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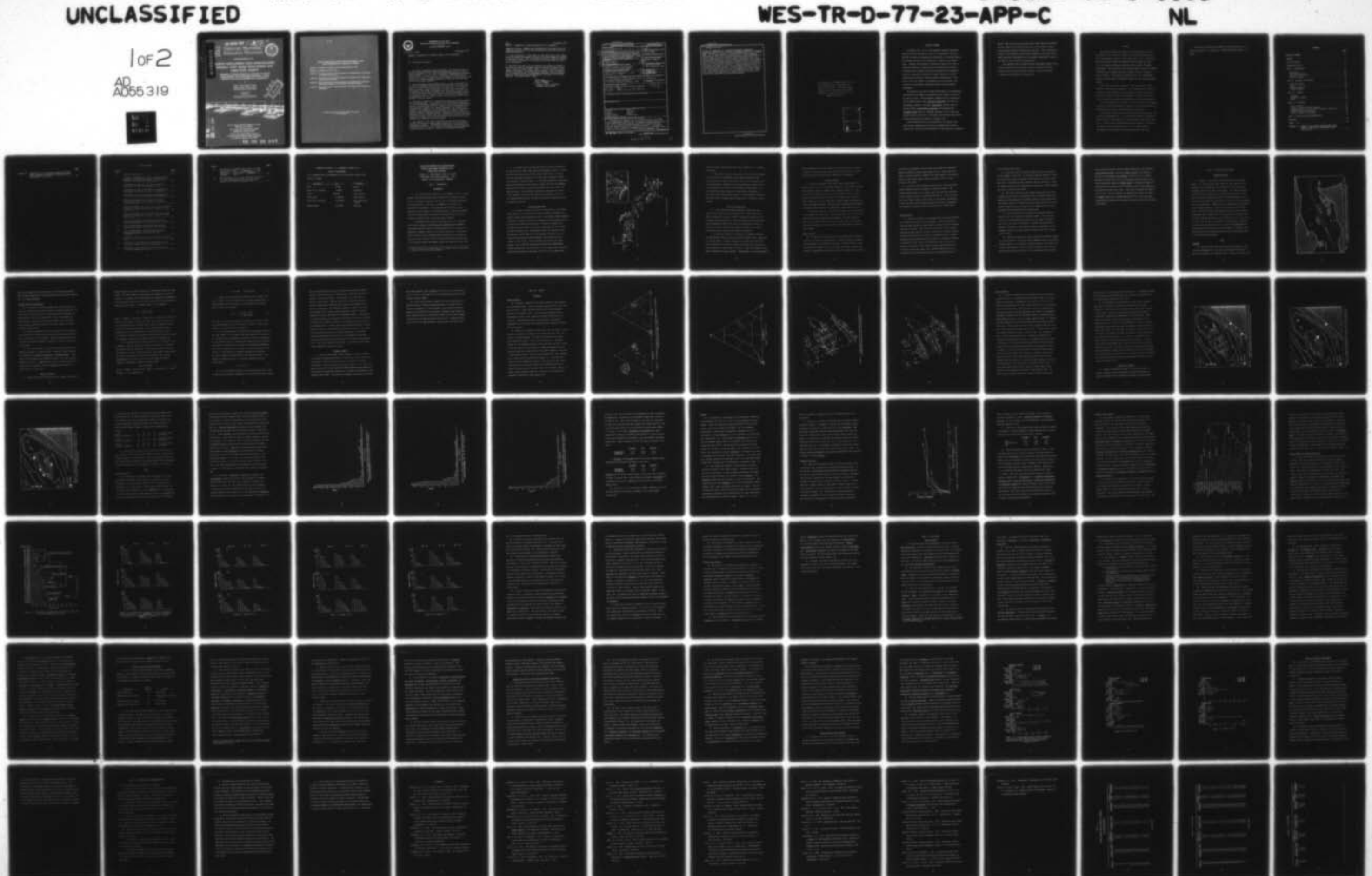

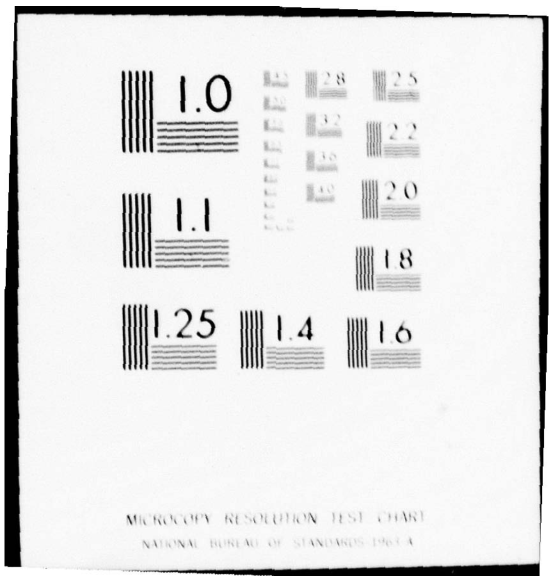
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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-23

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

APPENDIX C: ENVIRONMENTAL IMPACTS OF MARSH DEVELOPMENT WITH DREDGED MATERIAL: ACUTE IMPACTS ON THE MACROBENTHIC COMMUNITY

by

Robert J. Diaz, Donald F. Boesch
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

November 1977
Final Report

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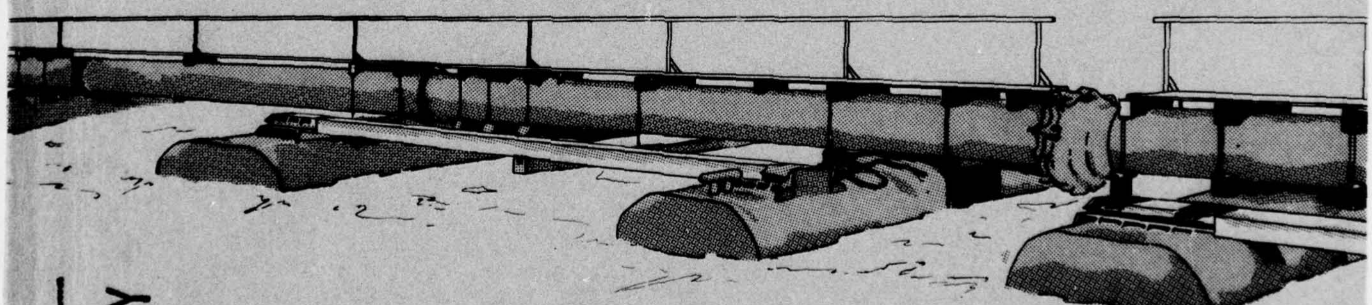

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW65-75-C-0053
(DMRP Work Unit No. 4A11K)

Monitored by Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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

Appendix A: Assessment of Vegetation on Existing Dredged Material Island

Appendix B: Propagation of Vascular Plants

Appendix C: Environmental Impacts of Marsh Development with Dredged Material: Acute Impacts on the Macrobenthic Community

Appendix D: Environmental Impacts of Marsh Development with Dredged Material: Botany, Soils, Aquatic Biology, and Wildlife

Appendix E: Environmental Impacts of Marsh Development with Dredged Material: Metals and Chlorinated Hydrocarbons in Vascular Plants and Marsh Invertebrates

Appendix F: Environmental Impacts of Marsh Development with Dredged Material: Sediment and Water Quality

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

28 November 1977

SUBJECT: Transmittal of Technical Report D-77-23, Appendix C

TO: All Report Recipients

1. The report transmitted herewith represents the results of one of a series of research efforts (work units) undertaken as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A is part of the Habitat Development Project, which has as one of its objectives the development of environmentally and economically feasible disposal alternatives compatible with the Corps' resource development directive.

2. Marsh development using dredged material is being investigated by the Habitat Development Project under both laboratory and field conditions. The study reported herein was an integral part of a series of research contracts jointly developed to achieve Task 4A objectives at the Windmill Point Marsh Development site, James River, Virginia, one of eight marsh development sites located in several geographic regions of the United States. Interpretations of this report's findings and recommendations are best made in context with the other reports in the Windmill Point site series.

3. This report, Appendix C, "Environmental Impacts of Marsh Development with Dredged Material: Acute Impacts on the Macrobenthic Community," is one of six appendixes published relative to the Waterways Experiment Station Technical Report D-77-23, entitled "Habitat Development Field Investigations, Windmill Point Marsh Development Site, James River, Virginia." The appendixes to the main report are contract studies that provide technical background and supporting data and may or may not represent discrete research products. Appendixes that are largely data tabulations or that clearly have only site-specific relevance are reproduced on microfiche; those with more general application (such as this appendix) are published as printed reports.

4. The purpose of this study, identified as Work Unit 4A11K, was to document the effects of marsh island construction on the preexisting macrobenthic community. Macrobenthos displaced by the new habitat or otherwise affected (e.g., by siltation from dredged material suspended in the effluent) was studied. Aspects of macrobenthos abundance,

community structure, biomass, and colonization are discussed by way of comparisons between field collections made before and after marsh construction activities.

5. A major conclusion of this report is that there was an acute impact within the habitat development site and in the area dredged for material to construct the dike. Any acute impacts beyond the immediate vicinity of the habitat development or borrow pit were undetectable six months after construction.

6. Data from this report will be combined with results of studies of the benthos at habitat development sites at Bolivar Peninsula, Texas (4A13), and Miller Sands, Oregon (4B05), to describe trends of benthic community development in dredged material marshes. This information will be presented as part of a Waterways Experiment Station Technical Report entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Impacts (2A08)."

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

Unclassified

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Dredged material	Windmill Point
Dredged material disposal	

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

Macrobenthos was sampled in a tidal freshwater portion of the James River, Virginia, near Windmill Point, in the area of construction of a wetlands habitat from dredged material. The habitat development was directed by the U. S. Army Engineer Waterways Experiment Station under the Dredged Material Research Program with the cooperation of the U. S. Army Engineer District, Norfolk. The benthic communities in the area of the habitat development site were dominated by the bivalve *Corbicula manilensis*; the
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20. ABSTRACT (Continued).

oligochaetes *Limnodrilus* spp., *Ilyodrilus templetoni*, *Limnodrilus hoffmeisteri*; and larvae of the insects *Coelotanypus scapularis* and *Hexagenia mingo*. The dominant organisms are generally eurytopic with respect to sediments; many had higher densities in muddy sediments, although *Corbicula* preferred sand. Most of the important species were highly opportunistic and thus the community was able to recover quickly from perturbations. This characteristic minimized the effects of habitat development. Acute impacts were detected at the habitat site where organisms were buried by construction and at the excavation where organisms were removed along with the sand and gravel used in construction of the dike. Long-term changes associated with the habitat were limited to areas of gross sediment alteration, such as at the excavation and dike perimeter. No other broad-scale effects, acute or long term, could be detected that were attributable to the habitat construction. More extensive acute effects due to sedimentation may have occurred but, because of its resilience, the community was able to recover in the 6 months that lapsed before postconstruction sampling.

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EXECUTIVE SUMMARY

In December 1974, the U.S. Army Engineer Waterways Experiment Station, with the cooperation of the U.S. Army Engineer District, Norfolk, directed the experimental construction of a wetlands habitat from dredged material in the James River, Virginia, near Windmill Point. Chemical and biological studies were conducted in order to assess the effects of construction on the preexisting ecosystem. The benthos was stressed as the most susceptible biotic component because of the direct alteration of benthic habitats by habitat construction and indirect effects caused by sedimentation. This report covers the results of assessments of the distribution and structure of macrobenthic communities before and after habitat development.

The benthos in the area of habitat development is overwhelmingly characterized by freshwater invertebrates even though this reach of the river is tidal. The macrobenthic communities were dominated by the introduced Asiatic clam, *Corbicula manilensis*; the tubificid oligochaetes, mainly of the genus *Limnodrilus*; and the larvae of dipteran (mainly *Coelotanypus scapularis*) and ephemeropteran (*Hexagenia mingo*) insects. Although sediments in this study area varied from silts and clays to fine sands, the dominant species were broadly distributed with respect to sediment type.

Acute effects were felt by the benthos at the habitat site, where bottom topography was altered and organisms were buried by construction, and at the site excavated for dike construction material.

However, when the area was surveyed 6 months after habitat development the only changes in the benthos found were in areas where sediment types had been changed by construction activities. This is believed to be due to the resilience of the benthic community in the tidal freshwater James River attributable to the extremely opportunistic nature of the fauna in this naturally stressed system.

A key question lies in long-term impact assessment related to the relative productivity and resource value of the artificial marsh versus the previous shallow benthic habitat. This is the subject of subsequent postoperation investigations.

PREFACE

This report presents the results of an investigation to assess the impacts of the James River Windmill Point marsh development site on the macrobenthic community. This study forms a part of the Dredged Material Research Program, Environmental Effects Laboratory (EEL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. The investigation was conducted under Contract No. DACW65-75-C-0053 to the Virginia Institute of Marine Science, Gloucester Point, Virginia. Contracting was handled by the U. S. Army Engineer District, Norfolk (NAO); LTC Ronald H. Routh, CE, NAO, was Contracting Officer.

The report was written by Robert J. Diaz and Donald F. Boesch, Division of Biological Oceanography. The following Virginia Institute of Marine Science personnel are acknowledged for their assistance in the study: Robert W. Virnstein and Kenneth A. Dierks for their work in the field and Joby Hauer and Colleen Stone for processing samples.

Dr. Selwyn Roback and Mr. Samuel L. H. Fuller, both of the Academy of Natural Sciences, Philadelphia, identified or confirmed specimens of chironomids, and molluscs and turbellarians, respectively.

The study was conducted under the direction of EEL personnel. The contract was managed by Mr. J. D. Lunz, Natural Resources Development Branch, under the supervision of Dr. Walt Gallaher, Branch Chief, and Dr. C. J. Kirby, Chief, Environmental Resources Division. The study was under the general supervision of Dr. H. K. Smith, Habitat Development Project Manager, and Dr. John Harrison, Chief, EEL.

Directors of WES during the conduct of the study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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

UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
cubic feet per second	0.02831685	cubic metres per second
pounds (mass)	0.4535924	kilograms

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

APPENDIX C: ENVIRONMENTAL IMPACTS OF MARSH DEVELOPMENT WITH DREDGED MATERIAL: ACUTE IMPACTS ON THE MACROBENTHIC COMMUNITY

PART I: INTRODUCTION

Background

1. The Dredged Material Research Program (DMRP) of the U. S. Army Engineer Waterways Experiment Station (WES) was initiated in 1973 in order to investigate problems related to the environmental management of dredged material. One task of the DMRP was to evaluate and determine the feasibility of creating desirable habitats, such as wetlands or tidal marshes, from dredged material. Habitat development sites were chosen around the country; discussed herein is the site located at Windmill Point on the James River, Virginia.

2. The Windmill Point habitat development site was constructed over a shoal resulting from historically (beginning in the 1890's) unconfined pipelined disposal of dredged material and is located in a completely freshwater portion of the tidal James River. From 1968 to 1971, 241,100 cu yd* of dredged material was placed on the shoal; by the end of 1971, a small 1.57-acre island developed that persisted up to the time the habitat development project was initiated in late 1974.

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* A table of factors for converting U.S. customary units of measurement to metric (SI) can be found on page 10.

3. In December 1974, the Norfolk District and the Environmental Effects Laboratory (EEL), WES, began an experimental project to create an artificial marsh-island complex using dredged material produced from the maintenance dredging of the James River navigation channel below Hopewell, Virginia (Figure 1). Retaining dikes were constructed with sand dredged from nearby Buckler's Point, and very fine sediment hydraulically dredged from the nearby channel was placed within the diked enclosure. An experimental program was undertaken to artificially propagate various wetland plants in the habitat, but most of the dredged material within the dikes was rapidly colonized naturally by emergent vegetation.

Scope and Objectives

4. In order to assess the effects of construction of the marsh-island habitat on the preexisting ecosystem, several biological and chemical studies were undertaken as part of the Corps' research program. Considerable emphasis was placed on chemistry of the dredged material pore water and effluent surface water. Botanical investigations considered vascular plants of both the preexisting 1.57-acre island and the new marsh-island. Macrobenthos, which was displaced by the new habitat or which might have been otherwise affected, e.g., by siltation from escaping dredged sediment, was studied and is the subject of this report. The macrobenthos was selected for study because: (1) it would be most directly affected by displacement, habitat modification, and siltation; (2) it includes mainly relatively long-lived and sedentary organisms; and (3) it can be sampled with

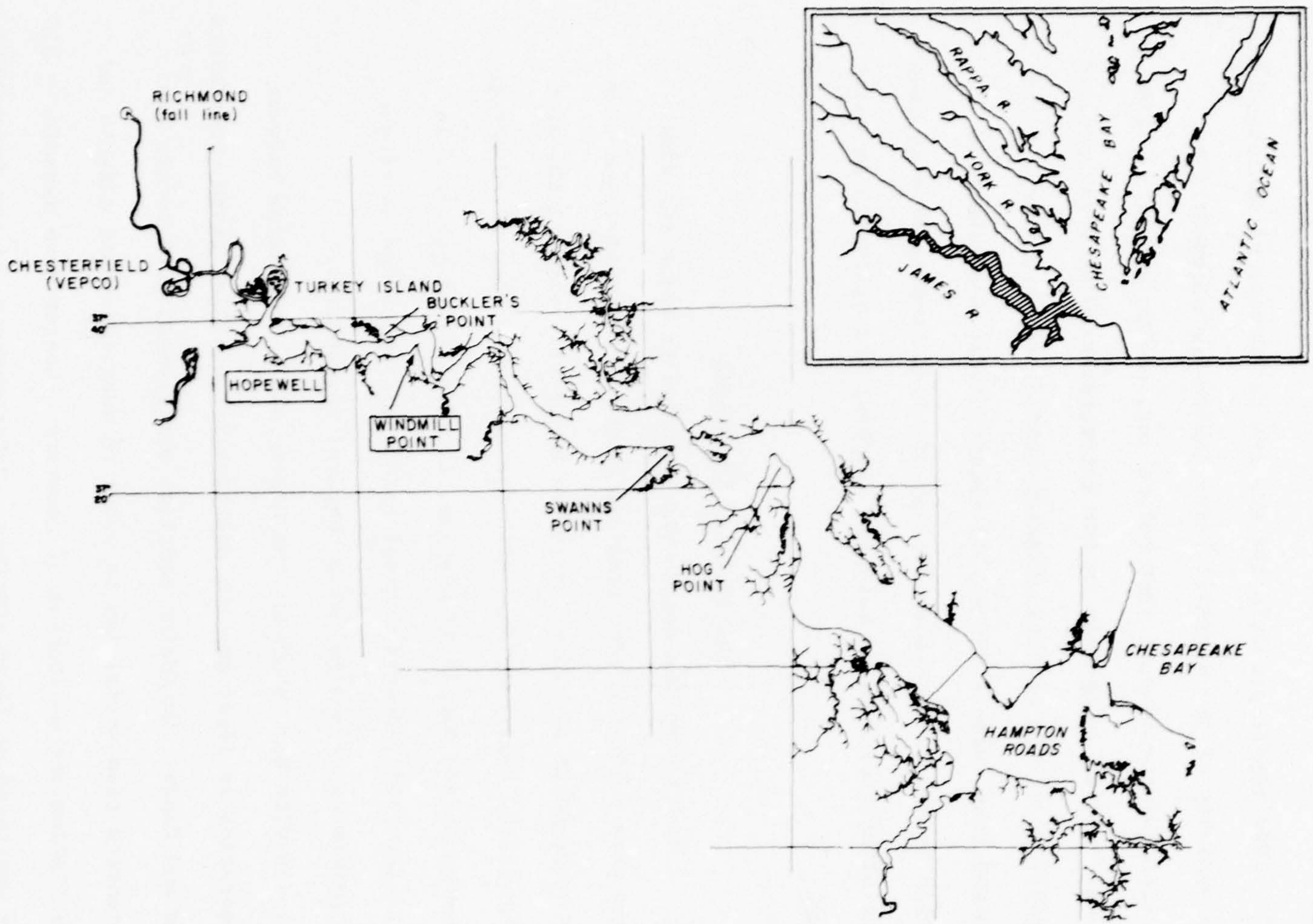

Figure 1. The tidal James River

greater accuracy and precision than other components, i.e. plankton and nekton.

5. This report presents the results of surveys of macrobenthos in the vicinity of the Windmill Point habitat development site. Collections were conducted just before and, on two occasions, after site construction. Emphasis in the interpretation of these data is on assessment of the effects of marsh habitat construction. It is also hoped that these studies will significantly contribute to knowledge of the poorly known ecology of tidal freshwater ecosystems and the effects of dredged material disposal and siltation on these systems.

Approach to Objectives

6. A fixed sampling design was employed in which the same stations were relocated each sampling period. These stations were mainly arranged in a grid or series of transects covering the area of marsh-island construction. Although suffering some disadvantages from nonrandomized sample allocation, the design was selected in order to accurately describe areal extent of impact and to reduce the interference of spatial with temporal variability.

7. As with most studies, the design was a compromise between the theoretically ideal and the practically feasible, given constraints of time and funds. Extensive sampling was planned just before and after construction activities in order to describe acute effects and focus attention for monitoring of recovery. Longer term dynamics could then be monitored at fewer stations. Unfortunately, it was impossible to

sample immediately after the completion of island construction because of delays in contracting and it was not until 6 months after construction that initial postoperational sampling was accomplished.

Physical Setting

8. The tidal freshwater James River extends approximately 50 miles from the fall line at Richmond, Virginia, to the average position of measurable salinity at Swanns Point, Virginia (Figure 1). This reach can be divided into two major regions based on biota, geomorphology, and physicochemical criteria. The upper tidal freshwater James extends from the fall line down to Turkey Island (river miles 85 to 65), just above Hopewell. The lower tidal freshwater James extends from Turkey Island downriver to Swanns Point (river miles 65 to 35).

9. The upper portion of the river is narrower (115 to 460 m) with large meanders and oxbow lakes. The cross-sectional area of the river increases gradually downstream from Richmond. The lower region is wider (275 to 3660 m) with broad flats on either side of the channel. The cross-sectional area of the river is much larger here than in the upper region.

Waste disposal

10. An important ecological factor in the upper tidal freshwater region is the effect of waste disposal. Organic loading is extremely high from domestic and industrial outfalls. Coliform bacteria counts are higher than anywhere else in the James River Basin, ranging from 10,000 to 1,000,000 bacteria/100 ml. Most of the organic and coliform

load comes from Richmond, which releases over 40,000 lb of municipal domestic biochemical oxygen demand (BOD) per day. Oxygen sags are a common occurrence during the summer in the main channel of this region because of this heavy organic loading (Virginia Division of Water Resources 1969, 1970).

11. The lower tidal freshwater region is also affected by high organic loading, mostly from Hopewell's industrial plants. BOD averages 80,000 lb/day, but coliform counts are lower than the upper region, ranging from 100 to 10,000 bacteria/100 ml. Since the river has a much larger volume in this region, it has greater assimilative ability and water quality improves greatly with distance downstream from Hopewell (Virginia Division of Water Resources, 1969, 1970).

Tidal influence

12. The tidal influence felt throughout the James below Richmond is an important feature of the environment. Currents generated by tides are much reduced from the nontidal currents in the free-flowing James above Richmond. This allows the deposition of fine alluvial sediments brought down by the river, such that all available benthic habitats are muddy except in areas of concentrated wave or current energy where more sand and gravel are found. In comparison, diverse assortments of sand, gravel, and boulders are found in the lotic portion of the river. This severely restricts the composition of the biota in the tidal James, since suitable substrates are not available for the diverse epifauna and crevice-dwelling fauna of

faster flowing fresh waters.

13. Tidal ebb and flow increases residence time of pollutants in this segment of the river. It typically takes an average of 7 days for a particle of water to traverse the 50 miles of the tidal freshwater zone. During floods this residence time may decrease to 3 days but under extreme low-flow conditions may increase to 17 days (Virginia Institute of Marine Science 1973a).

14. The exact position of the boundary between the lower tidal freshwater region and the oligohaline region is variable and diffuse depending on the magnitude of freshwater inflow into the James River. The boundary shifts up or downriver several miles seasonally, but the salinity typically does not exceed 2 $^{o}/oo$ at Swanns Point, 20 miles downstream from the Windmill Point marsh-island.

15. Only during periods of drought will measurable salinity penetrate into this typically freshwater segment. This event last occurred in the mid-1960's when the flow of the James at Richmond was 10 cfs, the lowest ever measured. Salinity intruded almost to Hopewell, allowing for considerable overlap and replacement of the freshwater fauna by estuarine species (Virginia Institute of Marine Science 1973b).

16. During this drought the typical tubificid-chironomid community, characteristic of the lower tidal freshwater region, was probably displaced upriver as the salinity advanced upstream. The fauna 10 to 15 miles below Hopewell in the vicinity of Windmill Point must have been very much like that typical of the oligohaline region (usually

found around Hog Island) and was probably dominated by the polychaete Scolecolepides viridis, the bivalve Rangia cuneata, and estuarine species of the amphipod genus Gammarus. With the return of normal salinities of less than 0.5 °/oo, the estuarine fauna returned to its former composition except for Rangia cuneata. Although the adults of this species have survived in the freshwater zone, no known spawning or recruitment has taken place there. Cain (1972) concluded that salinities of near 5 °/oo are required for spawning and survival of larvae. The Rangia populations, composed basically of the 1-year class, have persisted below Jordan Point for about 10 years, but only few very large clams remain.

PART II: MATERIALS AND METHODS

Sampling Stations

17. Samples of macrobenthos were obtained from 51 stations (Figure 2). Forty stations were aligned in four transects of 10 stations, each extending from the south shore across the habitat development site to the edge of the channel. Two control stations (42 and 43) were located on the old dredged material shoal to the west, away from the immediate vicinity of the development site. A third control station (41) was located to the east of the development site on the same shoal. Eight stations (A through H) were positioned in two transects adjacent to and in the excavation near Buckler's point. Two 0.05-m^2 Ponar grab samples were taken at each station 26 November and 2 December 1974. All stations were resampled 28-30 July 1975, with the exception of those stations (5, 6, 7, 15, 16, 17, 25, 26, 27, 35, 36, and 37) covered by the development. Stations 8, 13, 14, 24, 28, 38, 41, 42, A, B, C, and D were resampled for a third time on the anniversary of the development, 15 December 1975. These stations were selected because they were in areas most likely to be affected by development.

Fauna

Sampling

18. Water depth and Ponar grab volume were measured at each station in November 1974, July 1975, and December 1975 (Table 1). Most of the stations were shallower than 1 m except for those on the

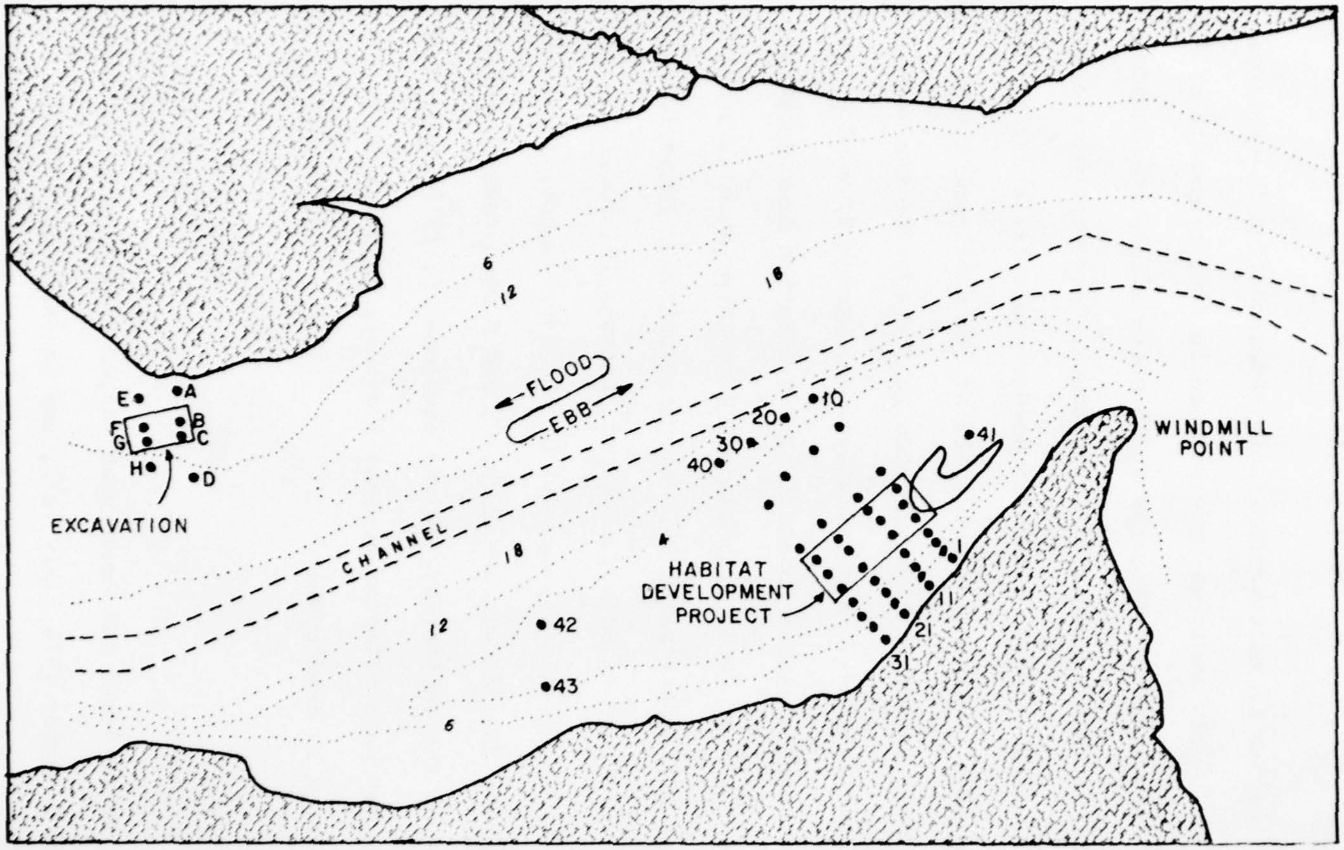

Figure 2. Location of sampling sites in the James River at the Windmill Point habitat development site and borrow pit used for acquisition of dike material

edge of the channel and in the borrow pit. The Ponar grab operated well, filling completely in softer sediments and to about half capacity (4.5 ℓ) in sandy sediments.

