling

Station*	Temp. (^0C)	Core Length (cm)	eH (mV) 1 cm	5 cm	10 cm	15 cm	20 cm	pH (in water) top	bottom
WP1	27	30	196	197	199	200	199	6.7	6.7
WP2	31	30	191	185	187	193	170	6.8	7.0
WP3	26.7	15	180	-400	-380			6.7	6.8
WP4	32	25	172	200	200	200	185	6.7	6.8
WP5		19	202	200	200	200		6.6	6.6
WP6	27	30	50	100	90	120	100	7.1	7.1
WP7		30	185	187	190	190	182	6.9	6.9
WP8	28	26	187	177	170	170	174	6.8	6.9
WP9			(not measured dry)					6.5	6.8
DSPW		10	198	196				6.4	
DSTy		17	197	190	196			6.3	

* See Table 55 for station description.

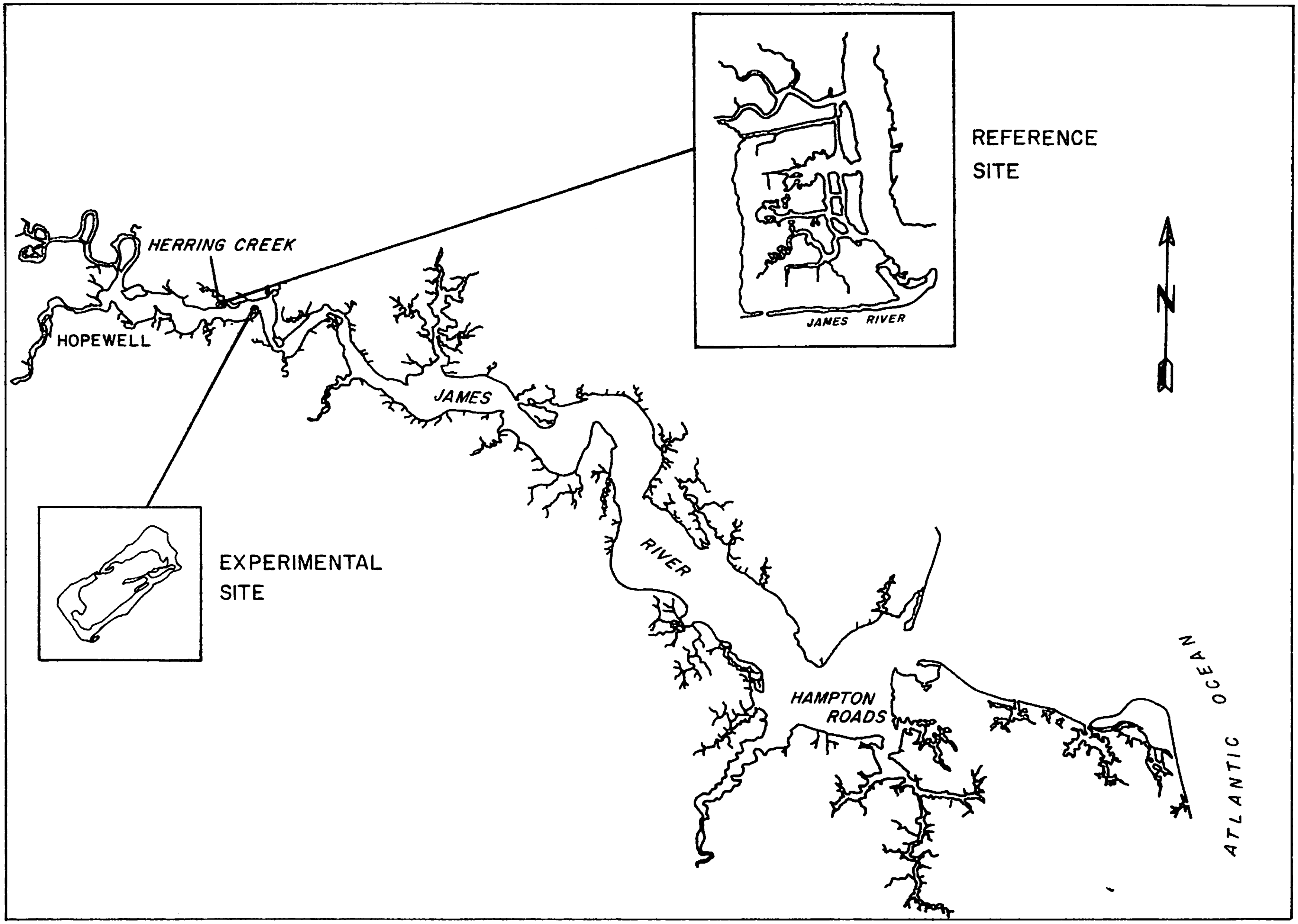


Figure 1. Location of experimental site (Dredged Material Island) and reference site (Herring Creek Marsh), Windmill Point Marsh Development Site, James River, Virginia

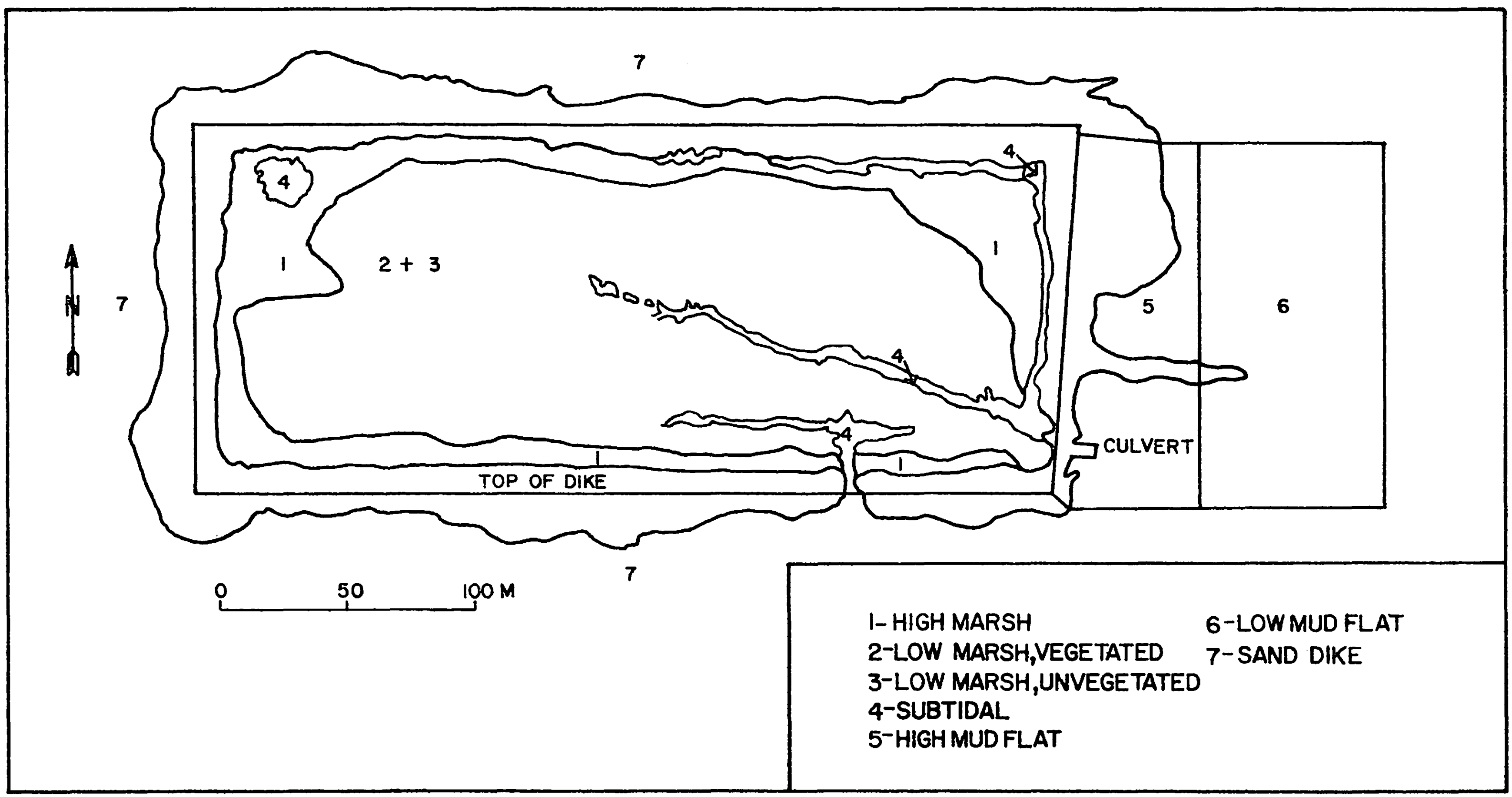


Figure 2. Habitat strata at the Windmill Point experimental site.

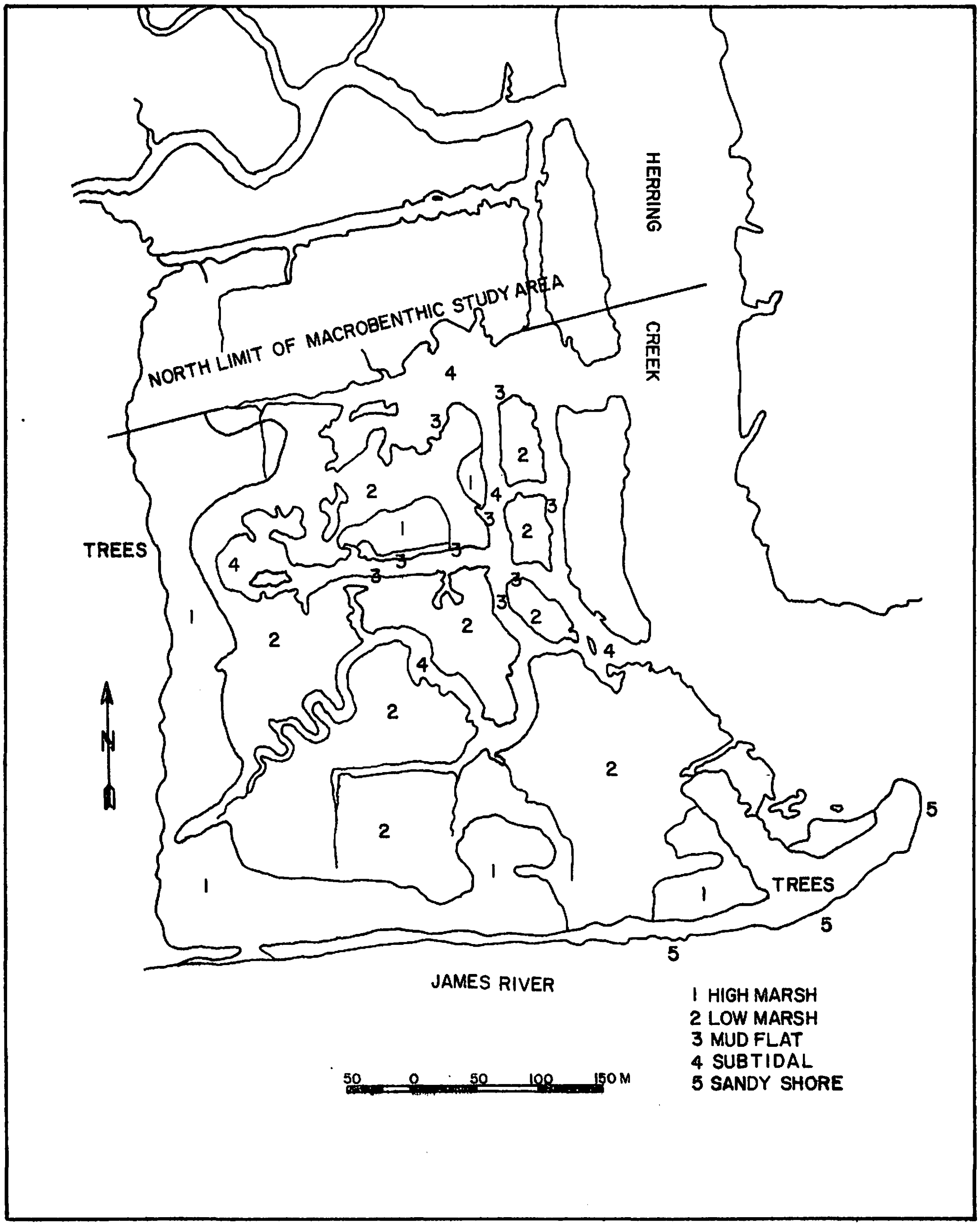


Figure 3. Habitat strata at the Herring Creek (Ducking Stool Point) reference site.

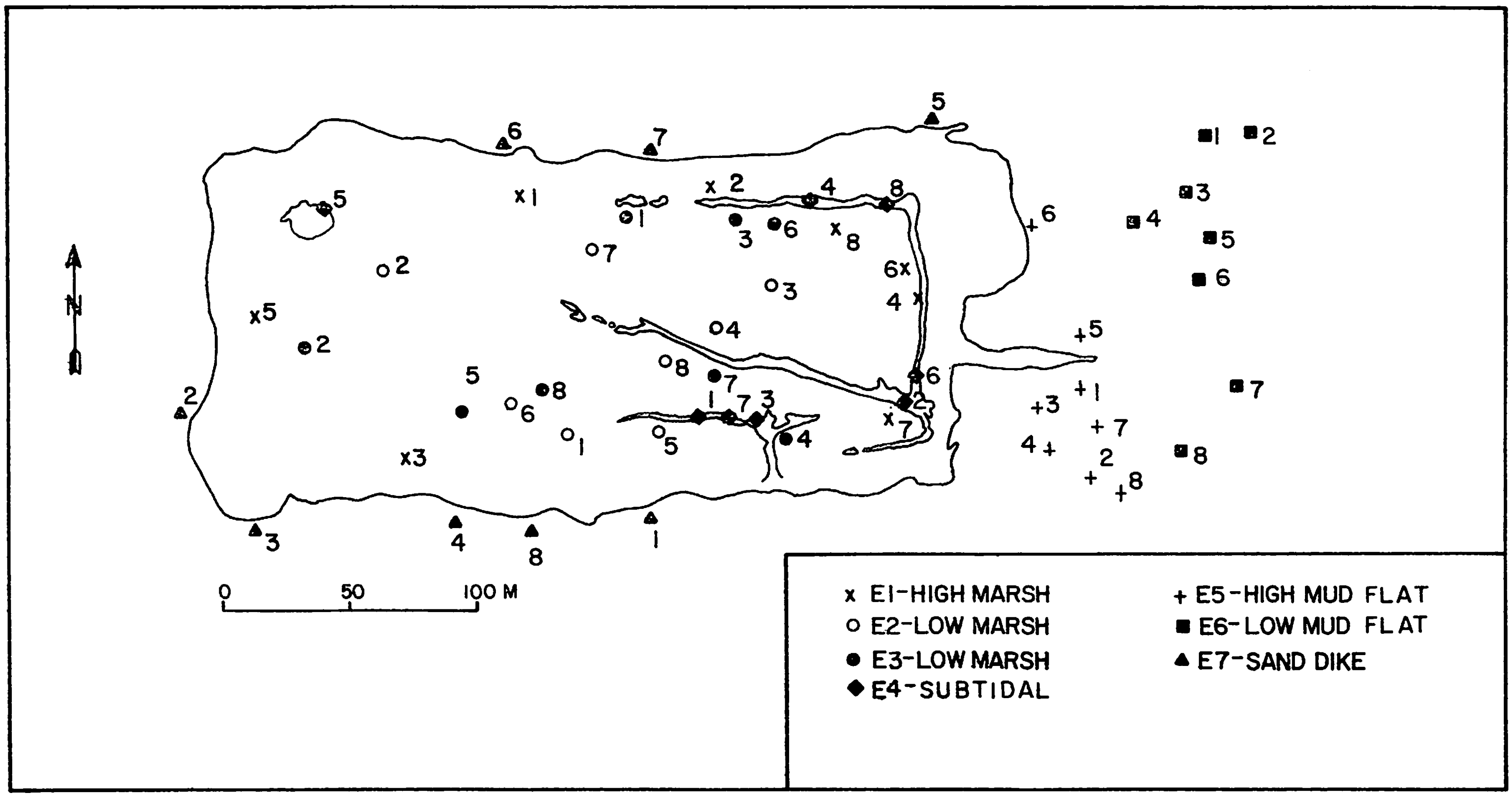


Figure 4. Location of replicate samples at the experimental site, July 1976.

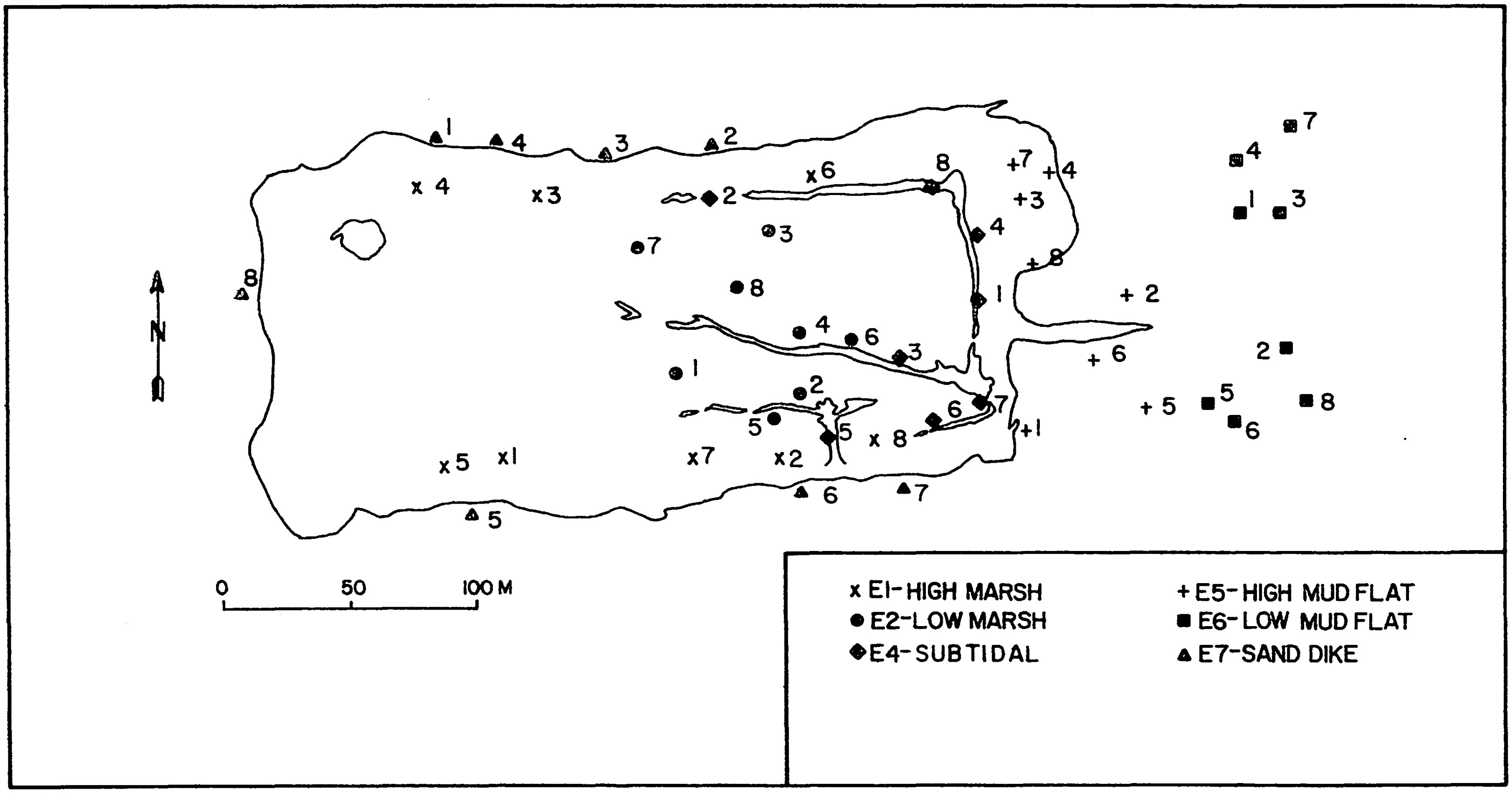


Figure 5. Location of replicate samples at the experimental site, November 1976.

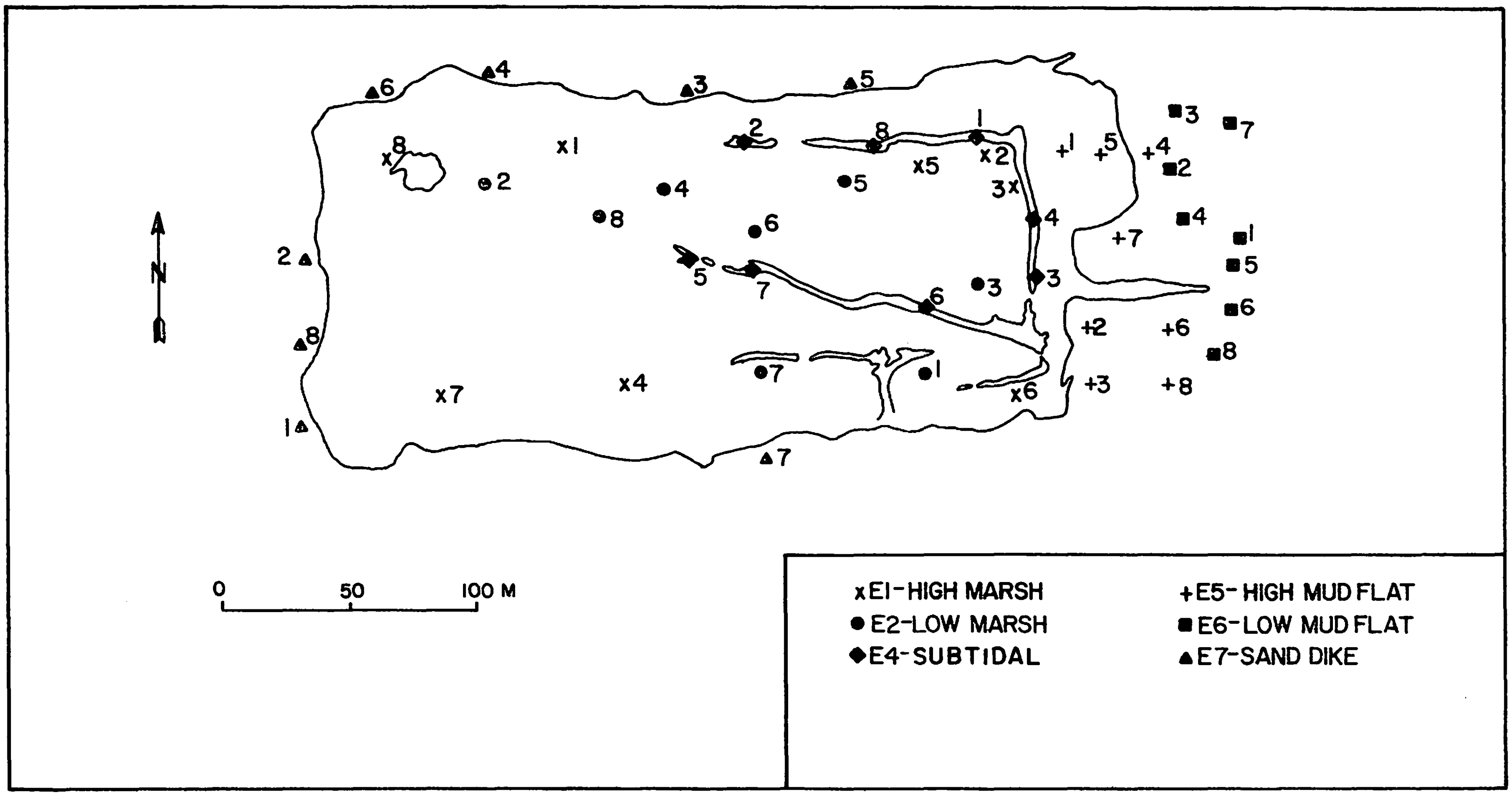


Figure 6. Location of replicate samples at the experimental site, January 1977.

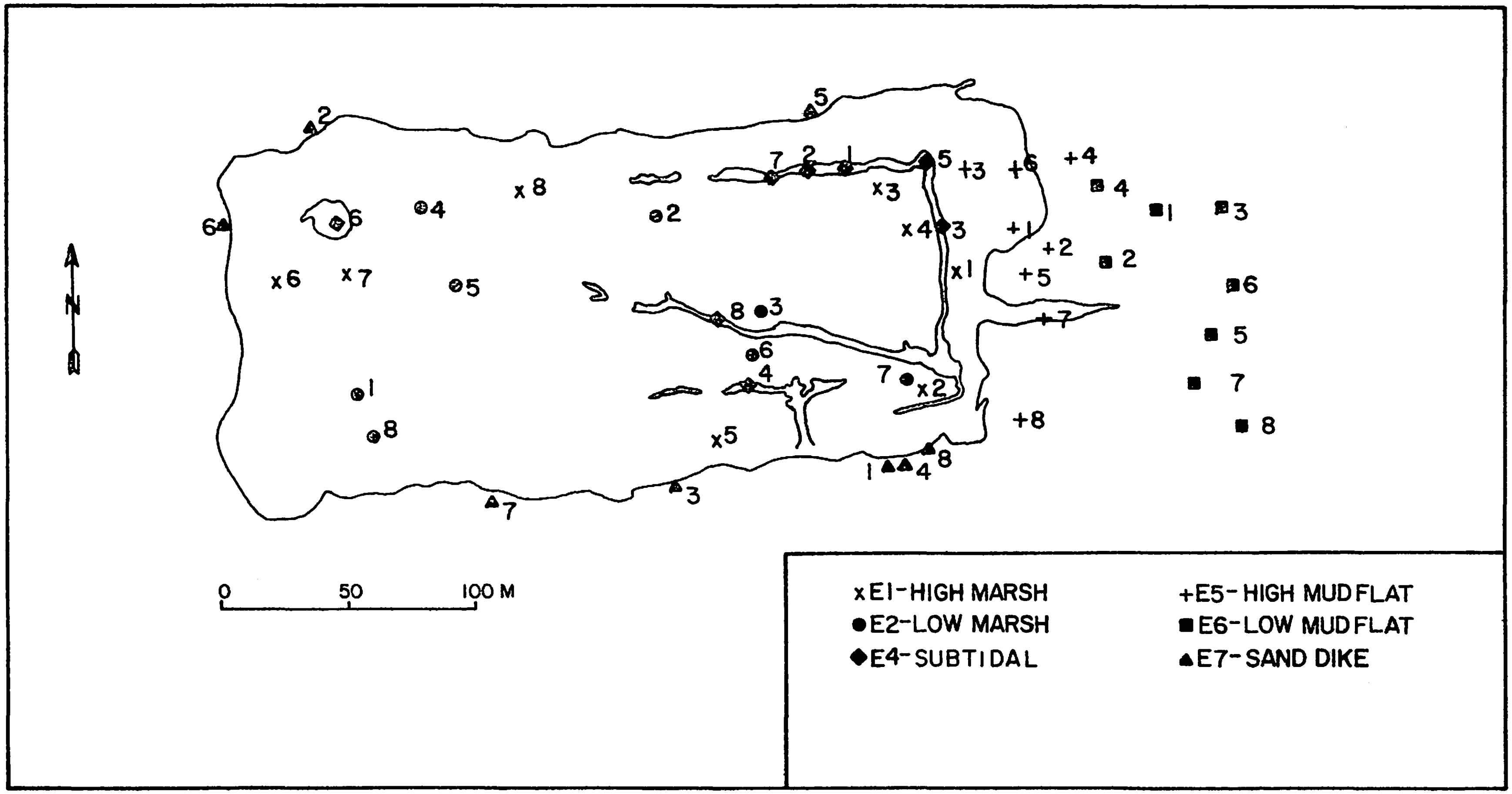


Figure 7. Location of replicate samples at the experimental site, April 1977.

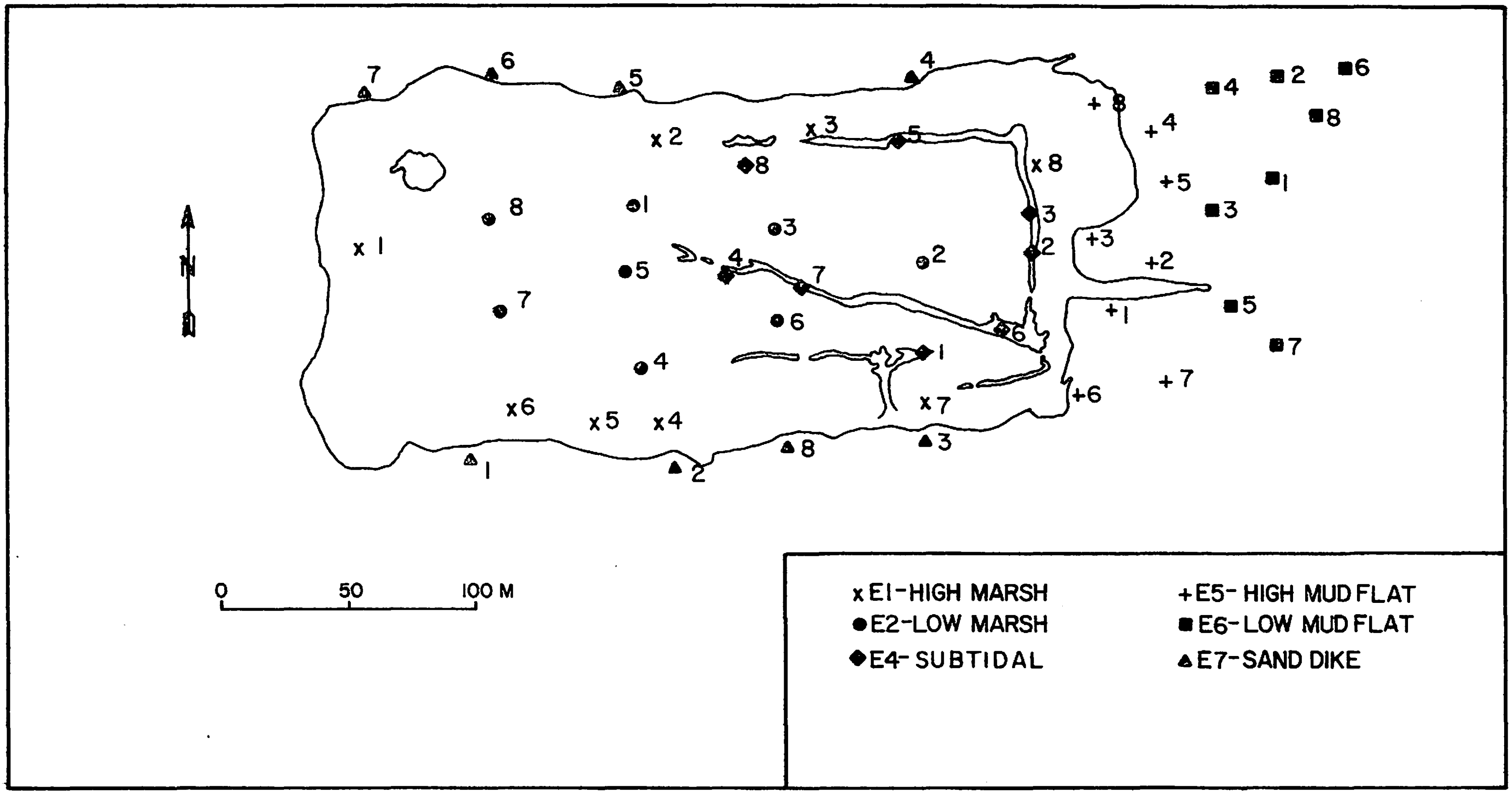


Figure 8. Location of replicate samples at the experimental site, July 1977.

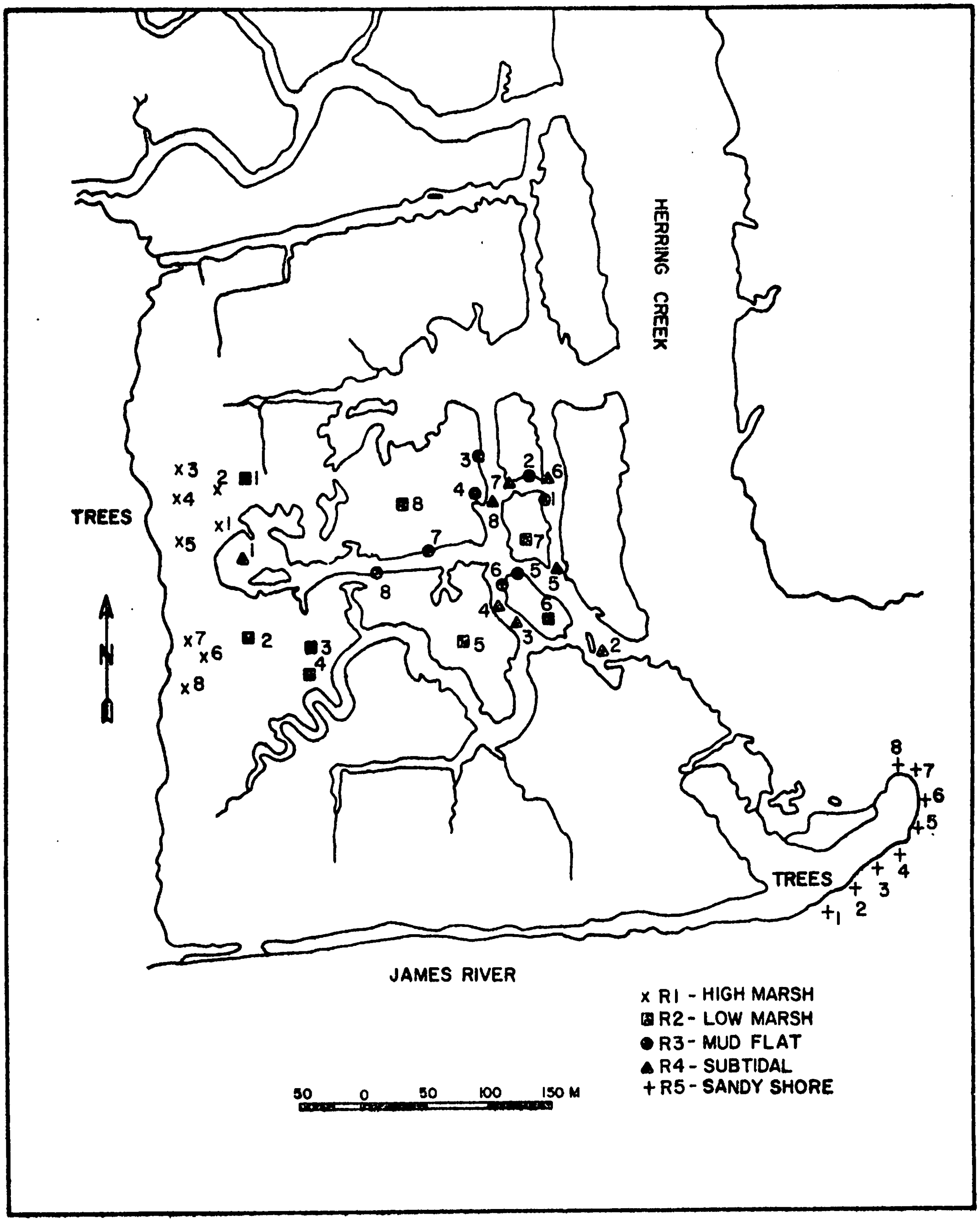


Figure 9. Location of replicate samples at the reference site, July 1976.

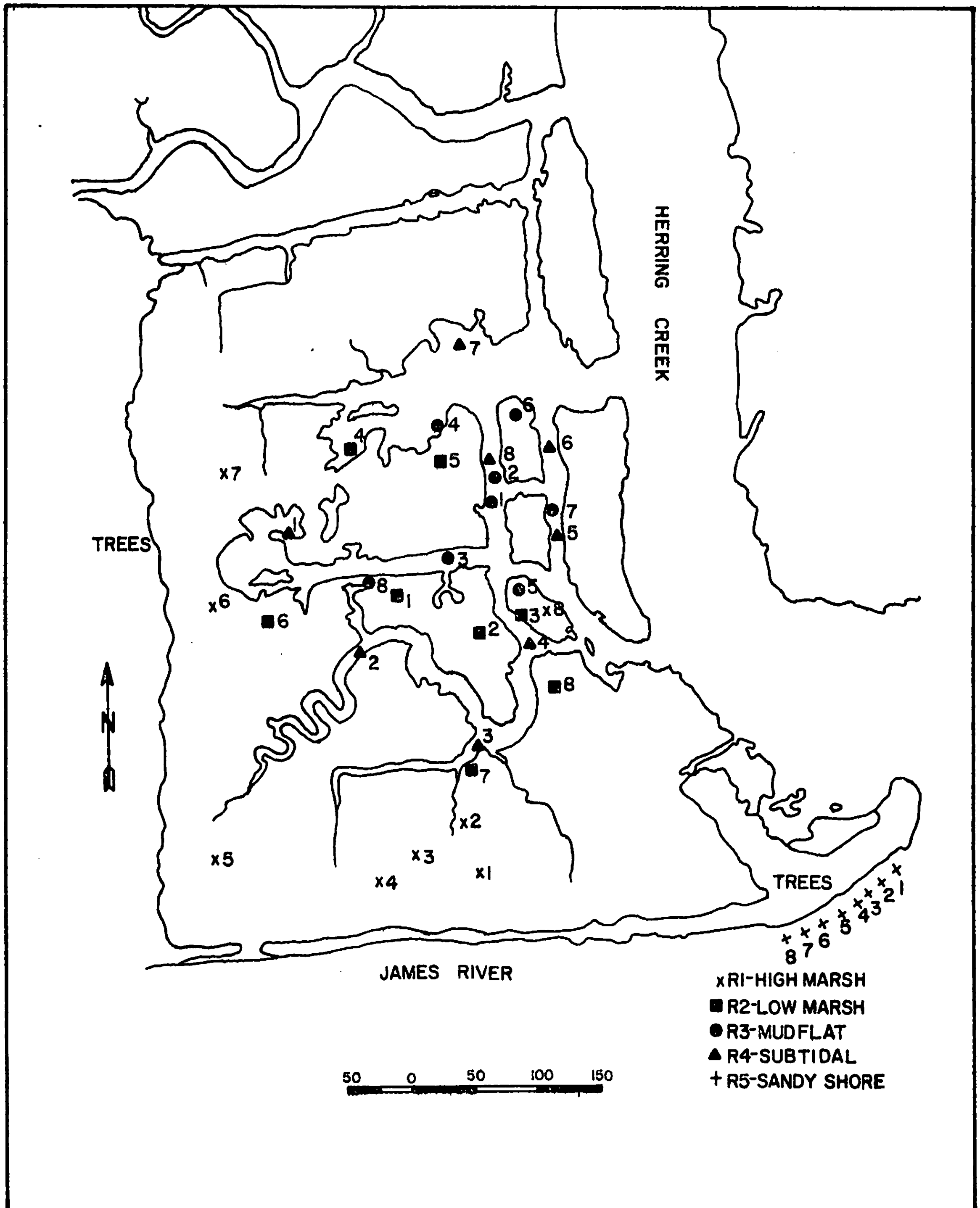


Figure 10. Location of replicate samples at the reference site, November 1976.

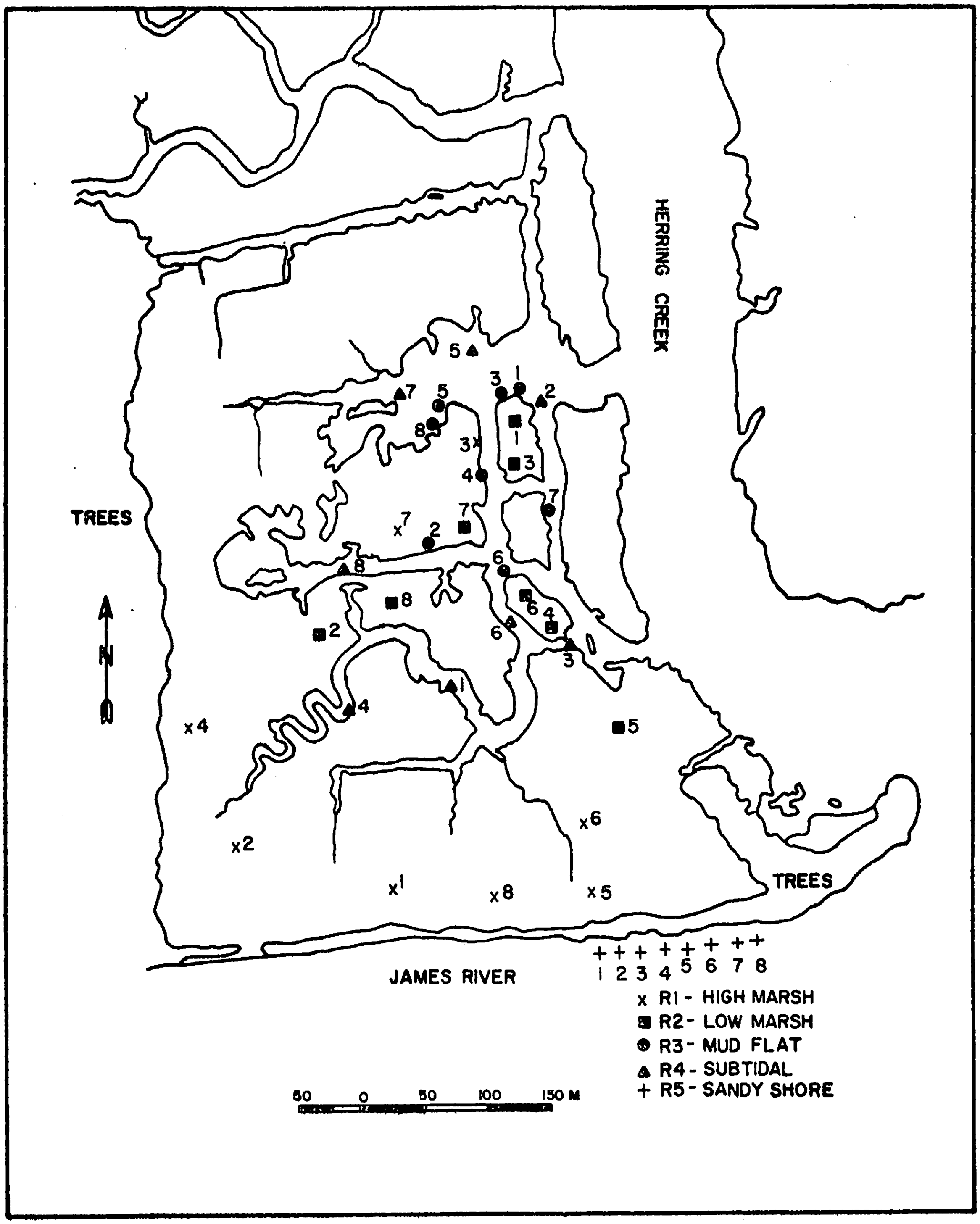


Figure 11. Location of replicate samples at the reference site, January 1977.

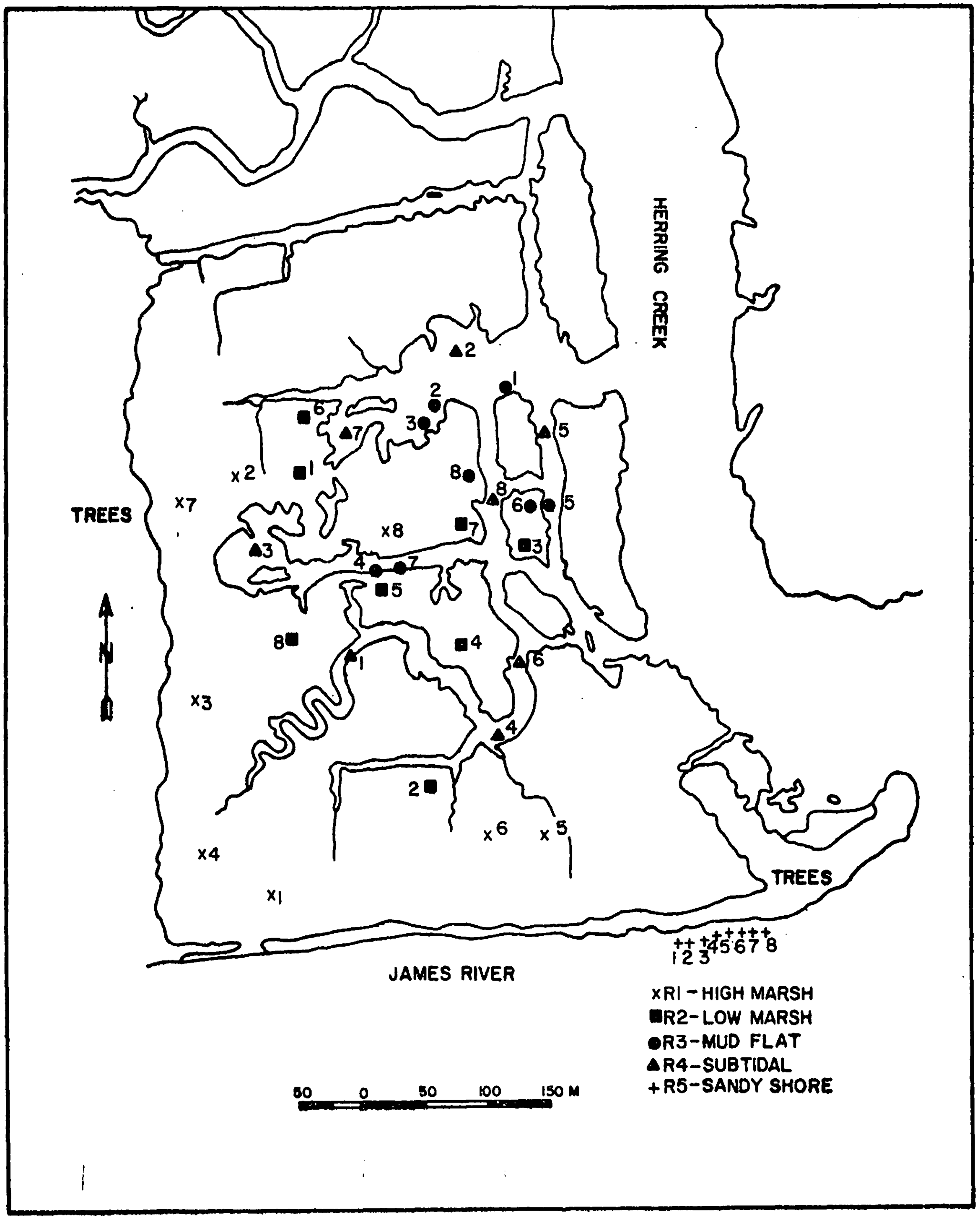


Figure 12. Location of replicate samples at the reference site, April 1977.