Identification and enumeration

19. The contents of each grab sample were sieved through a 0.5-mm screen, relaxed with 1 percent solution of propylene phenoxetol for half an 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 were sorted into major taxonomic groups and placed in 70 percent ethanol for identification and enumeration.

20. Several meiofaunal taxa were recovered from the samples but were excluded from analysis because the sample processing procedures were not quantitative for meiofauna. Among the meiofauna found were (in order of decreasing abundance) nematodes, copepods, cladocerans and ostracods.

21. Wet weight biomass after preservation was determined after blotting organisms on absorbent towels. Individual species biomass was determined for *Corbicula manilensis* and *Hexagenia mingo*. Oligochaetes and chironomids were weighed as groups. All other taxa were weighed as one group. *Corbicula* larger than 10 mm were removed from their shells for weighing, but small *Corbicula* were weighed after decalcification of the shells.

Numerical Analyses

22. Species diversity was measured by the commonly used index of

Shannon (Pielou 1975), which expresses the information content per individual. The index denotes the uncertainty in predicting the specific identity of a randomly chosen individual from a multispecies assemblage. The more species there are and the more evenly they are represented, the higher this uncertainty. The Shannon index H' is given by:

$$H' = - \sum_{i=1}^{s} p_i \log_2 p_i \qquad (1)$$

where s = number of species in a sample and p_i = proportion of the i-th species in the sample. 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).

23. 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 per unit area (in this case 0.2 m^2) or areal richness, and a measure standardized on the basis of the size of the sample in terms of numbers of individuals or numerical richness (SR):

$$SR = (S-1)/\ln N, \qquad (2)$$

where S = number of species and N = number of individuals in a sample. Evenness J' was expressed as:

$$J' = H'/\log_2 S \quad \text{(Pielou 1975)} \tag{3}$$

24. Numerical classification was used in order to detect and express changes in species composition at stations through time. A similarity measure, the Bray-Curtis (or Czekanowski) coefficient (Goodall 1973), was calculated:

$$S_{jk} = 1 - \frac{\sum_i |x_{ji} - x_{ki}|}{\sum_i (x_{ji} + x_{ki})} \tag{4}$$

where S_{jk} is the similarity between collections at stations j and k; x_{ji} is the abundance of the i-th species at station j; and x_{ki} the abundance of the i-th species at station k.

25. The transformation of original data is suggested because of the large numbers of a few species and small numbers of many species. In ecological terms transformation reduces the relative contribution of very abundant species to interstation similarity and the relative contribution of high density occurrences to interspecies similarity. Clifford and Stephenson (1975) present a detailed discussion of the effects of transformation on commonly used similarity measures. In order to dampen the sensitivity of the Bray-Curtis index to the numerically dominant species, all absolute abundances were log transformed as:

$$y = \ln (x + 1) \tag{5}$$

26. The relationships between the distribution patterns of pairs of species were studied by computation of the Bray-Curtis index as given

above, allowing instead the S_{jk} to represent the similarity between species j and k and the x_{ji} to represent the transformed abundance of species j at the i-th station. The entities, i.e., stations or species, could then be clustered based on the resulting similarity matrices using various strategies that express relationships in the form of a dendrogram. The dendrogram graphically depicts the interrelationships of the samples (normal analysis) or species (inverse analysis) to form a collection in a hierarchial fashion. The clusters or groups produced by the clustering algorithm do not have an objective existence but are rather a property of the numerical process and data set (Williams 1971). Cluster creation and interpretation must consider the above factors. Even though the technique is objective, its application and interpretation can be rather subjective. The flexible sorting strategy was chosen 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.

Sediment Samples

27. From each grab sample a small quantity of surface sediment was removed for grain-size analysis. Percent sand, silt, and clay was determined by sieving and pipette analysis following procedures of Folk (1968). Sand fractions were dry sieved using -2, -1, 0, and 2 phi American Society of Testing Materials (ASTM) standard sieves shaker by a Ro-Tap shaker to determine average size, uniformity, and skewness of the sediments (Folk 1968). The grain-size frequency distribution was broken

into eight arbitrary class intervals (>-2, -2 to -1, -1 to 0, 0 to 1, 1 to 2, 2 to 4, 4 to 8, and 8 to 14 ϕ) and factored according to procedures of Klovan (1966).

28. Since factor analysis compares the entire distribution of particle sizes by reducing interrelationships to a smaller set of factors or components, it thus provides a truer and more objective method for describing the relationship of sediment samples based on their complete grain-size distribution rather than the usual summary statistics such as mean and median particle size. Sediment descriptions refer to the Udden-Wentworth classification (Pettijohn 1957).

PART III: RESULTS

Sediments

Characterization

29. Typically, sediments in the tidal freshwater James consist of five textural types: sand, silty sand, sand-silt-clay, silty clay, and clayey silt. Silty clay and clayey silt are the predominant sediment types (Nichols 1972). The area around Windmill Point is depositional except for the southern shoreline, which tends to be erosional. Wind-generated waves, tidal currents, and alluvial sedimentation are the main forces maintaining the sediment structure in the study area.

30. When the percentages of sand, silt, and clay (Table 2) were plotted on triangular coordinates with 100 percent sand, silt, and clay at the angles (Figure 3), most of the stations fell along a band running from sand to silty clay and clayey silt. Sediments sampled in July exhibited greater scatter with fewer stations falling in the sand-silt-clay classification. Before the habitat was constructed, there was a small patch of fine sandy sediments to the west of the existing island. The only other significantly sandy sediments were located on the south shoreline (Figure 4). After dike construction, areas immediately adjacent to the habitat became sandier. There was also an increase in sand at the downstream station (41) and the stations near the southeast corner of the habitat (Figure 5). Deeper station sediments and areas to the west of the habitat were apparently unaffected by dike construction.

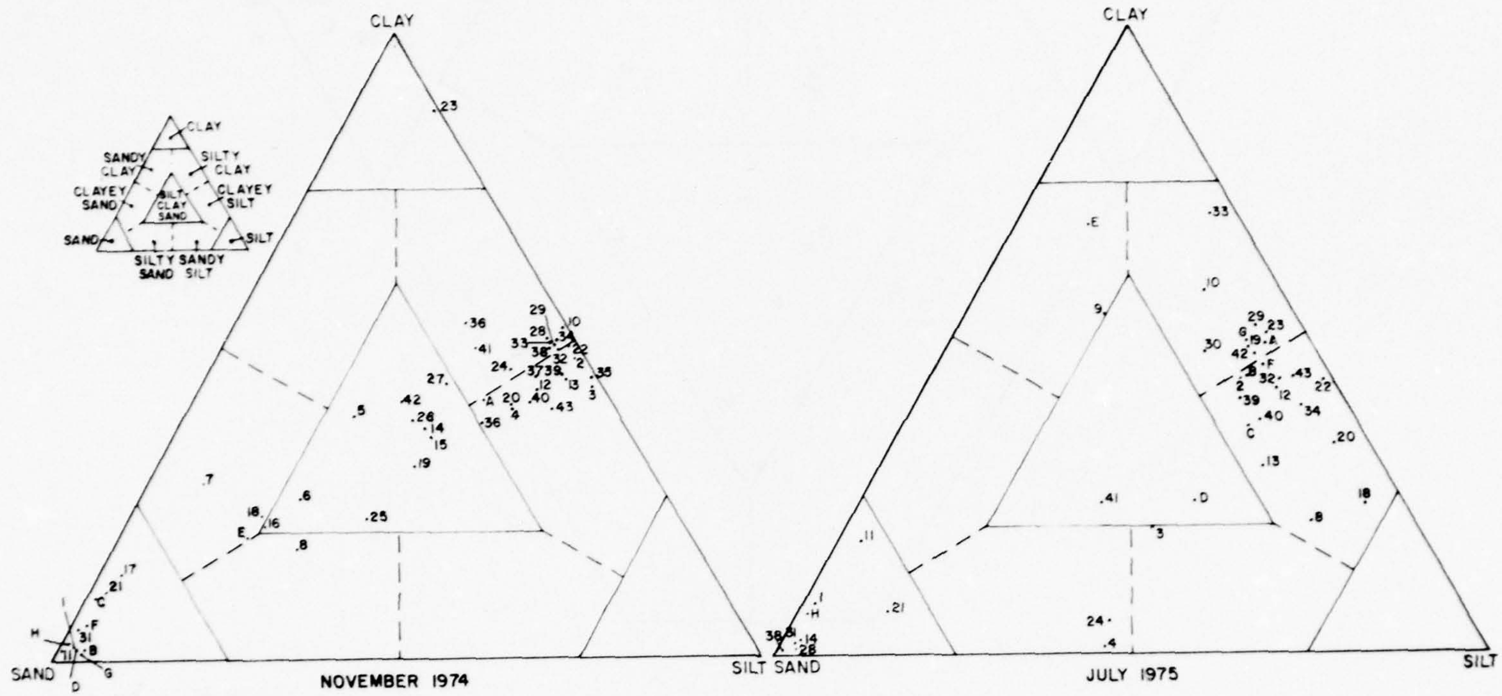

Figure 3. Percentages of sand, silt, and clay at stations sampled for the habitat development project (sheet 1 of 2)

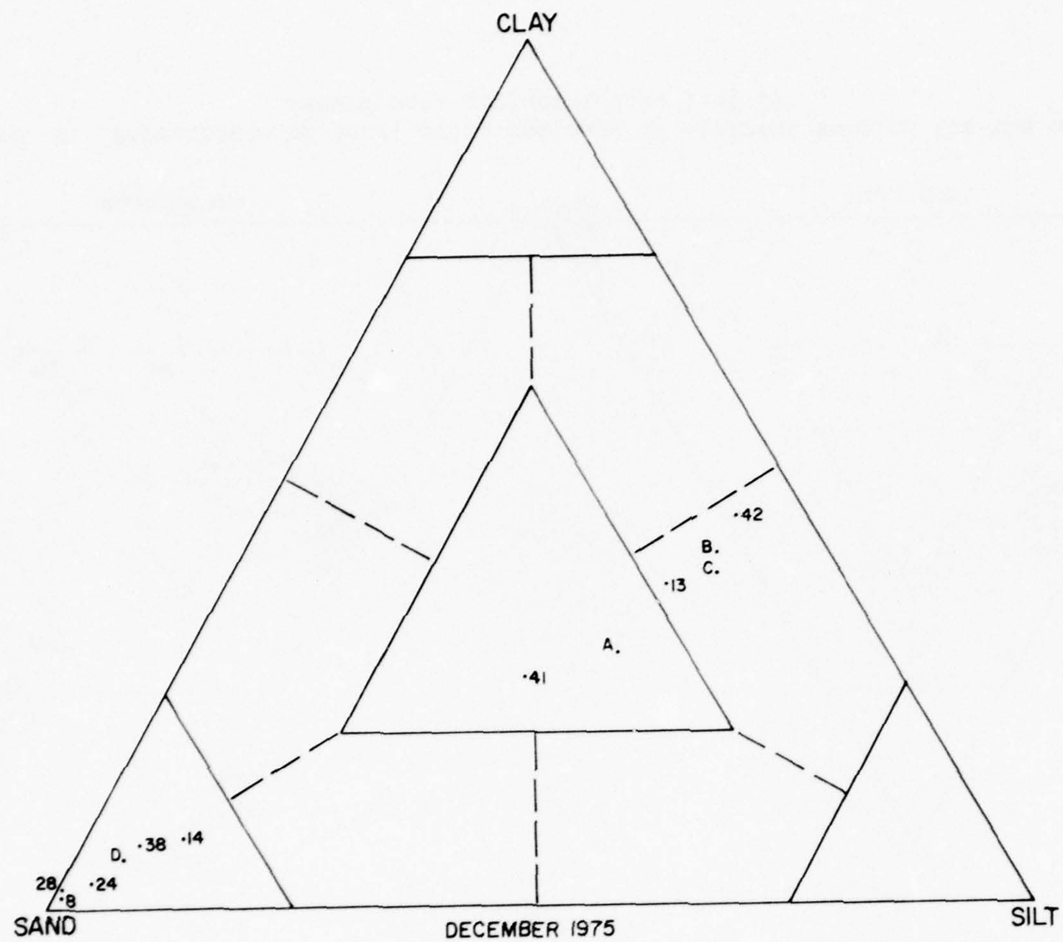

Figure 3 (sheet 2 of 2)

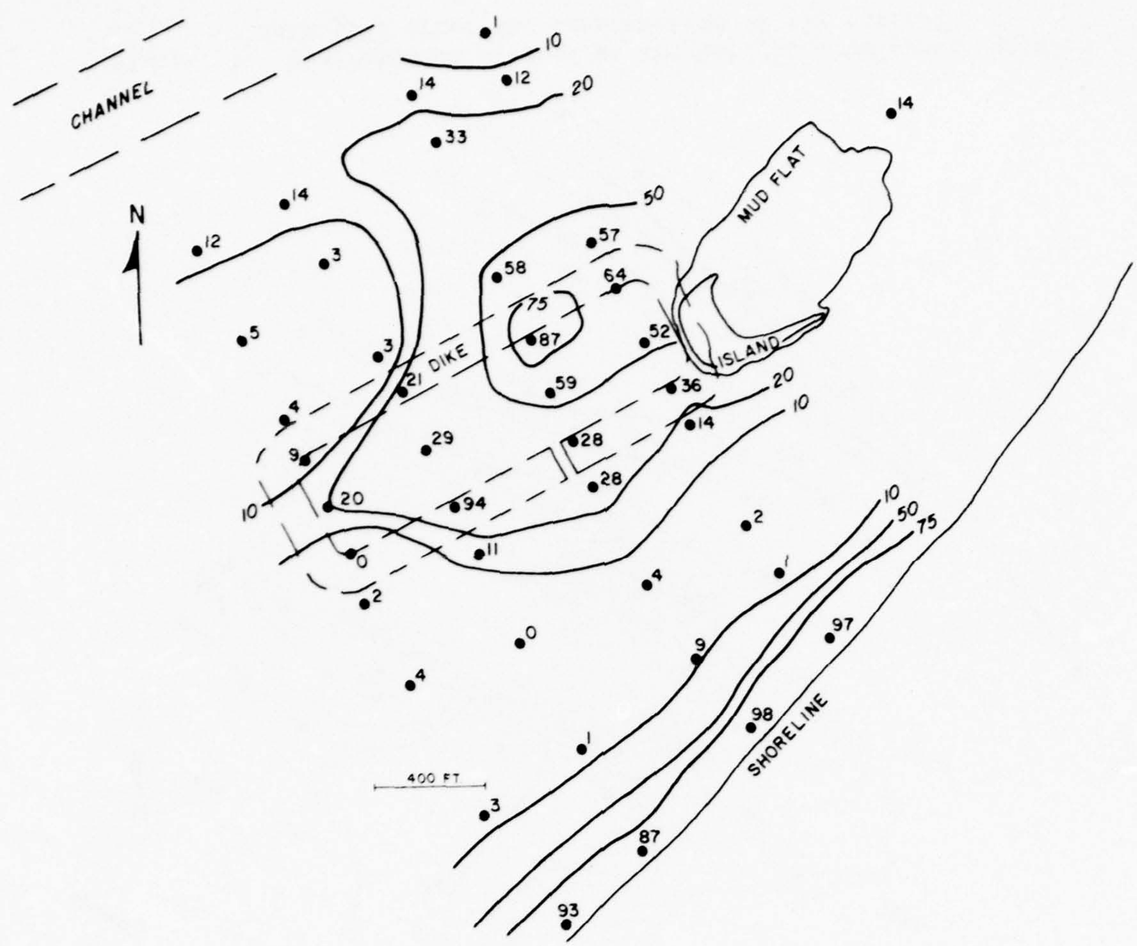

Figure 4. Distribution of sand at the habitat development site in November 1974 before the start of construction

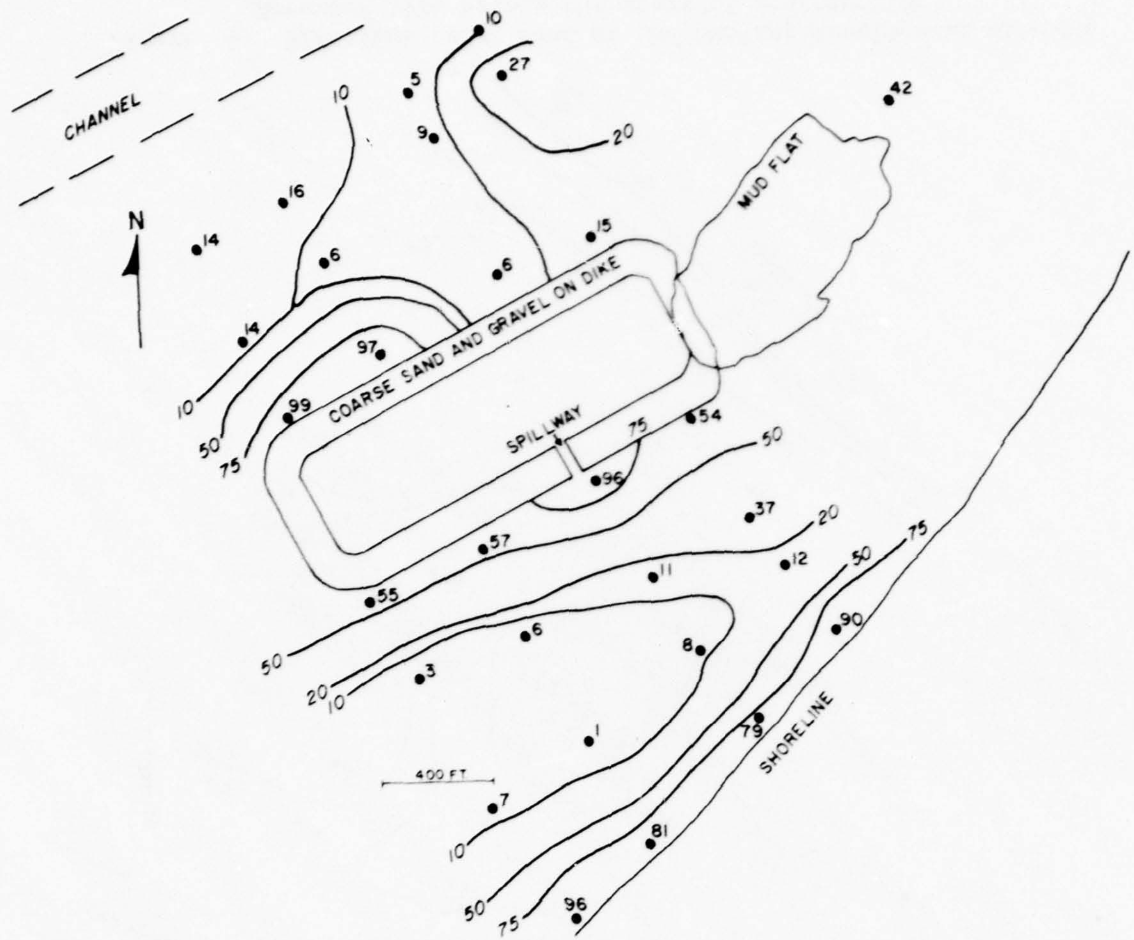

Figure 5. Distribution of sand at the habitat development site in July 1975 after the construction of the habitat

Factor analysis

31. In order to characterize the sediments more objectively and to make full use of the entire grain-size analysis (Table 3), factor analysis was employed. Communalities were high for all but 6 of 86 samples, indicating that the three rotated factors were a good description of the station data. When the three factors were normalized by squaring each factor score and dividing by the factor's corresponding communality, samples from all collections tended to concentrate with high loadings on Factor I and, to a lesser degree, Factor II. Stations with high loadings on Factor I were muddy with small median and mean grain sizes. They tended to be very closely grouped because the fines were evenly distributed between silt and clay. Stations away from the main group had different ratios of silt to clay. The clustering of most of the stations around Factor I indicated the homogeneity of sediments in the Windmill Point area. In November there was a small diffuse group of stations with increasing median (Md) and mean (M_z) grain size and increasing kurtosis (K_G) that loaded highly on Factor II (Table 2). In July there were three stations with high loadings on Factor II with similar size statistics. December stations that loaded on Factor II had coarser median and mean grain size than November and July stations. Stations with high loadings on Factor II represent medium to fine sand that are relatively well sorted. Stations with high loading on Factor III were coarser sands, except station 41 from December and station 25 from November (Table 3). Based on their sediment statistics, station 41 should have loaded

more on Factor II and station 25 more on Factor I. In general, stations had increasing median and mean grain size and were increasingly well sorted with higher loading on Factor III.

32. An environmental interpretation of these results suggests that Factor I represents areas where silts and clays are being deposited or areas that are not influenced by scouring tidal currents or wave action. Factor III represents areas where wave energy is concentrated, preventing the deposition of finer fractions. These areas are erosional and are the most dynamic environments in the Windmill Point area. Factor II is intermediate to Factors I and III, representing areas where some fines are deposited under conditions of reduced wave energy. If the amount of influence of the three factors is plotted on the habitat site map, the patterns of this interpretation become obvious (Figures 6, 7, and 8). The shoreline and habitat dike are the areas where wave energy is highest. The northwest corner of the habitat dike is the least stable area and loads highly on Factor III. The area to the west of the preexisting island was an intermediate energy area with wind waves sorting the sediments as they passed over the shallow flat. The deeper stations and stations away from the existing island were depositional areas where the wave energy had minimal effect.

Bathymetric Changes

33. Based on bathymetric surveys by the Norfolk District, greatest changes in depth attributable to habitat development occurred at stations in the excavation and between the south shores

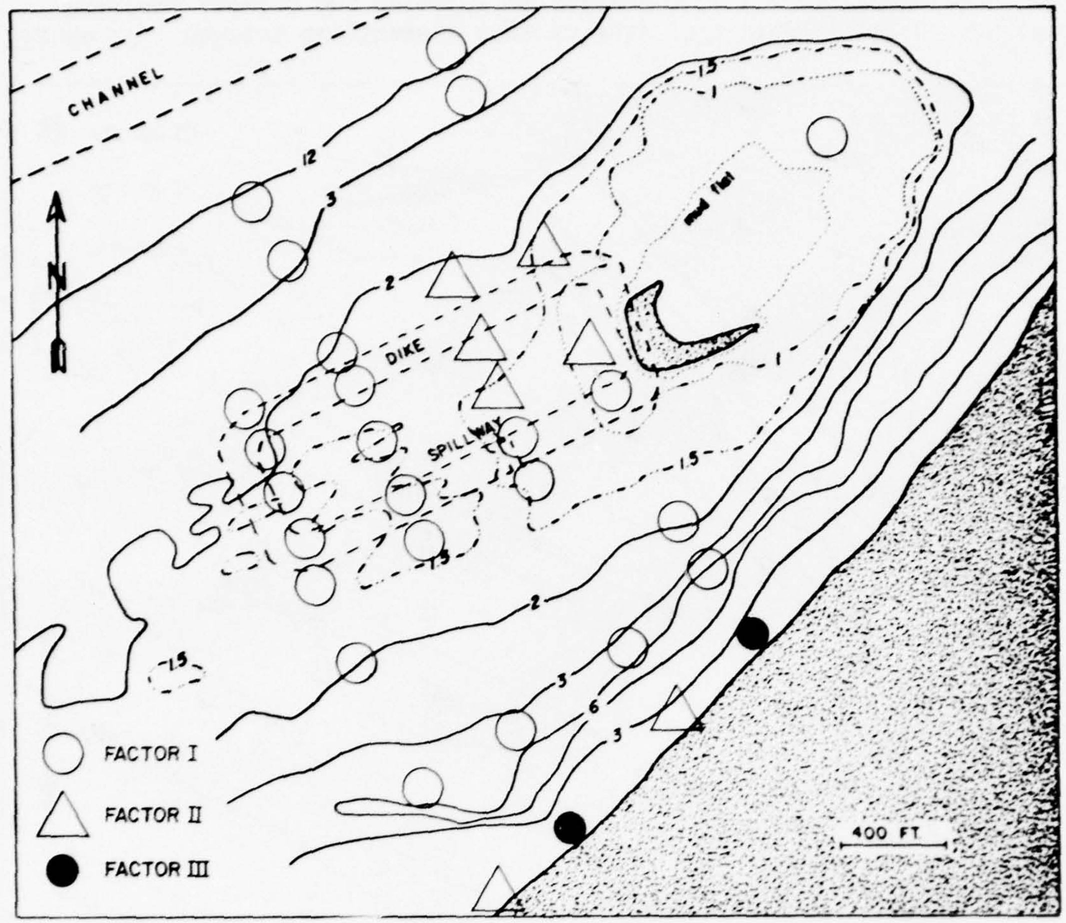

Figure 6. Habitat development site in November 1974 before construction, showing the patterns of influence of the three factors

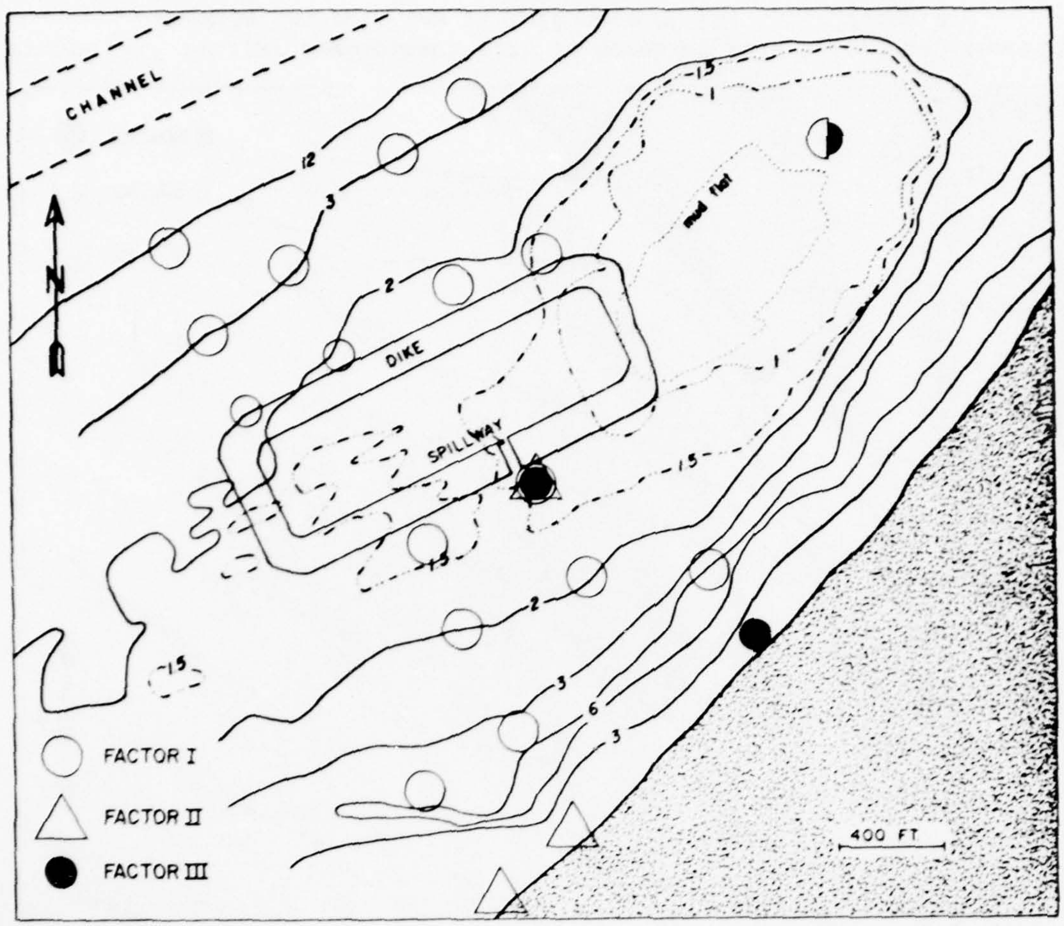

Figure 7. Habitat development site in July 1975 after construction of habitat, showing the patterns of influence of the three factors

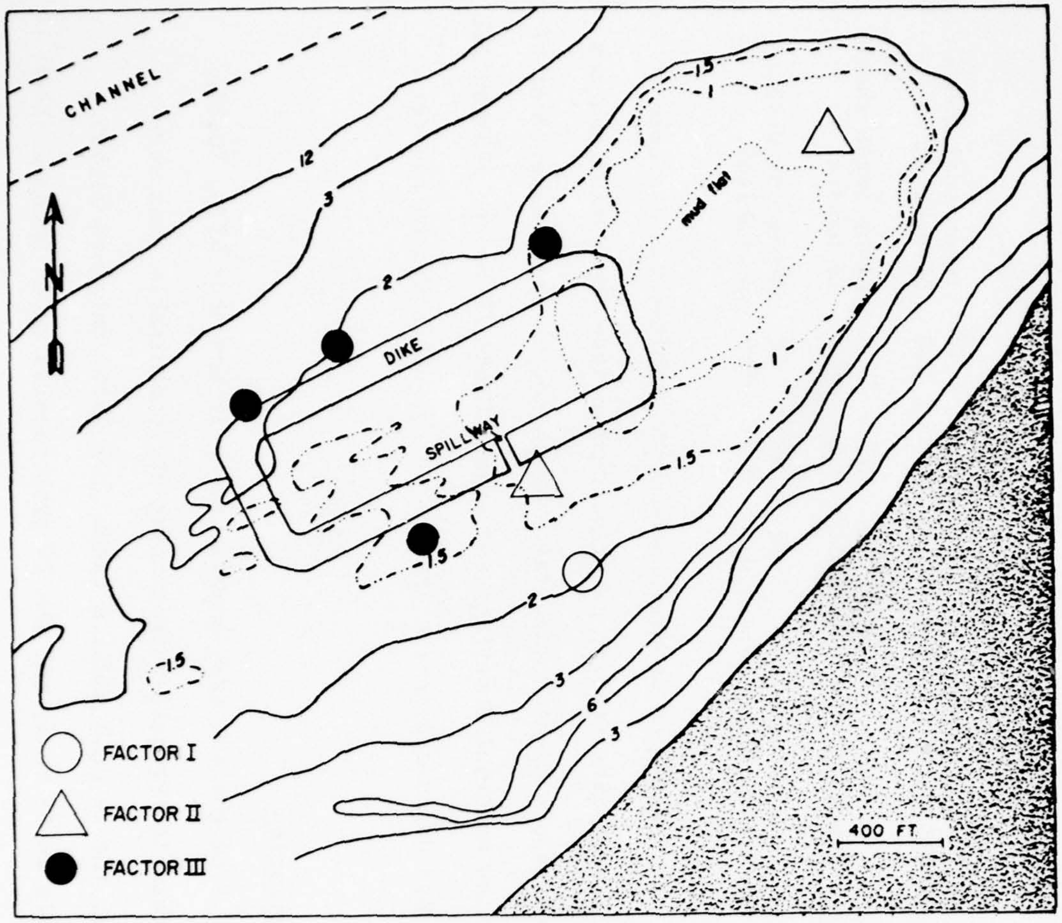

Figure 8. Habitat development site in December 1975 1 year after construction showing the patterns of influence of the three factors

of the habitat and mainland. The greatest increase in depth at the excavation was 17.7 ft with the average increase being about 13 ft. At the habitat site there was generally a decrease in depth at the stations immediately around the habitat dike, except stations 33 and 38, which deepened slightly. Changes can be summarized as follows:

Station	2	12	22	32	In channel south
Decrease in depth, ft	5.0	2.8	1.4	1.6	of habitat
Station	3	13	23	33	Along south shore
Decrease in depth, ft	0.9	0.2	0.2	-0.4	of habitat
Station	8	18	28	38	Along north shore
Decrease in depth, ft	0.4	0.1	0.2	-0.6	of habitat

34. The reduction in depth around the habitat was due both to the overflow of fine dredged material dumped into the island and the outward transport of dike material. While net currents swept most of the overflow material downriver and around Windmill Point, substantial amounts were deposited in the channel to the south of the habitat.