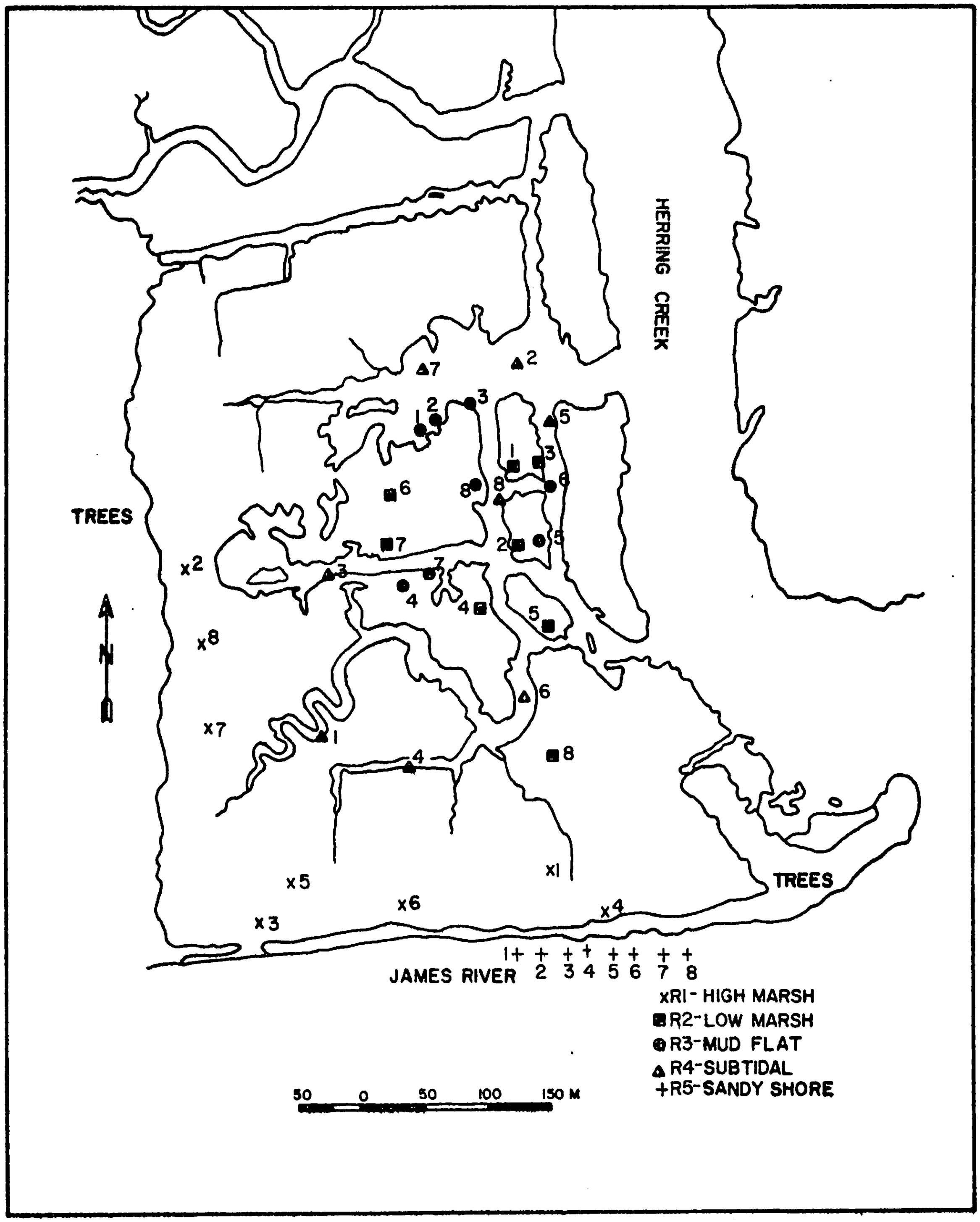


Figure 13. Location of replicate samples at the reference site, July 1977.

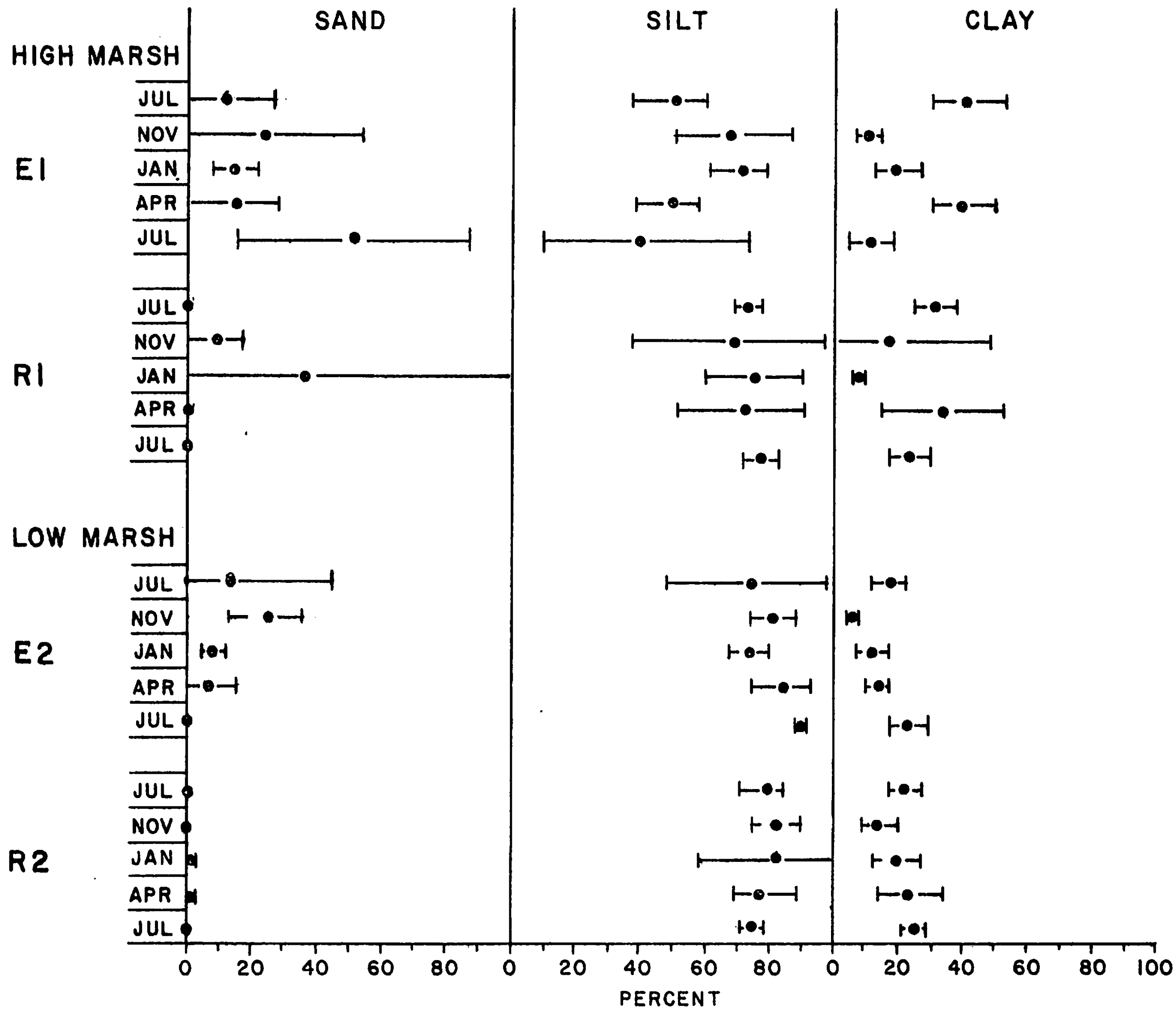


Figure 14. Mean and 95% confidence intervals of percent sand, silt, and clay by stratum and sampling period (Continued).

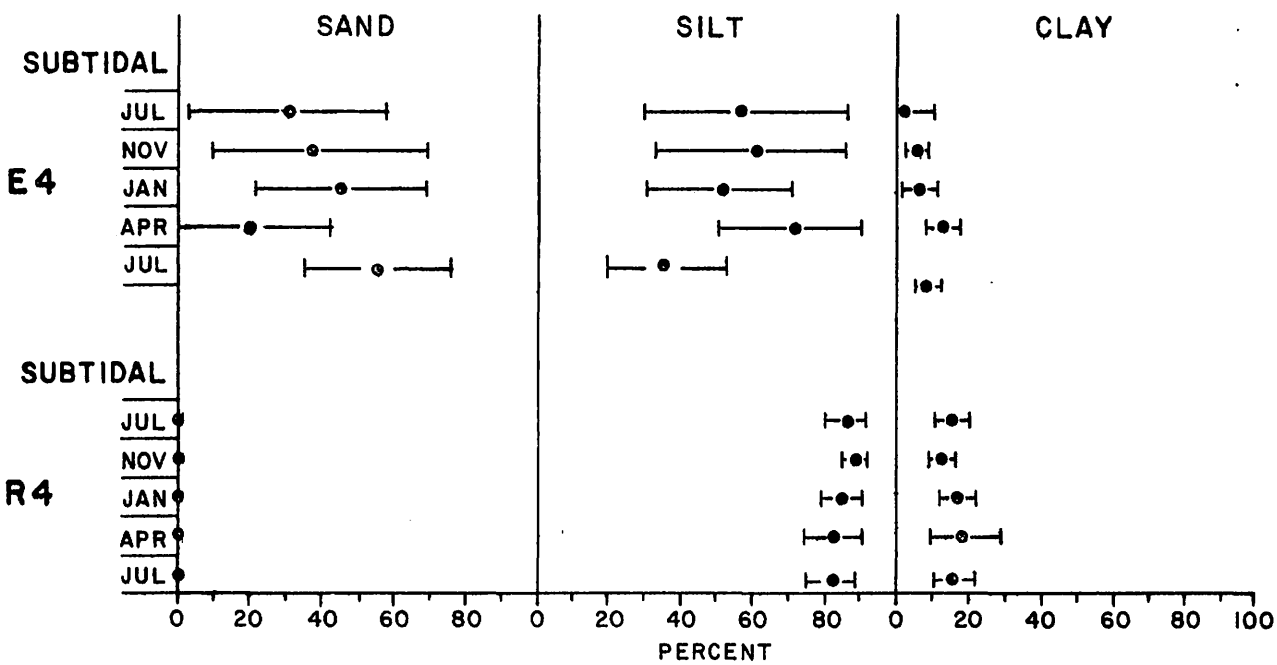


Figure 14. (Continued).

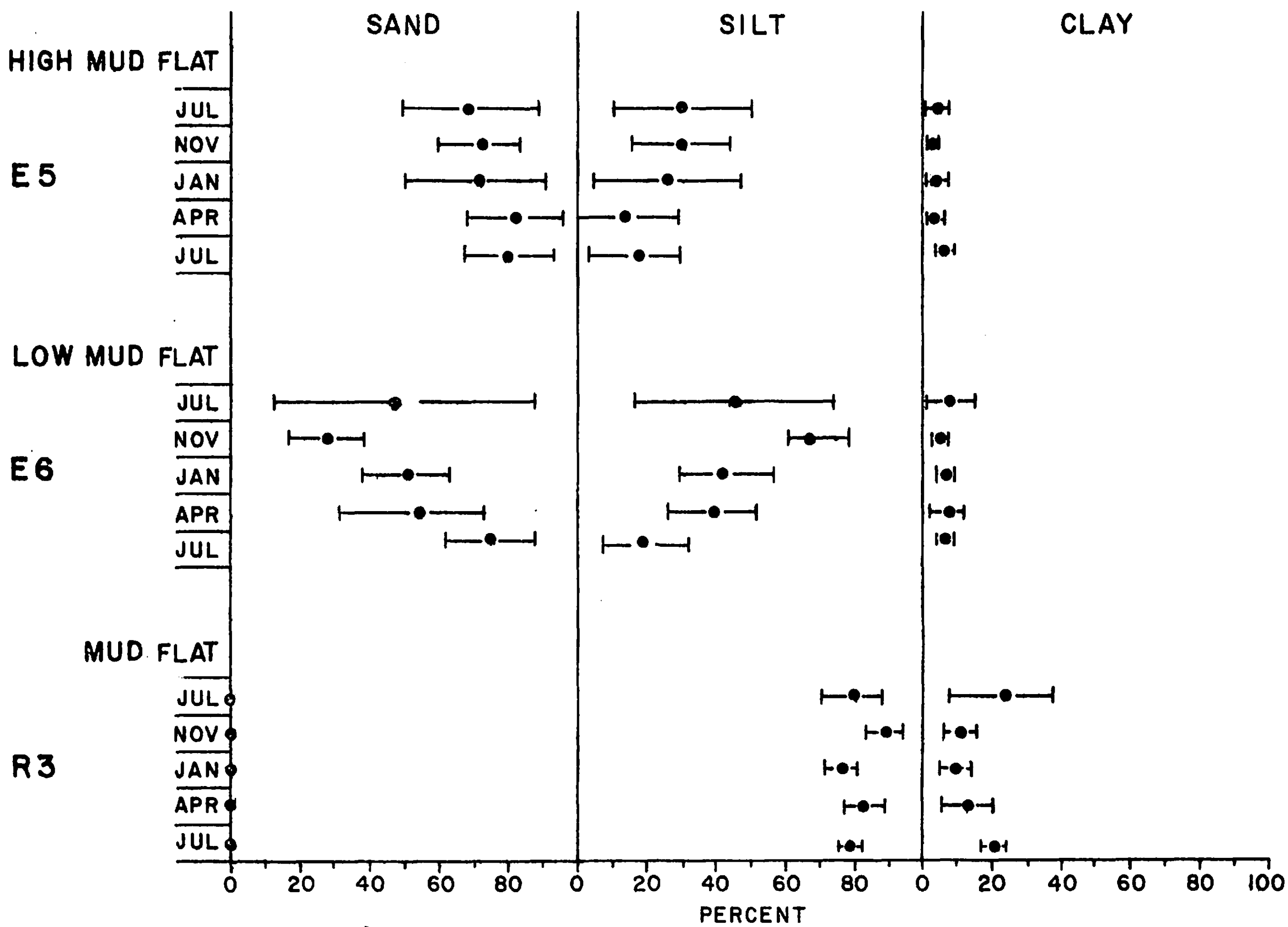


Figure 14. (Continued).

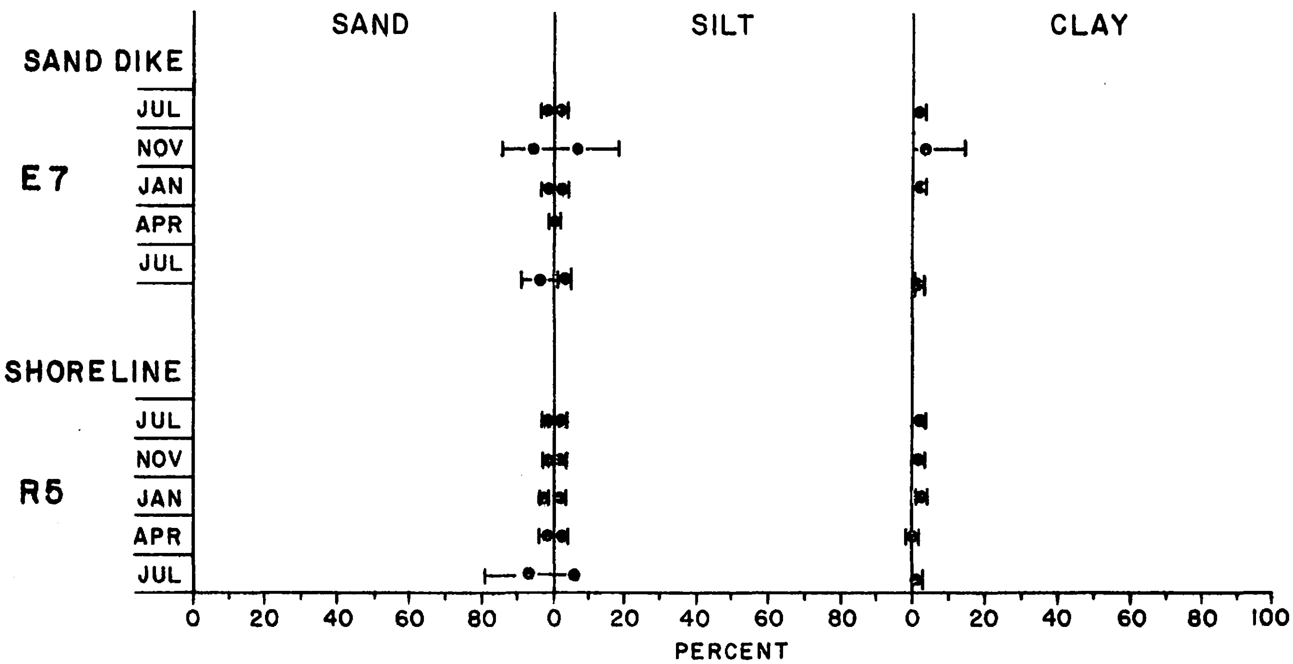


Figure 14. (Concluded).

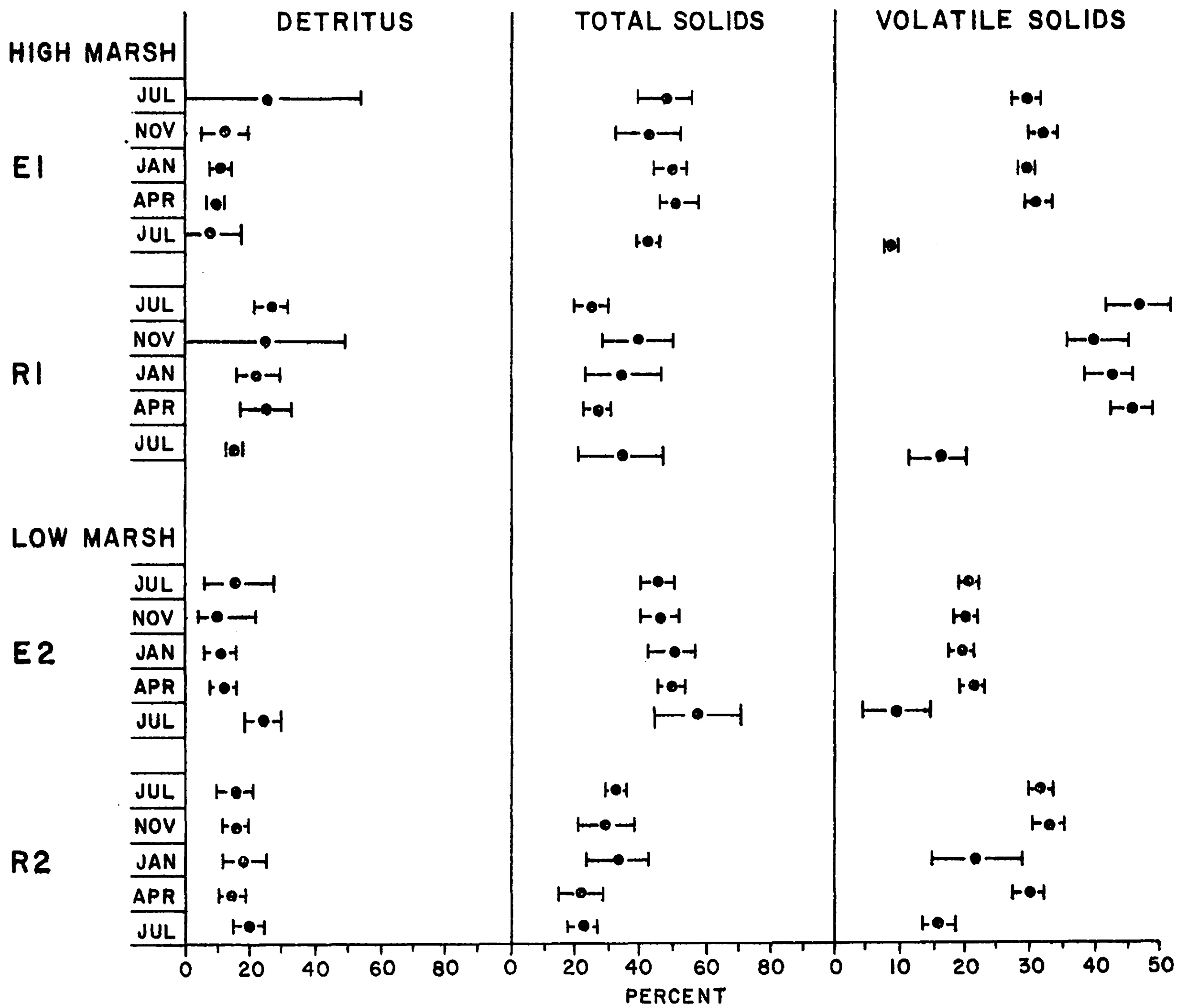


Figure 15. Mean and 95% confidence intervals of percent detritus, total solids, and volatile solids by stratum and sampling period (Continued).

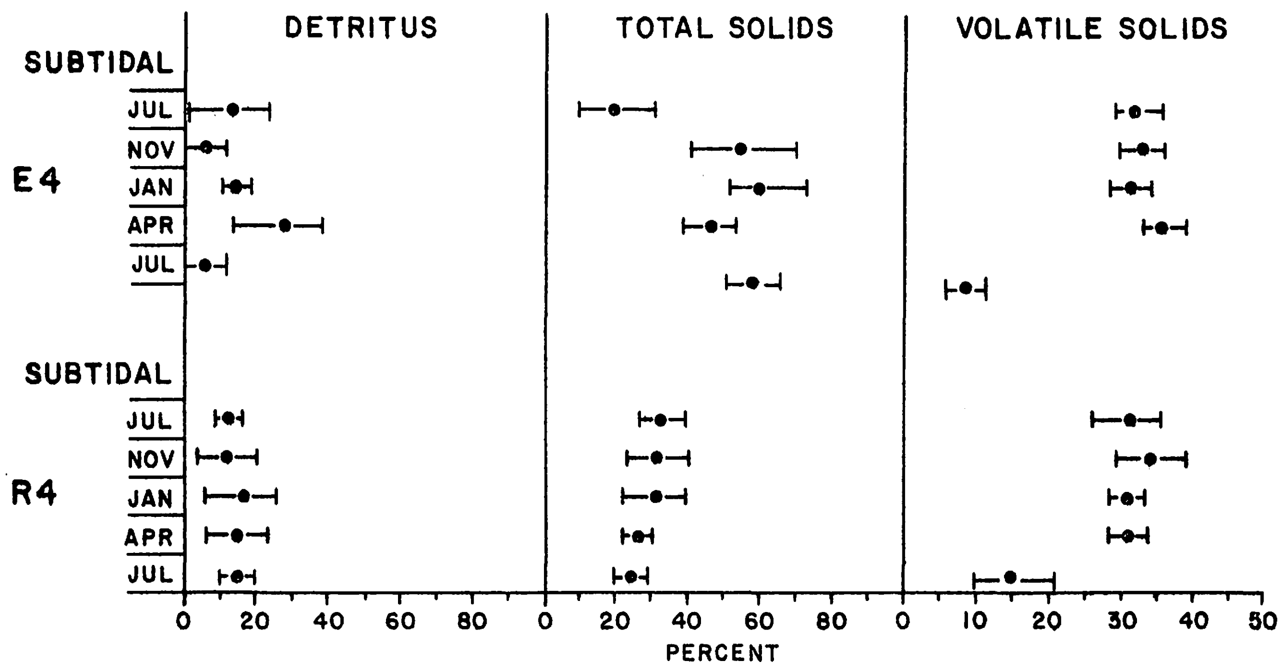


Figure 15. (Continued).

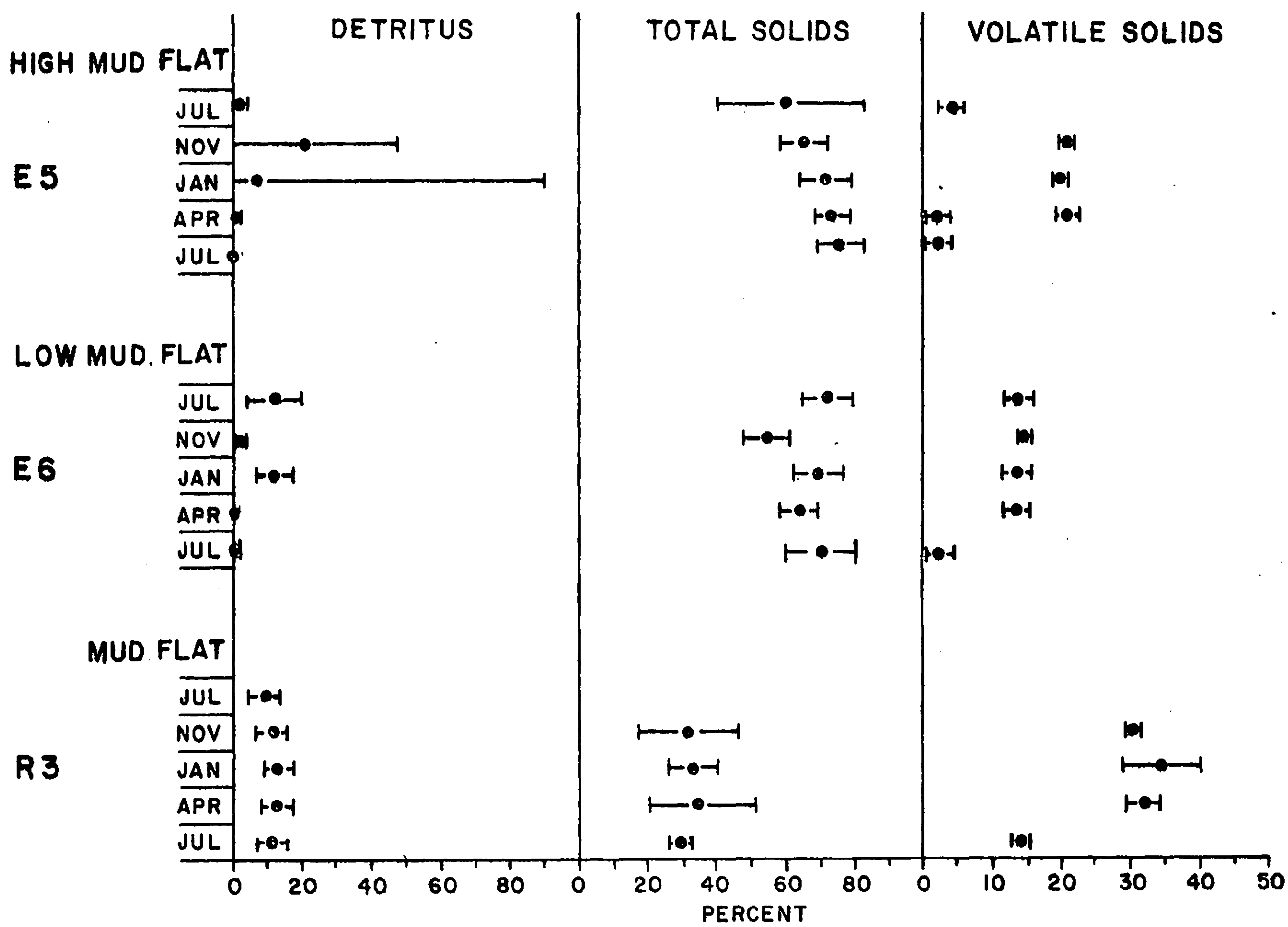


Figure 15. (Continued).