Fauna

Characterization

35. From the 102 grab samples taken in November 1974, 20,857 macrobenthic individuals representing 32 recognizable taxa were recovered; the 78 grab samples taken July 1975 contained 11,965 individuals in 35 taxa; and the 24 grab samples taken December 1975 contained 2,258 individuals in 23 taxa (Appendix A'). In total, the 204 grab samples yielded 35,080 individuals and 49 taxa (Appendix A'). For all three sampling periods, the oligochaete family Tubificidae

was numerically dominant followed by the bivalve Corbicula manilensis (Corbiculidae) and the dipteran insect family Chironomidae (Table 4). The remaining 15 families represented in the collections were represented by only one species each, except the Sphaeriidae of which there were two. Corbicula manilensis was numerically very important and individuals were separable into two distinct ecological forms based on size. Small Corbicula (<10-mm length) were treated separately from those larger. It was felt that while the larger clams were a persistent component of the community, smaller clams were ephemeral and their overwhelming densities would obscure the distribution and biomass patterns of the adults. Corbicula also becomes mature around 10 mm. Large numbers of small Corbicula were taken during all sampling periods and, from the shell length-frequency distributions of the populations (Figures 9, 10, and 11), it is very doubtful that more than a fraction of a percent survived from one sampling to the next. The family Chironomidae was represented by the most species, at least 17. Nine species of Tubificidae were identified (Appendix B').

36. Four genera (Limnodrilus, Corbicula, Ilyodrilus, and Coelotanypus) composed 97 percent of the individuals in November 1974, 90 percent in July 1975, and 87 percent in December 1975 (Tables 5, 6, and 7). The slight decrease in their dominance in July was due to the recruitment into the area of the more seasonally abundant insect larvae, such as the ephemeropteran Hexagenia that increased from 0.5 percent of the individuals in November to 1.6

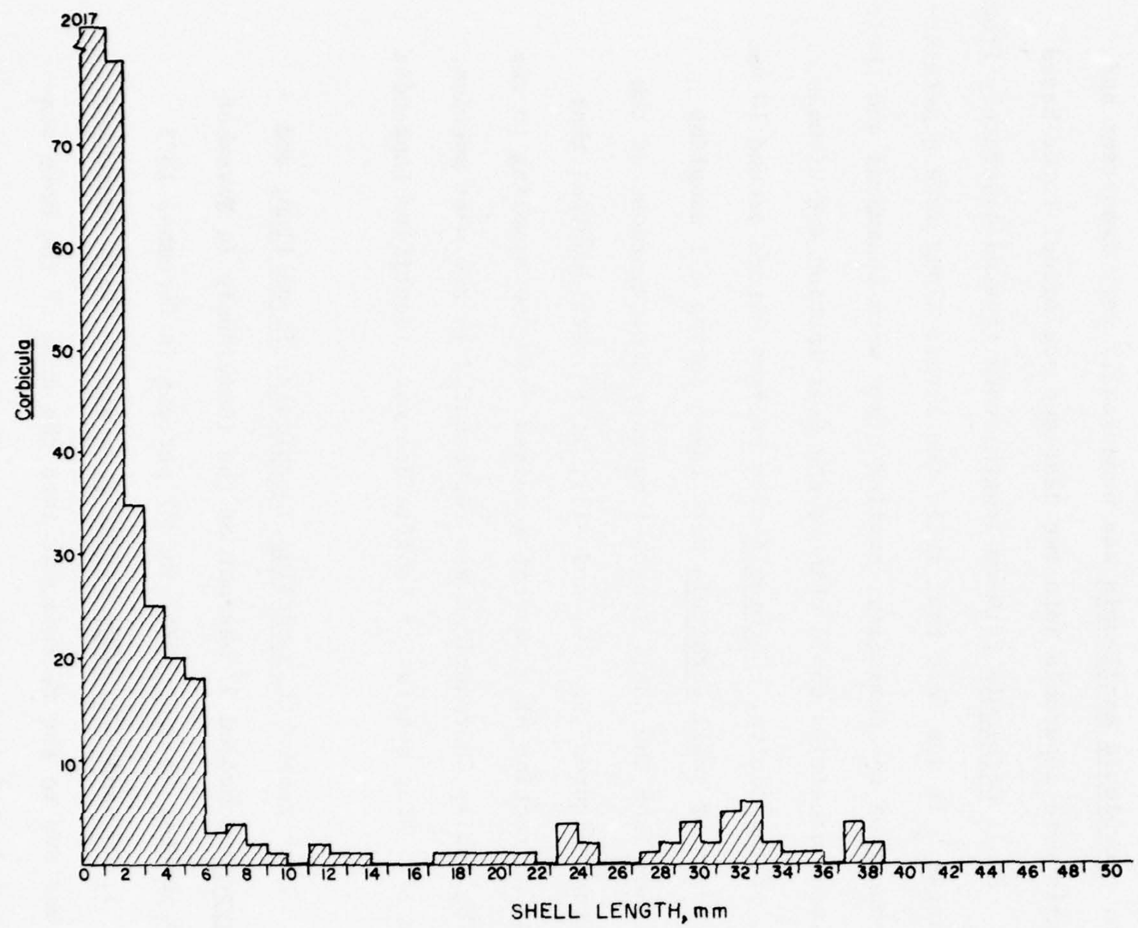

Figure 9. Shell length-frequency distribution histogram for *Corbicula manilensis* from the November 1974 collection

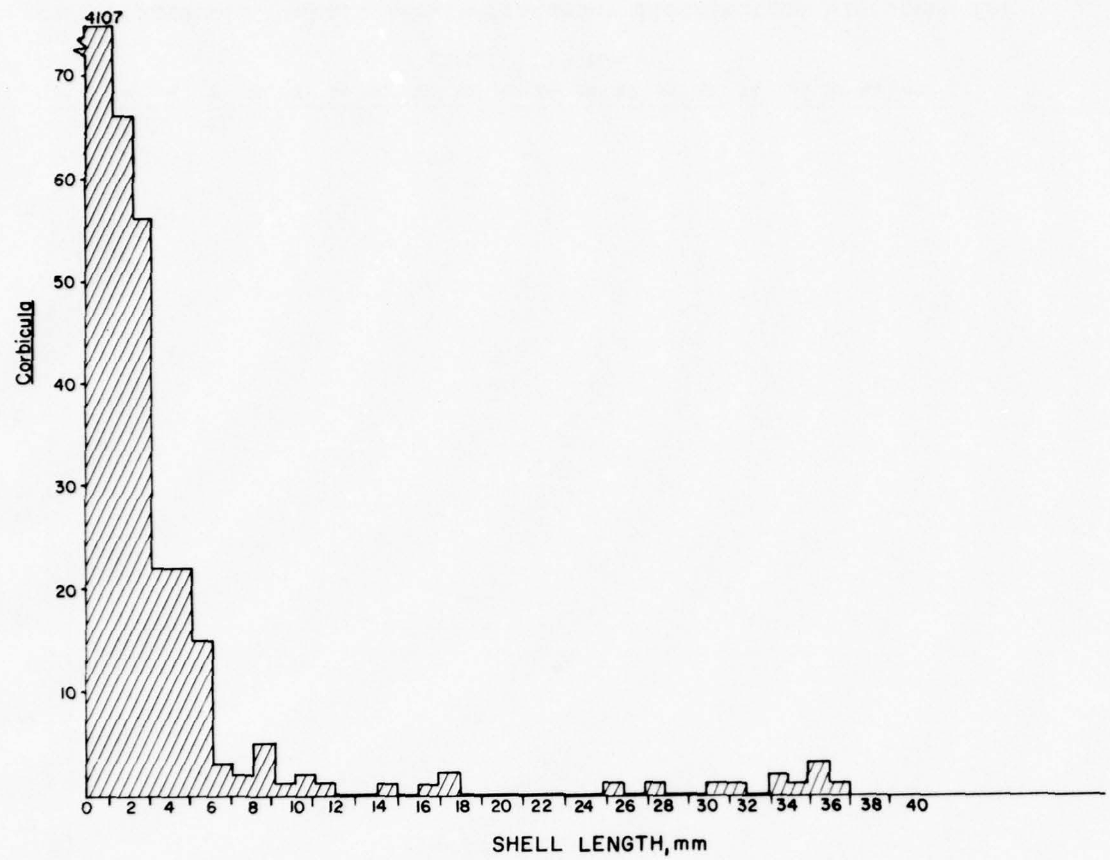

Figure 10. Shell length-frequency distribution histogram for <u>Corbicula manilensis</u> from the July 1975 collection

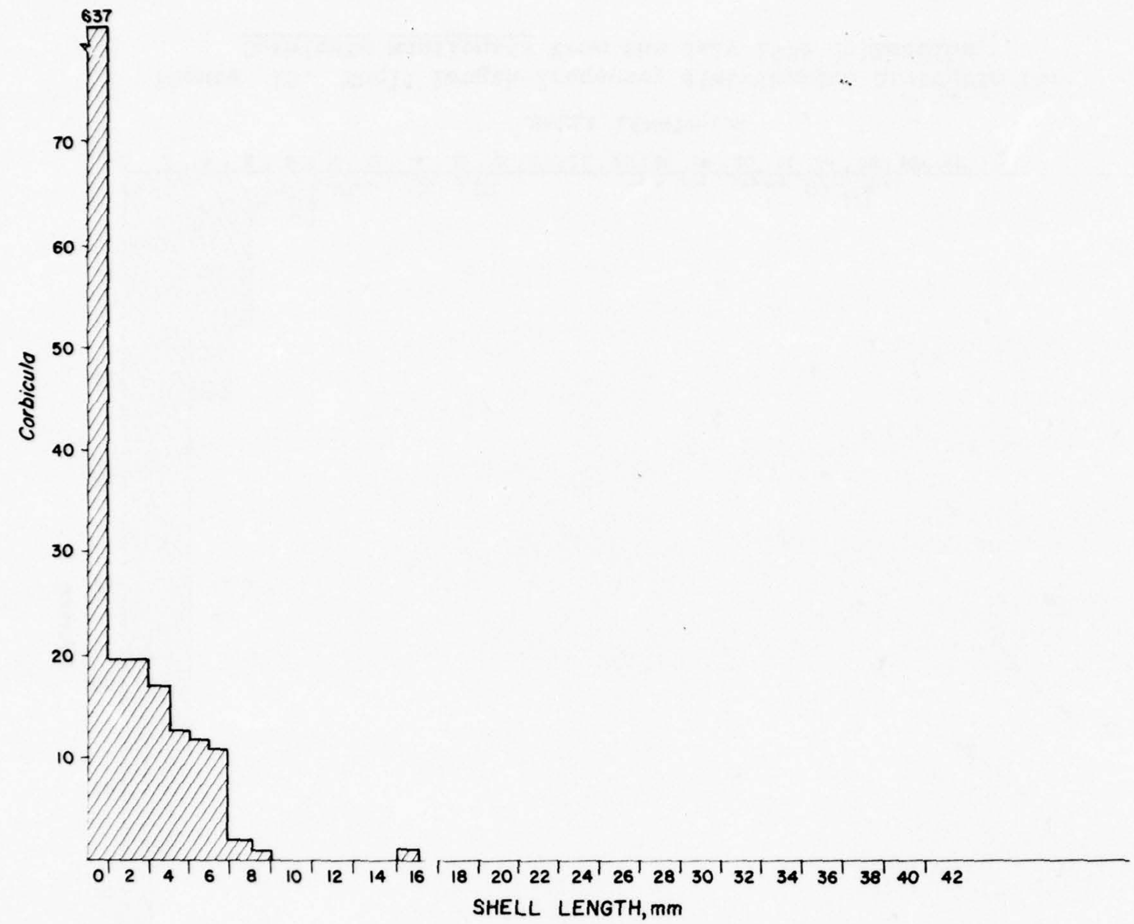

Figure 11. Shell length-frequency distribution histogram for *Corbicula manilensis* from the December 1975 collection

percent in July. The reduction in the domination by these four genera in December was a reflection of the sediment changes that occurred at the habitat site. When the percentages of each taxa were calculated for only the 12 stations that were sampled three times, there was even a more pronounced decline in the proportions of these genera (Tables 7, 8, and 9). Of these, Limnodrilus and Corbicula were mainly represented by immature individuals comprising 84, 73, and 61 percent of the total individuals from November, July, and December samplings, respectively. Adults comprised only the following percentages of the total:

	November	July	December
Limnodrilus	2.77	4.47	2.15
Corbicula	0.24	0.10	0.08

37. Hexagenia and Procladius were the next most abundant genera comprising the following percentages of the total:

	November	July	December
Hexagenia	0.49	1.55	4.73
Procladius	0.49	1.75	2.61

Hexagenia was the second largest animal in the collections, and when it occurred, it usually had a large influence on biomass. Procladius is a chironomid that preys on oligochaetes and also feeds on microflora (Roback 1953).

38. The total for all other genera combined comprised 0.19, 0.27, and 0.44 percent of the fauna for November, July, and December, respectively.

Biomass

39. The majority of the biomass in the macrobenthic communities around Windmill Point was in the form of large Corbicula and oligochaetes. These two categories constituted 89.96, 85.16, and 28.81 percent of the total biomass for November, July, and December, respectively. The decline in percentage in December was due to the absence of larger Corbicula; only two individuals (15 and 16 mm) were taken (Table 10). Large numbers of Corbicula shells, 32 to 47 mm, were observed washed ashore at the habitat site and mainland shoreline in March 1976. The mortalities are unexplained but may account for the lack of large specimens in the December 1975 collections. The contribution of small Corbicula to the biomass was slight in November and July despite their great abundance. In December there was a greater proportion of specimens in the 4- to 6-mm shell length range, which increased their contribution to the biomass (Table 11).

40. The oligochaetes composed a fairly constant percentage (around 20 percent) of the faunal biomass. Chironomid biomass was low in all collections, but the percentage contribution in December was fairly high due again to the absence of large Corbicula. The Hexagenia biomass pattern was similar to that for chironomids. Even though there were more Hexagenia in July (185) than November (100) or December (107), their percentage contribution was lowest. The July specimens were small, newly recruited that summer, while the November and December populations were composed mainly of larger individuals that would emerge the forthcoming summer. Tables 11, 12, and 13

show the breakdown of biomass at each of the sampling sites for all collections.

41. There was a variable relationship between sediment classification and biomass. In November, silty sand had the highest biomass averaging 54.5 g/m^2 due to high densities of large Corbicula. Sand-silt-clay, clayey silt, and silty clay stations had 36.5, 34.8, and 36.6 g/m^2, respectively. Sand stations had the lowest biomass (6.4 g/m^2). In July silty clay areas had the highest biomass (19.3 g/m^2), followed by sand (13.2), clayey silt (11.3), silty sand (8.2), and sand-silt-clay (5.0). In December, sand-silt-clay areas were highest with 20.5 g/m^2 and clayey silt (4.6) and sand (4.0) were lowest. In general, biomass measurements were greatly influenced by the occurrence or absence of large Corbicula.

Community structure

42. There were concordant changes in diversity between collection periods that corresponded to seasonal fluctuations (Tables 14, 15, and 16). From November to July diversity increased at all but two stations and decreased again at all but two stations in December. The increase of diversity in July was due more to an increase in evenness of species than an increase in species richness. Although there was a slight increase in the number of species taken in the July collection, it was not sufficient to cause the overall increase in diversity (Figure 12). The decrease in diversity again in December corresponded to lower evenness and richness components. The increase in the proportion of insect species and individuals

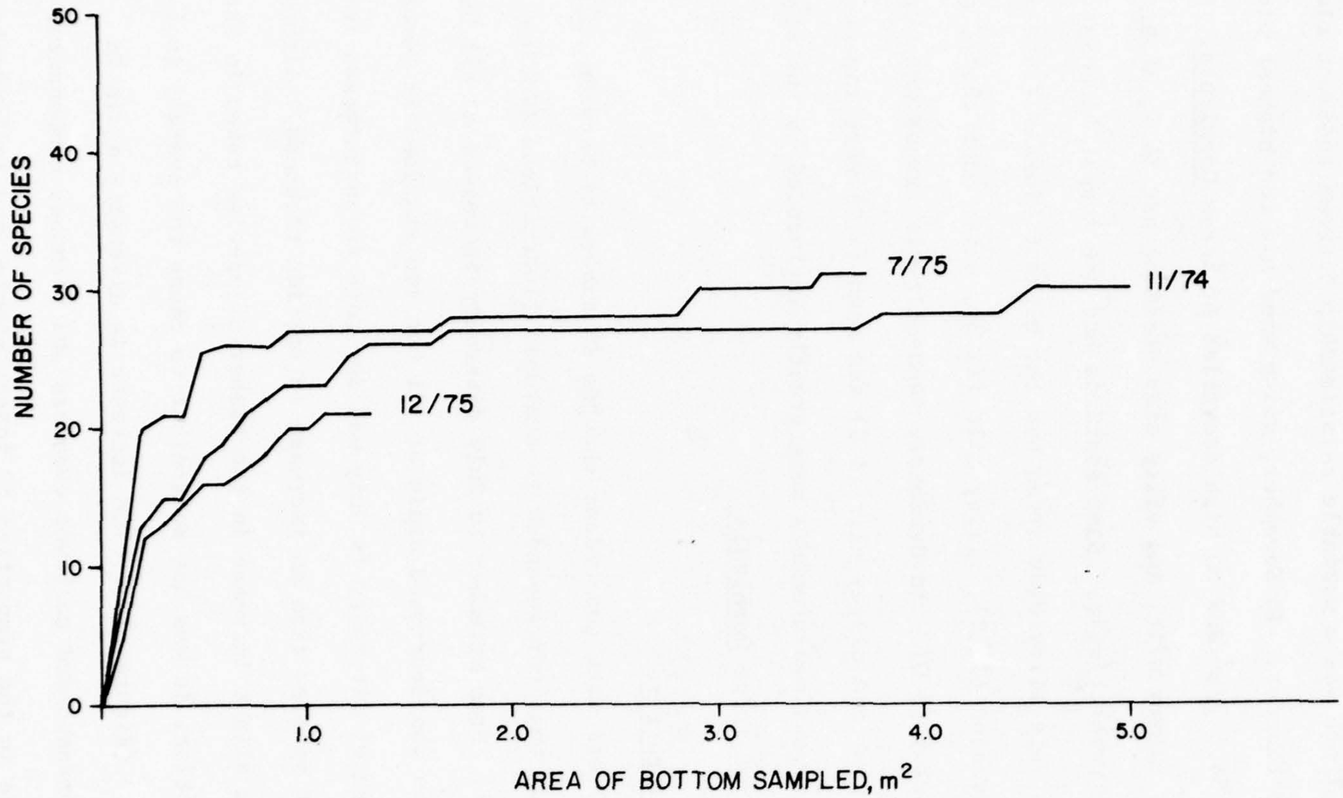

Figure 12. Cumulative species-area curves for the three collection dates

showed strongest seasonal trends with highest values, because of seasonal recruitment, in July. Branchiura sowerbyi and Urnatella gracilis, the only noninsect taxa that exhibited a clear seasonality, were more abundant in July.

43. Grain size of the sediments had a great influence on community structure. The mean diversity of sand, sand-silt-clay, and mud (clayey-silt and silty-clay) stations was as follows:

	November	July	December
Sand	0.85	1.86	1.59
Sand-Silt-Clay	1.15	1.70	2.12
Mud	1.28	1.92	1.57

44. Sand sites generally had lower diversity, except in July. The higher sand value for July was caused by the reduction in the number of small Corbicula at the sand sites, which increased evenness. Muddy sites, which composed the majority of the stations, tended to have the highest diversity except in December, when sand-silt-clay sites were higher because of high species richness. Abundances of species inhabiting the muddy sites were in general more evenly distributed. There were also more species occurring at muddy as opposed to sandy sites. Ablabesmyia sp. E, Chaoborus punctipennis, Hexagenia mingo, Peloscolex multisetosus, Limnodrilus profundicola, and Branchiura sowerbyi were species primarily found in mud, while tubificids with capillary setae and Enchytraeidae were primarily sand species. Many other species that occurred once or twice in the collections are not included in the mud-sand categories because of lack of distributional information.

Classification results

45. The inverse classificatory analysis of all collections together produced four interpretable species groups (Figure 13). The first split in the dendrogram seems to have been based on commonness. A large group of less common species was formed that could not be broken down any further into ecologically meaningful groups. The common species could be further divided into very common species, those preferring fine sediments and deep-water species groups. Hydrolimax grisea and Sphaerium transversum were included in the muddy species group; even though they occurred once or twice in sandy areas, the majority of their populations was in mud. Similarly, although Peloscolex multisetosus and Chaoborus punctipennis did have scattered occurrence in shallow water, their main populations were at the deepest stations. The very common group can be further divided into primary and secondary dominants with Limnodrilus spp. and small Corbicula as primary dominants. Among the secondary dominants were L. hoffmeisteri and Ilyodrilus templetoni and three chironomids that are known to be oligochaete predators, Coelotanypus scapularis, Procladius bellus, and Cryptochironomus spp.

46. Because of the homogeneity of the fauna and near proximity of stations, the normal analysis of the entire collections data was not ecologically informative and will not be included. However, normal analysis of only those stations sampled three times was instructive. The first dichotomy reflected sediment type dividing a large group of mud stations and a small group of sand stations. The

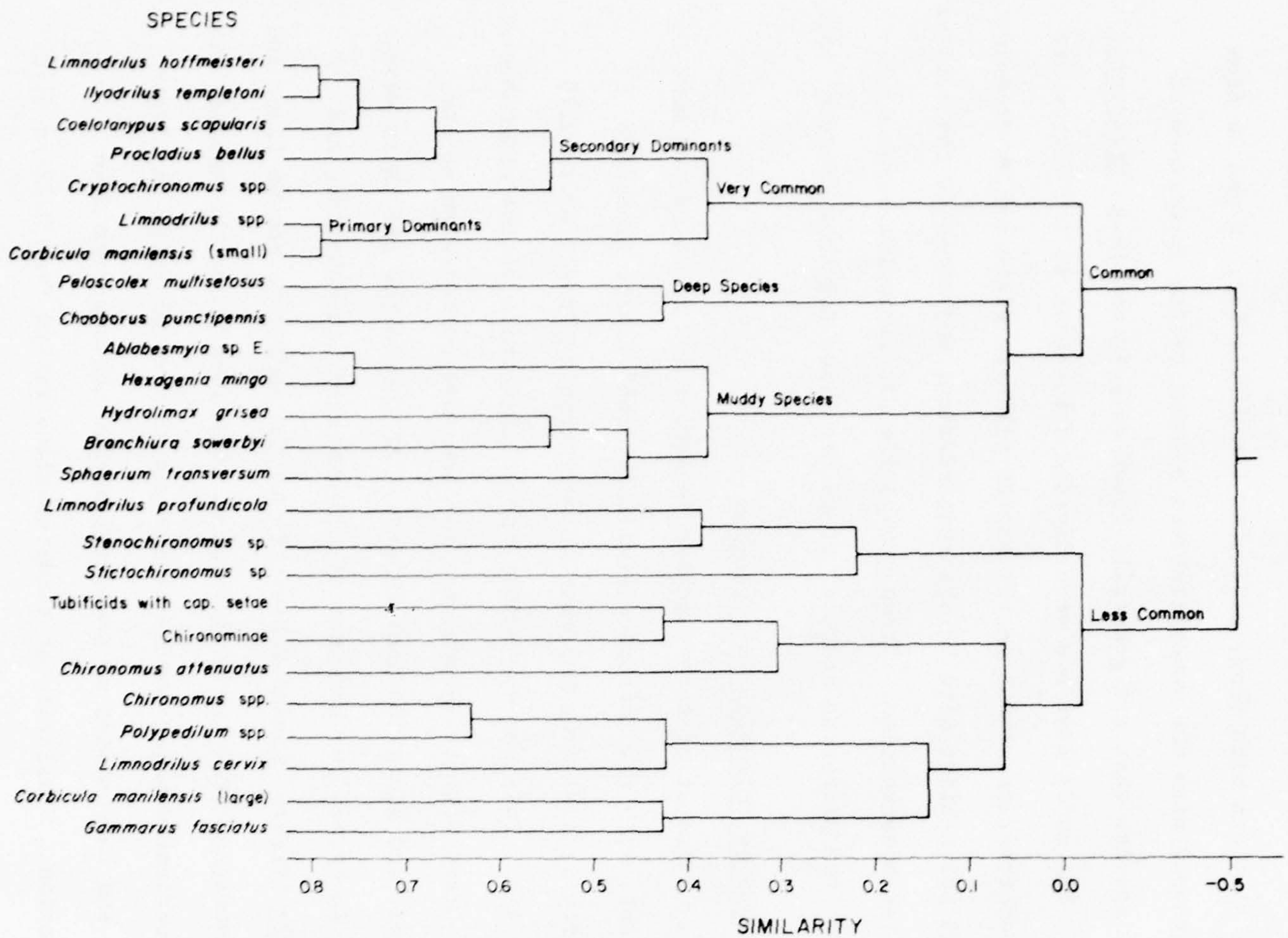

Figure 13. Hierarchical classification of species with at least 8 percent occurrence in all the collections

further classification of the sand stations separated those sandy stations at the borrow pit site before dredging and those stations adjacent to the habitat dike 1 year after construction. There were several stations with sandy sediments (in particular, 28 and 38 from July) grouped with the muddy stations because of the occurrence of several species that are generally found only in mud (e.g. *Hexagenia mingo*). The muddy stations were divided into those in the borrow pit after construction, those in the borrow pit area disturbed by dredging, those at the habitat site before construction, and those at the habitat site after construction. These groups are not exclusive since some stations from different areas or times are mixed together (Figure 14).

Faunal changes following construction

47. Fauna at stations located in deeper (>2 m) water was most persistent, with the intrasite similarity coefficient (complete similarity is 1.0) from November to July ranging from 0.69 to 0.79 (Table 17). This was due mainly to the uniformity of the oligochaete fauna. Least similar assemblages for the same period were at the borrow pit and along the habitat dike. At the borrow pit there were general increases in abundance of oligochaetes, chironomids, and *Corbicula* (Figure 15 and Table 18) as the sediments became finer and depth increased from 1.5 to 5.5-6.1 m. Stations along the habitat dike also experienced major dominance changes with a reduction in oligochaetes and chironomids as sediments became coarser from dike construction. Similarity at these stations ranged from 0.17 to 0.70. Other stations throughout the area had similarities ranging from 0.47

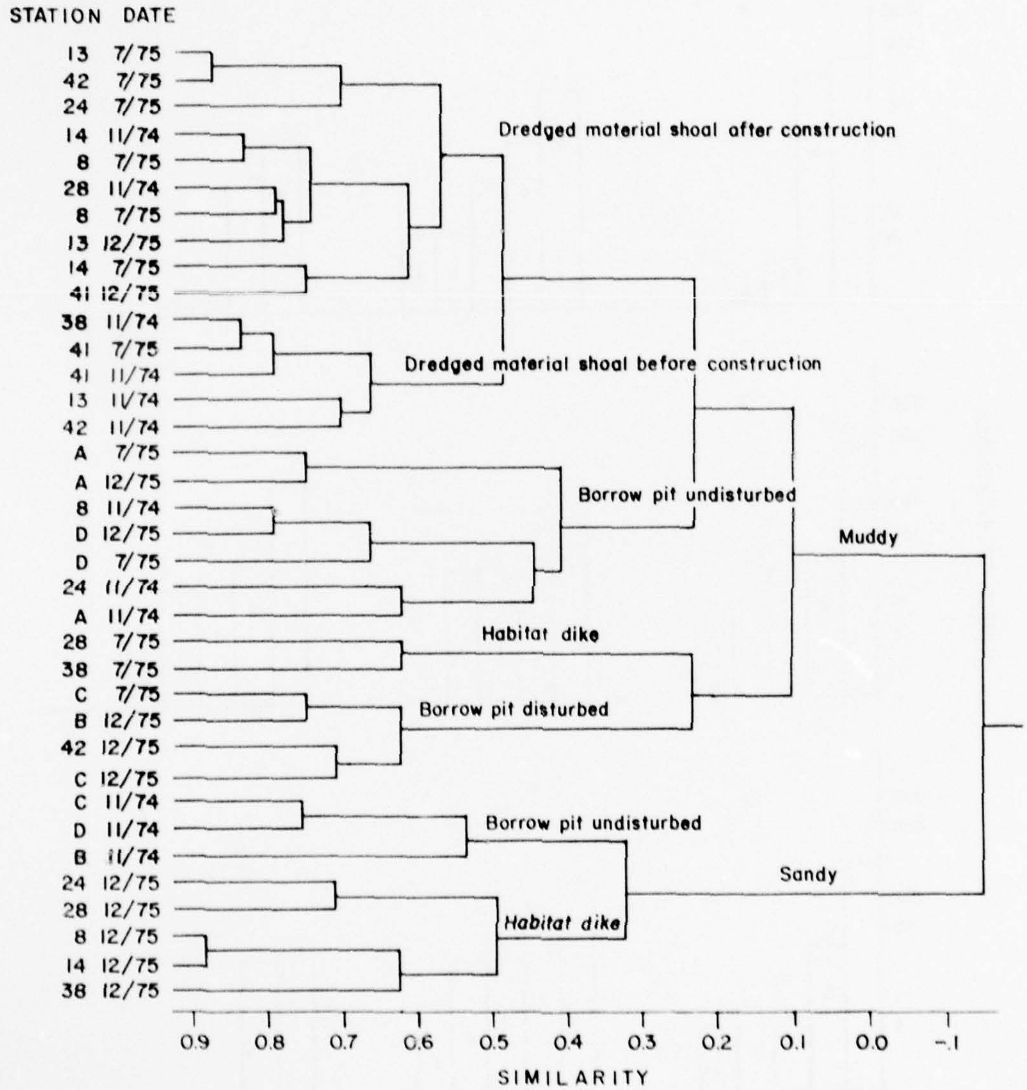

Figure 14. Hierarchical classification of collections from the 12 stations sampled three times

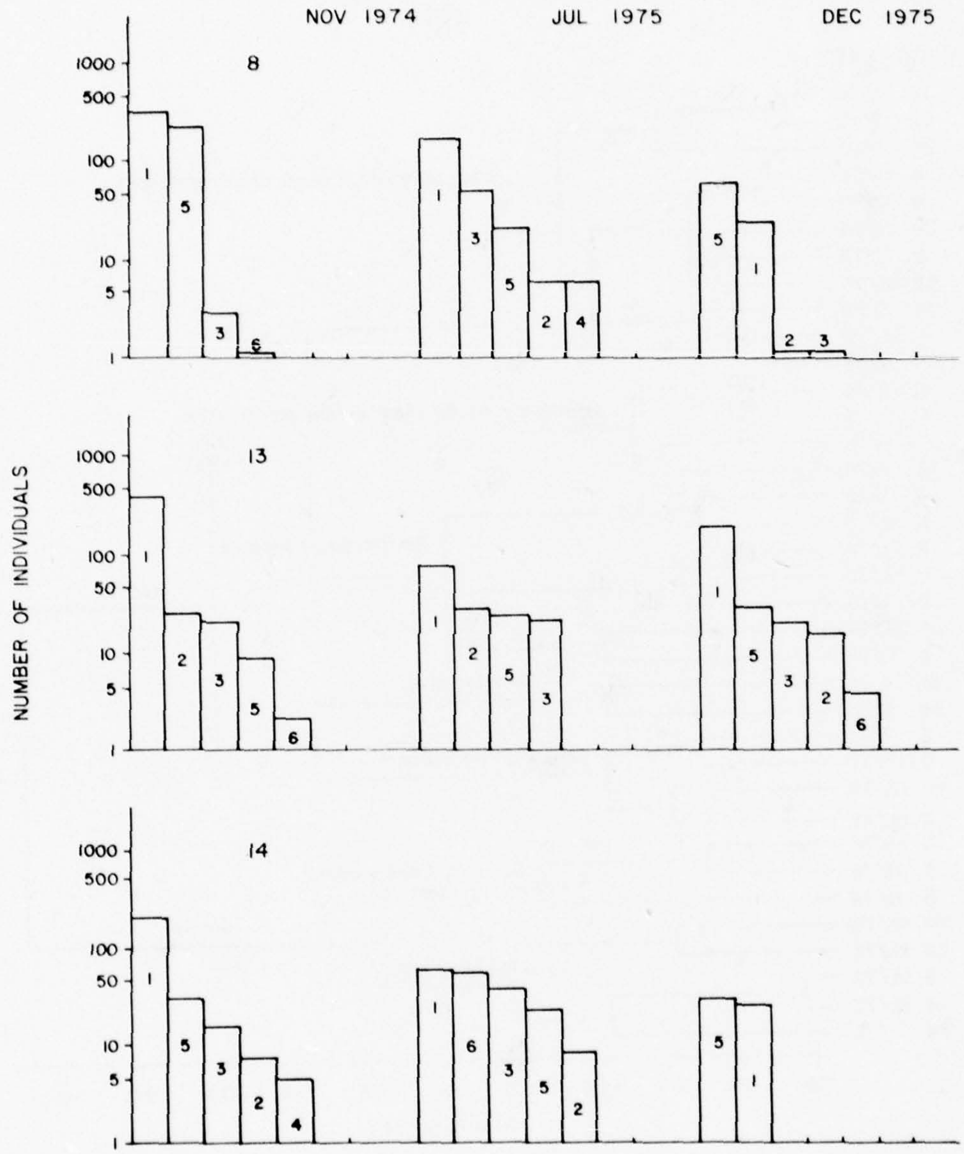

Figure 15. Distribution of dominant taxa at the 12 stations sampled three times: 1 - Limnodrilus, 2 - other tubificids, 3 - chironomids, 4 - Hexagenia, 5 - Corbicula, 6 - others (sheet 1 of 4)

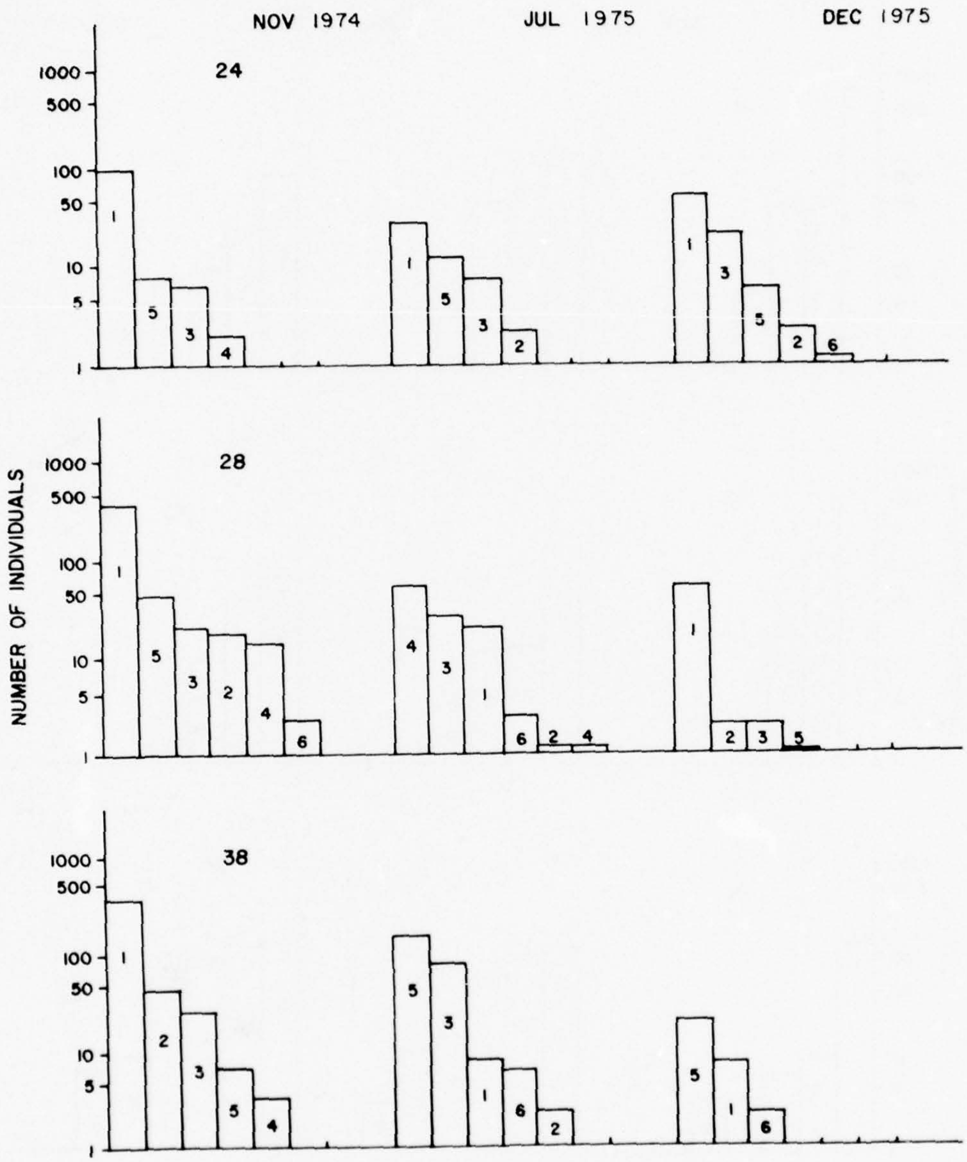

Figure 15 (sheet 2 of 4)

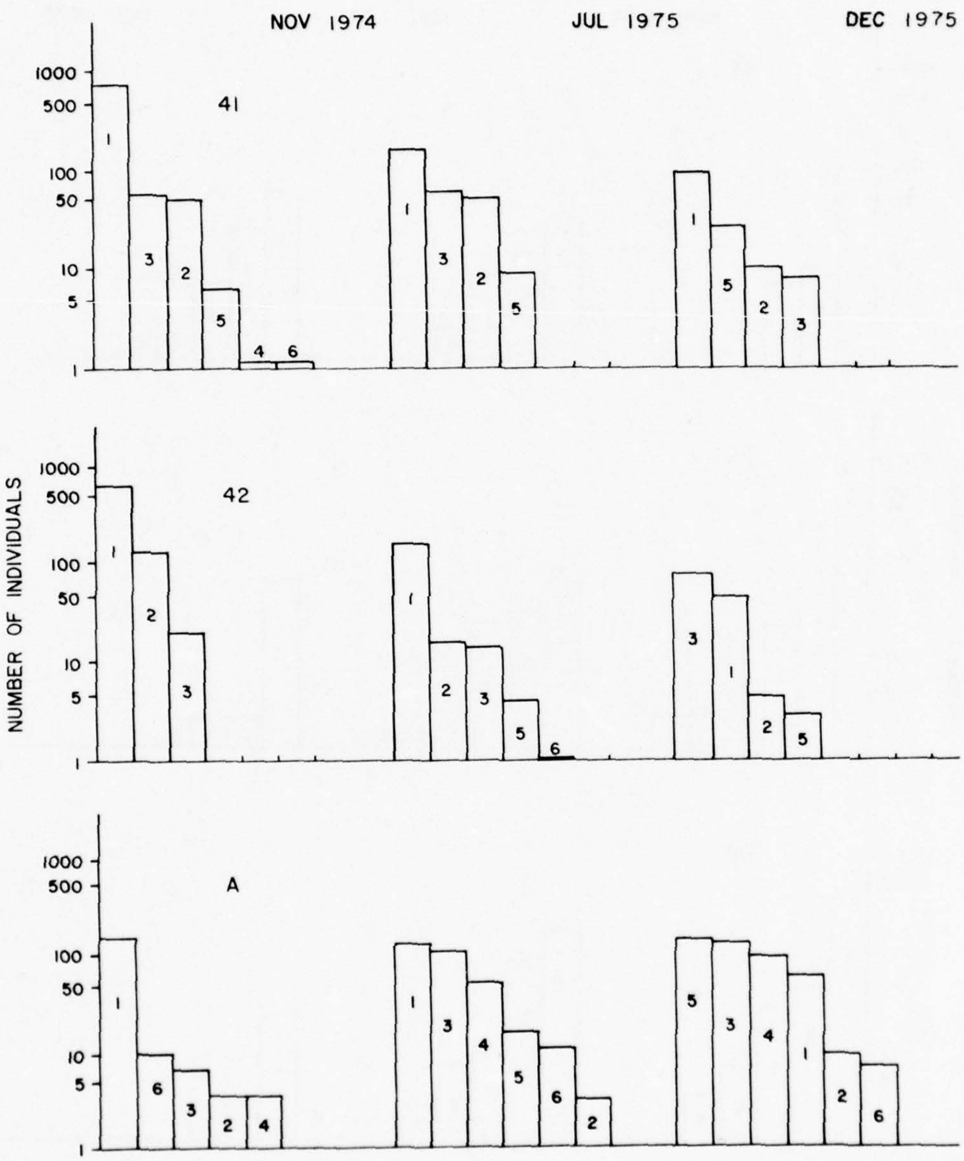

Figure 15 (sheet 3 of 4)

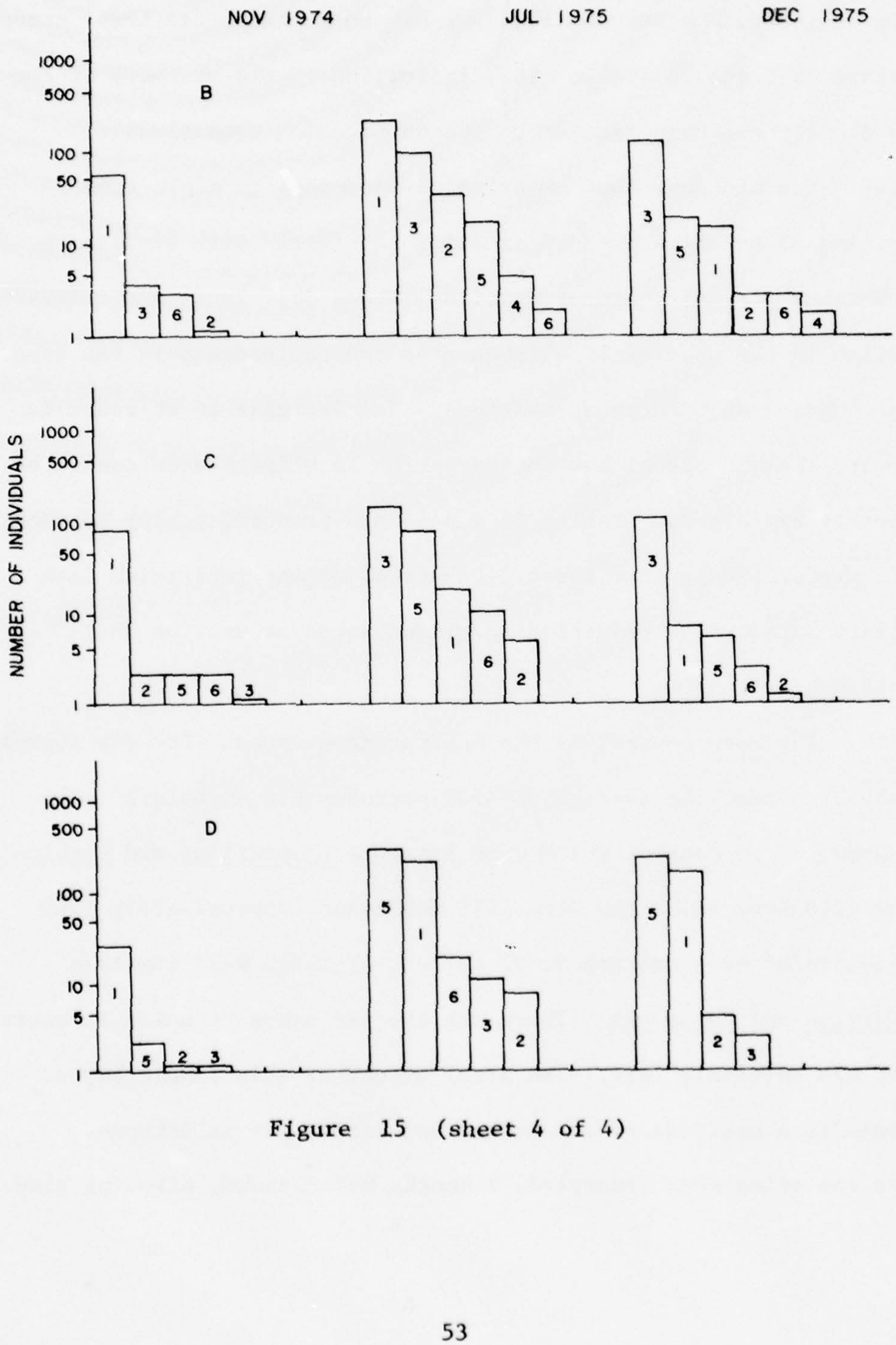

Figure 15 (sheet 4 of 4)

to 0.74 from sampling period to sampling period.

48. Similarity from July to December at the stations near the dike was generally low ranging from 0.30 to 0.57. The annual similarity at the sand stations from November to December was lower except for stations 8 and 38 (Table 18), indicating little recovery of the fauna along the dike perimeter to preconstruction conditions.

49. The stations that experienced decreases in depth from deposition of overflow dredged material had fairly high similarity from November to July, except stations 18 and 38. There was a drastic reduction in the species of oligochaetes and an increase in the species of chironomids at both these stations. The increase in chironomids was most likely seasonal but the reduction in oligochaetes cannot be completely explained. Station 38 did change from silty clay to sand, a less preferable habitat for oligochaetes, except tubificids with capillary setae. The reduction in oligochaetes at station 18 is unexplainable.

50. The area covered by the habitat development site was approximately 22 acres. An average of 4500 macrobenthic animals/m^2 were destroyed, 85 percent of which were immature Limnodrilus and Corbicula. At the site from which the dike fill was taken, approximately 1700 individuals/m^2 were destroyed, 97 percent of which were immature Limnodrilus and Corbicula. These are the two areas at which an acute impact was certainly felt. The areal extent of this impact beyond the immediate confines of the island and borrow pit is unknown. Before the sites were resampled, 8 months had elapsed, allowing time

for substantial recovery of populations of the opportunistic dominant species. It appears that any acute impacts must have been short-lived, except in the habitat development, dike perimeter, and borrow pit, where the habitats have been substantially modified.

51. Seasonality was mainly responsible for changes in the pattern of taxa occurrence. However, there were also changes attributable to the creation of the habitat site, mainly those induced by the gross alteration of sediment characteristics. Of the stations sampled three times, sediments at stations 8, 14, 24, and 38 changed from mud to sand after the habitat site was constructed. At all these stations, the numbers of oligochaetes declined greatly (Figure 15). Small *Corbicula* were apparently favored by this change in substrate. Abundances of the mud-dweller *Hexagenia* declined greatly from November to December. Sediments at stations 13, 41, 42, and A were apparently unaltered by habitat construction, yet there was also a decline in tubificids at these stations. However, their general dominance was maintained, except at stations 42 and A in December (Figure 15 and Table 18). In general, there were no widespread concordant changes in the fauna, other than expected seasonal changes, except for oligochaetes and *Hexagenia*.

52. When only the faunal assemblages at the 12 stations sampled three times were considered (Tables 7, 8, and 9), it was apparent that proportional representation in abundance had shifted. Again, the oligochaetes declined and *Corbicula* increased in importance due to sediment changes directly attributable to habitat development. In

general, the insects increased in importance, possibly because of a successful summer recruitment season.

53. This section is included only to give a gross idea of what the habitat development site interior was like soon after construction. A detailed evaluation of the developing macrobenthic communities is the subject of ongoing work under contract DACW76-C-0040 Postconstruction Studies at the Windmill Point Marsh Development Site.

Habitat site interior

54. The interior of the habitat development site provided a different type of substrate than the surrounding river bottom. During the first growing season, the interior was thickly vegetated with pickerelweed (*Pontederia cordata*) and arrowhead (*Sagittaria latifolia*), which increased the organic content of sediments and provided a greater diversity of habitats for epifauna (most of the Naididae) and epifaunal grazers, such as *Physa*. The most striking difference between the habitat and the surrounding river bottom was the unexplained absence of *Corbicula* from the habitat (only one individual was taken). This may be due to a combination of exposure to greater fluctuations in temperatures caused by the shallowness of the interior or the fineness of the sediments. *Corbicula* does set preferentially on sandier sediments (Sickel and Burbanck 1974). There may also be more intense predation pressure in the habitat from the large numbers of *Fundulus* observed utilizing the site.

55. The dominant species in the habitat were oligochaetes, mostly *Limnodrilus* spp. and Naididae. *Limnodrilus cervix* was more abundant

than *L. hoffmeisteri*, whereas the opposite was the case outside the habitat. The chironomids were also abundant, with *Trichocladius* sp. and Orthocladinae found only within the habitat. *Tanypus neopunctipennis* was the most abundant species followed by *Chironomus* spp. *Coelotanypus scapularis*, the dominant chironomid in the James River, was absent. The only unionid taken alive during the study was found in the habitat interior (Table 19).

56. In general, the fauna in the habitat interior had a fair resemblance to that of the rest of the river bottom. Even though seven species were found only within the habitat, they may also occur outside the habitat.

PART IV. DISCUSSION

Natural History

57. The turbellarians were represented by the single species Hydrolimax grisea. Not much is known about this species. It may be undergoing a resurgence or rediscovery on the east coast. It is always found in association with fine sediments and silty environments such as the tidal James River. Hydrolimax may feed on small bivalves or meiofauna. Diaz (1972) found it associated with small Corbicula and the oligochaete Peloscolex multisetosus.

58. The nemerteans, which have few freshwater species, were represented by the only species occurring in North America, Prostoma rubrum. Prostoma is found in association with aquatic vegetation on which it searches for oligochaetes, crustaceans, insects, and protozoans (Coe 1959). It was found around the outside perimeter of the habitat site on bits of plant matter.

59. Molluscs were represented by six species, four bivalves and two gastropods. The gastropods were Physa sp. and Goniobasis virginica. Physa, a pulmonate or air breather, is the common pond snail. It was found only within the habitat development site, for Physa prefers vegetated habitats in which it grazes on aufwuchs. Goniobasis, a prosobranch, was found alive only twice at station F in November and station 1 in July. Large numbers of eroded shells were found in sandier areas indicating that in the recent past it was more abundant. Wass* found many specimens around Hopewell in the

* Personal communication, February 1976, Dr. M. L. Wass, Virginia Institute of Marine Science.

early 1960's. The sphaeriid bivalves, fingernail clams, were represented by *Pisidium* sp. (possibly *casternatum*) and *Sphaerium transversum*.

60. Generally, sphaeriids have been thought intolerant of pollution, but as more is learned about the ecology of the group, many species have been seen to be tolerant of polluted conditions. Both of these species are favored by organic enrichment and are the most common sphaeriids in North America (Fuller 1974). *Pisidium* and *Sphaerium* represent the only indigenous bivalve fauna taken in the collections outside the habitat site. One unionid, freshwater mussel, probably *Elliptio complanata*, was taken in the habitat site in December. It was small (20 mm) and was most likely transported to the site in the dredged material or dike material. In the recent past unionids appeared to have declined in numbers. *Elliptio* and *Anadonta* are still the most abundant unionids in the tidal James River, preferring sandy and muddy habitats, respectively. The remains of large *Elliptio* populations are scattered throughout the entire tidal freshwater region, with largest densities of shell in shallow sandy areas. This reduction may be attributable to an increase in organic or toxic pollution as unionids are quite sensitive to pollutants (Fuller 1974).

61. The dominant bivalve in collections was the Asiatic clam *Corbicula manilensis*. It has recently become established throughout the tidal freshwater James River (Diaz 1972). *Corbicula* is an opportunistic species that in a short period has dominated the benthic

communities in terms of numbers and biomass. It is not known what effect Corbicula will have on the already depauperate molluscan fauna.

62. The Entoprocta were represented by the only species known from North America freshwater areas, Urnatella gracilis. It is a small colonial form (<5 mm long) that grows attached to hard substrates such as leaves, stones, or shells. Not much is known about its ecology.

63. The annelids, or segmented worms, were well represented in the collections. Most were oligochaetes, which present some taxonomic problems not found among the other fauna in the collections:

a. Literature on the Enchytraeidae is scarce, the only available being European.

b. The Naididae are very difficult to work with when preserved in formaldehyde.

c. Some of the Tubificidae (which make up the majority of the oligochaetes in the James River) cannot be positively identified to species unless the individual has fully matured; this is exemplified by the Limnodrilus spp. grouping.

As stated earlier, Limnodrilus spp. comprised the majority of all the oligochaetes. The other species comprised only a small percentage of the fauna. Branchiura sowerbyi, an introduced European species that is found associated with thermal effluents and shallow areas where temperatures can become high, was sparsely scattered over the study area. Aulodrilus pigueti and Potamothrix vejdovskyi were rare and were found only in the November collection. Ilyodrilus templetoni was widespread and had similar distribution patterns as the genus Limnodrilus, which preferred the finer sediments. The only oligochaetes to prefer sandy substrates were the Enchytraeidae, which were restricted mainly to the sandy shore zone. Many Enchytraeidae are semiaquatic, preferring damp soils. As a group, the oligochaetes are considered selective deposit feeders deriving most of their nutrition from microbes. The partitioning of the sediment microbial resources may allow many closely related species to coexist (Brinkhurst and Chua 1969, Wavre and Brinkhurst 1971, Brinkhurst, Chua, and Kaushik 1972, Chua and Brinkhurst 1972, and Brinkhurst 1974a.

64. The only leech to occur was Helobdella elongata. It is a small thin species with small suckers and is not restricted to hard substrates. It is mainly predaceous, most likely feeding on all components of the fauna (Sawyer 1974).

65. The peracarid crustaceans, which are generally well represented in fresh water, particularly the gammarids, were represented by only Gammarus fasciatus, a small amphipod that feeds on detritus. Distribution of this species was obscured by its sparse densities, but it most likely prefers vegetated areas or plant debris.

66. Insecta was the best represented class with three orders (Trichoptera, Ephemeroptera, and Diptera) and 21 species. The trichopterans (or caddis flies) were sparsely represented by two occurrences in July (stations D and 38) of Oecetis sp. The trichopterans, as a whole, are found in all types of sediments, but Oecetis forms a sand grain tube and is generally found on fine sandy substrates. Trichopterans, as well as the ephemeropterans, are regarded as beneficial insects, since the larvae form an important element in the diet of many fishes. These two orders of insects are better represented in more lotic environments than in tidal freshwaters. Koss, Jensen, and

Jones (1974) found six species in the tidal freshwater James River while Kirk (1974) studying a Piedmont section of the James River found 58 species.