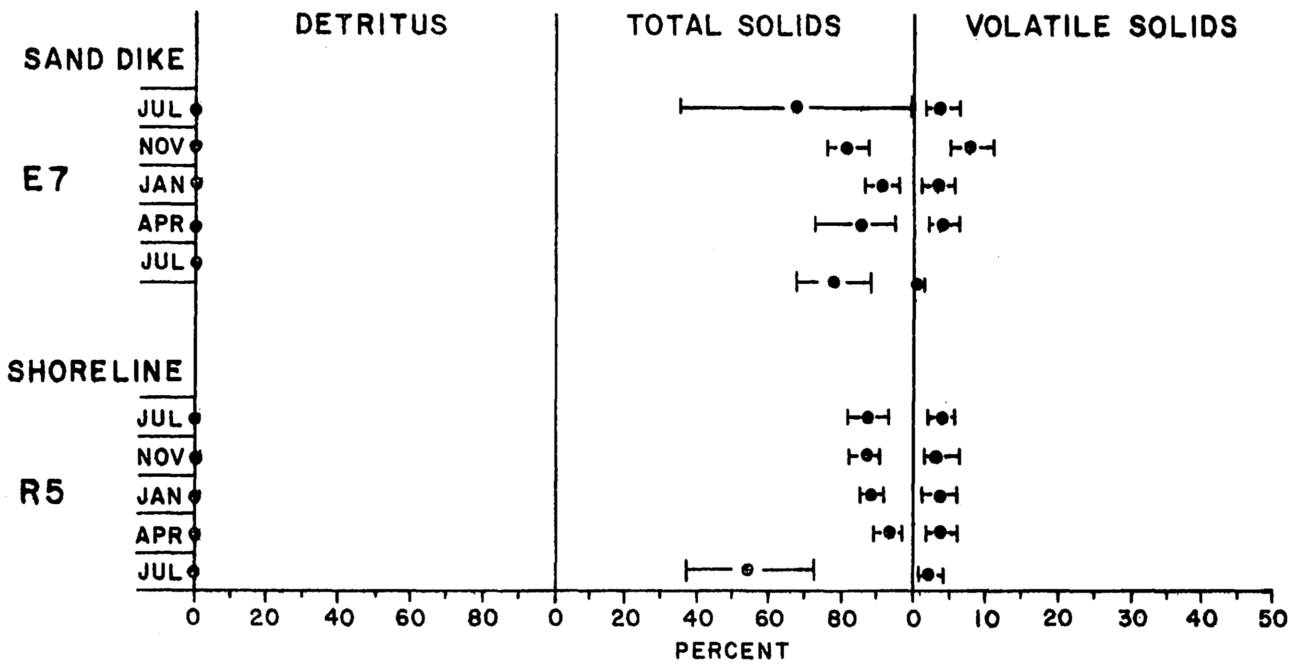


Figure 15. (Concluded).

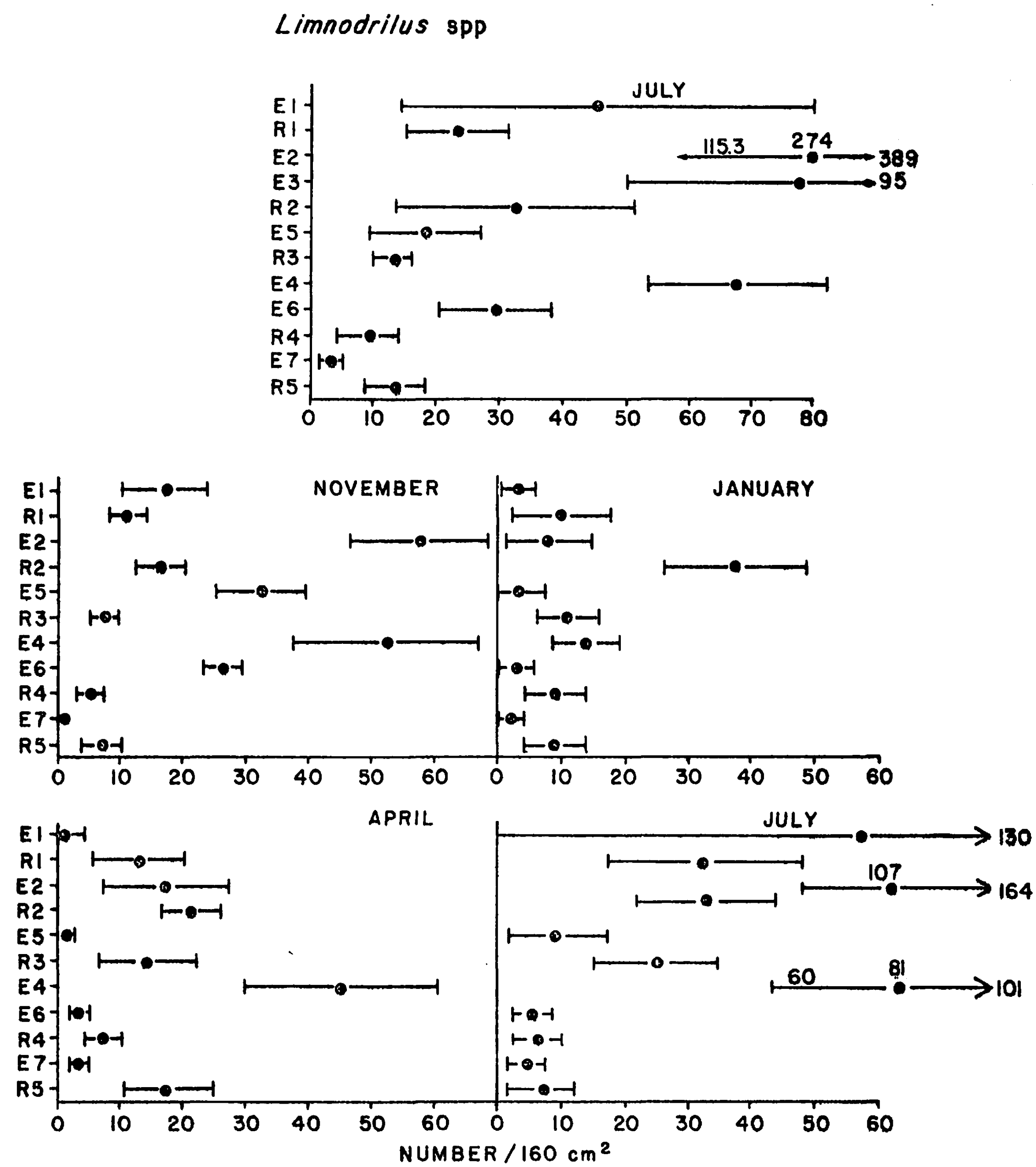


Figure 16. Mean and 80% confidence intervals of the density of the oligochaete Limnodrilus spp. (immature) by stratum and sampling period.

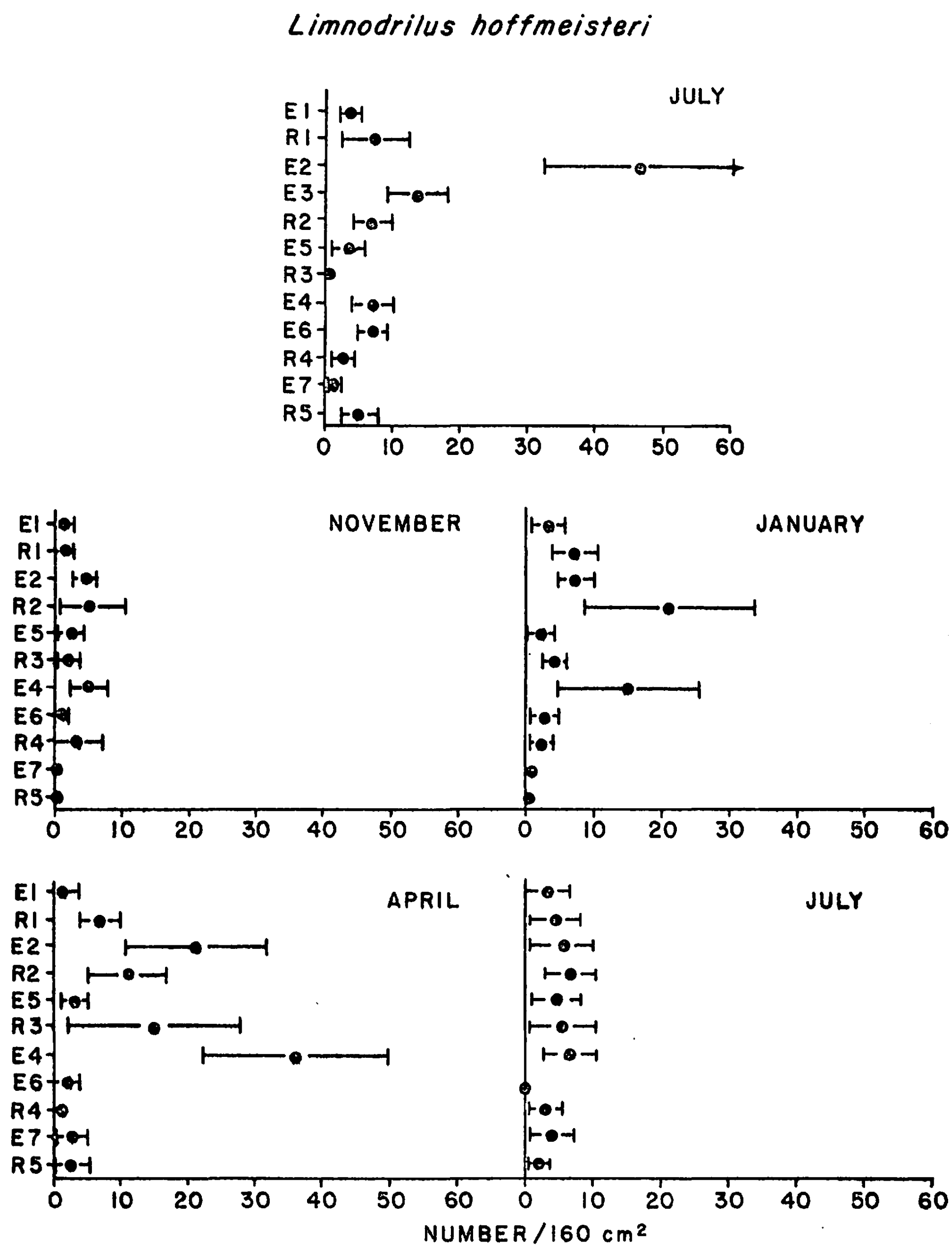


Figure 17. Mean and 80% confidence intervals of the density of the oligochaete Limnodrilus hoffmeisteri by stratum and sampling period.

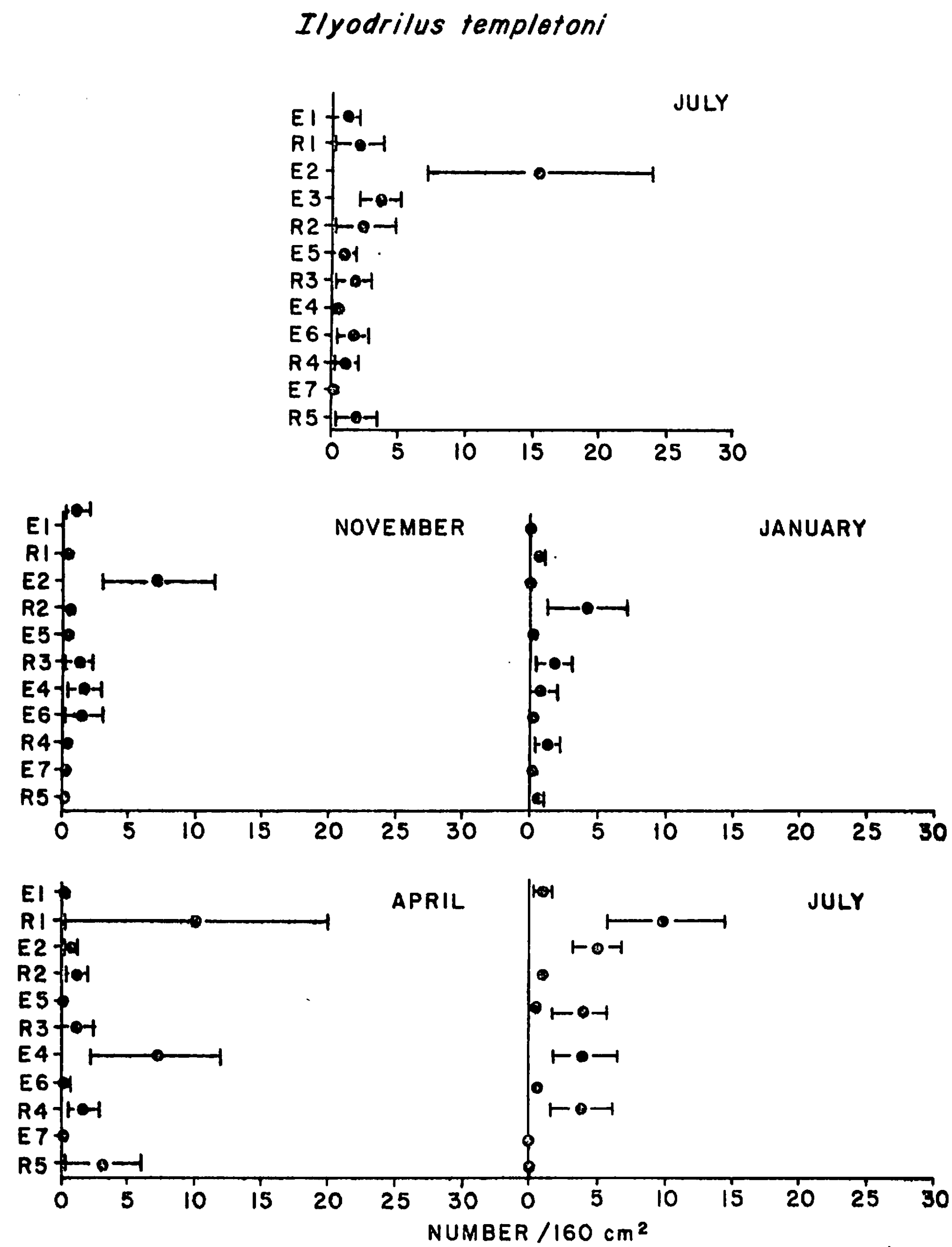


Figure 18. Mean and 80% confidence intervals of the density of the oligochaete Ilyodrilus templetoni by stratum and sampling period.

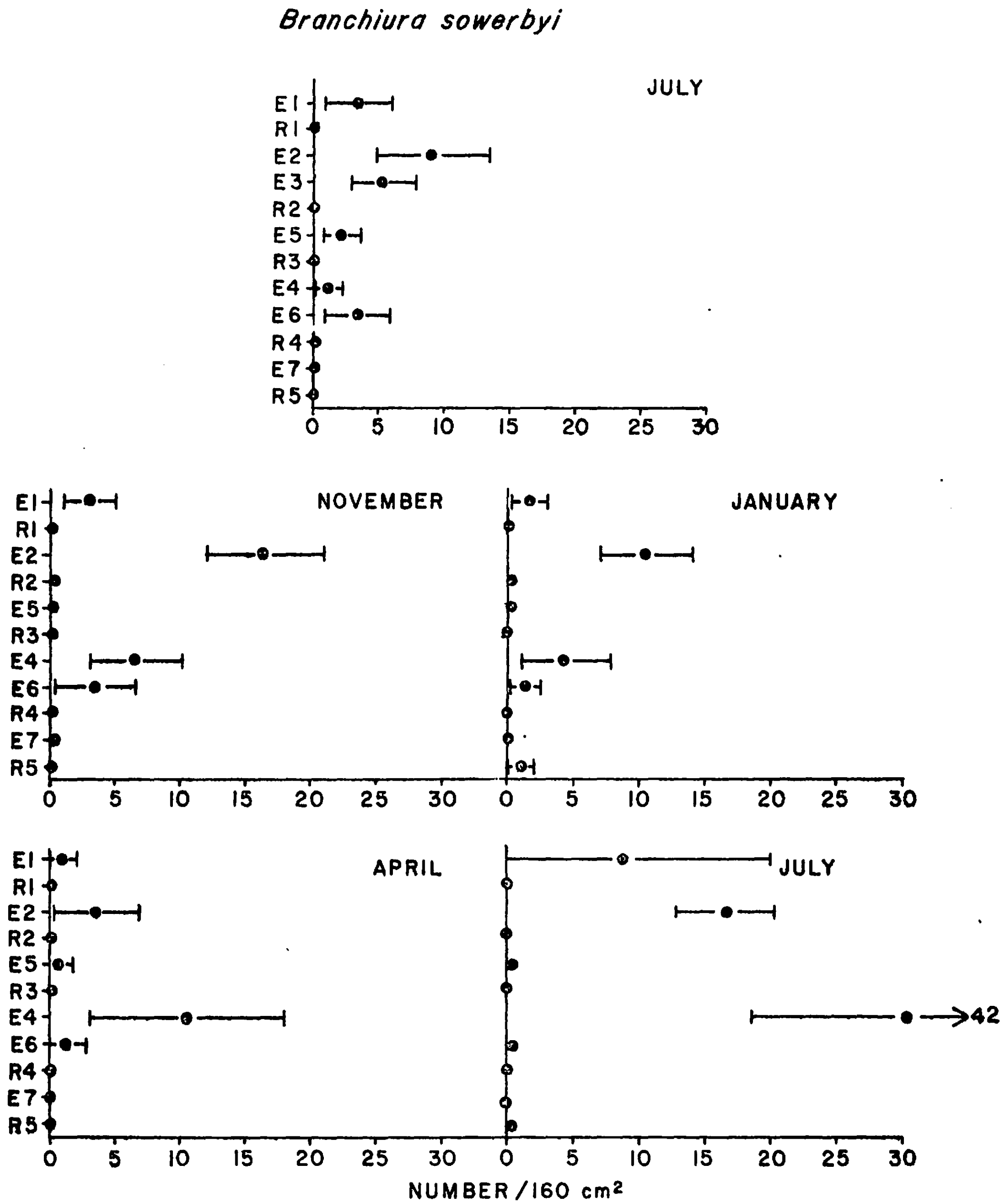


Figure 19. Mean and 80% confidence intervals of the density of the oligochaete Branchiura sowerbyi by stratum and sampling period.

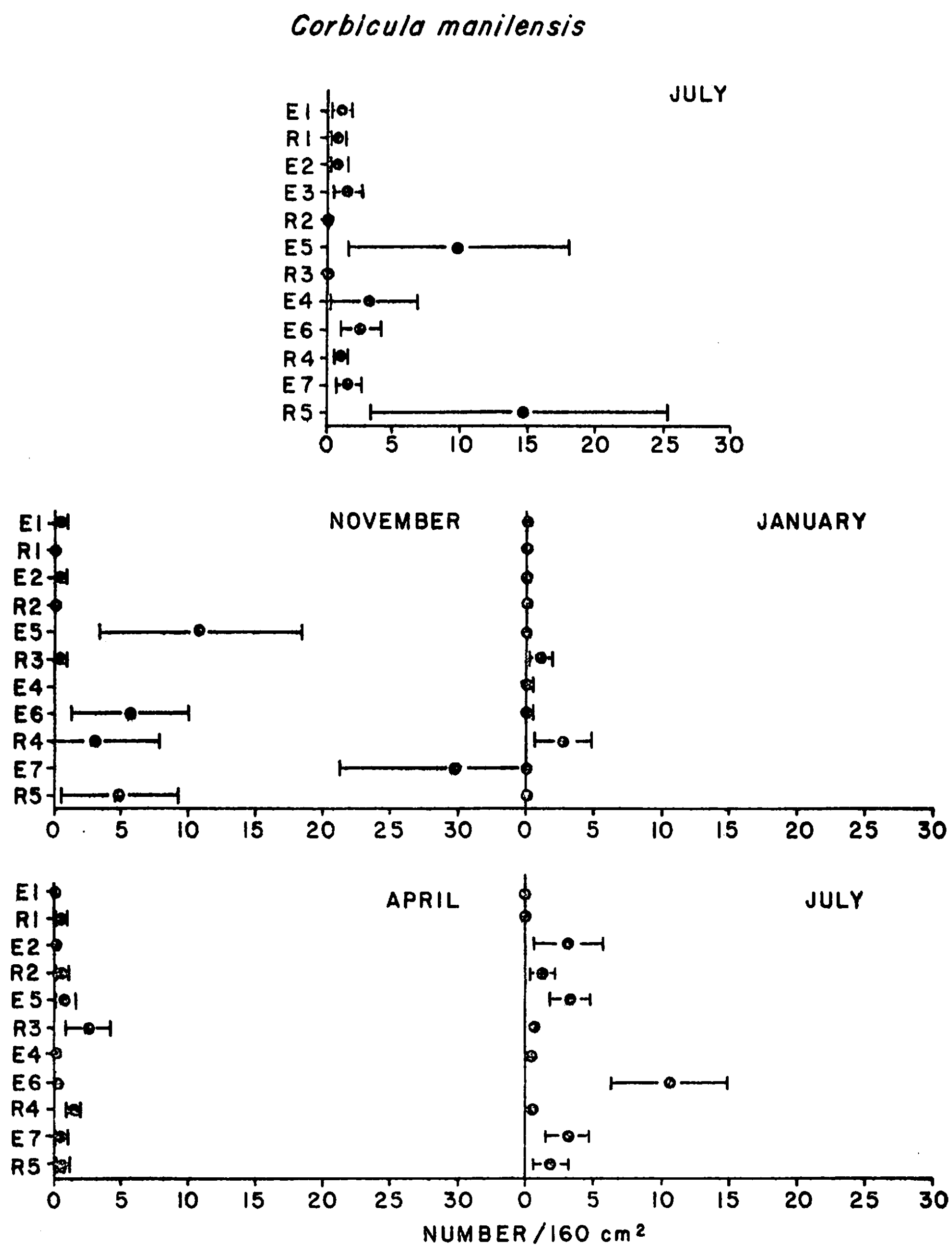


Figure 20. Mean and 80% confidence intervals of the density of the bivalve *Corbicula manilensis* by stratum and sampling period.