67. The ephemeropterans in this study were represented by *Stenonema* sp. and *Hexagenia mingo*. *Stenonema* is a small fragile species that lives crawling about the sediment surface feeding on algae and detritus. *Hexagenia* on the other hand is a large robust burrowing species that prefers muddy environments. It is well adapted for burrowing with large plumose gills for ventilating its burrow and highly specialized front legs, head, and mandibles.

68. Dipterans were represented by two families, Chaoboridae and Chironomidae. The Chaoboridae (or phantom midges) were represented by only one species, *Chaoborus punctipennis*, which is predaceous, feeding on zooplankton in the water column at night. During the day they are found in the shelter of the sediment substrate. The Chironomidae was the best represented family in the collections with species from two subfamilies, Tanypodinae and Chironominae. The Chironomidae are among the most important components in the diet of many fish species, including catfish, striped bass, and alosids in the James River. Most of the larvae live in tubes constructed of mud or detritus held together with secretions from silk glands. The tubes generally protrude from or lie flat on the sediment surface. Some of the predaceous species do not construct tubes but wander through the sediments in search of prey. Tanypodin larvae are generally considered predatory, feeding on other chironomids, oligochaetes, and meiofauna.

69. Ablabesmyia sp. E, the largest tanypodin in the Windmill Point area, was found with Limnodrilus setae in its gut along with diatoms and large quantities of silt. Loden (1974) found Ablabesmyia feeding on a variety of oligochaetes, and Roback (1953) found it to be entirely predaceous, feeding mainly on other chironomids and Hydracarina. Procladius bellus, Coelotanypus scapularis, and Tanypus neopunctipennis may also feed on other invertebrates, but no remains were found in the guts of a limited number of specimens examined (7 Procladius, 13 Coelotanypus, and 3 Tanypus). Procladius has been found to feed on oligochaetes (Loden 1974), but only diatoms were found in the guts of Procladius from the Windmill Point area. Evidence indicates the Tanypodinae taken in this study are most likely omnivorous. The Chironominae, on the other hand, which constituted the majority of the Chironomidae, are generally considered herbivorous or deposit feeders. However, larvae of species of Cryptochironomus, Glyptotendipes, Polypedilum, and Chironomus have been reported to feed on oligochaetes (Wirth and Stone 1956, Loden 1974).

70. The fishes were represented by the American eel, Anguilla rostrata, and the killifish, Fundulus luciae. The eel is a catadromous species that uses tidal freshwater areas as a nursery ground. It feeds on a variety of live and dead animals primarily at night, spending the day in the sediments. The killifishes are the most common small fishes in shallow, coastal waters inhabiting weedy, muddy places in marshes and bays. Many Fundulus exhibit a wide salinity tolerance, so it is not unusual to find a representative in tidal fresh water even though

the group prefers brackish waters. *Fundulus* is an omnivore that burrows in mud for protection and possibly in search of food.

Ecology of Tidal Freshwater Benthos

71. One of the more striking features of the tidal freshwater habitat is the low number of species when compared to nontidal freshwater habitats. The number of species reported from four studies in the freshwater James River is as follows:

Study Area	No. of Species	Author
Entire tidal zone	49	Diaz (1977)
Chesterfield area (tidal)	69	Koss, Jensen, and Jones (1974)
Windmill Point area (tidal)	46	This report
Bremobluf area (nontidal)	147	Kirk (1974)

72. The reason for the lower numbers in the tidal areas is lack of diverse habitats. The deposition of the bulk of the alluvial sediments entering the James in the tidal freshwater zone (Nichols 1972) reduces the available habitats to mostly muddy ones with isolated sandy substrates where wind and wave energy keep the fines from accumulating. Koss, Jensen, and Jones (1974) examined the largest number of different habitats, and their species list is more representative of tidal fresh water as a total ecosystem than this study or Diaz (1977), which examines mainly the muddy habitats. The majority of species reported from the nontidal James River (Kirk

1974) are associated with swift currents and hard substrates (such as stones). These habitats do not occur in tidal fresh water so species associated with them do not occur.

73. Tidal freshwater fauna is most similar to that of large lakes (such as the Great Lakes system, Johnson and Brinkhurst 1971) or the profundal zone of smaller lakes, polluted harbors, or near river mouths where sediments usually consist of silt, clay, and organic mud (Brinkhurst 1967, 1970; Johnson and Matheson 1968). Tidal freshwater fauna is also widely distributed. Among the tubificids, *Limnodrilus hoffmeisteri*, *L. profundicola*, *Branchiura sowerbyi*, and *Aulodrilus pigueti* are cosmopolitan in distribution. *Limnodrilus cervix* and *Peloscolex multisetosus* are Pan-American species and *Potamothrix vejdovskyi* and *Ilyodrilus templetoni* are widespread Eastern North American species (Brinkhurst and Jamieson 1971). The mayfly genus *Hexagenia* is generally distributed throughout North America (Needham, Traver, and Hsu 1935). The chironomids in general are very widely distributed being the most ubiquitous of all aquatic insects (Roback 1974). The turbellarian *Hydrolimax grisea* may prove to be a species more characteristic of tidal freshwater fauna than any other species once enough ecological data have been gathered. Its favored environments are silty-muddy habitats. *Hydrolimax* has been found in other tidal freshwater rivers: the Mattaponi River, Virginia (Diaz 1977); several rivers in Georgia (Fuller*); and possibly in

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* Personal Communication, December 1975, Mr. S.L.H. Fuller, Philadelphia Academy of Science.

the Delaware River (Hyman 1938). Johnson and Brinkhurst (1971) also found Hydrolimax in Lake Ontario.

74. Among the species that do occur in tidal fresh water, there is a high degree of eurytopy with very few species exhibiting any qualitative preferences. The greatest sediment preference is shown by the Enchytraeidae and ephemeropterans, which prefer sandy (enchytrachaeids and Stenonema) or muddy (Hexagenia) habitats. Basically, tidal fresh water is dominated by mud-loving species that are opportunistic and rather resilient to perturbations. The Agnes freshet (June 1972), which set high flow records for the James River, had little or no effect on the tidal freshwater communities (Boesch, Diaz, and Virnstein 1976).

75. Competition between species has not been studied but appears to be minimal. The recent introduction of Corbicula manilensis has not altered the composition of the fauna in any apparent way except that Corbicula is now the most abundant species in the tidal freshwater James River (Diaz 1972, 1977). To date no species have been eliminated by Corbicula's population explosion. The large amounts of food entering the James and available living space were apparently underutilized before Corbicula's invasion and it appears that these resources are still not limiting.

76. The ease with which Corbicula has populated the tidal freshwater James River may be a clue as to how little biologically structured and how greatly physically controlled tidal freshwater communities are. If interspecific competition and competitive

exclusion were intense, the spread and proliferation of *Corbicula* should not have been as dramatic. Even so, the evidence of food resource partitioning among cooccurring tubificids (Brinkhurst and Cook 1974) suggests that even in this physically rigorous environment there may be biological accommodation.

77. The chironomids of the genera *Coelotanypus*, *Cryptochironomus*, *Procladius*, *Ablabesmyia*, *Glyptotendipes*, *Tanypus*, *Polypedilum*, and *Chironomus* are the major benthic predators occurring in the tidal freshwater James River, and there is some question as to whether they are totally predaceous. Gut content analysis by Loden (1974), Wirth and Stone (1956), Roback (1953), and this study found no chironomid to be consistently carnivorous, although *Ablabesmyia* seemed to be the most consistent predator. Roback (1953) found it to be completely predaceous in the Savannah River, Georgia, but in the James River *Ablabesmyia* also contained quantities of algae in their guts. Predation by benthos on benthos is most likely insignificant when compared to predation by fishes, which in the James River are mainly omnivorous bottom feeders.

78. The more important benthic feeding fish in tidal fresh water are catfish, striped bass, carp, perch, eel, and cyprinodont minnow, all of which are opportunistic feeders (Markle and Grant 1970, Pfitzenmeyer 1973, Clady 1974, Massengill 1973, Heard 1975). In general, the composition of the benthic fauna found in fish guts gives a qualitative picture of what is in the bottom (Pfitzenmeyer 1973, Heard 1975). Oligochaetes, due to their life style, are generally

underrepresented in fish stomachs. Cropping of macroinvertebrate biomass by fish is obviously related to fish densities and seasonal activity. Studies in nontidal fresh water indicate that the standing stock of benthos reflects survival of fish predation at any particular time (Brinkhurst 1974b, Macan 1966, Hayne and Ball 1956).

Community Structure of the Tidal Freshwater James River

79. The dominant and most diverse taxa in the tidal freshwater James are tubificid oligochaetes and dipteran insect larvae of the family Chironomidae. These two families are well represented in most lotic and limnetic waters and their species composition and density of individuals vary in relation to the degree of pollution (Brinkhurst and Cook 1974, Roback 1974). Other taxonomic groups that are important in the benthic communities of the tidal freshwater James are the oligochaete families Naididae and Enchytraceidae, triclads, Hirudinea, Amphipoda, Ephemeroptera, Odonata, Trichoptera, Bryozoa, and various dipteran families.

80. Tubificids and chironomids have quite different life histories and modes of repopulation. Tubificids are aquatic throughout their lives and disperse only by crawling through the sediment or being swept passively by currents. They are hermaphroditic but rarely self-fertilize, so they must find a mate and copulate. They do not lay large numbers of eggs but typically deposit one egg at a time in a cocoon (Brinkhurst and Jamieson 1971). However, they are able to produce cocoons rapidly as evidenced by the thick mats of worms that can develop in a short period.

81. Only the developmental stages of chironomids live in an aquatic environment; adults are flying insects. This gives the chironomids great powers of dispersal and is the main reason why chironomids are generally the first benthic forms to recolonize defaunated areas, although at times unfavorable winds may blow away entire adult populations and cause repopulation failure. Larvae of some species are motile and can crawl along the bottom or actively swim, but most are sedentary tube dwellers. Larval movement plays only a secondary role in dispersion and recruitment. The larvae are generally short lived, and it is the egg laying of adult midges during warm seasons that maintains populations. During cold seasons there is little or no recruitment and larval development is typically arrested until warmer temperatures prevail allowing further development and metamorphosis.

82. The upper tidal freshwater region of the James River is characterized by lower diversity and species richness (Koss et al. 1974, Diaz 1977). The benthic fauna is most severely depressed just below Richmond, with a general recovery in both diversity and richness nearing Hopewell (Figure 1). The composition of the benthic community is rather uniform below Richmond. Before the introduction of Corbicula, the dominant organisms were the tubificids Limnodrilus spp., Ilyodrilus templetoni, and Aulodrilus pigueti and the chironomids Coelotanypus scapularis and Procladius spp. The tubificids were numerically dominant, but the chironomids were represented by more species.

83. The lower tidal freshwater James is composed of two biological subsections. Species diversity and richness are again depressed in the vicinity below Hopewell and the composition of the communities is like that in the upper tidal freshwater segment. The dominants are again various _Limnodrilus_ species, _Coelotanypus scapularis_, and _Ilyodrilus templetoni_. The earliest quantitative sampling in this area (in the fall of 1971) showed _Corbicula_ to be an established member of the community but not among the dominants. In 1971 the community was especially characterized by _Limnodrilus_ spp. and _Coelotanypus scapularis_, but by late 1972 _Limnodrilus_ spp. and _Corbicula_ dominated.

84. Downstream from Hopewell the pollution load is assimilated and diversity again increases to the highest levels for the entire tidal freshwater James River. The pre-_Corbicula_ dominants in this lower tidal freshwater area were _Limnodrilus_ spp., _Coelotanypus scapularis_, and _Rangia cuneata_. Among the subdominant species were _Ilyodrilus templetoni_, the chaoborid midge _Chaoborus punctipennis_, and the ephemeropteran _Hexagenia mingo_. When _Corbicula_ invaded this segment, it did not become as abundant as upriver, suggesting that the _Limnodrilus-Coelotanypus-Rangia_ community was more resistant to the invasion by _Corbicula_ than the communities in the upper tidal freshwater areas.

85. The heavy dominance of _Limnodrilus_ spp. in the upper part of the lower tidal freshwater region suggests poor water quality, but in the lower part of this segment _Limnodrilus_ is no longer the overwhelming dominant. The ratio of _Limnodrilus_ to other species decreases greatly. Here _Limnodrilus_ shares dominance with other species in a complex

community in contrast to its monocultural dominance in the simpler community upstream.

86. The distribution of benthic communities of the tidal freshwater James reflects the location of pollution sources along the river. Unfortunately, no historical data exist that would indicate the condition of the James before heavy industrialization and urbanization of Richmond and Hopewell. Tidal conditions and the deposition of fine sediments are natural factors that have always been important to benthic organisms in the James, although some faunal changes have occurred. For example, molluscs were more abundant in the past as evidenced by dense deposits of shells of unionids and *Goniobasis*. Past dominants were most likely similar to the present dominants, with sphaerids and unionids being the dominant bivalves. Thus, fauna of the tidal freshwater James was never like that in the Piedmont section above Richmond; rather it was similar to the lower tidal freshwater James but with more species represented. The fauna of the Piedmont section has upwards of 200 species, representing about 100 families (Kirk 1974). The tubificids are only a minor part of the fauna and are not as diverse as in the tidal freshwater James. The chironomids, on the other hand, are much more diverse in the Piedmont James with over 40 taxa represented compared to 25 found in the tidal sections.

Animal-Sediment Relationships

87. Generally the fauna of the tidal freshwater James is eurytopic, showing little qualitative preference for sediment type. The only very common species that did not exhibit this eurytopy was

the mud-dwelling mayfly Hexagenia; only one small (2.2 mm long) individual was found at a sandy site (station 21) in July. The other six most common species were found in all sediment types, but there were quantitative differences between the sediment types (Figure 16). The oligochaetes Limnodrilus spp., L. hoffmeisteri, and Ilyodrilus templetoni and the chironomid Coelotanypus scapularis preferred silty and clayey sediments. Procladius bellus tended to be more abundant in finer sediments but was also commonly found at sand sites. Among the other common species that preferred finer sediments were Peloscolex multisetosus, Branchiura sowerbyi, Hydrolimax grisea, Sphaerium transversum, Chaoborus punctipennis, and Ablabesmyia sp. E.

88. The only common species to show preference for sandy sediments was small Corbicula manilensis. Sickel and Burbanck (1974) found that larval Corbicula exhibited marked preference for settlement on fine to coarse sand. Less common species inhabiting sandy substrates were the Enchytraeidae, Aulodrilus pigueti, and tubificids with capillary setae.

89. Diversity, biomass, and community structure are all very dependent on and controlled by the sediments. For example, a controlling factor may be the available surface area for growth of the bacteria that the oligochaetes feed upon. So, more oligochaetes are found in fine-grained sediments where the amount of surface area is highest. These fine-grained sediments may in turn regulate the distribution of oligochaete predators. The majority of the sedimentary factors influencing the distribution of organisms are probably much more subtle and have yet to be discovered.

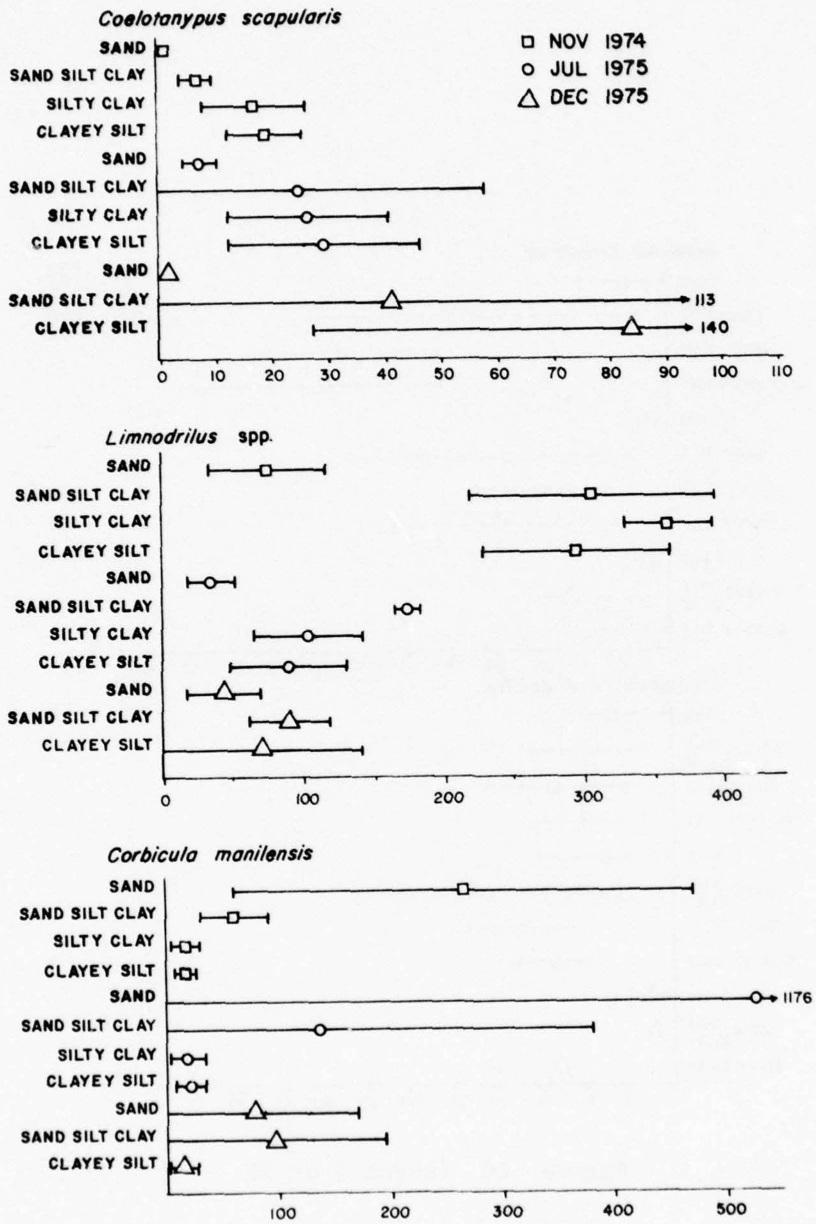

Figure 16. Mean abundance and 95 percent confidence intervals for seven common species from the James River, Windmill Point habitat development site
(sheet 1 of 3)

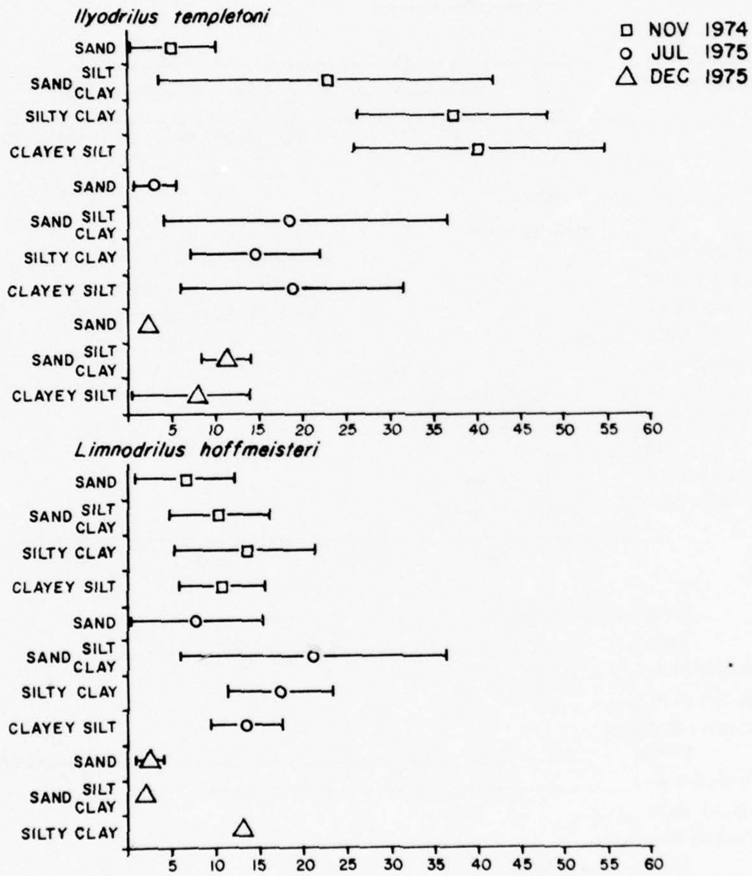

Figure 16 (sheet 2 of 3)

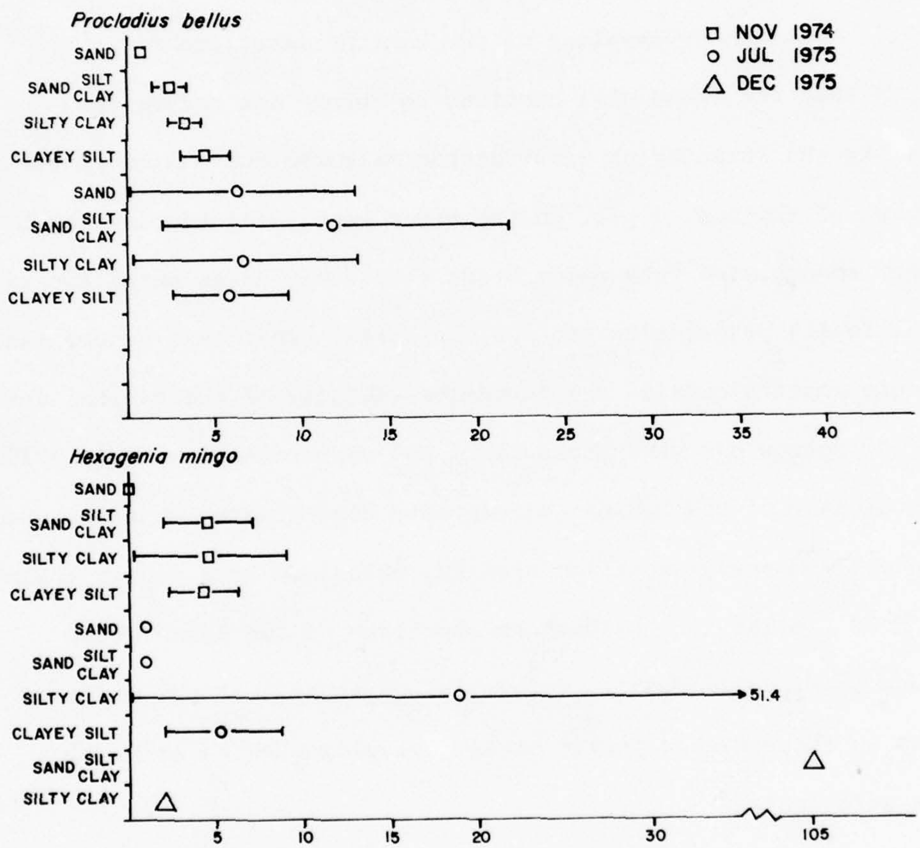

Figure 16 (sheet 3 of 3)

Effects of Habitat Development

90. Acute effects on the benthos were witnessed in the immediate area of the artificial marsh-island development and in the area dredged for dike material fill. Both the habitat and excavation interiors sustained substantial faunal changes that lasted at least until December 1975.

91. Preliminary sampling of the habitat interiors seems to indicate that the fauna will continue to change and become less similar to the surrounding river bottom as marsh succession proceeds. The fauna of the borrow pit, on the other hand, will continue to have a higher resemblance with muddy areas than sandy areas until the pit returns to its predredging profile and surface sediments become sandy. Any acute impacts outside the immediate vicinity of the habitat development or borrow pit were short lived and undetectable by July 1975. The outer face of the habitat development dike created what amounted to a new high energy shoreline that was colonized by a faunal assemblage most similar to the southern shoreline of the James River upstream of Windmill Point. *Corbicula manilensis* was the dominant species in these higher energy areas, but oligochaetes and insect larvae were sparse.

92. The benthic fauna of the freshwater tidal James River is extremely eurytopic with respect to sediment type and other environmental characteristics. Furthermore, life history characteristics of dominant species suggest that they can rapidly repopulate defaunated bottoms, greatly reducing time required to bring a disturbed area back

to its normal condition. The ubiquity and resilience of the fauna minimized the impact of the habitat development project. Yet, uncertainties in assessment remain due to delay and infrequency in sampling and poorly known seasonality of the fauna. Generally, there was no widespread adverse impact from the habitat development site on the benthic communities in the Windmill Point area. All changes that occurred among the species could have been due to seasonality, except for those few species that were affected by local changes in sediments.

PART V: CONCLUSIONS AND RECOMMENDATIONS

93. Conclusions of the study were as follows:

a. There was an acute impact within the habitat development site and in the area dredged for material to construct the dike. Any acute impacts beyond the immediate vicinity of the habitat development or borrow pit were undetectable 6 months after construction.

b. Substantial alterations to the sedimentary regime were caused by the habitat dike and borrow pit (the habitat dike perimeter is a coarse-grained high energy environment and the borrow pit is a sink for fine sediments).

c. Changes in the fauna attributable to the habitat development were associated with the changes in sediments from the dike construction. However, no widespread habitat changes attributable to habitat development were detected in the Windmill Point area.

d. Except for those few species that were affected by sediment changes, population changes over the period sampled could have been caused by seasonality.

e. The eurytopy, resilience, and opportunistic nature of the tidal freshwater fauna worked to mask and dampen biological impacts of the habitat development.

f. The benthic communities that were developing within the habitat site during the study were different from the surrounding river bottom and will continue to change as the habitat undergoes succession.

94. Recommendations of the study were as follows:

a. Any use of dredged material for artificial marsh habitat creation should be weighed against the adverse impacts of the project on the environment. The benefits of such developments may include disposal of unwanted dredged material and creation of habitats suitable for wildlife and beneficial to aquatic organisms. However, these must be considered in light of the environmental costs: loss of shallow-water benthic habitat and effects of activities associated with island creation but not with required maintenance dredging, e.g. borrow pits for suitable dike material.

b. Several assumptions usually made in such assessments deserve questioning. One concerns the relative value of wetlands, both as a wildlife habitat and as a resource for the aquatic ecosystem. For example, waterfowl populations may be limited by events outside the region in question, such that creation of new wetland habitat may not affect these populations. Also, some wetland types are more important to the aquatic ecosystem than others, and some may be less important than the shallow benthic habitats they would displace. The James River site is an area where the artificial marsh, because of the vegetation type and turbidity, is probably more beneficial to productivity of the aquatic system than the shallow bottom displaced, but one can think of other estuarine systems where the reverse would be more likely.

c. A major shortfall in understanding concerns the importance in terms of nutrient dynamics, productivity, and trophic importance to fisheries of benthic subsystems. It seems that most attention is now being focused on the effects on and recovery of benthic animal communities, but little effort is being devoted toward understanding the functional role of the benthos in aquatic ecosystems. This knowledge is needed to assist in gaging the importance of observed impacts and in weighing trade-offs of environmental modifications, e.g. marsh-island vs. shallow benthic habitat or small deep excavation vs. no excavation.

REFERENCES

Armstrong, N. E., P. H. Storrs, and E. A. Pearson. 1971. Development of a gross toxicity criterion in San Francisco Bay. Proc. 5th Int. Conc. Water Pollut. Res. III, pp. 1-15.

Boesch, D. F. 1972. Species diversity of marine macrobenthos in the Virginia area. Chesapeake Sci. 13:206-211.

Boesch, D. F. 1973. Classification and community structure of macrobenthos in the Hampton Roads area, Virginia. Marine Biol. 21: 226-244.

Boesch, D. F., R. J. Diaz, and R. W. Virnstein. 1976. Effects of Tropical Storm Agnes on soft bottom macrobenthic communities of the James and York River estuaries and the bay mouth. Chesapeake Sci. 17:246-259.

Brinkhurst, R. O. 1967. The distribution of aquatic oligochaetes in Saginow Bay, Lake Huron. Limnol. Oceanogr. 12:137-143.

Brinkhurst, R. O. 1970. Distribution and abundance of tubificid (Oligochaeta) species in Toronto Harbour, Lake Ontario. J. Fish. Res. Bd. Canada 27:1961-1969.

Brinkhurst, R. O. 1974a. Factors mediating interspecific aggregation of tubificid oligochaetes. J. Fish. Res. Bd. Canada 31:460-462.

Brinkhurst, R. O. 1974b. The benthos of lakes. St. Martin's Press, New York. 190 pp.

Brinkhurst, R. O. and K. E. Chua. 1969. Preliminary investigation of the exploitation of some potential nutritional resources by three sympatric tubificid oligochaetes. J. Fish. Res. Bd. Canada 26:2559-2668.

Brinkhurst, R. O. and D. G. Cook. 1974. Aquatic earthworms (Annelida: Oligochaeta), pp. 143-156. In: C. W. Hart, Jr. and S.L.H. Fuller (eds.). Pollution ecology of freshwater invertebrates. Academic Press, New York.

Brinkhurst, R. O. and B. G. M. Jamieson. 1971. The aquatic Oligochaeta of the world. Oliver and Boyd, Edinburgh. 860 pp.

Brinkhurst, R. O., K. E. Chua, and N. K. Kaushik. 1972. Interspecific interactions and selective feeding by tubificid oligochaetes. Limnol. Oceanogr. 17:122-133.

Cain, T. D. 1972. The reproductive cycle and larval tolerances of Rangia cuneata in the James River, Virginia. Unpublished Ph.D. Thesis, University of Virginia, Charlottesville. 121 p.

Chua, K. E. and R. O. Brinkhurst. 1972. Evidence of interspecific interactions in the respiration of tubificid oligochaetes. J. Fish. Res. Bd. Canada 30:617-622.

Clady, M. D. 1974. Food habits of yellow perch, smallmouth bass and largemouth bass in two unproductive lakes in Northern Michigan. American Mid. Nat. 91:453-459.

Clifford, H. T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press. New York. 229 pp.

Coe, W. R. 1959. Nemertea, pp. 366-367. In: W. T. Edmondson (ed.). Freshwater biology. Wiley, N. Y.

Diaz, R. J. 1972. Asiatic clam, Corbicula manilensis (Philippi), in the tidal James River, Virginia. Chesapeake Sci. 15:118-120.

Diaz, R. J. 1977. The effects of pollution on benthic communities of the tidal James River, Virginia. Dissertation of the University of Virginia, Charlottesville. 149 pp.

Folk, R. L. 1968. Petrology of sedimentary rocks. Hemphill's, Austin. 170 pp.

Fuller, S. L. H. 1974. Clams and mussels (Mollusca:Bivalvia), pp. 215-257. In: C. W. Hart and S. L. H. Fuller (eds.). Pollution ecology of freshwater invertebrates. Academic Press, New York.

Goodall, D. W. 1973. Sample similarity and species correlation, pp. 107-156. In: R. H. Whittaker (ed.). Ordination and classification of communities. Handb. Veg. Sci. 5, Junk, The Hague.

Goodman, D. 1975. The theory of diversity-stability relationships in ecology. Quart. Rev. Biol. 50:237-266.

Hayne, D. W. and R. C. Ball. 1956. Benthic productivity as influenced by fish predation. Limnol. Oceanogr. 1:162-175.

Heard, R. W. 1975. Feeding habits of white catfish from a Georgia estuary. Florida Sci. 38:20-28.

Hyman, L. H. 1938. North American Rhabdocoela and Alloeocoela. II. Rediscovery of Hydrolimax grisea Haldeman. American Mus. Novit. 1004:1-19.

Jacobs, J. 1975. Diversity, stability and maturity in ecosystems influenced by human activities, pp. 187-207. In: W. H. van Dobben and R. H. Lowe-McConnell (eds.). Unifying concepts in ecology. Junk. The Hague.

Johnson, M. G. and R. O. Brinkhurst. 1971. Associations and species diversity in benthic macroinvertebrates of Bay of Quinte and Lake Ontario. J. Fish. Res. Bd. Canada 28:1699-1714.

Johnson, M. G. and D. H. Matheson. 1968. Macroinvertebrate communities of Hamilton Bay and adjacent Lake Ontario. Limnol. Oceanogr. 13:99-111.

Kirk, W. L. 1974. Macroinvertebrates, pp. 141-419. In: Virginia Institute for Scientific Research, Richmond, Virginia, The Effects of Thermal Loading by the Bremo Power Station on a Piedmont Section of the James River, Vol. I. Final Report for Virginia Electric and Power Company.

Klovan, J. E. 1966. The use of factor analysis in determining depositional environments from grain size distributions. J. Sed. Petrology. 36:115-125.

Koss, R. W., L. D. Jensen, and R. D. Jones. 1974. Benthic invertebrates, pp. 121-142. In: L. D. Jensen (ed.). Environmental responses to thermal discharges from the Chesterfield Station, James River, Virginia. Cooling Water Studies for Electric Power Research Institute, Research Project RP-49.

Loden, M. S. 1974. Predation by chironomid (Diptera) larvae on oligochaetes. Limnol. Oceanogr. 19:156-159.

Macan, T. T. 1966. The influence of predation on the fauna of a moorland fishpond. Arch. Hydrobiol. 61;432-452.

Markle, D. F. and G. C. Grant. 1970. The summer food habits of young-of-the year striped bass in three Virginia rivers. Chesapeake Sci. 11:50-54.

Massengill, R. R. 1973. Change in feeding and body condition of brown bullheads overwintering in the heated effluent of a power plant. Chesapeake Sci. 14:138-141.

Needham, J. G., J. R. Traver, and Y. C. Hsu. 1935. The biology of mayflies. Comstock, New York. 759 pp.

Nichols, M. M. 1972. Sediments of the James River estuary, Virginia. Geol. Soc. Am. Mem. 133:169-211.

Pettijohn, F. J. 1957. Sedimentary rocks. Harpers, New York. 526 pp.

Pielou, E. C. 1975. Ecological diversity. Wiley-Interscience, New York. 196 pp.

Pfitzenmeyer, H. T. 1973. Hydrological and ecological effects of clargement of the Chesapeake and Delaware Canal. Appendix III. Benthos of Maryland waters in and near the Chesapeake and Delaware Canal. Natural Resources Institute, Maryland. NRI 73-113. 41 pp.

Roback, S. S. 1953. Savannah River tendipedid larvae [Diptera: Tendipedidae (=Chironomidae)]. Proc. Acad. Nat. Sci. Philadelphia. 105:91-132.

Roback, S. S. 1974. Insects (Arthropoda:Insecta), pp. 313-376. In: C. W. Hart, Jr. and S. L. H. Fuller (eds.). Pollution Ecology of Freshwater Invertebrates. Academic Press, New York.

Sawyer, R. T. 1974. Leeches (Annelida:Hirudinea), pp. 82-142. In: C. W. Hart, Jr. and S. L. H. Fuller (eds.). Pollution Ecology of Freshwater Invertebrates. Academic Press, New York.

Sickel, J. B. and W. D. Burbanck. 1974. Bottom substratum preference of Corbicula manilensis (Pelecypoda) in the Altamaha River, Georgia. The ASB Bulletin. 21:84.

Virginia Division of Water Resources. 1969. James River basin comprehensive water resources plan. Vol. I - Introduction. Planning Bull. 213, 218 pp.

Virginia Division of Water Resources. 1970. James River basin comprehensive water resources plan. Vol. III - Hydrologic analysis. Planning Bull. 215, 387 pp.

Virginia Institute of Marine Science. 1973a. James River comprehensive water quality management study, Vol. 4, Physical Data. 378 pp.

Virginia Institute of Marine Science. 1973b. James River comprehensive water quality management study, Vol. 2, Biological Data. 693 pp.

Wavre, M. and R. O. Brinkhurst. 1971. Interactions between some tubificid oligochaetes and bacteria found in the sediments of Toronto Harbour, Ontario. J. Fish. Res. Bd. Canada 28:335-341.

Wilhm, J. L. and T. C. Dorris. 1968. Biological parameters for water quality criteria. BioScience 18:447-481.

Williams, W. T. 1971. Principles of clustering. An. Rev. Ecol. Syst. 2:303-326.

Wirth, W. W. and A. Stone. 1956. Aquatic Diptera, pp. 372-482. In: R. L. Usinger (ed.). Aquatic insects of California. University of California Press, Berkeley.

Table 1

Water Depth and Volume of Sample

at each Station

Station	Depth, m November 1974	Depth, m July 1975	Depth, m December 1975	Volume, ℓ November	Volume, ℓ July	Volume, ℓ December
1	0.6	0.6	---	6.0	4.5	---
2	2.1	2.1	---	9.0	9.0	---
3	0.9	0.8	---	9.0	9.0	---
4	0.6	0.6	---	9.0	9.0	---
5	0.6	---	---	9.0	---	---
6	0.6	---	---	9.0	---	---
7	0.6	---	---	9.0	---	---
8	0.8	0.6	0.6	9.0	9.0	4.5
9	0.9	1.2	---	6.0	9.0	---
10	4.6	3.7	---	9.0	9.0	---
11	0.6	0.6	---	6.0	4.5	---
12	1.8	1.8	---	9.0	9.0	---
13	0.9	0.9	1.5	9.0	9.0	4.5
14	0.6	0.6	0.6	9.0	9.0	4.5
15	0.6	---	---	9.0	---	---
16	0.6	---	---	9.0	---	---
17	0.6	---	---	9.0	---	---
18	0.6	0.6	---	9.0	9.0	---
19	2.1	1.8	---	9.0	9.0	---
20	4.6	3.7	---	9.0	9.0	---
21	0.5	0.5	---	9.0	6.0	---

(continued)

Table 1 (continued)

Station	Depth, m			Volume, ℓ		
	November 1974	July 1975	December 1975	November	July	December
22	0.6	1.4	---	9.0	9.0	---
23	0.6	0.9	---	9.0	9.0	---
24	0.9	0.5	0.6	9.0	6.0	4.5
25	0.6	---	---	9.0	---	---
26	0.6	---	---	9.0	---	---
27	0.6	---	---	9.0	---	---
28	0.6	0.6	0.6	9.0	9.0	9.0
29	1.5	1.5	---	9.0	9.0	---
30	4.6	3.7	---	9.0	9.0	---
31	0.5	0.5	---	6.0	4.5	---
32	1.5	1.5	---	9.0	9.0	---
33	0.8	0.8	---	9.0	9.0	---
34	0.5	0.5	---	6.0	6.0	---
35	0.6	---	---	9.0	---	---
36	0.6	---	---	9.0	---	---
37	0.6	---	---	9.0	---	---
38	0.6	0.6	0.6	9.0	9.0	4.5
39	1.5	1.8	---	9.0	9.0	---
40	4.0	3.7	---	9.0	9.0	---
41	0.5	0.6	0.9	9.0	9.0	6.0
42	1.2	1.2	1.5	9.0	9.0	9.0
43	1.2	1.2	---	9.0	9.0	---
A	1.2	0.9	0.9	9.0	9.0	4.5
B	1.2	6.1	4.6	9.0	9.0	9.0
C	2.0	4.6	4.8	9.0	9.0	9.0
D	2.4	1.8	1.9	9.0	9.0	4.5

(continued)

Table 1 (concluded)

Station	Depth, m			Volume, ℓ		
	November 1974	July 1975	December 1975	November	July	December
E	1.2	1.2	---	9.0	6.0	---
F	1.2	4.6	---	9.0	9.0	---
G	1.2	4.6	---	9.0	9.0	---
H	1.2	1.2	---	6.0	4.5	---

AD-A055 319 VIRGINIA INST OF MARINE SCIENCE GLOUCESTER POINT DIV --ETC F/G 6/6
HABITAT DEVELOPMENT FIELD INVESTIGATIONS, WINDMILL POINT MARSH --ETC(U)
NOV 77 R J DIAZ, D F BOESCH DACW65-75-C-0053

UNCLASSIFIED WES-TR-D-77-23-APP-C NL

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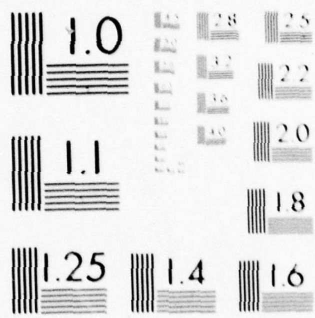

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table 2

Sediment Statistics for Samples Taken at Each Station

Station	Date	Percent Sand	Percent Silt	Percent Clay	Md*	M_Z**	σ_I+	SK_I#	K_G#	Classification
1	11/74	96.7	1.2	2.1	1.6	1.36	0.33	-1.86	0.15	sand
	7/75	90.3	1.7	8.0	0.8	1.03	1.61	0.61	4.31	sand
2	11/74	1.3	50.9	47.8	6.5	6.33	2.37	-0.16	1.25	clay silt
	7/75	12.2	44.4	43.4	7.5	7.12	2.34	-0.21	0.96	clay silt
3	11/74	1.6	55.2	43.2	7.7	7.63	1.53	-0.07	1.06	clay silt
	7/75	37.0	43.2	19.8	---	----	----	----	----	clay silt
4	11/74	14.5	46.2	39.3	---	----	----	----	----	clay silt
	7/75	53.9	46.1	0.0	---	----	----	----	----	silty sand
5	11/74	35.7	26.7	37.6	6.1	5.56	3.3	-0.15	0.60	sand-silt-clay
6	11/74	51.7	22.8	25.5	4.1	4.93	4.03	0.14	0.22	sand-silt-clay
7	11/74	64.1	7.8	28.1						clayey sand
8	11/74	56.6	25.9	17.5	2.7	3.86	3.19	0.51	0.63	silty sand
	7/75	14.8	64.9	20.3	6.2	6.21	2.02	0.03	0.98	clay silt
	12/75	98.7	0.5	0.8	1.2	0.93	0.85	-0.10	2.01	sand
9	11/74	11.7	44.6	43.7	7.5	7.20	2.59	-0.19	1.23	clay silt
	7/75	26.7	19.5	53.8	8.2	7.21	2.63	-0.33	0.61	sandy clay
10	11/74	0.7	47.8	51.7	8.1	8.01	1.55	-0.03	1.05	silty clay
	7/75	10.2	32.0	57.8	---	----	----	----	----	silty clay
11	11/74	97.9	0.4	1.7	1.0	1.13	0.72	0.41	1.63	sand
	7/75	79.1	3.3	17.6	---	----	----	----	----	sand
12	11/74	9.3	47.6	43.1	7.4	7.23	2.34	-0.20	1.12	clay silt
	7/75	8.4	50.0	41.6	---	----	----	----	----	clay silt

(continued)

* Median particle size (phi units).
**Mean particle size (phi units).
\+ Standard deviation (phi units).
++Skewness.
\# Kurtosis.

Table 2 (continued)

Station	Date	Percent Sand	Percent Silt	Percent Clay	Md*	M_Z**	σ_I+	SK_I#	K_G#	Classification
13	11/74	4.5	50.9	44.6						clay silt
	7/75	17.0	53.8	29.2	6.6	6.53	1.38	0.01	0.93	clay silt
	12/75	18.0	45.3	36.7	7.0	6.70	2.51	-0.11	0.84	clay silt
14	11/74	28.3	35.2	36.5	6.6	6.30	2.82	-0.14	0.71	sand-silt-clay
	7/75	96.5	2.2	1.3	8.2	7.22	1.04	-0.44	0.61	sand
	12/75	82.1	10.8	7.1	0.4	1.63	2.43	0.86	1.43	sand
15	11/74	28.1	36.6	35.3	6.3	6.03	2.88	-0.12	0.75	sand-silt-clay
16	11/74	59.4	20.7	19.9	2.8	4.01	3.19	0.47	0.67	sand-silt-clay
17	11/74	86.9	4.9	8.2	1.5	1.90	1.75	0.41	1.23	sand-silt-clay
18	11/74	58.5	18.8	22.7	2.2	3.81	5.18	0.61	0.65	clayey sand
	7/75	5.5	70.8	23.7	6.8	6.72	2.09	-0.13	1.31	clay silt
19	11/74	32.8	36.9	30.3	6.0	5.65	3.06	-0.11	0.68	sand-silt-clay
	7/75	9.3	42.4	48.3	8.0	7.53	2.61	-0.28	9.60	silty clay
20	11/74	14.5	45.6	39.9	7.2	6.86	2.50	-0.19	0.89	clay silt
	7/75	5.0	62.0	33.0	---	----	----	----	----	clayey silt
21	11/74	86.8	2.3	10.9	2.2	2.36	2.08	0.29	2.07	sand
	7/75	80.8	12.6	6.6	1.6	2.31	2.22	0.57	1.80	sand
22	11/74	1.4	49.3	49.3	7.7	7.61	1.63	-0.02	1.02	silty clay
	7/75	1.1	55.5	43.4	7.7	7.71	1.61	0.01	1.03	clay silt
23	11/74	0.2	12.1	87.7	---	----	----	----	----	clay
	7/75	5.6	44.0	50.5	8.1	7.81	2.06	-0.19	1.02	silty clay
24	11/74	11.1	43.6	45.3	7.8	7.63	2.86	-0.10	1.04	silty clay
	7/75	50.7	44.5	4.8	4.0	4.31	1.84	0.28	1.01	silty sand
	12/75	94.3	3.2	2.5	1.3	0.13	1.12	1.53	2.60	sand
25	11/74	44.0	34.1	21.9	4.6	5.32	2.45	0.38	0.78	sand-silt-clay

(continued)

Table 2 (continued)

Station	Date	Percent Sand	Percent Silt	Percent Clay	Md*	M_Z**	σ_I+	SK_I#	K_G#	Classification
26	11/74	28.9	33.2	37.9	6.6	6.51	2.75	0.02	0.69	sand-silt-clay
27	11/74	21.4	34.8	43.8	7.3	6.62	2.83	-0.31	0.82	sand-silt-clay
28	11/74	3.4	46.6	50.0	8.0	5.41	1.88	2.77	1.01	silty clay
	7/75	97.4	2.1	0.5	---	0.56	0.99	1.01	1.41	sand
	12/75	98.1	1.0	0.9	-0.7	0.33	1.11	1.53	2.64	sand
29	11/74	3.1	48.0	48.9	8.0	7.76	1.92	-0.16	0.99	silty clay
	7/75	6.1	42.0	51.8	8.1	7.81	2.08	-0.24	0.83	silty clay
30	11/74	13.5	33.4	53.1	8.1	7.43	2.58	-0.38	1.02	silty clay
	7/75	15.8	36.3	47.9	7.1	6.91	2.43	-0.08	0.86	silty clay
31	11/74	93.4	1.8	4.8	1.7	1.92	1.43	4.50	2.21	sand
	7/75	96.4	2.1	1.5	1.6	1.88	1.09	0.23	1.43	sand
32	11/74	2.9	48.2	48.3	7.9	7.94	2.03	0.01	0.97	clayey silt
	7/75	7.1	49.8	43.1	7.7	7.51	2.13	-0.13	0.95	clay silt
33	11/74	3.9	47.0	49.1	8.1	8.02	2.11	-0.03	1.01	silty clay
	7/75	3.2	27.6	69.2	---	----	----	----	----	silty clay
34	11/74	2.4	47.8	49.8	8.0	7.81	1.83	-0.11	0.96	silty clay
	7/75	54.6	6.4	39.0	---	----	----	----	----	clay silt
35	11/74	0.2	55.2	44.6	7.7	7.78	2.01	0.01	1.03	clayey silt
36	11/74	19.7	43.1	37.2	6.9	6.67	2.32	-0.09	0.72	clayey silt
37	11/74	8.7	46.6	44.7	7.7	7.31	2.12	-0.01	0.92	clayey silt
38	11/74	4.2	46.9	48.9	8.0	7.7	1.93	-1.09	1.06	silty clay
	7/75	99.3	0.5	0.2	0.2	-0.21	1.16	0.23	0.54	sand
	12/75	87.8	5.9	6.3	---	0.23	2.71	1.01	3.41	sand
39	11/74	4.8	50.3	44.9	---	----	----	----	----	clay silt
	7/75	14.5	45.5	40.0	7.4	7.43	1.63	0.02	1.03	clay silt

(continued)

Table 2 (continued)

Station	Date	Percent Sand	Percent Silt	Percent Clay	Md*	M_Z**	σ_I+	SK_I#	K_G#	Classification
40	11/74	11.5	48.0	40.5	6.4	6.41	2.01	-0.01	1.03	clay silt
	7/75	13.8	50.0	36.2	7.2	6.95	2.32	-0.18	0.91	clayey silt
41	11/74	14.5	36.3	49.2	8.0	7.31	2.65	-0.39	1.08	silty clay
	7/75	42.1	34.2	23.6	4.6	4.43	3.12	-0.02	0.61	sand-silt-clay
	12/75	78.7	14.7	6.6	1.7	2.52	2.33	0.58	1.10	sand-silt-clay
42	11/74	29.1	29.8	41.1	7.0	6.51	2.71	-0.17	0.65	sand-silt-clay
	7/75	9.0	43.7	47.3	7.8	7.31	1.93	-0.28	0.91	silty clay
	12/75	6.7	48.8	44.5	7.8	7.62	2.03	-0.15	0.98	clay silt
43	11/74	8.9	51.5	39.6	---	----	----	----	----	clay silt
	7/75	5.2	51.0	43.8	7.6	7.43	1.91	0.17	1.04	clay silt
A	11/74	17.7	41.4	40.9	7.2	6.81	2.63	-0.25	0.96	clay silt
	7/75	6.2	44.8	49.0	8.0	7.41	1.92	0.17	1.04	silty clay
	12/75	27.4	44.0	28.6	6.1	5.92	2.80	-0.06	0.83	sand-silt-clay
B	11/74	94.7	3.8	1.5	1.2	1.03	1.00	0.05	1.02	sand
	7/75	11.8	44.4	43.8	7.6	7.21	2.13	-0.19	0.89	clay silt
	12/75	10.8	48.2	41.0	7.5	7.20	2.31	-0.16	0.90	clay silt
C	11/74	88.2	1.8	10.0	1.7	1.92	1.50	0.30	1.41	sand
	7/75	15.3	49.0	35.7	7.0	6.82	2.31	-0.12	0.87	clay silt
	12/75	12.2	49.7	38.1	7.1	6.94	2.43	-0.17	1.02	clay silt
D	11/74	95.8	2.1	2.1	---	----	----	----	----	sand
	7/75	29.0	47.1	23.9	5.4	5.51	3.02	0.50	0.74	sand-silt-clay
	12/75	89.9	5.1	5.0	0.3	1.02	1.97	0.85	1.83	sand
E	11/74	62.0	18.4	19.7	2.3	3.92	3.31	0.60	0.79	clay sand
	7/75	21.3	10.5	68.2	8.7	7.4	2.91	-0.43	0.79	sandy clay
F	11/74	92.3	2.2	5.5	1.4	1.73	1.86	0.54	2.01	sand
	7/75	8.6	46.1	45.3	7.8	7.33	2.31	-0.14	1.01	clay silt

(continued)

Table 2 (concluded)

Station	Date	Percent Sand	Percent Silt	Percent Clay	Md*	M_Z**	σ_I+	SK_I#	K_G#	Classification
G	11/74	95.6	3.2	1.2	3.0	3.0	0.55	-1.5	0.97	sand
	7/75	9.0	42.2	48.8	7.9	7.52	2.13	-0.23	0.94	silty clay
H	11/74	96.5	0.8	2.7	1.5	1.46	0.73	0.00	2.30	sand
	7/75	92.4	0.6	7.0	1.7	2.60	2.11	0.71	1.54	sand

Table 3

Grain-size Analysis Data Expressed as Particle Size (phi units) at Which a Given Percentage of the Sediment is Coarser

Station	Cumulative Percent						
	5	16	25	50	75	84	95
				November 1974			
1	-1.5	0.0	0.4	1.6	2.5	2.8	3.6
2	0.6	4.2	4.9	6.5	7.8	8.3	9.5
3	4.9	6.1	6.6	7.7	8.6	9.1	10.1
5	0.8	1.4	2.1	6.1	8.5	9.2	10.3
6	0.5	0.9	1.2	4.1	8.3	9.8	12.5
8	0.8	0.7	1.1	2.7	6.7	8.2	9.5
9	1.0	4.7	5.6	7.5	8.8	9.4	10.4
10	5.3	6.5	7.0	8.1	9.1	9.6	10.7
11	0.3	0.6	0.7	1.0	1.4	1.8	3.1
12	2.2	4.9	5.7	7.4	8.7	9.3	10.4
14	1.7	3.1	3.7	6.6	8.6	9.2	10.3
15	1.4	2.8	3.5	6.3	8.3	9.0	10.2
16	0.4	0.9	1.1	2.8	6.7	8.3	9.6
17	-0.2	0.5	0.8	1.5	2.8	3.7	66.1
18	0.2	0.8	1.0	2.2	7.1	8.5	9.9
19	1.1	1.9	3.0	6.0	8.4	9.0	10.1
20	2.3	4.1	5.0	7.2	8.7	9.3	10.4
21	-0.6	1.1	1.4	2.2	3.3	3.8	9.0
22	4.9	6.0	6.5	7.7	8.7	9.2	10.4
24	2.4	4.7	5.6	7.8	9.4	10.3	12.1
25	2.3	3.0	3.4	4.6	7.2	8.4	9.6
26	2.7	3.5	3.8	6.6	8.7	9.5	11.0
27	1.5	3.1	4.4	7.3	8.8	9.4	10.4
28	4.4	5.8	6.5	8.0	9.0	9.6	10.6
29	4.3	5.7	6.4	8.0	9.0	9.6	10.6
30	2.2	4.5	5.7	8.1	9.1	9.7	10.7
31	0.6	1.1	1.3	1.7	2.5	3.1	7.1
32	4.5	5.8	6.5	7.9	9.4	10.1	11.4
33	4.1	5.7	6.4	8.1	9.4	10.2	11.8
34	4.6	5.9	6.5	8.0	9.1	9.6	10.7
35	4.3	5.7	6.3	7.7	9.0	9.8	11.2

(continued)

Table 3 (continued)

Station	Cumulative Percent 5	16	25	50	75	84	95
			November 1974 (continued)				
36	3.2	3.8	4.6	6.9	8.6	9.2	10.3
37	3.5	5.0	5.8	7.7	8.9	9.4	10.5
38	4.2	5.7	6.4	8.0	9.0	9.5	10.6
40	2.7	4.4	5.0	6.4	7.8	8.5	9.8
41	1.7	4.3	5.4	8.0	9.0	9.6	10.6
42	2.4	3.3	3.8	7.0	8.8	9.4	10.4
A	1.9	3.8	4.8	7.2	8.8	9.4	10.4
B	---	---	---	1.2	1.6	1.8	4.2
C	-0.1	0.7	1.1	1.7	2.7	3.4	5.6
E	---	1.0	1.3	2.3	6.6	8.4	10.3
F	0.2	0.6	0.8	1.4	2.4	3.2	8.2
G	2.1	2.5	2.6	3.0	3.4	3.6	4.0
H	---	1.0	1.2	1.5	1.8	1.9	3.4
			July 1975				
1	0.1	0.4	0.5	0.8	1.3	1.9	8.6
2	2.7	4.5	5.5	7.5	8.8	9.4	10.5
8	3.0	4.2	4.8	6.2	7.6	8.3	9.7
9	3.0	3.7	4.0	8.2	9.3	9.8	10.9
13	3.0	4.1	4.9	6.6	8.2	9.0	10.5
14	3.0	3.7	4.0	8.2	9.3	9.8	10.9
18	1.7	5.0	5.5	6.8	7.9	8.5	9.8
19	3.4	5.0	5.9	8.0	9.0	9.6	10.7
21	---	0.7	1.1	1.6	3.0	4.7	8.4
22	5.0	6.1	6.7	7.7	8.9	9.4	10.5
23	3.9	5.6	6.4	8.1	9.2	9.8	10.9
24	1.8	2.7	3.1	4.0	5.6	6.4	8.0
28	---	---	---	---	1.2	1.7	3.8
29	3.7	5.5	6.2	8.1	9.4	10.0	11.2
30	3.0	4.2	5.1	7.1	8.7	9.4	10.6
31	---	1.0	1.2	1.6	2.3	2.8	3.8
32	3.6	5.3	6.0	7.7	9.0	9.6	10.6
38	---	-2.0	-1.0	0.2	0.8	1.2	2.4
39	4.8	5.8	6.3	7.4	8.5	9.1	10.2
40	2.7	4.3	5.2	7.2	8.6	9.2	10.3

(continued)

Table 3 (concluded)

Station	Cumulative Percent 5	16	25	50	75	84	95
	July 1975 (continued)						
41	0.3	0.6	0.9	4.6	6.8	8.0	9.1
42	3.7	5.0	5.9	4.8	8.8	9.3	10.2
43	3.7	5.4	6.1	7.6	8.7	9.2	10.2
A	3.7	5.4	6.2	8.0	9.0	9.6	10.6
B	3.3	4.7	5.6	7.6	8.9	9.4	10.5
C	2.8	4.2	5.0	7.0	8.5	9.2	10.3
D	1.2	2.3	2.9	5.4	8.0	8.8	10.5
E	2.0	3.5	5.0	8.7	9.7	10.2	11.1
F	3.3	4.7	6.0	7.8	9.0	9.6	10.7
G	3.7	5.0	6.0	7.9	9.0	9.6	10.6
H	0.7	1.1	1.3	1.7	3.3	5.1	8.3
	December 1975						
8	---	---	---	1.2	0.6	1.6	3.0
13	2.6	3.9	4.7	7.0	8.6	9.4	10.6
14	---	---	---	0.4	2.5	4.6	8.6
24	---	---	---	-0.8	0.5	1.2	5.0
28	---	---	---	-0.7	0.7	1.7	4.5
38	---	---	---	1.0	2.5	8.4	
41	0.2	0.7	0.9	1.7	3.7	5.1	8.3
42	3.7	5.4	6.1	7.8	9.0	9.6	10.7
A	1.4	2.9	4.0	6.1	8.3	8.9	10.2
B	3.2	4.7	5.5	7.5	8.8	9.5	10.5
C	1.9	4.4	5.2	7.1	8.5	9.2	10.4
D	---	---	---	0.3	1.8	2.9	8.0

Table 4

Percentage of the Total Individuals, Number of Species, and Individuals in the Three Most Abundant Taxa

		November 1974	July 1975	December 1975
Tubificidae	Total percent	73.3	45.2	36.2
	Individual	15296	5405	817
	Species	9	7	6
Corbiculidae	Total percent	20.4	38.0	32.0
	Individual	4253	4533	724
	Species	1	1	1
Chironomidae	Total percent	3.9	14.5	26.0
	Individual	807	1685	595
	Species	10	12	8
Others	Total percent	2.4	2.3	5.8
	Individual	501	347	122
	Species	10	13	6

Table 5

Overall Abundance and Proportional Importance of Species, November 1974

Species	Number of individuals (5.0 m^2)	Percent of total
Limnodrilus spp. immature	13,353	65.02
Corbicula manilensis (small)	4,202	20.46
Ilyodrilus templetoni	1,227	5.97
Coelotanypus scapularis	509	2.48
Limnodrilus hoffmeisteri	445	2.16
Procladius bellus	101	0.49
Hexagenia mingo	100	0.49
Limnodrilus profundicola	76	0.37
Cryptochironomus spp.	73	0.36
Peloscolex multisetosus	70	0.34
Limnodrilus cervix	59	0.29
Ablabesmyia sp. E	55	0.27
Corbicula manilensis (large)	51	0.25
Aulodrilus pigueti	48	0.23
Sphaerium transversum	26	0.12
Enchytraeidae	20	0.10
Stictochironomus devinctus	18	0.09
Stictochironomus sp.	17	0.08
Chironomus spp.	16	0.08
Hydrolimax grisea	14	0.06
Branchiura sowerbyi	12	0.06
Gammarus fasciatus	11	0.05
Dicrotendipes nervosus	8	0.04
Polypedilum spp.	7	0.03
Naididae	4	0.02
Tubificids with capillary setae	4	0.02
Helobdella elongata	4	0.02
Pisidium sp.	2	0.01
Cladotanytarsus sp.	2	0.01
Potamothrix vejdovskyi	2	0.01
Chaoborus punctipennis	1	0.00
Urnatella gracilis	1*	0.00
	20,538	100.00

* Occurrences.