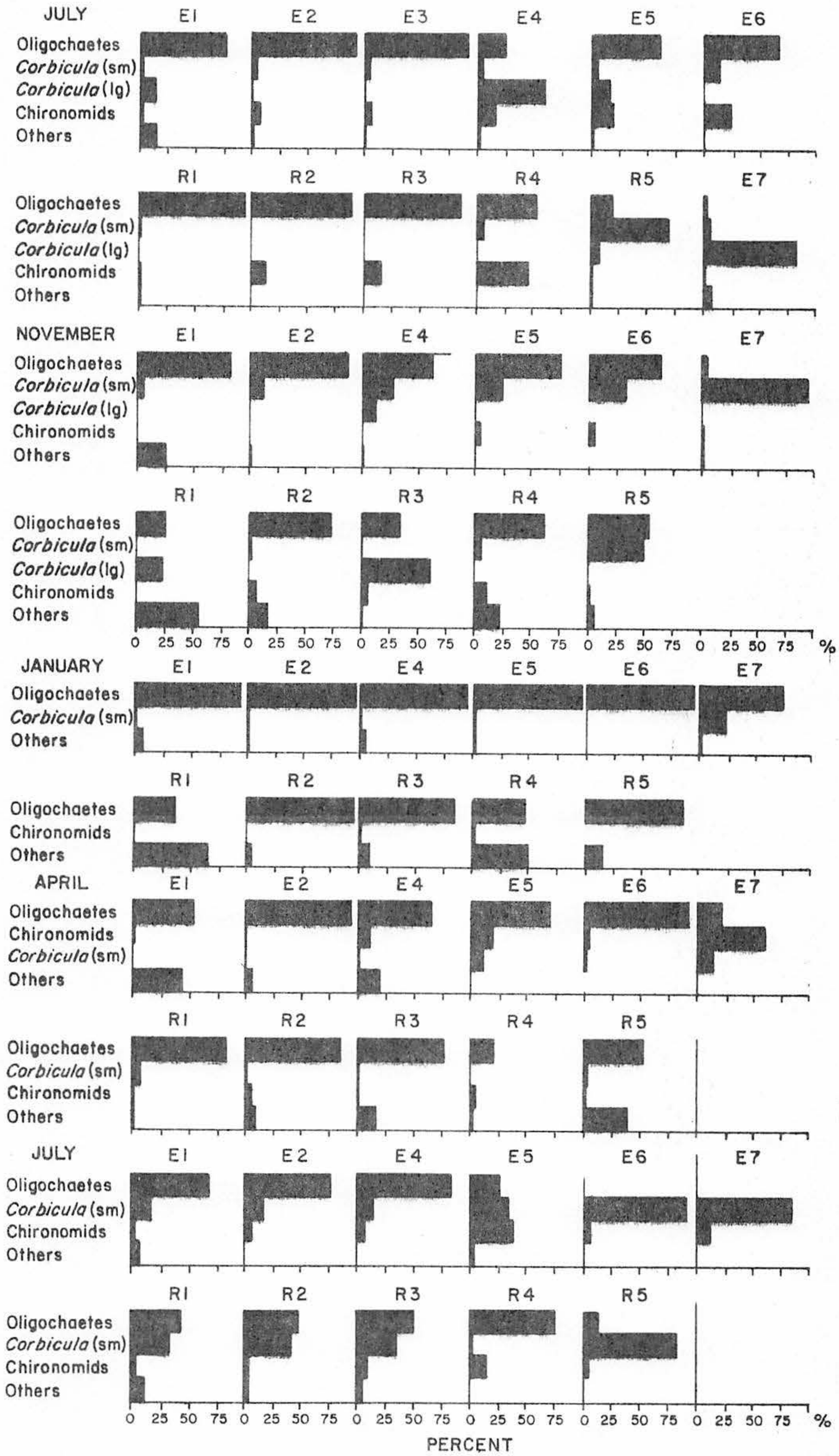


Figure 21. Percent composition of biomass by dominant taxa for each sampling period.

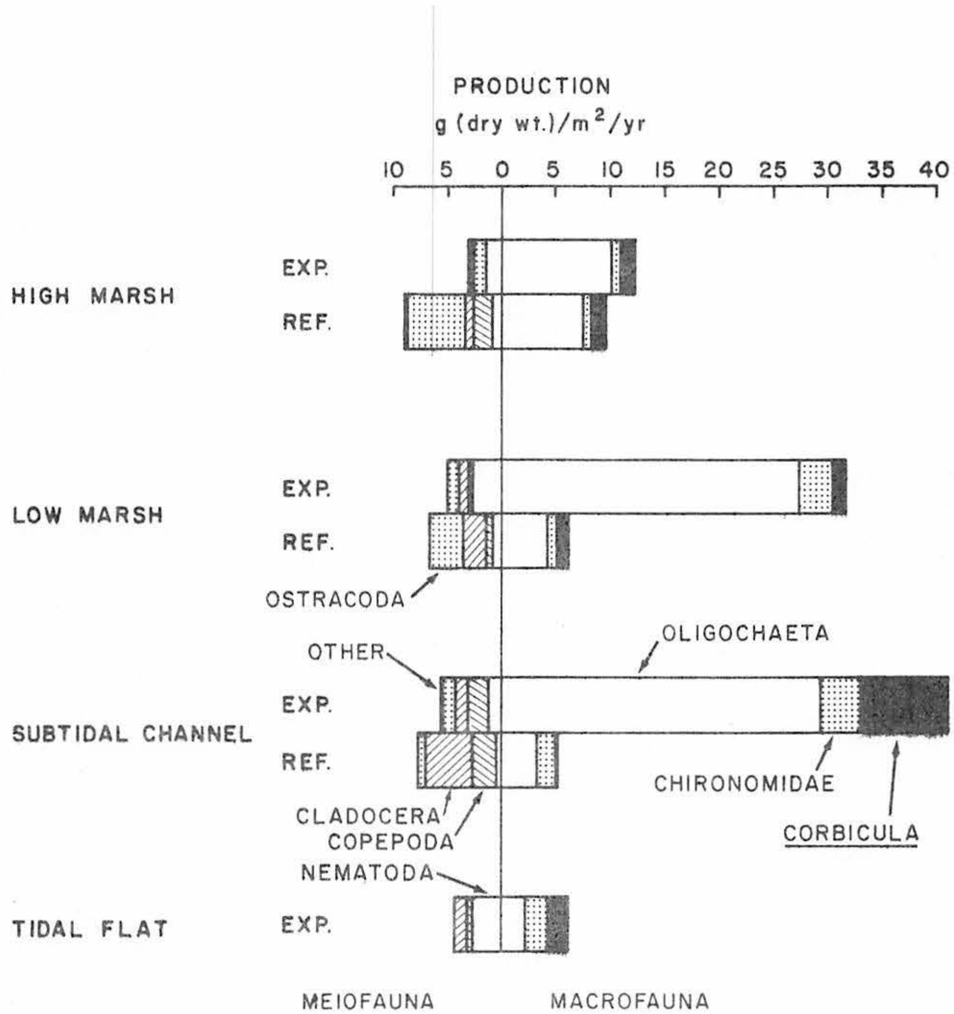


Figure 22. Estimated annual production in major habitats as contributed by major macrofaunal and meiofaunal taxa.

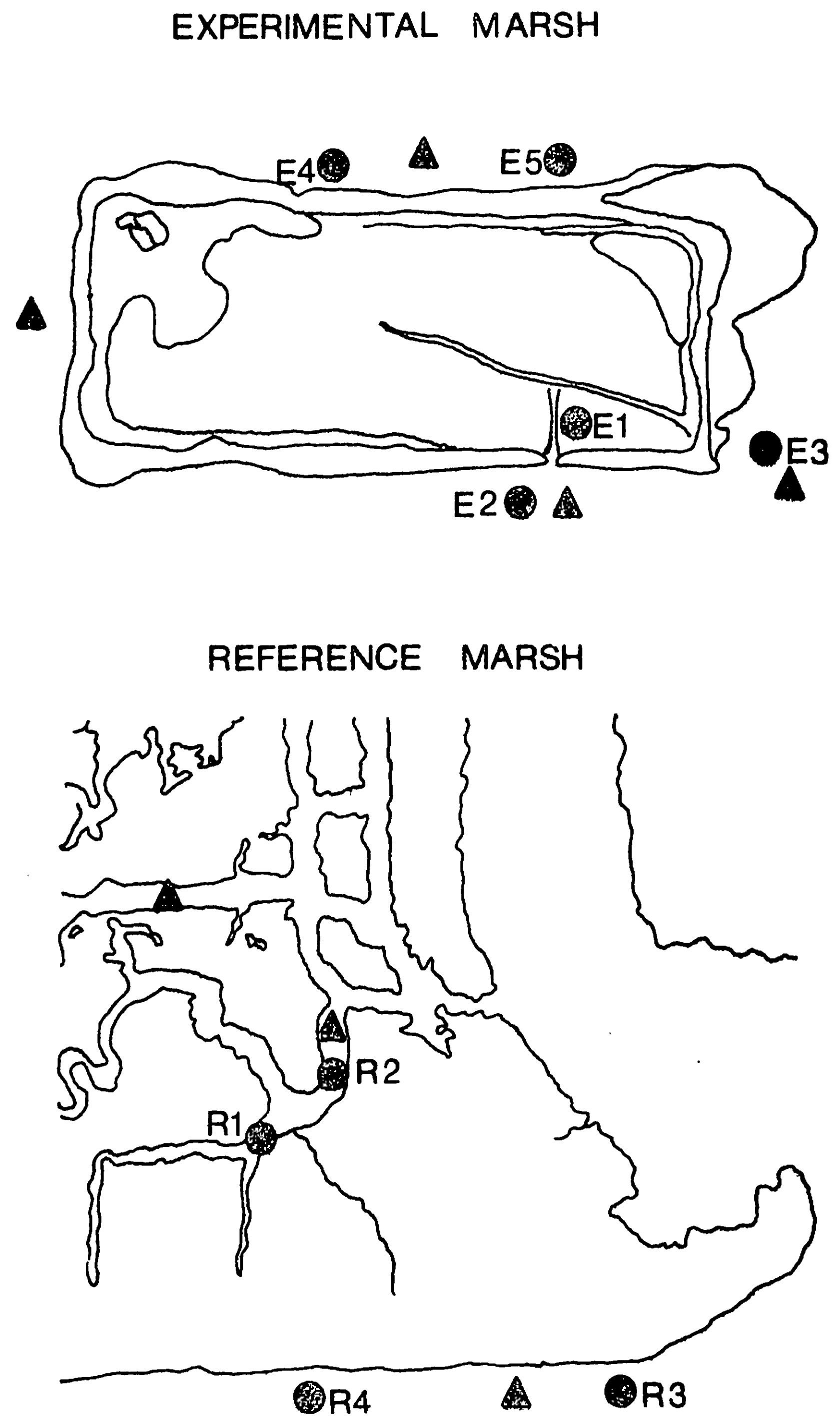


Figure 23. Nekton (circles) and water quality (triangles) sampling stations.

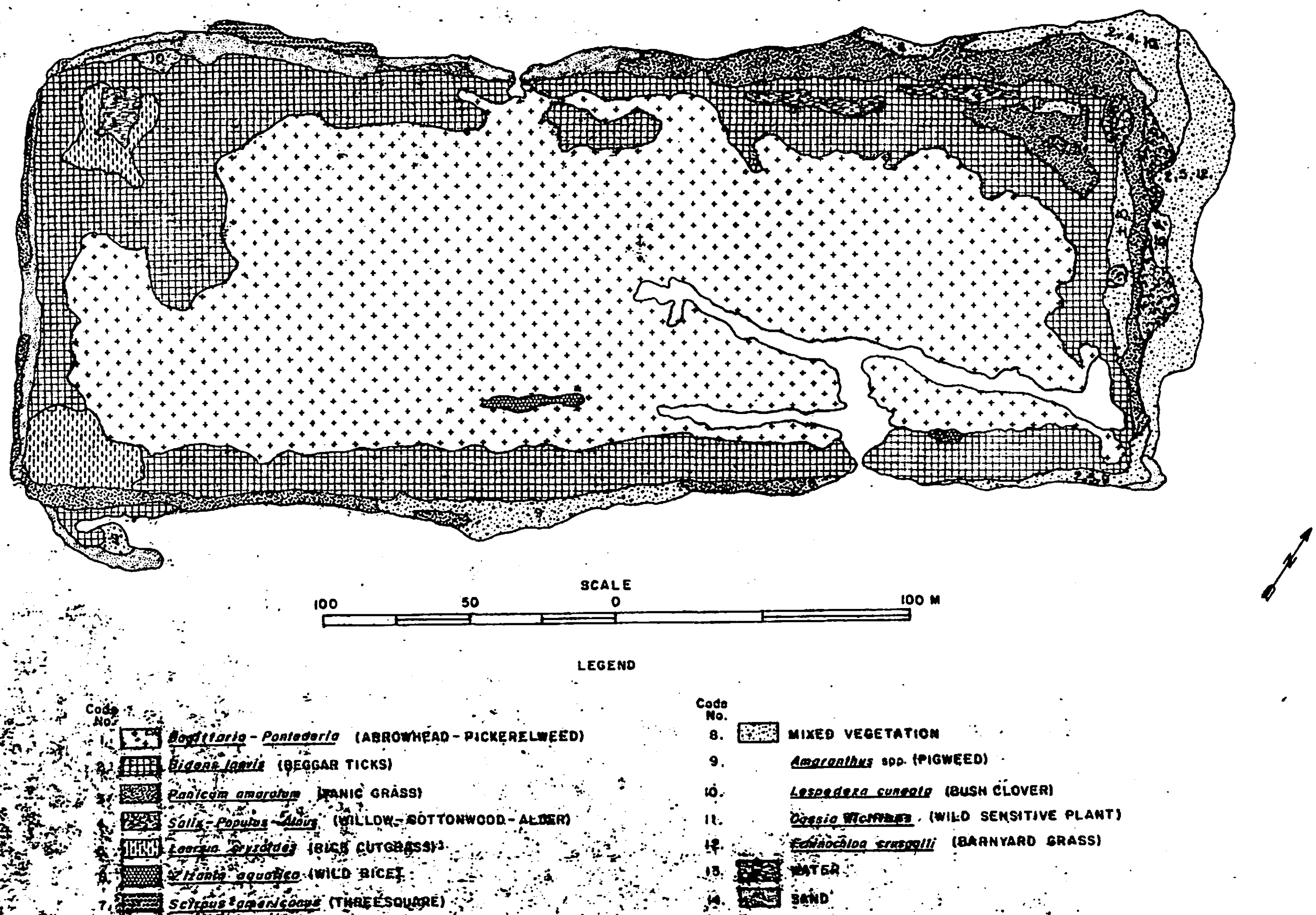


Figure 24. Vegetation types at the experimental site, September 1977.

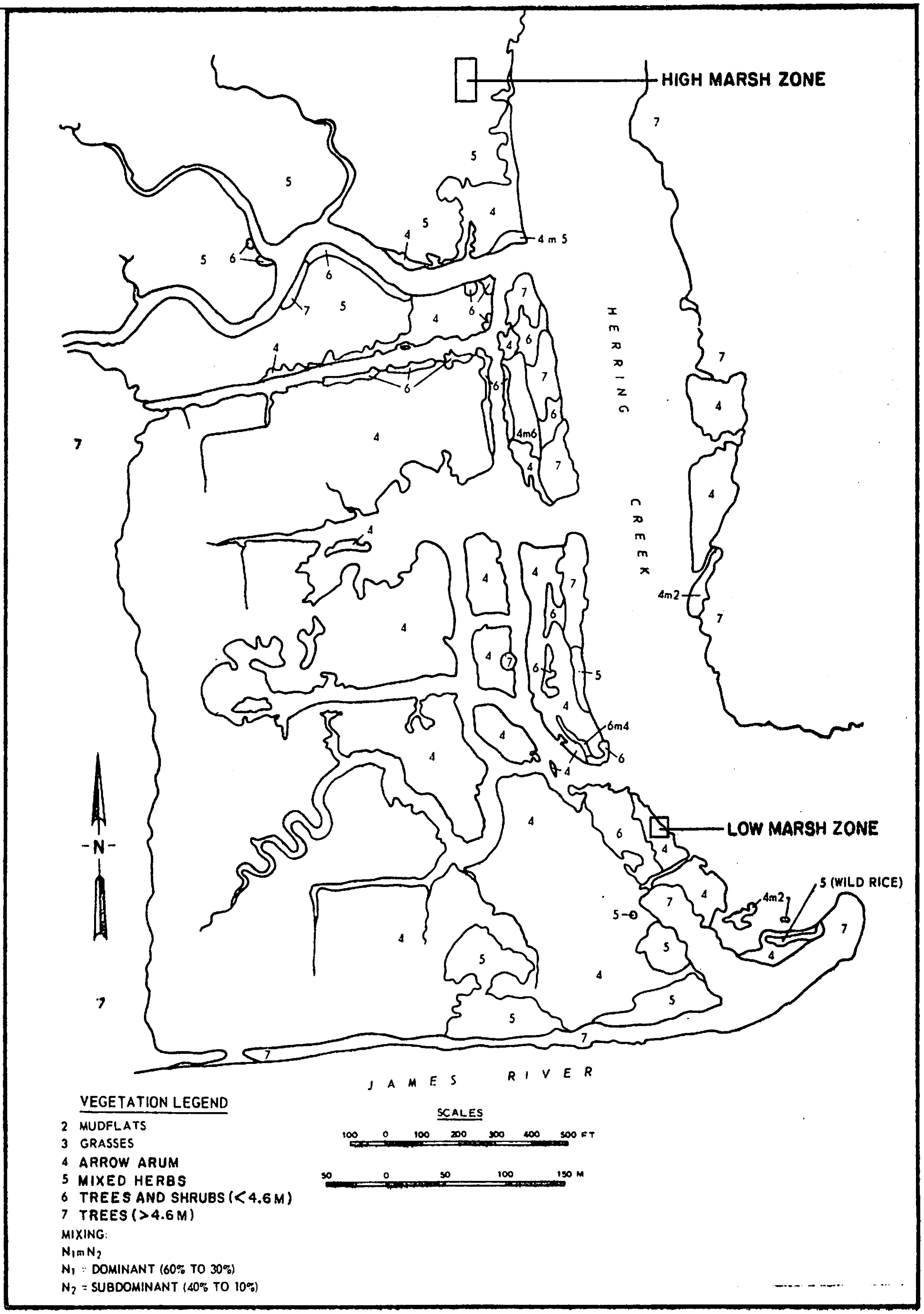


Figure 25. Vegetation types and botanical sampling zones at the reference site, June-August 1977.

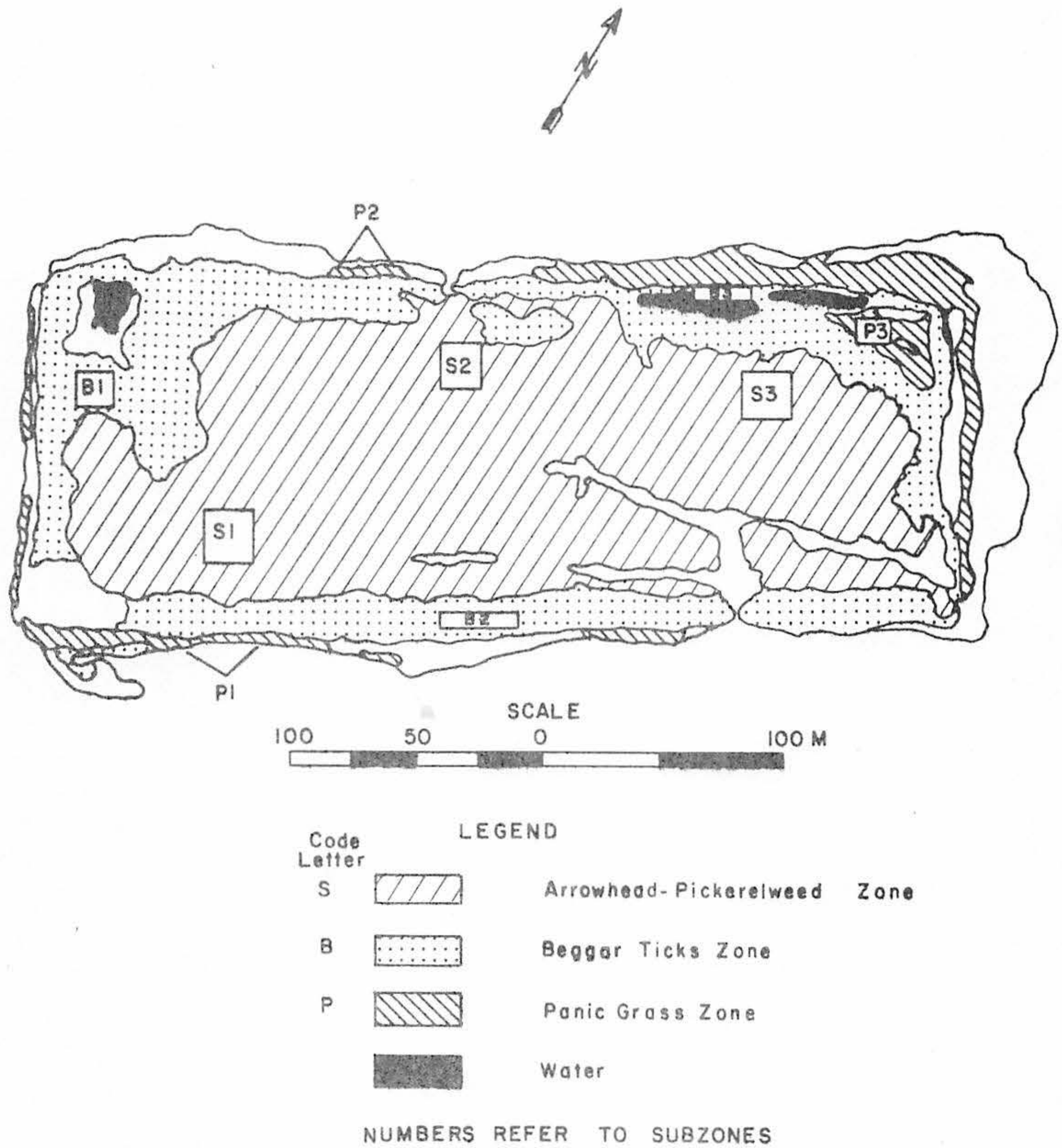


Figure 26. Botanical sampling zones and subzones at the experimental site, June-August 1977. Rectangles represent subzones sampled. The P1 and P2 subzones were too narrow to be depicted; thus only their lengths are indicated. P2, S1, S3, B2, and B3 were also sampled for soils in 1976.

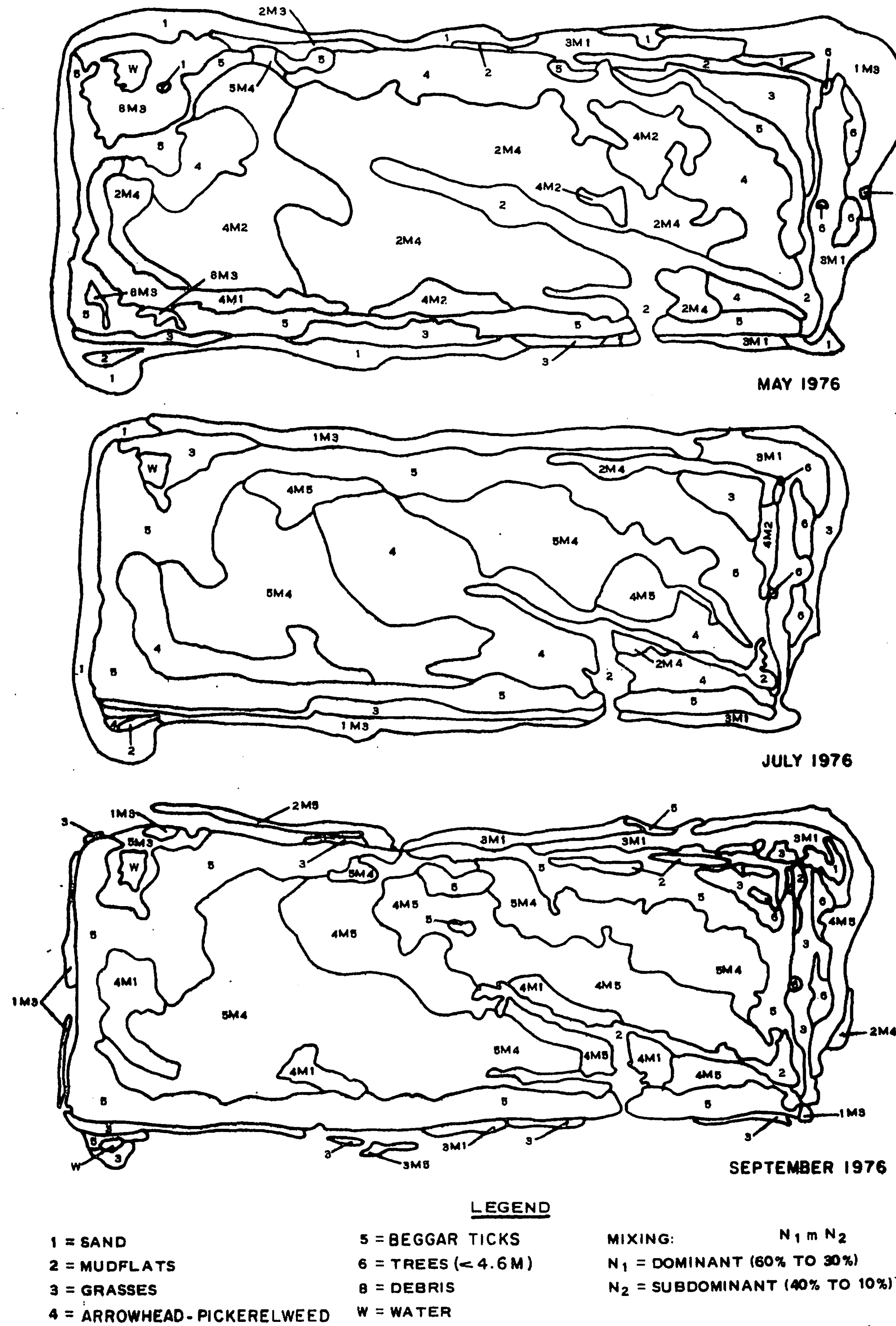


Figure 27. Experimental site vegetation cover, May-September 1976 (scales vary).