Table 6

Overall Abundance and Proportional Importance of Species, July 1975

Species	Number of individuals (3.8 m^2)	Percent of total
Corbicula manilensis (small)	4,521	37.77
Limnodrilus spp.	4,171	34.84
Coelotanypus scapularis	1,013	8.46
Limnodrilus hoffmeisteri	509	4.25
Ilyodrilus templetoni	497	4.15
Procladius bellus	210	1.75
Hexagenia mingo	185	1.54
Tubificids with capillary setae	127	1.06
Polypedilum spp.	119	1.00
Chironomus spp.	116	0.97
Cryptochironomus spp.	74	0.62
Tanypus neopunctipennis	60	0.50
Peloscolex multisetosus	45	0.34
Chaoborus punctipennis	40	0.33
Sphaerium transversum	36	0.30
Hydrolimax grisea	34	0.28
Dicrotendipes nervosus	32	0.27
Ablabesmyia sp. E	30	0.25
Branchiura sowerbyi	27	0.23
Limnodrilus cervix	24	0.20
Pseudochironomus sp.	17	0.14
Dero digitata	16	0.13
Helobdella elongata	16	0.13
Corbicula manilensis (large)	12	0.10
Paracladopelma sp.	10	0.08
Urnatella gracilis	8*	0.07
Limnodrilus profundicola	5	0.04
Gammarus fasciatus	3	0.03
Goniobasis virginica	2	0.02
Stenonema annexum	2	0.02
Ocetis sp.	2	0.02
Xenochironomus sp.	2	0.02
Stictochironomus sp.	2	0.02

(continued)

Table 6 (concluded)

Species	Number of individuals (3.8 m^2)	Percent of total
Anguilla rostrata	2	0.02
Unionid	1	0.01
	11,970	100.00

* Occurrences.

Table 7

Overall Abundance and Proportional Importance of Species, December 1975

Species	Number of individuals (1.2 m^2)	Percent of total
Corbicula manilensis (small)	722	31.98
Limnodrilus spp.	702	31.09
Coelotanypus scapularis	419	18.55
Hexagenia mingo	107	4.74
Procladius bellus	59	2.61
Ablabesmyia sp. E	53	2.35
Ilyodrilus templetoni	52	2.30
Limnodrilus hoffmeisteri	31	1.37
Limnodrilus cervix	25	1.10
Chironomus spp.	23	1.01
Cryptochironomus spp.	21	0.93
Sphaerium transversum	13	0.57
Polypedilum spp.	8	0.35
Chaoborus punctipennis	5	0.22
Prostoma rubrum	4	0.17
Tubificids with capillary setae	3	0.13
Branchiura sowerbyi	3	0.13
Stictochironomus sp.	2	0.08
Corbicula manilensis (large)	2	0.08
Glyptotendipes sp.	2	0.08
Limnodrilus profundicola	1	0.08
Gammarus fasciatus	1	0.04
	2,258	100.00

Table 8

Abundance and Proportional Importance of

Species Collected at Only the 12 Stations

Sampled Three Times, November 1974

Species	Number of individuals (1.2 m^2)	Percent of total
Limnodrilus spp.	3,335	76.74
Corbicula manilensis (small)	371	8.54
Ilyodrilus templetoni	250	5.75
Coelotanypus scapularis	111	2.55
Limnodrilus hoffmeisteri	100	2.30
Hexagenia mingo	31	0.71
Limnodrilus profundicola	28	0.64
Cryptochironomus spp.	22	0.50
Procladius bellus	20	0.46
Ablabsmyia sp. E	15	0.34
Sphaerium transversum	14	0.32
Corbicula manilensis (large)	11	0.25
Chironomus spp.	6	0.13
Peloscolex multisetosus	6	0.13
Gammarus fasciatus	6	0.13
Limnodrilus cervix	4	0.09
Branchiura sowerbyi	3	0.06
Stictochironomus sp.	3	0.06
Hydrolimax grisea	2	0.04
Polypedilum spp.	2	0.04
Dicrotendipes nervosus	2	0.04
Stictochironomus devinctus	1	0.02
Aulodrilus pigueti	1	0.02
Helobdella elongata	1	0.02
Dero digitata	1	0.02
	4,346	100.00

Table 9

Abundance and Proportional Importance of Species Collected at Only the Three Stations Sampled Three Times, July 1975

Species	Number of individuals ($1.2\ m^2$)	Percent of total
Limnodrilus spp.	1,120	38.11
Corbicula manilensis (small)	681	23.17
Coelotanypus scapularis	410	13.95
Ilyodrilus templetoni	144	4.89
Limnodrilus hoffmeisteri	132	4.49
Polypedilum spp.	105	3.57
Hexagenia mingo	65	2.21
Procladius bellus	62	2.11
Chironomus spp.	35	1.19
Peloscolex multisetosus	26	0.88
Dicrotendipes nervosus	24	0.81
Ablabesmyia sp. E	23	0.78
Cryptochironomus spp.	20	0.68
Hydrolimax grisea	17	0.57
Chaoborus punctipennis	17	0.57
Sphaerium transversum	15	0.51
Branchiura sowerbyi	8	0.27
Limnodrilus cervix	6	0.20
Pseudochironomus sp.	5	0.17
Tubificids with capillary setae	5	0.17
Chironomidae	5	0.17
Chironomus attenuatus	3	0.10
Corbicula manilensis (large)	2	0.06
Gammarus fasciatus	2	0.06
Oecetis sp.	2	0.06
Helobdella elongata	1	0.03
Paracladopelma sp.	1	0.03
Tanypus neopunctipennis	1	0.03
Tanypodinae	1	0.03
Anguilla rostrata	1	0.03
	2,939	100.00

Table 10

Biomass Statistics Combined for all Collection Dates*

	Nov 1974		July 1975		Dec 1975	
	Weight, g ($5.0\ m^2$)	Percentage	Weight, g ($3.8\ m^2$)	Percentage	Weight, g ($1.2\ m^2$)	Percentage
Corbicula manilensis (large)	103.03	70.00	31.70	62.21	0.75	7.65
Corbicula manilensis (small)	4.51	3.07	2.45	4.81	2.24	22.74
Oligochaetes	29.37	19.96	11.70	22.95	2.09	21.16
Chironomids	3.27	2.22	2.31	4.53	1.48	15.04
Hexagenia	6.57	4.46	1.26	2.47	2.45	24.84
Other	0.44	0.30	1.44	2.83	0.84	8.58
Total	147.19	100.00	50.86	100.00	9.85	100.00

*All weights are total wet weight of the taxa per collection period.

Table 11

Biomass* at Stations Sampled in December 1975

Station	Corbicula Large (>10 mm)	Corbicula Small (<10 mm)	Oligochaetes	Chironomids**	*Hexagenia*	Other	Total
8		0.084	0.008	0.002			0.094
13		0.028	0.442	0.053			0.523
14		0.335	0.053	0.002			0.390
24	0.754	0.030	0.085	0.051			0.920
28		0.357	0.049	0.005			0.411
38		0.165	0.059				0.224
41		0.666	0.492	0.021			1.179
42		0.028	0.094	0.179			0.301
A		0.141	0.020	0.315	2.439		2.915
B		0.192	0.047	0.347	0.010		0.596
C		0.020	0.041	0.370			0.431
D		0.196	0.144	0.007			0.347
IIL			0.060	0.025		0.345	0.430
IIU			0.492	0.106		0.500	1.098

* Grams wet weight per 0.10 m^2.

**Estimated weight based on average weight of 336 chironomid larvae at 0.0023 g/individual.

Table 12

Biomass* at Stations Sampled in November 1974

Station	Corbicula Large (>10 mm)	Corbicula Small (<10 mm)	Oligochaetes	Chironomids**	Hexagenia	Other	Total
1		0.414	0.048	0.062			0.524
2		0.027	0.928	0.234			1.189
3	3.819	0.136	0.919	0.074	0.102	0.012	5.062
4		0.073	0.586	0.049	0.586		1.294
5	3.212	0.016	0.386		0.130		3.744
6	1.955	0.138	0.471	0.012			2.576
7	1.255	0.122	0.166	0.037	0.192		1.772
8	7.701	0.125	0.486	0.012			8.324
9	0.096	0.088	0.699	0.062			0.945
10		0.013	1.608	0.144		0.020	1.785
11	0.263	0.179	0.005	0.008			0.455
12	5.193	0.086	0.318	0.037	0.082		5.716
13	5.649	0.021	0.525	0.074		0.010	6.279
14	3.866	0.063	0.432	0.053	0.403		4.817
15	0.204	0.061	0.980	0.033	0.257	0.013	1.548
16	4.130	0.069	0.315	0.004		0.013	4.531
17	2.043	0.093	0.618	0.012			2.766
18	1.883	0.153	0.414	0.012	0.111	0.007	2.580

(continued)

* Grams wet weight per 0.10 m^2.
**Estimated weight based on average weight of 233 chironomid larvae at 0.0041 g/individual.

Table 12 (continued)

Station	Corbicula Large (>10 mm)	Corbicula Small (<10 mm)	Oligochaetes	Chironomids**	Hexagenia	Other	Total
19	5.129	0.120	0.498	0.033	0.036		5.816
20		0.048	1.376	0.062		0.024	1.510
21	0.831	0.386	0.042	0.062			1.321
22	5.776	0.048	0.525	0.201			6.550
23	0.102	0.077	0.728	0.049	0.112		1.068
24	4.681	0.068	0.162	0.025			4.936
25	4.616	0.025	0.800	0.074	0.778		6.293
26		0.064	0.502	0.066	0.185		0.817
27		0.086	0.435	0.057	0.917		1.495
28	0.376	0.032	0.436	0.098	0.898		1.840
29	6.682	0.085	0.891	0.066	0.009		7.733
30	0.857	0.060	2.071	0.131			3.119
31	0.154	0.205	0.056	0.057			0.472
32	2.404	0.068	0.540	0.135			3.147
33		0.032	0.256	0.020			0.308
34	5.318	0.076	0.491	0.078			5.963
35	2.944	0.027	0.647	0.111			3.729
36	10.295	0.046	0.902	0.094	0.100		11.437
37	2.164	0.039	0.414	0.066			2.683
38		0.058	0.829	0.115	0.208		1.210
39	7.196	0.078	0.829	0.176	0.627		8.906
40		0.056	1.498	0.148			1.702
41	1.438	0.036	1.399	0.230	0.050	0.006	3.159
42		0.057	1.579	0.018			1.654

(continued)

Table 12 (concluded)

Station	Corbicula Large (>10 mm)	Corbicula Small (<10 mm)	Oligochaetes	Chironomids**	*Hexagenia*	Other	Total
43		0.033	0.628	0.102			0.763
A	0.082	0.030	0.294	0.029	0.208	0.272	0.915
B	0.126	0.136	0.010	0.016			0.288
C	0.262	0.108	0.106	0.004		0.032	0.512
D	0.202	0.105	0.005	0.004			0.316
E		0.165	0.435	0.004	0.581	0.029	1.214
F	0.128	0.052	0.032	0.004			0.216
G		0.041	0.033	0.012			0.086
H		0.090	0.020				0.110

Table 13

Biomass* at Stations Sampled in July 1975

Station	Corbicula Large (>10 mm)	Corbicula Small (<10 mm)	Oligochaetes	Chironomids**	Hexagenia	Other	Total
1	0.324	0.566	0.141	0.017			1.048
2		0.056	0.373	0.010			0.439
3	-----	-----	-----	-----	-----	-----	-----
4		0.066	0.223	0.105	0.063		0.457
8	1.027	0.043	0.133	0.083	0.183		1.469
9	0.429		0.212	0.010			0.651
10		0.010	0.874	0.010			0.894
11	4.170	0.233	0.050	0.034			4.487
12		0.017	0.130	0.021	0.009		0.177
13		0.079	0.193	0.034			0.306
14		0.026	0.109	0.129			0.264
18	0.329		0.033	0.043			0.405
19			0.133	0.013			0.146
20		0.002	1.188	0.049			1.239
21	3.108	0.066	0.175	0.038			3.387
22	0.161	0.020	0.183	0.021			0.385
23	0.104	0.213	0.101	0.011			0.429

(continued)

* Grams wet weight per 0.10 m^2.
**Estimated weight based on average weight of 1096 chironomid larvae at 0.0014 g/individual.

Table 13 (concluded)

	Corbicula						
Station	Large (>10 mm)	Small (<10 mm)	Oligochaetes	Chironomids**	*Hexagenia*	Other	Total
24	1.087	0.046	0.037	0.011			1.181
28	0.336	0.199	0.068	0.052		0.010	0.665
29	0.571	0.034	0.366	0.081	0.013	0.026	1.091
30		0.106	0.823	0.032			0.961
31	0.073	0.010	0.068	0.106			0.257
32		0.021	0.164	0.028			0.213
33	11.734	0.019	0.409	0.045			12.207
34	0.400	0.013	0.255	0.029			0.697
38		0.132	0.008	0.102			0.242
39	2.649	0.089	0.330	0.029	0.059		3.156
40	0.126	0.016	0.760	0.031			0.933
41	0.114	0.023	0.368	0.088			0.593
42		0.023	0.484	0.022			0.529
43	1.959	0.023	0.157	0.024			2.163
A	0.050	0.048	0.301	0.154	0.474		1.027
B	0.223	0.043	0.315	0.126	0.010	0.496	1.213
C	2.420	0.053	0.106	0.188			2.767
D	0.310	0.031	0.058	0.018			0.417
E		0.013	0.053	0.105	0.432	0.028	0.631
F		0.010	0.652	0.175	0.017	0.451	1.305
G		0.020	0.009	0.085			0.114
H		0.084	0.121	0.021			0.226
IIL			0.130	0.123		0.433	0.686
IIU			1.400	0.007			1.407

Table 14

Statistics for Community Structural Parameters at Stations Sampled in November 1974

Station	Individuals/ 0.1 m^2	Individuals/ℓ	Species/ 0.1 m^2	Diversity H'	Evenness J'	Richness
1	810	67.5	7	0.86	0.31	0.90
2	447	24.8	7	1.53	0.54	0.98
3	325	18.0	12	1.28	0.36	1.90
4	393	21.8	9	0.84	0.27	1.34
5	203	11.3	10	1.52	0.46	1.69
6	531	29.5	10	1.25	0.38	1.43
7	287	15.9	12	1.46	0.41	1.94
8	612	34.0	9	1.15	0.36	1.25
9	332	27.7	6	0.91	0.35	0.86
10	445	24.7	8	1.33	0.44	1.15
11	190	15.8	6	0.58	0.22	0.95
12	149	8.3	8	1.65	0.55	1.40
13	485	26.9	9	0.74	0.23	1.29
14	270	15.0	10	1.39	0.41	1.61
15	836	46.4	13	1.36	0.37	1.78
16	274	15.2	10	1.56	0.47	1.60
17	399	22.2	10	1.61	0.48	1.50
18	385	21.4	13	1.71	0.46	2.02
19	399	22.2	11	0.76	0.22	1.67
20	338	18.8	9	1.44	0.46	1.37
21	698	38.8	11	0.96	0.28	1.53

(continued)

Table 14 (continued)

Station	Individuals/ 0.1 m^2	Individuals/ℓ	Species/ 0.1 m^2	Diversity H'	Evenness J'	Richness
22	254	14.1	11	1.69	0.49	1.81
23	461	25.6	8	0.88	0.29	1.14
24	115	6.4	11	1.10	0.35	2.11
25	251	13.9	16	1.69	0.42	2.71
26	289	16.0	10	1.42	0.43	1.59
27	441	24.5	10	1.37	0.41	1.48
28	552	30.7	13	1.38	0.37	1.90
29	569	31.6	14	1.12	0.29	2.05
30	680	37.8	13	1.60	0.43	1.84
31	693	57.8	9	0.79	0.25	1.22
32	307	17.0	12	1.71	0.48	1.92
33	113	6.3	8	1.45	0.48	1.48
34	280	23.3	6	1.16	0.45	0.89
35	345	19.2	8	1.36	0.45	1.10
36	743	41.3	12	1.15	0.32	1.66
37	392	21.8	10	1.08	0.32	1.51
38	479	26.6	9	1.18	0.37	1.30
39	837	46.5	18	1.62	0.39	2.53
40	604	33.6	9	1.61	0.51	1.25
41	808	44.9	14	1.05	0.28	1.94
42	638	35.4	11	1.29	0.37	1.55
43	359	19.9	8	1.16	0.39	1.19
A	182	10.1	11	1.38	0.40	1.92
B	77	4.3	8	0.97	0.32	1.61
C	84	4.7	8	1.08	0.36	1.58

(continued)

Table 14 (concluded)

Station	Individuals/ 0.1 m^2	Individuals/ℓ	Species/ 0.1 m^2	Diversity H'	Evenness J'	Richness
D	34	1.9	5	0.76	0.33	1.13
E	74	4.1	4	0.38	0.19	0.70
F	4	0.2	2	0.81	0.81	0.72
G	47	2.6	4	1.08	0.54	0.78
H	41	3.4	3	0.62	0.39	0.54

Table 15

Statistics for Community Structural Parameters at Stations

Sampled in July 1975

Station	Individuals/ 0.1 m^2	Individuals/ℓ	Species/ 0.1 m^2	Diversity H'	Evenness J'	Richness
1	2459	273.2	9	0.20	0.06	1.02
2	212	11.8	6	1.29	0.50	0.93
3	313	17.4	14	1.87	0.49	2.26
4	322	17.8	14	2.47	0.65	2.25
8	300	16.7	16	2.06	0.52	2.63
9	116	6.4	8	1.28	0.43	1.47
10	144	8.0	9	1.57	0.50	1.61
11	1003	111.4	11	0.80	0.23	1.45
12	107	5.9	9	2.21	0.70	1.71
13	169	9.4	6	2.19	0.85	0.97
14	147	8.2	11	2.72	0.79	2.00
18	60	3.3	10	2.32	0.70	2.20
19	106	5.9	4	1.30	0.65	0.64
20	360	20.0	9	1.81	0.57	1.36
21	231	19.5	12	2.14	0.60	2.02
22	140	7.8	7	1.98	0.71	1.21
23	68	3.8	6	1.75	0.67	1.18
24	47	3.9	9	2.46	0.77	2.08
28	119	6.6	13	2.53	0.68	2.51
29	338	18.8	16	2.53	0.63	2.58
30	288	16.0	7	1.57	0.56	1.06

(continued)

Table 15 (concluded)

Station	Individuals/ 0.1 m^2	Individuals/ℓ	Species/ 0.1 m^2	Diversity H	Evenness J'	Richness
31	203	22.6	12	2.77	0.77	2.07
32	95	5.3	5	1.85	0.80	0.88
33	229	12.7	9	1.84	0.58	1.47
34	269	22.4	15	2.71	0.69	2.50
38	258	14.3	14	1.99	0.52	2.34
39	234	13.0	13	2.06	0.56	2.10
40	232	12.9	11	1.77	0.51	1.84
41	316	17.6	11	2.18	0.63	1.74
42	169	9.4	7	1.79	0.64	1.17
43	132	7.3	8	2.10	0.70	1.43
A	316	17.6	15	2.85	0.73	2.43
B	360	20.0	13	2.11	0.57	2.04
C	243	13.5	8	1.85	0.62	1.27
D	487	27.0	15	1.70	0.44	2.26
E	334	27.8	10	2.48	0.74	1.55
F	158	8.8	10	1.78	0.54	1.78
G	81	4.5	6	1.30	0.50	1.14
H	110	12.2	8	1.94	0.65	1.49
IIL	122	15.2	9	2.06	0.65	1.66
IIU	574	71.8	6	0.49	0.19	0.79

Table 16

Statistics for Community Structural Parameters at Stations

Sampled in December 1975

Station	Individuals/ 0.1 m^2	Individuals/ℓ	Species/ 0.1 m^2	Diversity H'	Evenness J'	Richness
8	125	13.9	5	1.00	0.43	0.83
13	271	30.1	11	1.77	0.51	1.78
14	79	8.8	5	1.47	0.63	0.92
24	94	10.5	11	2.46	0.71	2.20
28	57	3.0	7	1.40	0.50	1.48
38	36	4.0	5	1.61	0.69	1.12
41	174	14.5	10	1.64	0.49	1.74
42	136	7.5	7	1.65	0.59	1.22
A	487	54.1	14	2.60	0.68	2.10
B	193	11.0	10	1.73	0.52	1.71
C	178	9.4	7	1.38	0.49	1.16
D	426	47.3	8	1.04	0.35	1.16

Table 17

Bray-Curtis Similarity Coefficient Between Sampling Periods for Collections Made at Each Station

Station	November to July	July to December	November to December
1	0.51		
2	0.73		
3	0.70		
4	0.69		
8	0.52	0.42	0.62
9	0.62		
10	0.76		
11	0.48		
12	0.74		
13	0.70	0.79	0.70
14	0.69	0.57	0.50
18	0.17		
19	0.63		
20	0.79		
21	0.63		
22	0.65		
23	0.50		
24	0.66	0.54	0.55
28	0.47	0.37	0.39
29	0.70		
30	0.73		
31	0.47		
32	0.59		
33	0.66		
34	0.59		
38	0.26	0.30	0.41
39	0.61		
40	0.79		
41	0.74	0.62	0.51
42	0.69	0.68	0.50
43	0.74		
A	0.55	0.73	
B	0.39	0.61	
C	0.37	0.57	
D	0.29	0.73	
E	0.35		

(continued)

Table 17 (concluded)

Station	November to July	July to December	November to December
F	0.13		
G	0.17		
H	0.54		

Table 18

Distribution of Dominant Taxa at the 12 Stations Sampled Three Times

	Limnodrilus			Other Tubificids			Chironomids			Hexagenia			Corbicula			Others		
Stations	Nov	Jul	Dec	Nov	Jul	Dec	Nov	Jul	Dec	Nov	Jul	Dec	Nov	Jul	Dec	Nov	Jul	Dec
8	348	201	32		7	1	5	58	1		7		260	25	91	2		1
13	432	84	196	25	34	14	18	24	23				9	27	34	5		
14	209	63	35	8	9		31	44	3	5			35	29	43			2
24	99	26	60		2	2	6	8	22	2			8	11	8			
28	442	24	53	19	1	2	24	39	2	16	1		48	53	1	3	1	
38	396	8	9	46	2	2	28	98		3	1		6	148	25	1	1	
41	698	185	106	50	59	13	51	46	8	1			2	9	46	1		
42	515	132	50	103	16	5	19	15	78					5	3	2		
A	154	121	82	4	4	11	7	107	136	4	52	105		18	144	10	14	9
B	67	203	16	1	35	3	6	94	151		5	2		17	18	3	8	1
C	74	22	8	2	6		1	123	161				2	82	6	2	19	3
D	30	189	111	1	8	5		12	3				2	259	307		20	

Note: Readings indicate number of individuals.

Table 19

Species Found in the Habitat Development Site*

Sample	Near Station 7 7/75	Near Station 7 12/75	Near Station 27 7/75	Near Station 27 12/75
Branchiura sowerbyi			3	9
Ilyodrilus templetoni			13	31
Limnodrilus spp.	28	28	536	294
Limnodrilus cervix	5	5	7	16
Limnodrilus hoffmeisteri			10	15
**Naididae		63		88
**Tubificids ?				15
Corbicula manilensis (small)				1
Sphaerium transversum	1			
**Unionidae		1		
***Physa* sp.				17
Chironomus attenuatus				25
Chironomus spp.	26			
Cryptochironomus spp.	2			
Dicrotendipes nervosus				1
Glyptotendipes sp.				5
**Orthocladinae				1
Polypedilum spp.	2			2
Procladius bellus			5	
Pseudochironomus sp.	1			
Tanypus neopunctipennis	57			
***Trichocladius* sp.				12
***Fundulus luciae*				1

*Samples are semiquantitative representing approximately 0.05 m^2 of bottom.
**Found only within the habitat development site.

Appendix A':

Summary of Collections from the James River, Windmill Point Habitat Development Project, 1974 and 1975. (Abundances are reported by species and are the combined totals from two Ponar grab samples representing a total of 0.10 m^2.)