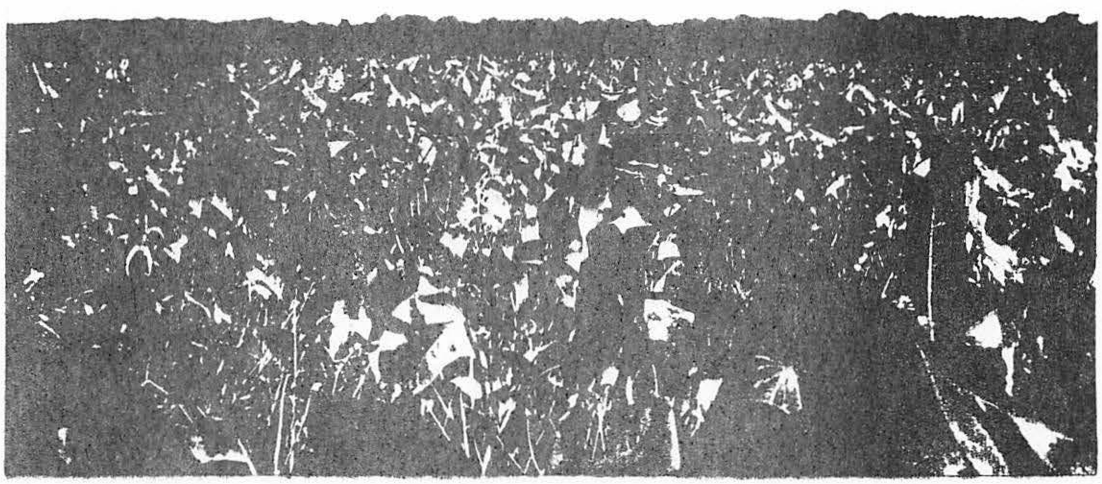


Figure 28. Arrowhead-pickerelweed zone, 26 July 1977.

Figure 29. Beggar ticks zone, 27 June 1977. Note muskrat lodge in center.

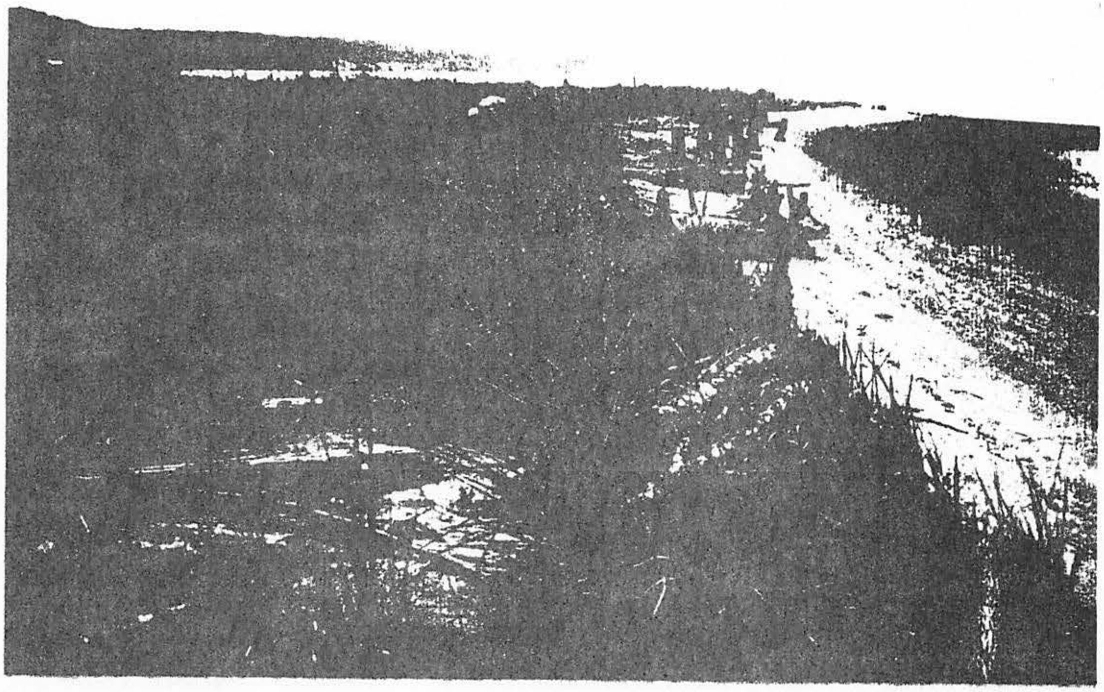


Figure 30. Panic grass zone, 23 June 1977. Panic grass is in center, with beggar ticks at left and remnants of threesquare and cordgrass plantings at upper right.

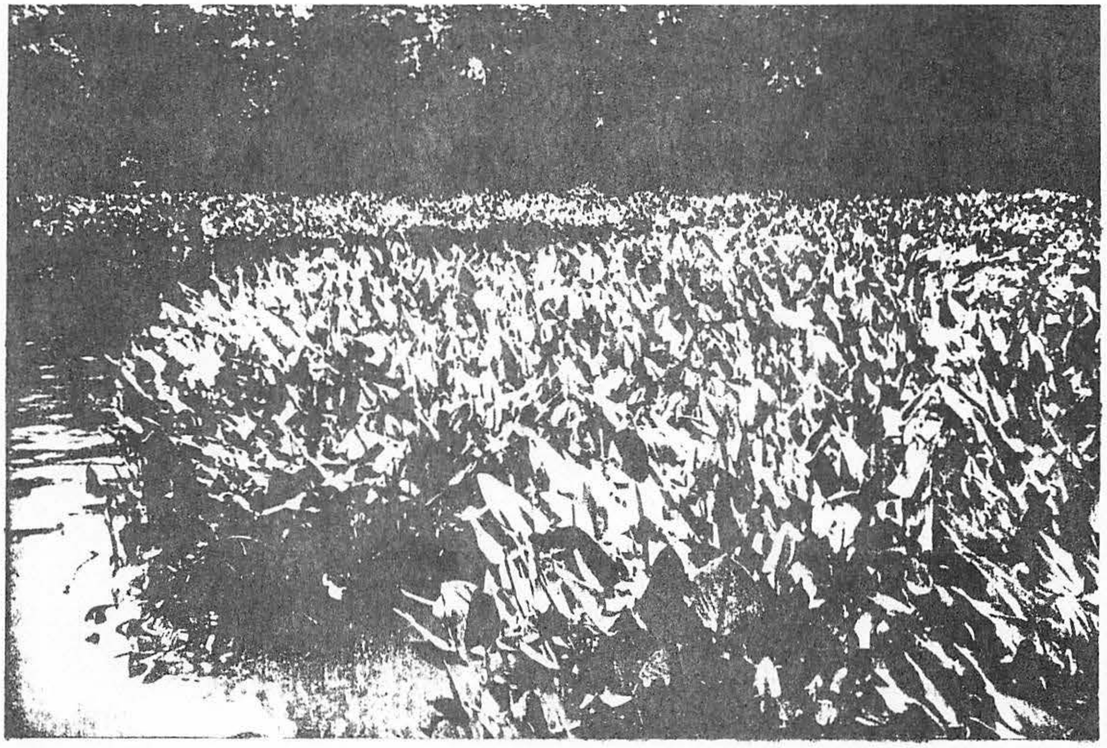


Figure 31. Low marsh zone, 19 May 1977. Arrow arum and pickerelweed are the dominant species.

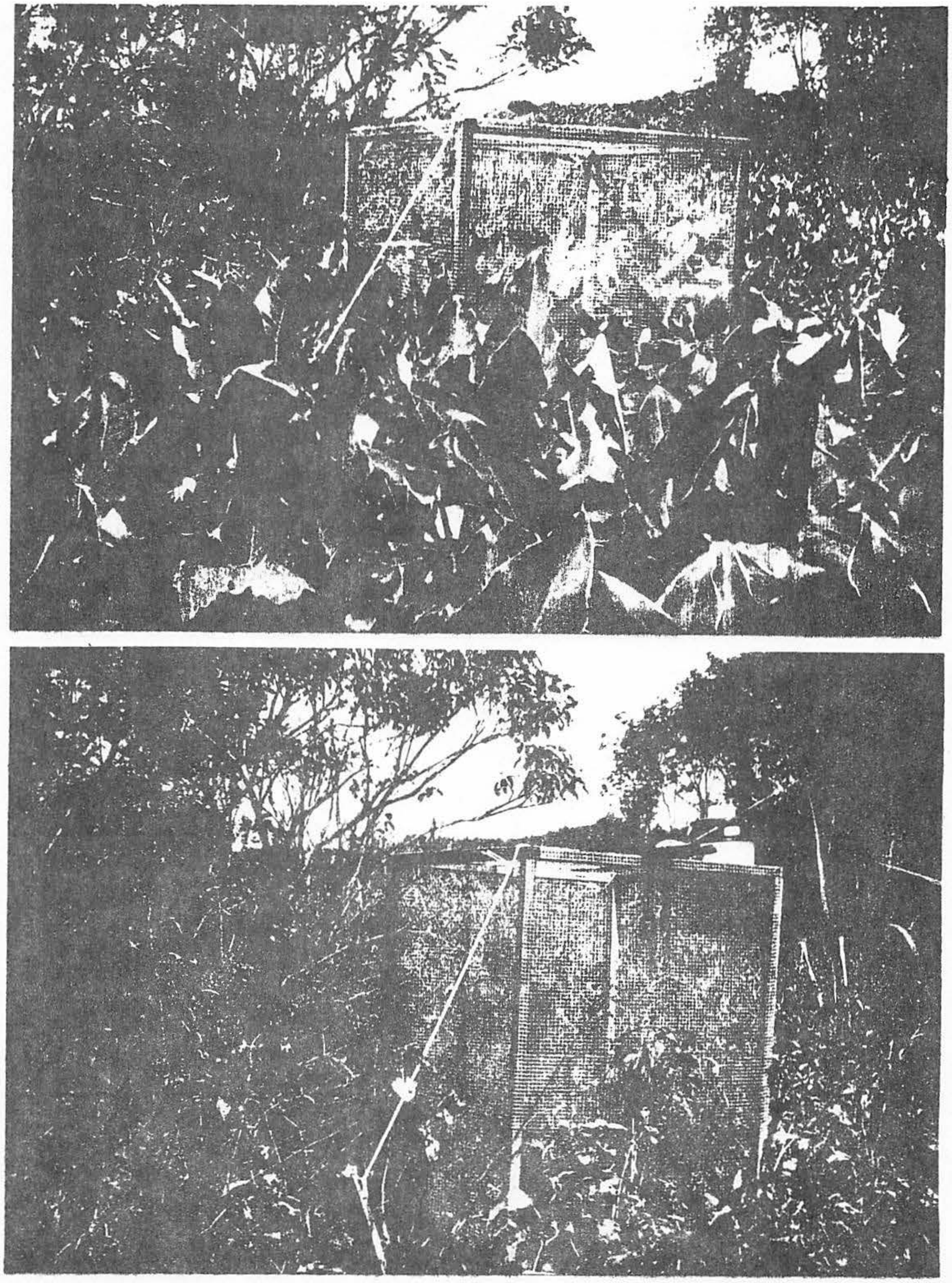


Figure 32. High marsh zone. Top picture was taken 19 May 1977; bottom picture of same location was taken three months later. Loss of vegetation was due to insects. Cage exclosure was unsuccessfully used to determine animal grazing pressures.

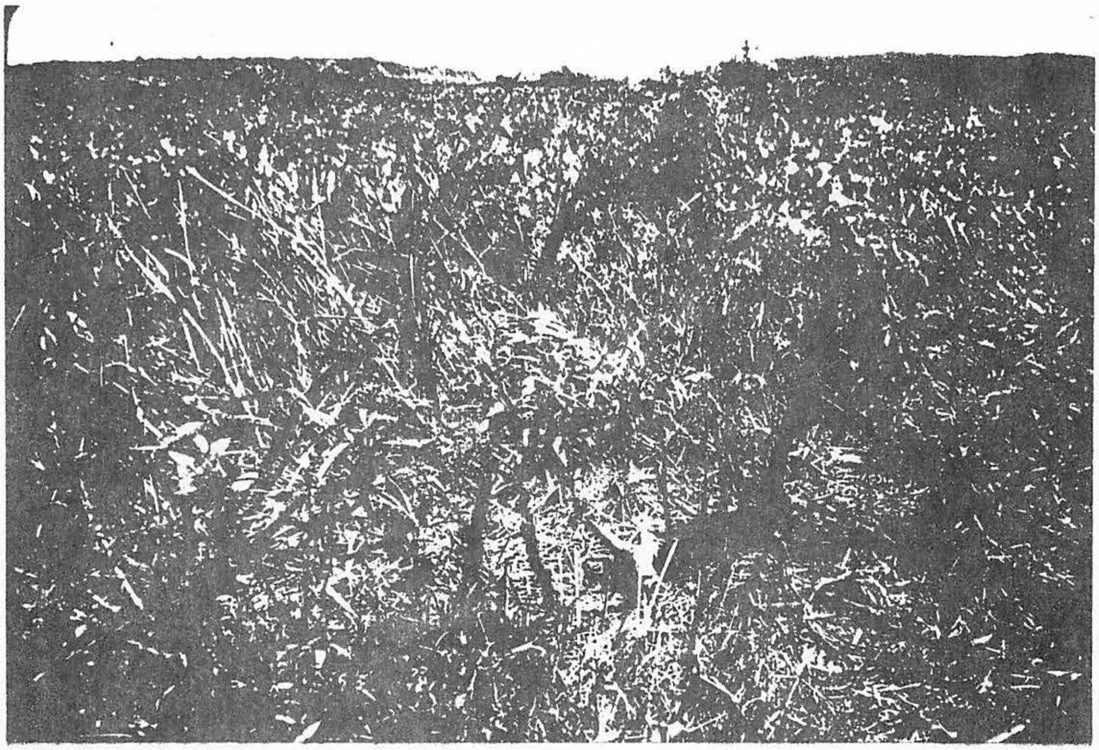


Figure 33. Wind damage in beggar ticks zone, 26 July 1977.

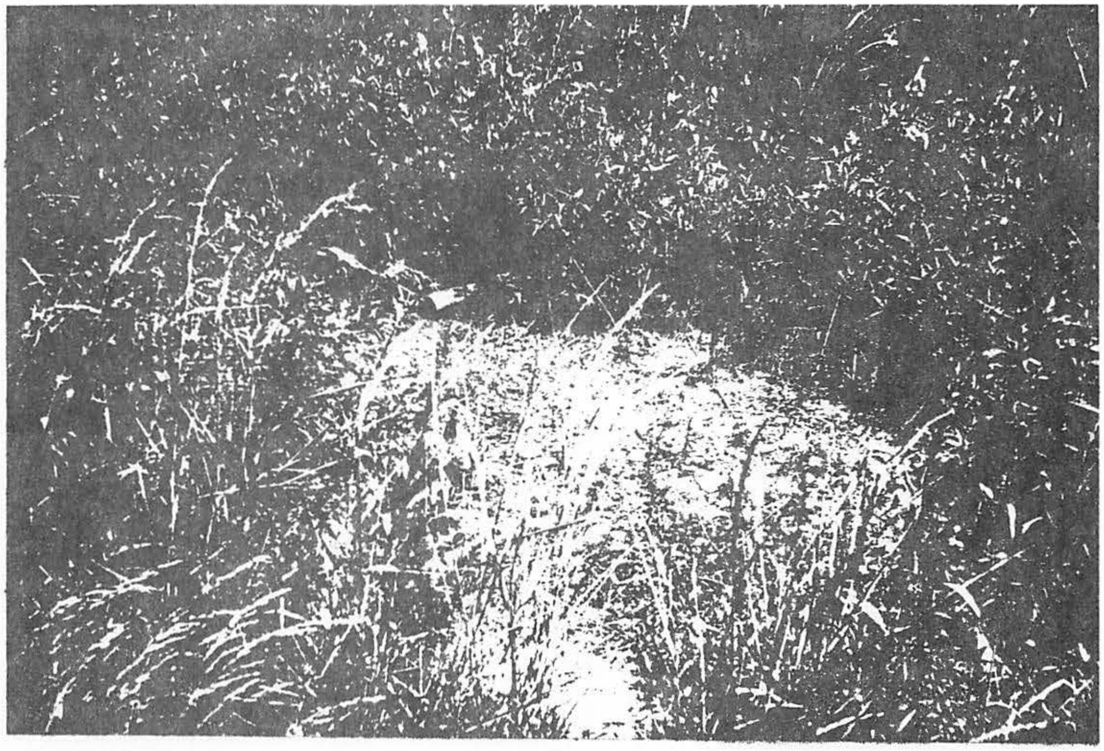


Figure 34. Beggar ticks zone, 26 July 1977. Recent muskrat "eat-out".

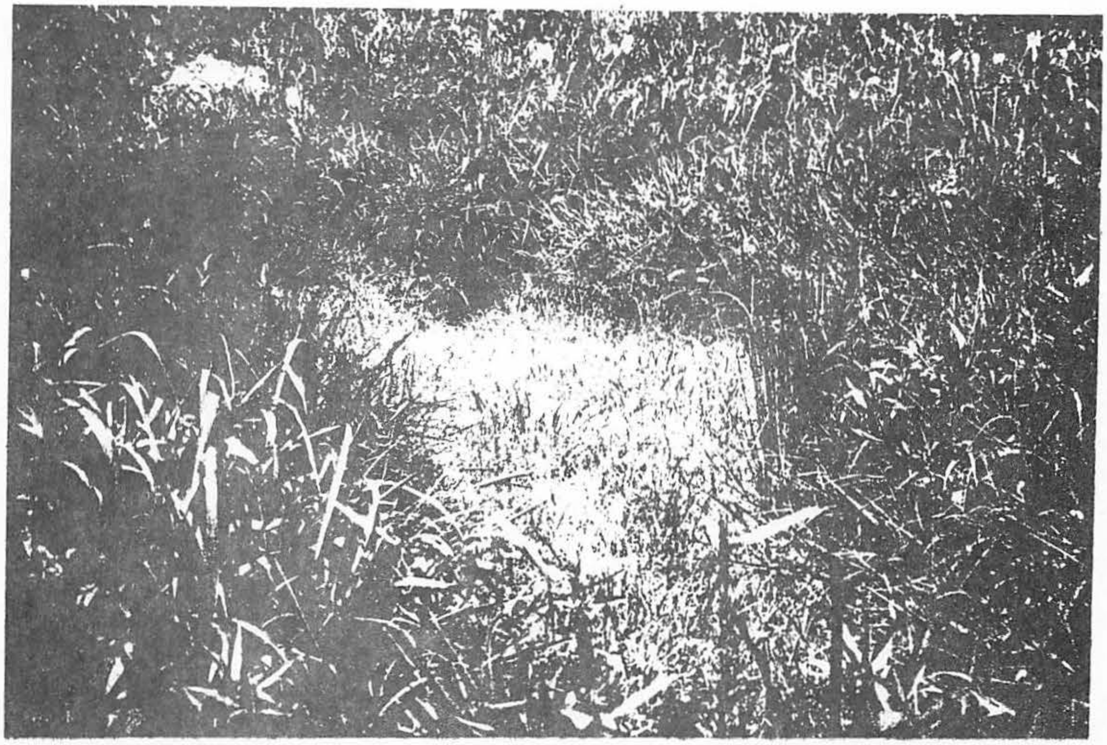


Figure 35. Beggar ticks zone, 26 July 1977. Old muskrat "eat-out" being revegetated by rice cutgrass.

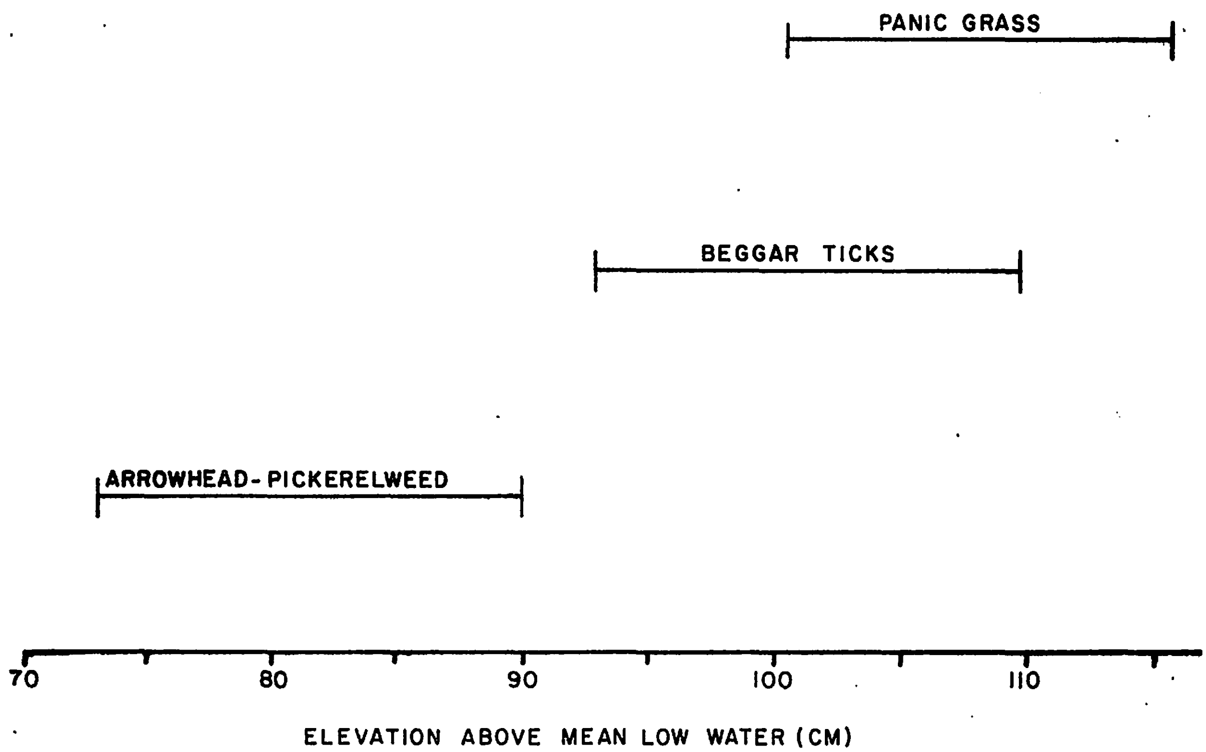


Figure 36. Elevation ranges of plant zones sampled.

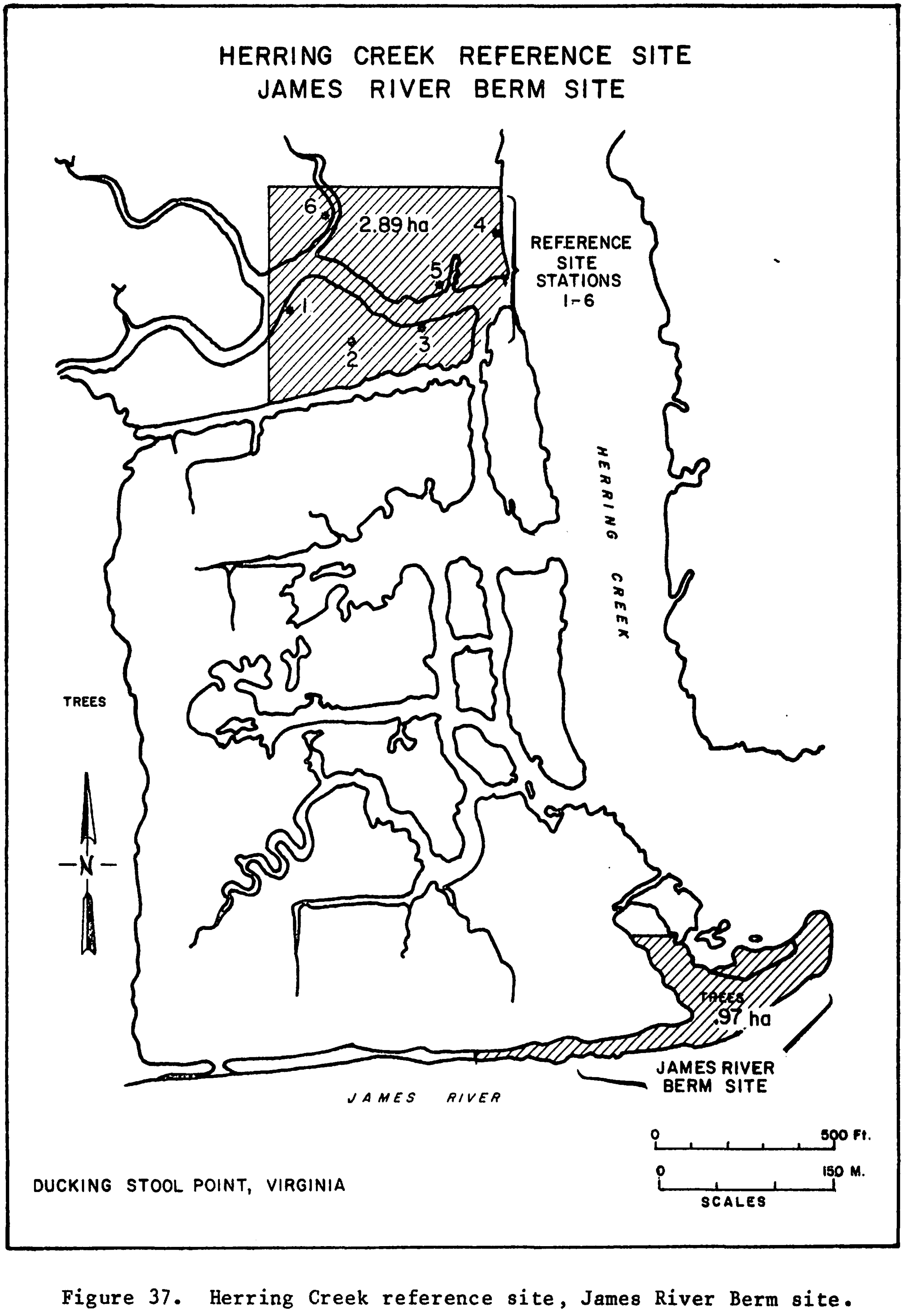


Figure 37. Herring Creek reference site, James River Berm site.

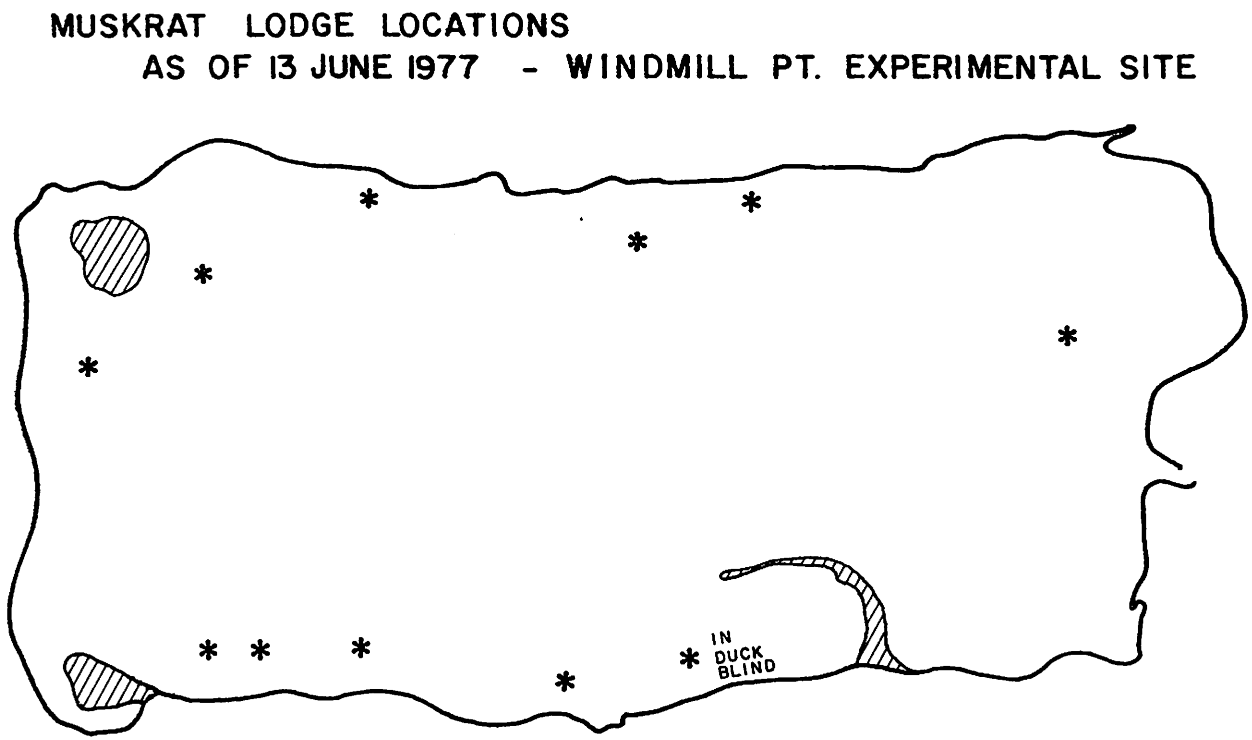
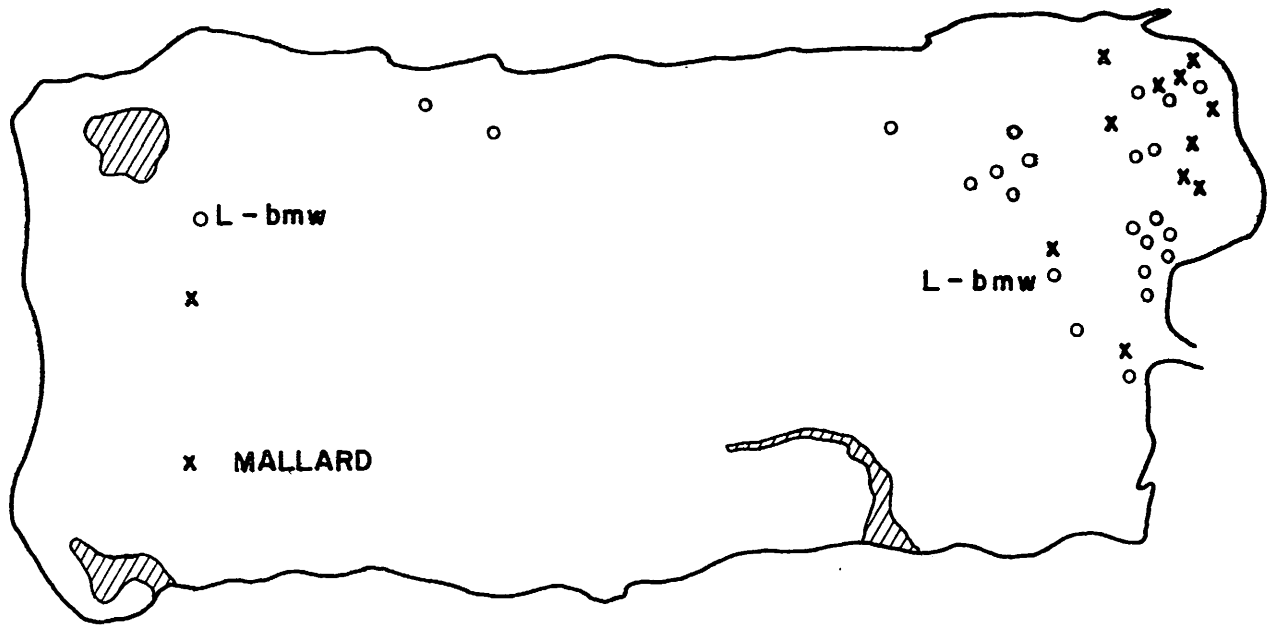


Figure 38. Muskrat lodge locations at the Windmill Point experimental site.

1977 NEST LOCATIONS*– WINDMILL PT. EXPERIMENTAL SITE



x = CONTAINED EGGS OR NESTLINGS

o = DID NOT CONTAIN EGGS OR NESTLINGS

L-bmw = LONG-BILLED MARSH WREN

*ALL ARE RED-WINGED BLACKBIRD NESTS EXCEPT WHERE INDICATED

Figure 39. 1977 nest locations at the Windmill Point experimental site.

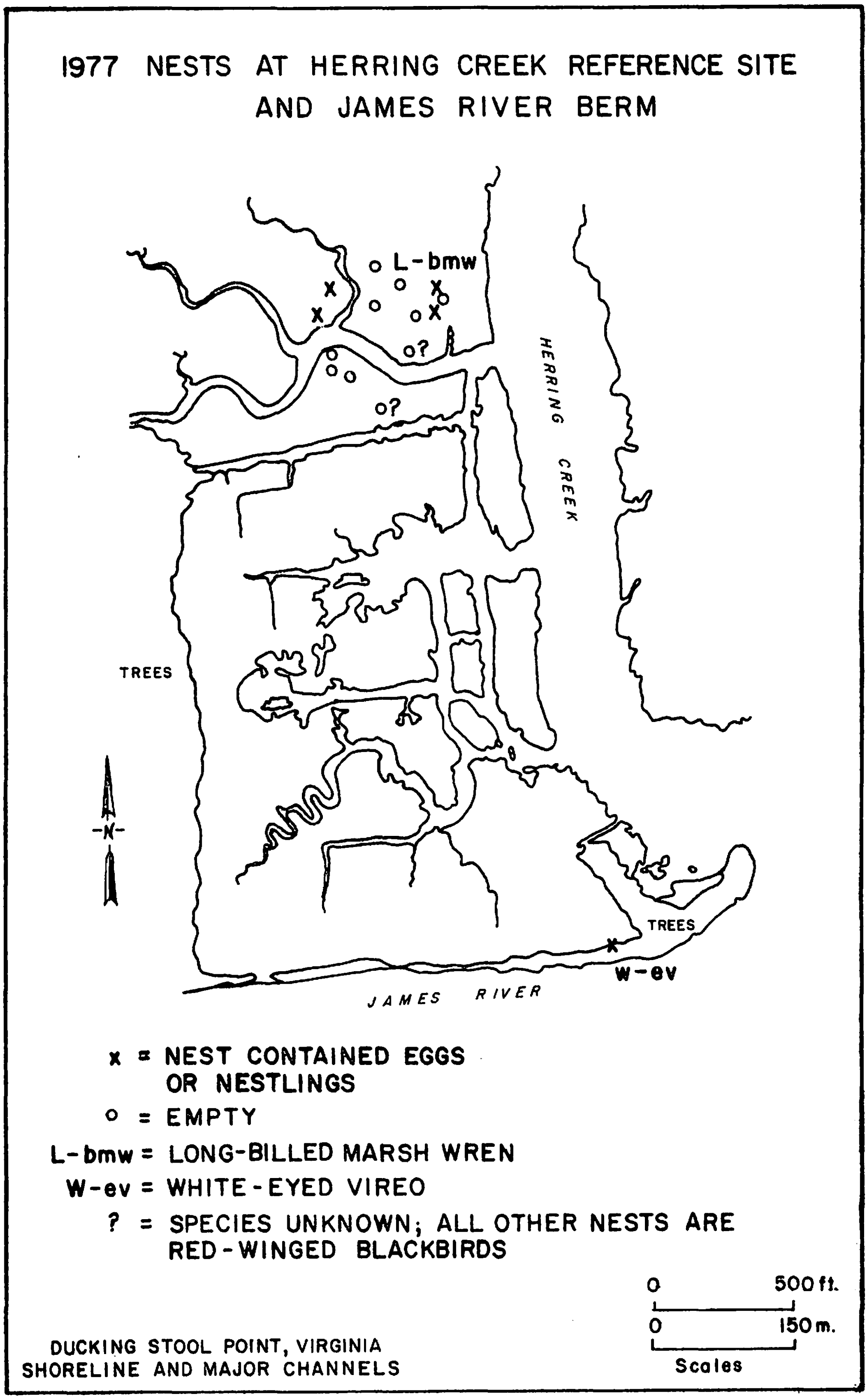


Figure 40. 1977 nest locations at the Herring Creek reference site and the James River Berm.

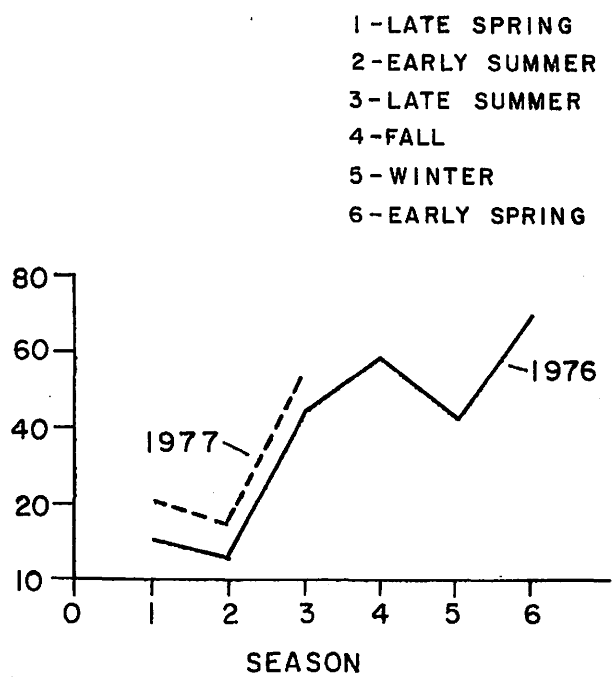


Figure 41. Mean seasonal density of birds at Windmill Point experimental site.

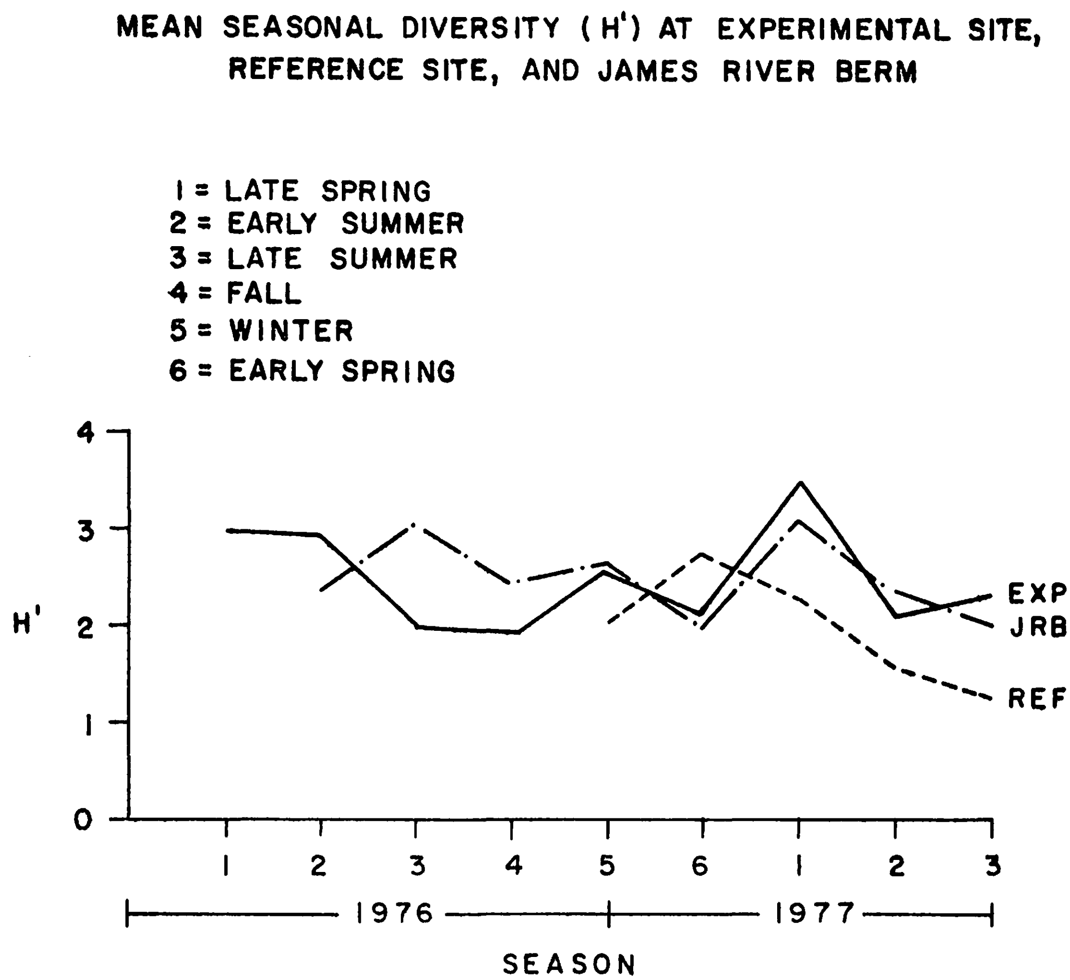


Figure 42. Mean seasonal diversity (H') at the experimental and reference sites and the James River Berm.

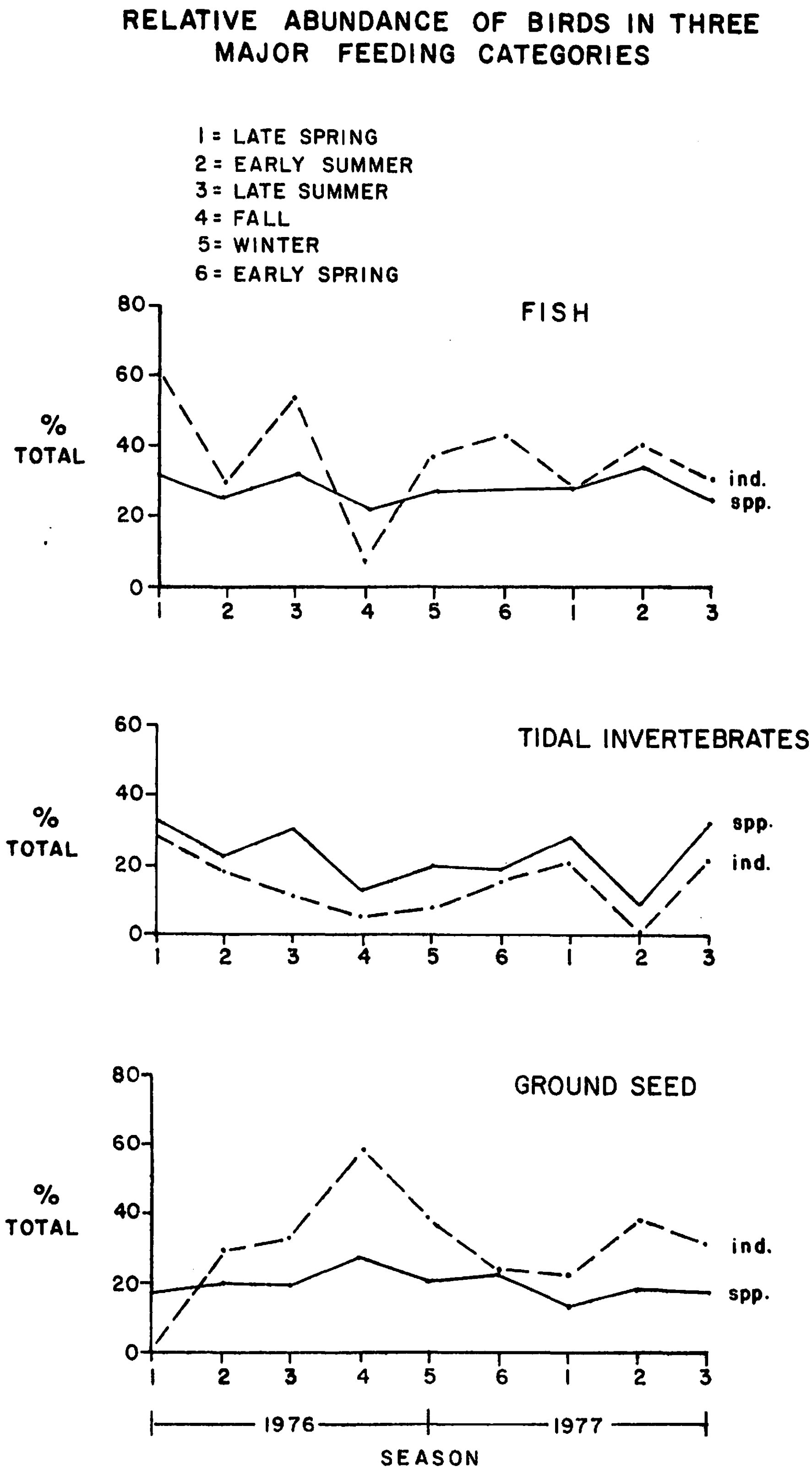


Figure 43. Relative abundance of birds in three major feeding categories.

FORAGING DIVERSITY AT EXPERIMENTAL, REFERENCE AND JAMES RIVER BERM SITES

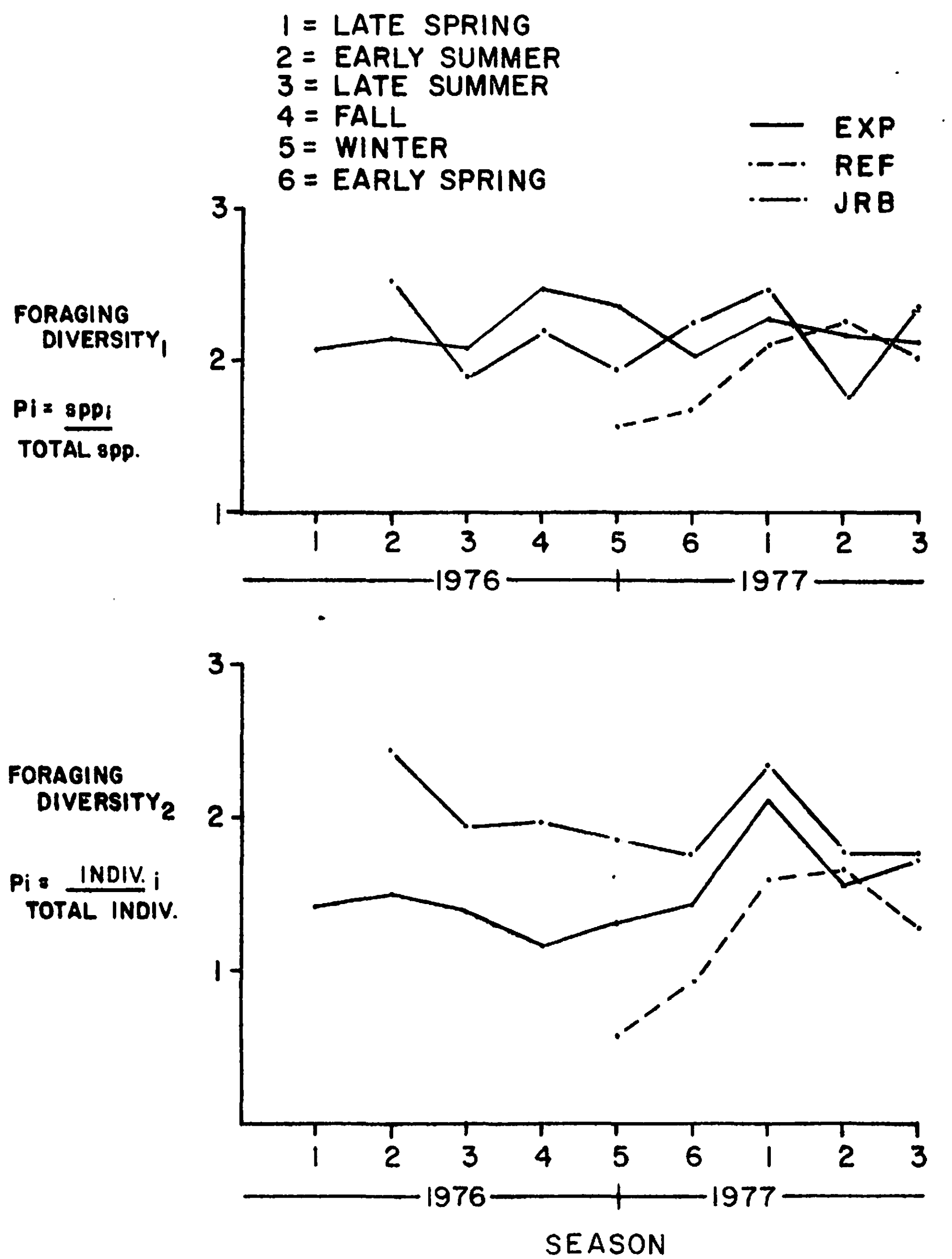
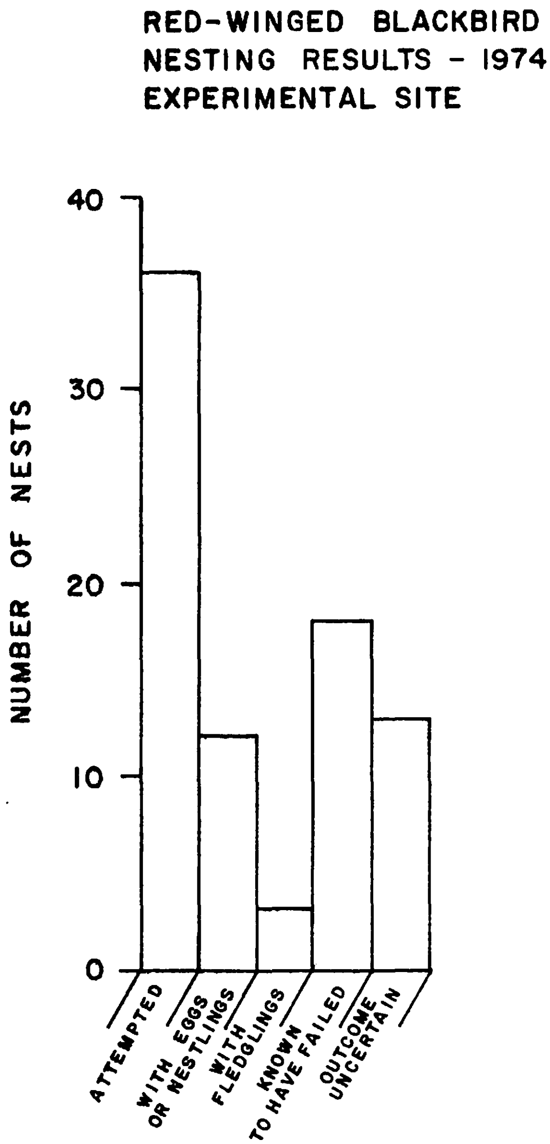


Figure 44. Foraging diversity at the experimental and reference sites and the James River Berm.