Species	Station 1		Station 2		Station 3	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Hydrolimax grisea		2		4		2
Prostoma rubrum						
Corbicula manilensis (small)	690	2406	23	17	10	19
Corbicula manilensis (large)					2	
Sphaerium transversum						
Pisidium sp.		1	1		3	4
Goniobasis virginica		1				
Urnatella gracilis						
Aulodrilus pigueti	39				1	
Branchiura sowerbyi						
Ilyodrilus templetoni			57	6	13	7
Limnodrilus cervix						
Limnodrilus hoffmeisteri			6	16	10	37
Limnodrilus immature spp.	62	16	303	162	263	204
Limnodrilus profundicola						1
Peloscolex multisetosus						
Potamothrix vejdovskyi						
Tubificidae (cap. setae)		22				
Dero digitata						
Enchytraeidae	4					
Helobdella elongata					1	
Gammarus fasciatus						
Oecetis sp.						
Hexagenia mingo					4	1
Stenonema annexum						1
Ablabesymia sp. E					5	
Chironomus spp.						
Chironominae						1
Cladotanytarsus sp.						
Coelotanypus scapularis		2	50	7	11	25
Cryptochironomus spp.	3	6				2
Dicrotendipes nervosus		1				

Species	Station 1		Station 2		Station 3	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Glyptotendipes sp.						
Paracladopelma sp.						
Polypedilum spp.	7					
Procladius bellus			7		2	7
Pseudochironomus sp.		3				
Stictochironomus devinctus	5					
Stictochironomus sp.						
Tanypodinae						2
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis						
Anguilla rostrata						

Species	Station 4		Station 5	Station 6	Station 7
	Nov 1974	July 1975	Nov 1974	Nov 1974	Nov 1974
Hydrolimax grisea					2
Prostoma rubrum					
Corbicula manilensis (small)	12	44	39	116	78
Corbicula manilensis (large)			2	1	1
Sphaerium transversum					
Pisidium sp.		3			
Goniobasis virginica					
Urnatella gracilis					
Aulodrilus pigueti					
Branchiura sowerbyi		1	1		1
Ilyodrilus templetoni	21	13	9	11	7
Limnodrilus cervix		1	2	10	
Limnodrilus hoffmeisteri	1	28	3	9	2
Limnodrilus immature spp.	343	154	139	379	185
Limnodrilus profundicola			6	2	1

Species	Station 4 Nov 1974	Station 4 July 1975	Station 5 Nov 1974	Station 6 Nov 1974	Station 7 Nov 1974
Peloscolex multisetosus					
Potamothrix vejdovskyi			1		
Tubificidae (cap. setae)					
Dero digitata					
Enchytraeidae					
Helobdella elongata					
Gammarus fasciatus					
Oecetis sp.					
Hexagenia mingo	4	3	1		1
Stenonema annexum					
Ablabesymia sp. E				1	
Chironomus spp.	1	4		1	
Chironominae		1			
Cladotanytarsus sp.					
Coelotanypus scapularis	6	41			5
Cryptochironomus spp.	1	10		1	2
Dicrotendipes nervosus					
Glyptotendipes sp.					
Paracladopelma sp.					
Polypedilum spp.		1			
Procladius bellus	4	18			
Pseudochironomus sp.					
Stictochironomus devinctus					
Stictochironomus sp.					1
Tanypodinae					
Tanypus neopunctipennis					
Xenochironomus sp.					
Chaoborus punctipennis					
Anguilla rostrata					

Species	Station 8 Nov 1974	Station 8 July 1975	Station 8 Dec 1975	Station 9 Nov 1974	Station 9 July 1975
Hydrolimax grisea					
Prostoma rubrum					
Corbicula manilensis (small)	258	25	91	8	
Corbicula manilensis (large)	2				
Sphaerium transversum					
Pisidium sp.					1
Goniobasis virginica					
Urnatella gracilis					
Aulodrilus pigueti					
Branchiura sowerbyi					
Ilyodrilus templetoni		6		25	2
Limnodrilus cervix	1	1			
Limnodrilus hoffmeisteri	2	18	1	4	15
Limnodrilus immature spp.	343	182	31	280	88
Limnodrilus profundicola	2				2
Peloscolex multisetosus		1			
Potamothrix vejdovskyi					
Tubificidae (cap. setae)			1		
Dero digitata					
Enchytraeidae					
Helobdella elongata					
Gammarus fasciatus	1				
Oecetis sp.					
Hexagenia mingo		7			
Stenonema annexum					
Ablabesymia sp. E		1			
Chironomus spp.		1			1
Chironominae					
Cladotanytarsus sp.					
Coelotanypus scapularis	1	41		14	6
Cryptochironomus spp.	2	3		1	

Species	Station 8 Nov 1974	Station 8 July 1975	Station 8 Dec 1975	Station 9 Nov 1974	Station 9 July 1975
Dicrotendipes nervosus					
Glyptotendipes sp.					
Paracladopelma sp.	1	1			
Polypedilum sp.		1	1		
Procladius bellus		10			
Pseudochironomus sp.					
Stictochironomus devinctus					
Stictochironomus sp.					
Tanypodinae					
Tanypus neopunctipennis	1				
Xenochironomus sp.					
Chaoborus punctipennis	1				1
Anguilla rostrata					

Species	Station 10 Nov 1974	Station 10 July 1975	Station 11 Nov 1974	Station 11 July 1975	Station 12 Nov 1974	Station 12 July 1975
Hydrolimax grisea					2	6
Prostoma rubrum						
Corbicula manilensis (small)	4	2	173	866	14	10
Corbicula manilensis (large)		1		2	2	
Sphaerium transversum						
Pisidium sp.						
Goniobasis virginica						
Urnatella gracilis						
Auldorilus piqueti						
Branchiura sowerbyi						
Ilyodrilus templetoni	30	11	3	4	18	3
Limnodrilus cervix						

Species	Station 10		Station 11		Station 12	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Limnodrilus hoffmeisteri	35	21		1	1	11
Limnodrilus immature spp.	336	99	11	7	100	59
Limnodrilus profundicola	1	2				
Peloscolex multisetosus	4					
Potamothrix vejdovskyi						
Tubificidae (cap. setae)				98		
Dero digitata						
Enchytraeidae			1			
Helobdella elongata						
Gammarus fasciatus						1
Oecetis sp.						
Hexagenia mingo					3	2
Stenonema annexum				1		
Ablabesymia sp. E						
Chironomus spp.				1		
Chironominae						
Cladotanytarsus sp.						
Coelotanypus scapularis	30	6		11	9	9
Cryptochironomus spp.			1			
Dicrotendipes nervosus						
Glyptotendipes sp.						
Paracladopelma sp.				8		
Polypedilum spp.						
Procladius bellus	5	1				6
Pseudochironomus sp.				4		
Stictochironomus devinctus			1			
Stictochironomus sp.						
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis		1		1		
Anguilla rostrata						

Species	Station 13			Station 14		
	Nov 1974	July 1975	Dec 1975	Nov 1974	July 1975	Dec 1975
Hydrolimax grisea						
Prostoma rubrum						
Corbicula manilensis (small)	7	27	34	33	29	43
Corbicula manilensis (large)	2			2		
Sphaerium transversum			4			
Pisidium sp.						
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi						
Ilyodrilus templetoni	25	34	14	8	9	
Limnodrilus cervix					3	5
Limnodrilus hoffmeisteri		13	13	5	6	2
Limnodrilus immature spp.	432	71	183	204	54	28
Limnodrilus profundicola						
Peloscolex multisetosus						
Potamothrix vejdovskyi						
Tubificidae (cap. setae)						
Dero digitata						
Enchytraeidae						
Helobdella elongata	1					
Gammarus fasciatus						
Oecetis sp.						
Hexagenia mingo				5		
Stenonema annexum						
Ablabesymia sp. E	2		6			
Chironomus spp.			1	5	17	
Chironominae						
Cladotanytarsus sp.						
Coelotanypus scapularis	11	20	9	5	9	
Cryptochironomus spp.	3		1	2	3	

Species	Station 13			Station 14		
	Nov 1974	July 1975	Dec 1975	Nov 1974	July 1975	Dec 1975
Dicrotendipes nervosus						2
Glyptotendipes sp.						
Paracladopelma sp.						
Polypedilum spp.			2	14	14	1
Procladius bellus	2	4	4	5	1	
Pseudochironomus sp.						
Stictochironomus devinctus						
Stictochironomus sp.						
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis						
Anguilla rostrata						

Species	Station 15	Station 16	Station 17	Station 18	
	Nov 1974	Nov 1974	Nov 1974	Nov 1974	July 1975
Hydrolimax grisea				1	
Prostoma rubrum					
Corbicula manilensis (small)	146	71	114	160	
Corbicula manilensis (large)		2	2	1	
Sphaerium transversum					
Pisidium sp.	2	4			
Goniobasis virginica					
Urnatella gracilis					
Aulodrilus pigueti					
Branchiura sowerbyi	1				
Ilyodrilus templetoni	49	3	14	6	
Limnodrilus cervix	4	3	11	3	
Limnodrilus hoffmeisteri	12	18	15	28	

Species	Station 15 Nov 1974	Station 16 Nov 1974	Station 17 Nov 1974	Station 18 Nov 1974	Station 18 July 1975
Limnodrilus immature spp.	602	170	237	176	
Limnodrilus profundicola		1	1	3	
Peloscolex multisetosus	1				
Potamothrix vejdovskyi					
Tubificidae (cap. setae)					
Dero digitata		1			15
Enchytraeidae			2		
Helobdella elongata				1	
Gammarus fasciatus	1				
Oecetis sp.					
Hexagenia mingo	6			3	
Stenonema annexum					
Ablabesymia sp. E	3			1	
Chironomus spp.			2		26
Chironominae					
Cladotanytarsus sp.					
Coelotanypus scapularis	4		1		4
Cryptochironomus spp.	1	1		1	8
Dicrotendipes nervosus					1
Glyptotendipes sp.					
Paracladopelma sp.					
Polypedilum spp.					1
Procladius bellus				1	1
Pseudochironomus sp.					1
Stictochironomus devinctus					
Stictochironomus sp.					
Tanypodinae					
Tanypus neopunctipennis					
Xenochironomus sp.					
Chaoborus punctipennis					
Anguilla rostrata					

Species	Station 19		Station 20		Station 21	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Hydrolimax grisea						
Prostoma rubrum						
Corbicula manilensis (small)	18		19	8	566	103
Corbicula manilensis (large)	3				1	1
Sphaerium transversum						
Pisidium sp.	1					
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi						
Ilyodrilus templetoni	5	12	15	102		1
Limnodrilus cervix						
Limnodrilus hoffmeisteri	5	9	21	16		23
Limnodrilus immature spp.	357	76	255	196	131	72
Limnodrilus profundicola			10			
Peloscolex multisetosus	1		2	3		3
Potamothrix vejdovskyi						
Tubificidae (cap. setae)						
Dero digitata						
Enchytraeidae					3	
Helobdella elongata						
Gammarus fasciatus			1		1	
Oecetis sp.						
Hexagenia mingo	1					1
Stenonema annexum						
Ablabesymia sp. E						
Chironomus spp.						
Chironominae						
Cladotanytarsus sp.						
Coelotanypus scapularis	5	9	11	27	1	9
Cryptochironomus spp.					1	7
Dicrotendipes nervosus						

Species	Station 19 Nov 1974	Station 19 July 1975	Station 20 Nov 1974	Station 20 July 1975	Station 21 Nov 1974	Station 21 July 1975
Glyptotendipes sp.						
Paracladopelma sp.				1		1
Polypedilum spp.					1	1
Procladius bellus			4	4	1	9
Pseudochironomus sp.						
Stictochironomus devinctus					1	
Stictochironomus sp.					1	
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis				3		
Anguilla rostrata						

Species	Station 22 Nov 1974	Station 22 July 1975	Station 23 Nov 1974	Station 23 July 1975	Station 24 Nov 1974	Station 24 July 1975	Station 24 Dec 1975
Hydrolimax grisea							
Prostoma rubrum							2
Corbicula manilensis (small)	19	9	25	3	6	10	6
Corbicula manilensis (large)	1				2	1	2
Sphaerium transversum							
Pisidium sp.							
Goniobasis virginica							
Urnatella gracilis							
Aulodrilus pigueti							
Branchiura sowerbyi				2			
Ilyodrilus templetoni	17	10	16	3		2	2
Limnodrilus cervix		5			2		13
Limnodrilus hoffmeisteri	1	22		10	2	7	4

Species	Station 22		Station 23		Station 24		
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975	Dec 1975
Limnodrilus immature spp.	165	78	398	42	95	19	43
Limnodrilus profundicola	7						
Peloscolex multisetosus							
Potamothrix vejdovskyi							
Tubificidae (cap. setae)							
Dero digitata							
Enchytraeidae							
Helobdella elongata							
Gammarus fasciatus							
Oecetis sp.							
Hexagenia mingo			10		2		
Stenonema annexum							
Ablabesymia sp. E	1		5		1		
Chironomus spp.	1				1		17
Chironominae							
Cladotanytarsus sp.							
Coelotanypus scapularis	42	15	3	8	2	4	
Cryptochironomus spp.	3				1	1	
Dicrotendipes nervosus			3				
Glyptotendipes sp.							1
Paracladopelma sp.							
Polypedilum spp.							1
Procladius bellus	2		1		1	2	3
Pseudochironomus sp.							
Stictochironomus devinctus							
Stictochironomus sp.							
Tanypodinae						1	
Tanypus neopunctipennis							
Xenochironomus sp.							
Chaoborus punctipennis							
Anguilla rostrata							

Species	Station 25	Station 26	Station 27	Station 28		
	Nov 1974	Nov 1974	Nov 1974	Nov 1974	July 1975	Dec 1975
Hydrolimax grisea				2		
Prostoma rubrum						
Corbicula manilensis (small)	7	23	77	48	52	1
Corbicula manilensis (large)	2		1		1	
Sphaerium transversum						
Pisidium sp.						
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi						
Ilyodrilus templetoni	5	23	14	19	1	2
Limnodrilus cervix	9	3	3		1	7
Limnodrilus hoffmeisteri	11	5	4	14		3
Limnodrilus immature spp.	187	217	320	427	23	43
Limnodrilus profundicola	1			1		
Peloscolex multisetosus						
Potamothrix vejdovskyi						
Tubificidae (cap. setae)						
Dero digitata	1			1		
Enchytraeidae						
Helobdella elongata						
Gammarus fasciatus					1	
Oecetis sp.						
Hexagenia mingo	9	2	9	16	1	
Stenonema annexum						
Ablabesymia sp. E	9	3	5	10		
Chironomus spp.	1				5	
Chironominae						
Cladotanytarsus sp.						
Coelotanypus scapularis	3	10		8	6	
Cryptochironomus spp.	1	2	4	2		1
Dicrotendipes nervosus					2	

Species	Station 25	Station 26	Station 27	Station 28		
	Nov 1974	Nov 1974	Nov 1974	Nov 1974	July 1975	Dec 1975
Glyptotendipes sp.						
Paracladopelma sp.						
Polypedilum spp.	1				17	1
Procladius bellus	2	1	4	3	6	
Pseudochironomus sp.					3	
Stictochironomus devinctus						
Stictochironomus sp.	2			1		
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis						
Anguilla rostrata						

Species	Station 29		Station 30		Station 31	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Hydrolimax grisea	1	1	3		1	
Prostoma rubrum						
Corbicula manilensis (small)	22	63	40	15	594	55
Corbicula manilensis (large)	2	2				
Sphaerium transversum	1					
Pisidium sp.	1	5				
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi						
Ilyodrilus templetoni	61	21	65	23		1
Limnodrilus cervix						
Limnodrilus hoffmeisteri	1	17	45	24		1
Limnodrilus immature spp.	460	160	482	199	73	60

Species	Station 29 Nov 1974	Station 29 July 1975	Station 30 Nov 1974	Station 30 July 1975	Station 31 Nov 1974	Station 31 July 1975
Limnodrilus profundicola						
Peloscolex multisetosus	3		12	1		
Potamothrix vejdovskyi						
Tubificidae (cap. setae)						
Dero digitata						
Enchytraeidae					10	
Helobdella elongata		5	1			10
Gammarus fasciatus					1	
Oecetis sp.						
Hexagenia mingo	1	4				
Stenonema annexum						
Ablabesymia sp. E.						
Chironomus spp.		2			1	
Chironominae						
Cladotanytarsus sp.			1			
Coelotanypus scapularis	7	27	23	23		19
Cryptochironomus spp.	3	4	2		2	11
Dicrotendipes nervosus		2	1			
Glyptotendipes sp.						
Paracladopelma sp.		2				
Polypedilum spp.						7
Procladius bellus	5	22	4			22
Pseudochironomus sp.						2
Stictochironomus devinctus					10	2
Stictochironomus sp.						
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis				3		
Anguilla rostrata						

Species	Station 32		Station 33		Station 34	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Hydrolimax grisea	1					1
Prostoma rubrum						
Corbicula manilensis (small)	10			12	15	8
Corbicula manilensis (large)	2		7		1	
Sphaerium transversum						3
Pisidium sp.						
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi						
Ilyodrilus templetoni	46	11	18	32	27	31
Limnodrilus cervix						
Limnodrilus hoffmeisteri	4	17		11		30
Limnodrilus immature spp.	205	46	80	140	218	114
Limnodrilus profundicola			2			
Peloscolex multisetosus	4			1		
Potamothrix vejdovskyi						
Tubificidae (cap. setae)						
Dero digitata	1					
Enchytraeidae						
Helobdella elongata						
Gammarus fasciatus			1			
Oecetis sp.						
Hexagenia mingo				1		15
Stenonema annexum						
Ablabesymia sp. E						3
Chironomus spp.	13					1
Chironominae						1
Cladotanytarsus sp.						
Coelotanypus scapularis	25	20	3	26	17	33
Cryptochironomus spp.	3					3
Dicrotendipes nervosus	1		1			

Species	Station 32 Nov 1974	Station 32 July 1975	Station 33 Nov 1974	Station 33 July 1975	Station 34 Nov 1974	Station 34 July 1975
Glyptotendipes sp.						
Paracladopelma sp.						5
Polypedilum spp.						1
Procladius bellus	5		1	5	2	20
Pseudochironomus sp.						
Stictochironomus devinctus						
Stictochironomus sp.						
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis	1		1			
Anguilla rostrata						

Species	Station 35 Nov 1974	Station 36 Nov 1974	Station 37 Nov 1974	Station 38 Nov 1974	Station 38 July 1975	Station 38 Dec 1975
Hydrolimax grisea					1	
Prostoma rubrum						2
Corbicula manilensis (small)	6	25	8	6	148	23
Corbicula manilensis (large)	1	4	2			
Sphaerium transversum						
Pisidium sp.						
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti			3			
Branchiura sowerbyi						
Ilyodrilus templetoni	77	55	44	43		2
Limnodrilus cervix		3				
Limnodrilus hoffmeisteri		16		15		3

Species	Station 35 Nov 1974	Station 36 Nov 1974	Station 37 Nov 1974	Station 38 Nov 1974	Station 38 July 1975	Station 38 Dec 1975
Limnodrilus immature spp.	233	609	318	381	8	6
Limnodrilus profundicola		5				
Peloscolex multisetosus	1		1	3		
Potamothrix vejdovskyi						
Tubificidae (cap. setae)					2	
Dero digitata						
Enchytraeidae						
Helobdella elongata						
Gammarus fasciatus						
Oecetis sp.					1	
Hexagenia mingo		3		3	1	
Stenonema annexum						
Ablabesymia sp. E		3				
Chironomus spp.					13	
Chironominae					2	
Cladotanytarsus sp.						
Coelotanypus scapularis	23	15	10	24	1	
Cryptochironomus spp.		2	2	1	3	
Dicrotendipes nervosus					22	
Glyptotendipes sp.						
Paracladopelma sp.						
Polypedilum spp.					54	
Procladius bellus		3	3	3	1	
Pseudochironomus sp.					2	
Stictochironomus devinctus	3					
Stictochironomus sp.	1		1			
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis						
Anguilla rostrata						

Species	Station 39 Nov 1974	Station 39 July 1975	Station 40 Nov 1974	Station 40 July 1975	Station 41 Nov 1974	Station 41 July 1975	Station 41 Dec 1975
Hydrolimax grisea	1			1			
Prostoma rubrum							
Corbicula manilensis (small)	36	60	20	13	1	9	46
Corbicula manilensis (large)	2	2		1	1		
Sphaerium transversum		5					
Pisidium sp.	1				1		
Goniobasis virginica							
Urnatella gracilis							
Aulodrilus pigueti	4						
Branchiura sowerbyi							
Ilyodrilus templetoni	97	12	84	22	47	37	13
Limnodrilus cervix					1	1	
Limnodrilus hoffmeisteri	20	3	29	11	11	13	1
Limnodrilus immature spp.	609	127	415	156	675	171	104
Limnodrilus profundicola	8				11		1
Peloscolex multisetosus	7		20	6	3	22	
Potamothrix vejdovskyi							
Tubificidae (cap. setae)							
Dero digitata		1					
Enchytraeidae							
Helobdella elongata							
Gammarus fasciatus							
Oecetis sp.							
Hexagenia mingo	9	3			1		
Stenonema annexum							
Ablabesymia sp. E	3						
Chironomus spp.	1	2	1				1
Chironominae						1	
Cladotanytarsus sp.				1			
Coelotanypus scapularis	22	10	26	18	45	42	4
Cryptochironomus spp.	3			1	5	1	1
Dicrotendipes nervosus	1	5					

Species	Station 39 Nov 1974	Station 39 July 1975	Station 40 Nov 1974	Station 40 July 1975	Station 41 Nov 1974	Station 41 July 1975	Station 41 Dec 1975
Glyptotendipes sp.							
Paracladopelma sp.							
Polypedilum spp.						2	2
Procladius bellus	10	2	8	2			
Pseudochironomus sp.							
Stictochironomus devinctus	3						
Stictochironomus sp.					1		
Tanypodinae							
Tanypus neopunctipennis				1			
Xenochironomus sp.		2					
Chaoborus punctipennis							
Anguilla rostrata							

Species	Station 42 Nov 1974	Station 42 July 1975	Station 42 Dec 1975	Station 43 Nov 1974	Station 43 July 1975	Station A Nov 1974	Station A July 1975	Station A Dec 1975
Hydrolimax grisea							2	
Prostoma rubrum								
Corbicula manilensis (small)		5	3		18		18	144
Corbicula manilensis (large)					1			
Sphaerium transversum							8	9
Pisidium sp.						10		
Goniobasis virginica								
Urnatella gracilis								
Aulodrilus pigueti	1							
Branchiura sowerbyi						3	4	1
Ilyodrilus templetoni	103	16	5	33	7	1		10
Limnodrilus cervix								
Limnodrilus hoffmeisteri	34	33		8	16	12	14	1

Species	Station 42			Station 43		Station A		
	Nov 1974	July 1975	Dec 1975	Nov 1974	July 1975	Nov 1974	July 1975	Dec 1975
Limnodrilus immature spp.	470	99	50	285	70	142	107	81
Limnodrilus profundicola	11							
Peloscolex multisetosus				8	3			
Potamothrix vejdovskyi								
Tubificidae (cap. setae)								
Dero digitata								
Enchytraeidae								
Helobdella elongata								
Gammarus fasciatus							1	
Oecetis sp.								
Hexagenia mingo						4	52	105
Stenonema annexum								
Ablabesymia sp. E	1					1	18	47
Chironomus spp.	1		2			3		1
Chironominae							2	
Cladotanytarsus sp.								
Coelotanypus scapularis	12	13	69	20	15	2	67	78
Cryptochironomus spp.	3			1		1	6	6
Dicrotendipes nervosus								
Glyptotendipes sp.								1
Paracladopelma sp.								
Polypedilum spp.							5	
Procladius bellus	1	2	7		2		9	2
Pseudochironomus sp.								
Stictochironomus devinctus	1							1
Stictochironomus sp.								
Tanypodinae								
Tanypus neopunctipennis								
Xenochironomus sp.								
Chaoborus punctipennis		1		1			3	
Anguilla rostrata								

Species	Station B Nov 1974	Station B July 1975	Station B Dec 1975	Station C Nov 1974	Station C July 1975	Station C Dec 1975
Hydrolimax grisea		5			9	
Prostoma rubrum						
Corbicula manilensis (small)		17	18	1	82	6
Corbicula manilensis (large)				1		
Sphaerium transversum						
Pisidium sp.				3		
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi		3	1			
Ilyodrilus templetoni	1	32	2	2	4	
Limnodrilus hoffmeisteri	1	12		4	2	
Limnodrilus immature spp.	66	191	16	70	20	8
Limnodrilus profundicola						
Peloscolex multisetosus					2	
Potamothrix vejdovskyi						
Tubificidae (cap. setae)						
Dero digitata						
Enchytraeidae						
Helobdella elongata						
Gammarus fasciatus	3		1	2		
Oecetis sp.						
Hexagenia mingo		5	2			
Stenonema annexum						
Ablabesymia sp. E		4				
Chironomus spp.						1
Chironominae						
Cladotanytarsus sp.						
Coelotanypus scapularis	1	83	130		118	128
Cryptochironomus spp.	2	1	7			3
Dicrotendipes nervosus				1		
Glyptotendipes sp.						

Species	Station B Nov 1974	Station B July 1975	Station B Dec 1975	Station C Nov 1974	Station C July 1975	Station C Dec 1975
Paracladopelma sp.						
Polypedilum spp.	2	1				
Procladius bellus		5	14		5	29
Pseudochironomus sp.						
Stictochironomus devinctus						
Stictochironomus sp.	1					
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis		2			10	3
Anguilla rostrata		1				

Species	Station D Nov 1974	Station D July 1975	Station D Dec 1975	Station E Nov 1974	Station E July 1975
Hydrolimax grisea		9			
Prostoma rubrum					
Corbicula manilensis (small)	1	259	307		33
Corbicula manilensis (large)	1				
Sphaerium transversum		7			
Pisidium sp.					
Goniobasis virginica					
Urnatella gracilis					
Aulodrilus pigueti					
Branchiura sowerbyi		1	1	1	13
Ilyodrilus templetoni	1	3	2		
Limnodrilus cervix					
Limnodrilus hoffmeisteri		14	3	2	11
Limnodrilus immature spp.	30	175	108	70	115

Species	Station D Nov 1974	Station D July 1975	Station D Dec 1975	Station E Nov 1974	Station E July 1975
Limnodrilus profundicola					
Peloscolex multisetosus		1			
Potamothrix vejdovskyi					
Tubificidae (cap. setae)		3	2		
Dero digitata					
Enchytraeidae					
Helobdella elongata		1			
Gammarus fasciatus					
Oecetis sp.		1			
Hexagenia mingo					88
Stenonema annexum					
Ablabesymia sp. E					4
Chironomus spp.					
Chironominae		1			
Cladotanytarsus sp.					
Coelotanypus scapularis		8	1		52
Cryptochironomus spp.		2	2	1	
Dicrotendipes nervosus					
Glyptotendipes sp.					
Paracladopelma sp.					
Polypedilum spp.		1			2
Procladius bellus					15
Pseudochironomus sp.					1
Stictochironomus devinctus					
Stictochironomus sp.					
Tanypodinae					
Tanypus neopunctipennis					
Xenochironomus sp.					
Chaoborus punctipennis		2			
Anguilla rostrata					

Species	Station F		Station G		Station H	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Hydrolimax grisea						
Prostoma rubrum						
Corbicula manilensis (small)		8		15		53
Corbicula manilensis (large)						
Sphaerium transversum						
Pisidium sp.						
Goniobasis virginica						
Urnatella gracilis						
Aulodrilus pigueti						
Branchiura sowerbyi						
Ilyodrilus templetoni		1		1		2
Limnodrilus cervix						
Limnodrilus hoffmeisteri	3	11	4		4	5
Limnodrilus immature spp.		11	37	4	36	32
Limnodrilus profundicola						
Peloscolex multisetosus						1
Potamothrix vejdovskyi						
Tubificidae (cap. setae)			3		1	2
Dero digitata						
Enchytraeidae						
Helobdella elongata						
Gammarus fasciatus						
Oecetis sp.						
Hexagenia mingo		2				
Stenonema annexum						
Ablabesymia sp. E						
Chironomus spp.						
Chironominae						
Cladotanytarsus sp.						
Coelotanypus scapularis		107		58		14
Cryptochironomus spp.	1					

Species	Station F		Station G		Station H	
	Nov 1974	July 1975	Nov 1974	July 1975	Nov 1974	July 1975
Dicrotendipes nervosus						
Glyptotendipes sp.						
Paracladopelma sp.						
Polypedilum spp.						
Procladius bellus		5		1		1
Pseudochironomus sp.						
Stictochironomus devinctus			3			
Stictochironomus sp.						
Tanypodinae						
Tanypus neopunctipennis						
Xenochironomus sp.						
Chaoborus punctipennis		11		2		
Anguilla rostrata		1				

Appendix B':

Taxonomic List of all Species Taken in the James River, Windmill Point Habitat Development Project Collections, 1974 and 1975

Phylum: Platyhelminthes
  Class: Turbellaria
    Order: Alloecoela
      Family: Plagiostomidae
          Hydrolimax grisea Haldeman

Phylum: Nemertea
  Prostoma rubrum (Leidy)

Phylum: Mollusca
  Class: Pelecypoda
    Order: Heterodonta
      Family: Corbiculidae
        Corbicula manilensis (Philippi)
      Family: Unionidae
        Elliptio complanata (Lightfoot)
      Family: Sphaeriidae
        Sphaerium transversum (Say)
        Pisidium sp.

  Class: Gastropoda
      Family: Pleuroceridae
        Goniobasis virginica Gmelin (Walker)
      Family: Physidae
        Physa sp.

Phylum (or Class): Entoprocta
      Family: Urnatellidae
        Urnatella gracilis Leidy

Phylum: Annelida
  Class: Oligochaeta
    Order: Plesiopora
      Family: Tubificidae
        Aulodrilus pigueti Kowalewski
        Branchiura sowerbyi Beddard
        Ilyodrilus templetoni (Southern)
        Limnodrilus cervix Brinkhurst
        Limnodrilus hoffmeisteri Claparede
        Limnodrilus immature spp.
        Peloscolex multisetosus (Smith)
        Potamothrix vejdovskyi (Hrabe)
        Tubificidae (cap. setae)
      Family: Naididae
        Dero digitata (O. F. Muller)
      Family: Enchytraeidae

  Class: Hirudinea
    Order: Rhynchobdellida
      Family: Piscicolidae
        Helobdella elongata (Castle)

Phylum: Arthropoda
  Class: Crustacea
    Order: Amphipoda
      Family: Gammaridae
        Gammarus fasciatus Say
  Class: Insecta
    Order: Trichoptera
      Family: Leptoceridae
        Oecetis sp. McLachlan

    Order: Ephemeroptera
      Family: Ephemeridae
        Hexagenia mingo Walsh
      Family: Heptageniidae
        Stenonema annexum Traver

    Order: Diptera
      Family: Chironomidae
        Ablabesmyia sp. E Roback
        Chironomus spp.
        Chironominae
        Cladotanytarsus sp.
        Coelotanypus scapularis (Loew)
        Cryptochironomus spp.
        Dicrotendipes nervosus (Staeg.)
        Glyptotendipes sp.
        Orthocladinae
        Paracladopelma sp.
        Polypedilum spp.
        Procladius bellus (Loew)
        Pseudochironomus sp.
        Stictochironomus devinctus (Say)
        Stictochironomus sp.
        Tanypodinae
        Tanypus neopunctipennis Subl.
        Trichocladius sp.
        Xenochironomus sp.
      Family: Chaoboridae
        Chaoborus punctipennis (Say)

Phylum: Chordata
  Class: Osteichthyes
    Order: Apodes
      Family: Anguillidae
        Anguilla rostrata (LeSueur)
      Family: Poeciliidae
        Fundulus luciae (Baird)

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References: p. 81-87.

1. Benthos. 2. Community. 3. Disposal areas. 4. Dredged material. 5. Dredged material disposal. 6. Habitats.

(Continued on next card)

Diaz, Robert J

Habitat development field investigations, Windmill Point marsh development site, James River, Virginia; Appendix C: Environmental impacts of marsh development ... 1977. (Card 2)

7. James River. 8. Marshes. 9. Windmill Point. I. Boesch, Donald F., joint author. II. United States. Army. Corps of Engineers. III. Virginia Institute of Marine Science, Gloucester Point. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-23, Appendix C

TA7.W34 no.D-77-23 Appendix C