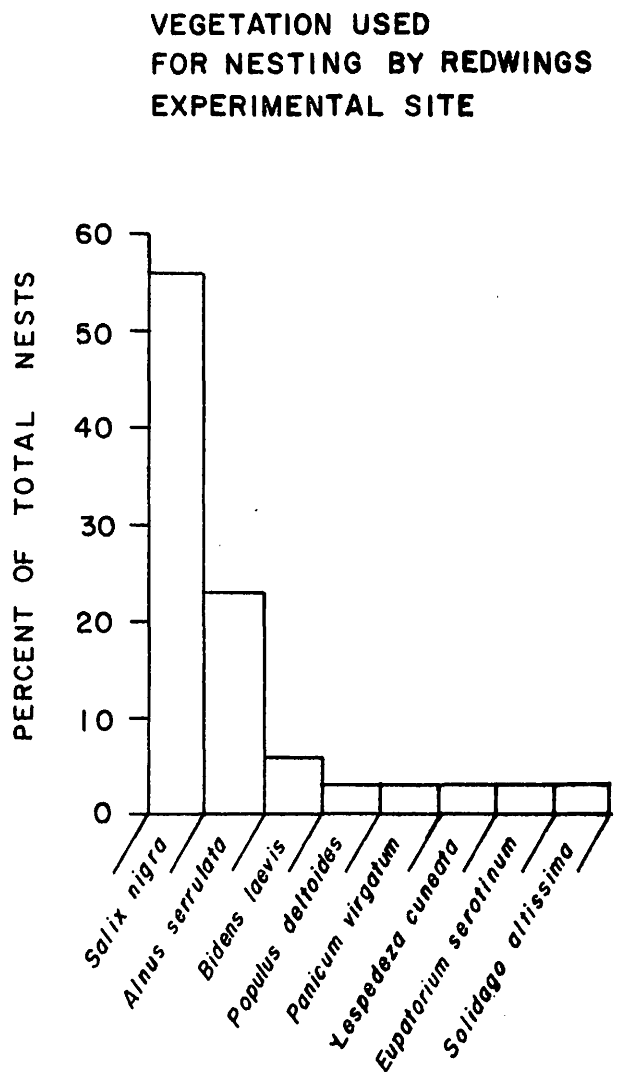


Figure 45. Nesting results and vegetation used for nesting by red-winged blackbirds at the experimental site.

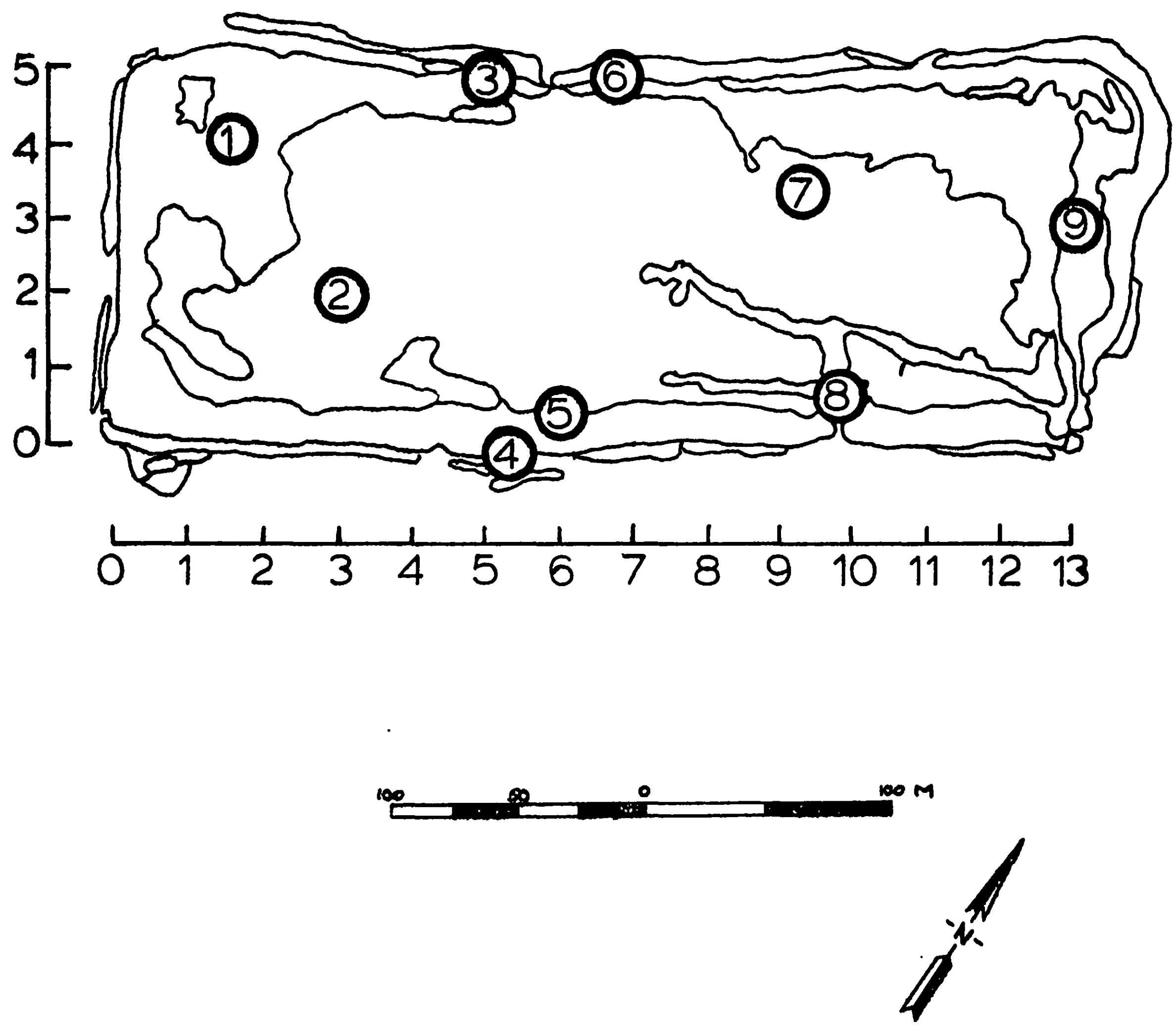


Figure 46. Soil sampling stations at the experimental site. (See Table 55 for descriptions).

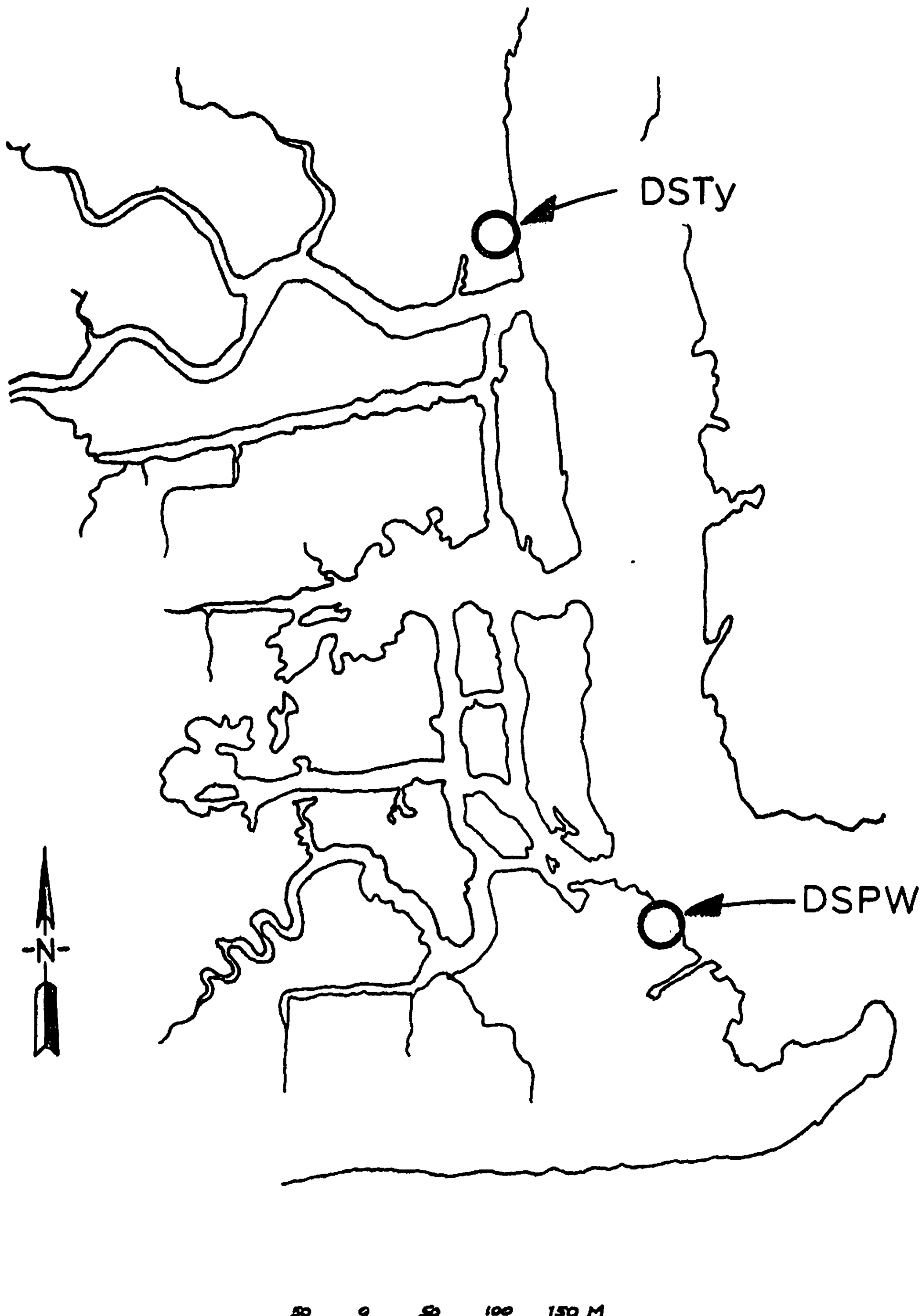


Figure 47. Soil sampling stations at the reference site. (See Table 55 for descriptions).

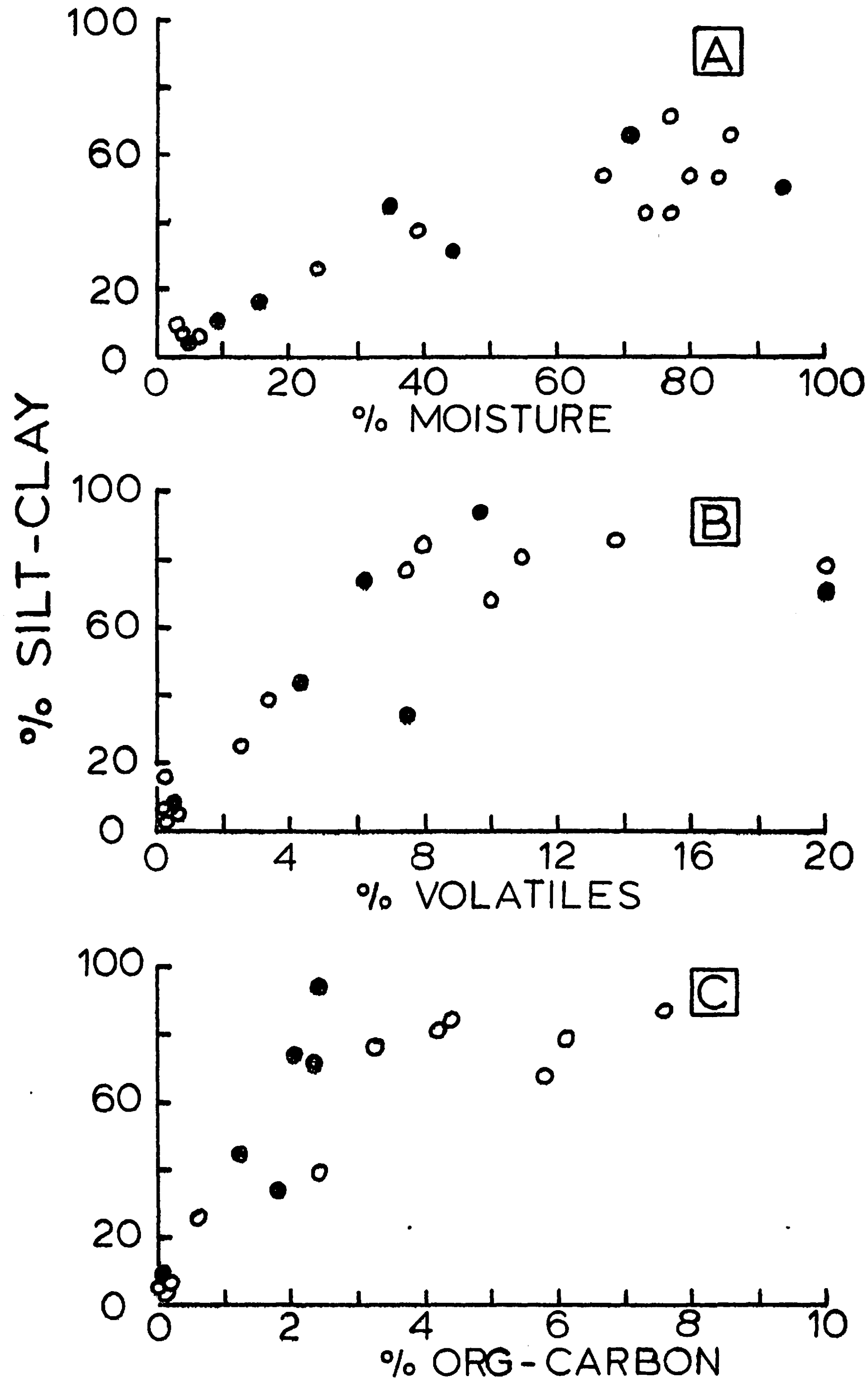


Figure 48. Correspondence between soil silt-clay fraction and moisture, volatiles and organic carbon content of experimental and reference site soils. Open circles indicate top soil subsample; solid circles indicate greater than 15 cm subsamples.

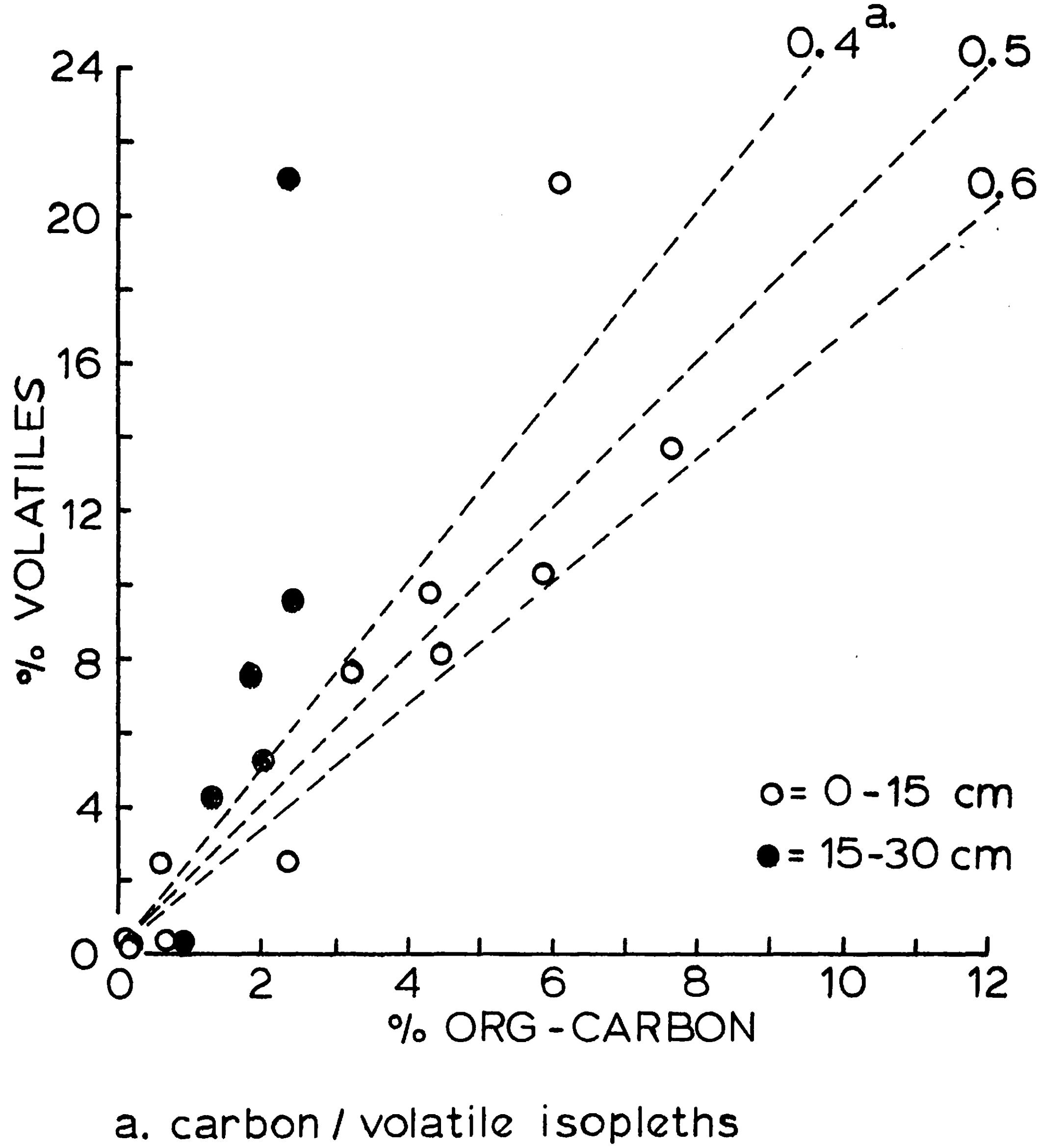


Figure 49. Soil % volatiles vs. % organic-carbon for the experimental and reference sites.

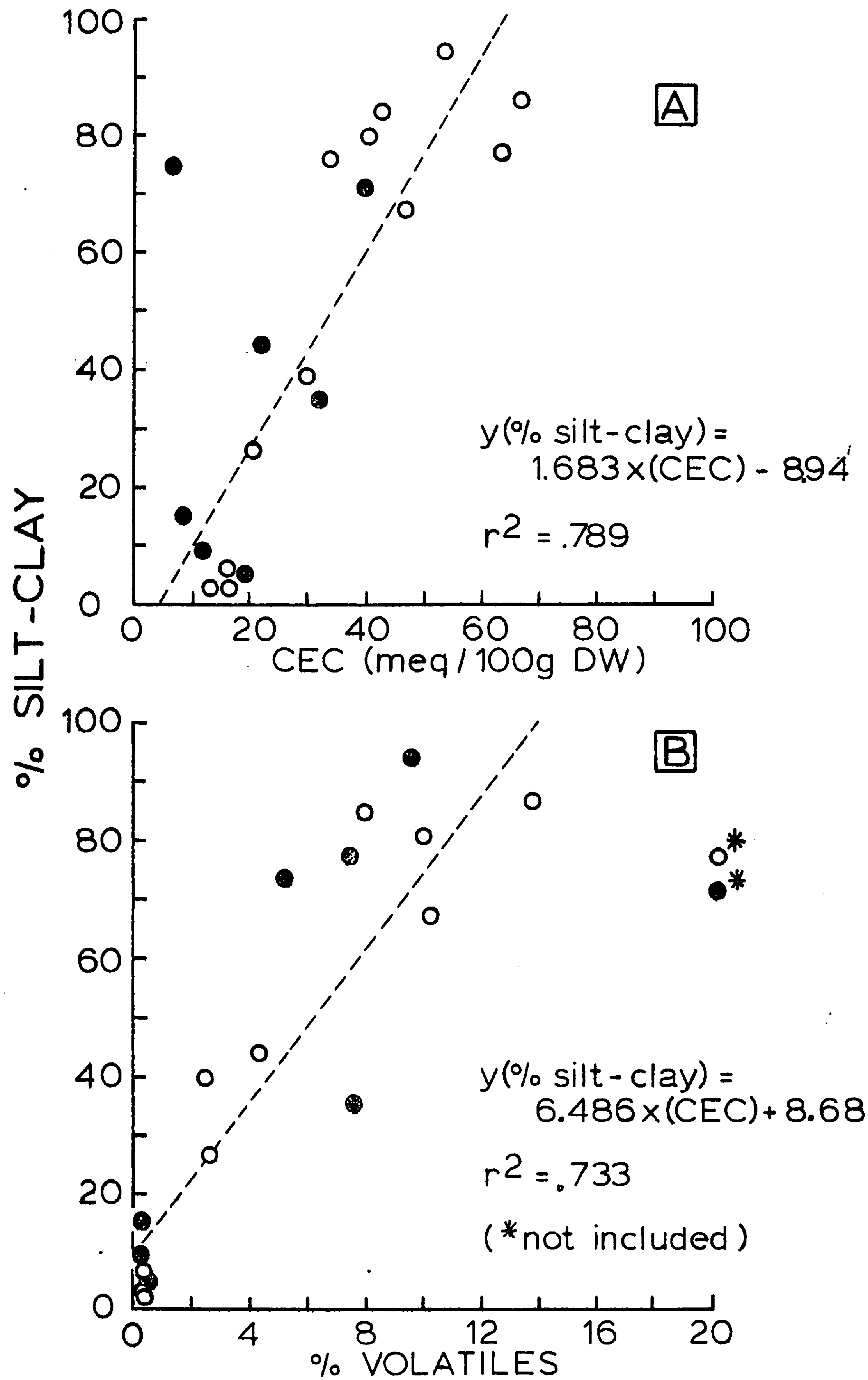


Figure 50. Correlation between % silt-clay fraction and CEC and % volatiles for the experimental and reference sites.