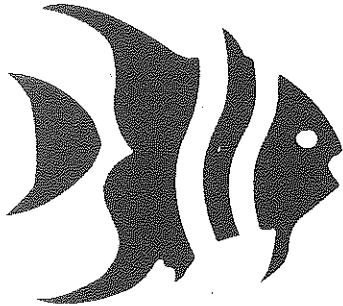


SCHROEDER

# DAUPHIN ISLAND SEA LAB



## TECHNICAL REPORT

REPORT No. 83-003

ANALYSIS OF AN ENVIRONMENTAL MONITORING PROGRAM  
THEODORE SHIP CHANNEL AND BARGE CHANNEL EXTENSION  
MOBILE BAY, ALABAMA

VOLUME I

TEXT W/FIGURES AND TABLES

**Dauphin Island Sea Lab**  
**Dauphin Island, Alabama 36528**

ANALYSIS OF AN ENVIRONMENTAL MONITORING PROGRAM  
THEODORE SHIP CHANNEL AND BARGE CHANNEL EXTENSION  
MOBILE BAY, ALABAMA

VOLUME I

TEXT W/FIGURES AND TABLES

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## TABLE OF CONTENTS

	Page
List of Contributors-----	ii
Table of Contents - Volume I-----	iii
Table of Contents - Volume II - Data Management and Analysis-----	iv
List of Textual Figures-----	v
List of Textual Tables-----	vii
Acknowledgments-----	ix
Introduction-----	1
The Baseline Study-----	12
Methods and Materials-----	17
Results and Discussion-----	27
A. Hydrography-----	27
B. Sediments/Sediment Chemistry-----	44
C. Benthic Fauna-----	50
D. Oyster Reefs-----	100
E. Recommendations for Further Studies-----	103
References-----	104

TABLE OF CONTENTS  
(VOLUME II)

	PAGE
List of Figures.....	iii
List of Tables.....	iv
Introduction.....	1
Rationale and Organizaton.....	1
A. Rationale.....	1
B. Organization.....	2
Status of the Data Management System.....	4
A. Overview.....	4
B. Individual Data Management Work Elements.....	11
Quality Assurance - Quality Control.....	12
References.....	25
Appendix A. Data Formats.....	26
Appendix B. Programs For Physical Data.....	27
Appendix C. Programs For Biological Data.....	28
Appendix D. Programs For Sedimentological Data.....	29

## LIST OF FIGURES

- Figure 1A. Vicinity and Locality of Theodore Industrial Park Ship Channel, Mobile, Alabama.
- Figure 1B. Station Locality Map, Theodore Industrial Park Ship Channel Project, Mobile, Alabama.
- Figure 2. Theoretical Food Web in a Juncus marsh.
- Figure 3. Theoretical Food Web in a Submarine Meadow e.g. Ruppia, Thalassia.
- Figure 4. Chronology of Endeco 101 Refractometer-Thermograph Deployment (1980-1982).
- Figure 5. Meteorological Data Column Explanations/Daily Weather Observation Form.
- Figure 6. Flow Diagram Illustrating Information Flow Through the Data Management System.
- Figure 7. Mean Monthly Bottom Temperature Values , in °C, Calculated from the Combined "B" and "T" Station Data Sets.
- Figure 8. Mean Monthly Bottom Salinity Values, in ppt, Calculated from the Combined "B" and "T" Station Data Sets.
- Figure 9. Mean Monthly Bottom Dissolved Oxygen Values, in Percent Saturation, Calculated from the Combined "B" and "T" Station Data Sets.
- Figure 10. Mean Monthly Surface and Bottom Total Solids Values, in mg/l, Calculated from the "T" Station Data Set.
- Figure 11A. Graph of Macroinvertebrate Diversity (H') at Station B-1.
- Figure 11B. Graph of Macroinvertebrate Diversity (H') at Station B-4.
- Figure 11C. Graph of Macroinvertebrate Diversity (H') at Station B-8.
- Figure 11D. Graph of Macroinvertebrate Diversity (H') at Station B-7.
- Figure 12A. Graph of Macroinvertebrate Evenness (J') at Station B-1.
- Figure 12B. Graph of Macroinvertebrate Evenness (J') at Station B-4.
- Figure 12C. Graph of Macroinvertebrate Evenness (J') at Station B-8.
- Figure 12D. Graph of Macroinvertebrate Evenness (J') at Station B-7.
- Figure 13A. Graph of Macroinvertebrate Richness (R) at Station B-1.
- Figure 13B. Graph of Macroinvertebrate Richness (R) at Station B-4.

- Figure 13C. Graph of Macroinvertebrate Richness (R) at Station B-8.
- Figure 13D. Graph of Macroinvertebrate Richness (R) at Station B-7.
- Figure 14A. Graph of Polychaete Diversity ( $H'$ ) at Station B-1.
- Figure 14B. Graph of Polychaete Diversity ( $H'$ ) at Station B-4.
- Figure 14C. Graph of Polychaete Diversity ( $H'$ ) at Station B-8.
- Figure 14D. Graph of Polychaete Diversity ( $H'$ ) at Station B-7.
- Figure 15A. Graph of Polychaete Evenness ( $J'$ ) at Station B-1.
- Figure 15B. Graph of Polychaete Evenness ( $J'$ ) at Station B-4.
- Figure 15C. Graph of Polychaete Evenness ( $J'$ ) at Station B-8.
- Figure 15D. Graph of Polychaete Evenness ( $J'$ ) at Station B-7.
- Figure 16A. Graph of Polychaete Richness (R) at Station B-1.
- Figure 16B. Graph of Polychaete Richness (R) at Station B-4.
- Figure 16C. Graph of Polychaete Richness (R) at Station B-8.
- Figure 16D. Graph of Polychaete Richness (R) at Station B-7.
- Figure 17. Height frequency Distributions of Oysters and Oyster Spat on Whitehouse Reef.

## LIST OF TEXTUAL TABLES

Table 1A.	Vittor's DISL (1979) Table 39 Data for Stations B-1, B-4, B-7, and B-8.
Table 1B.	Vittor's DISL (1979) Table 39 Data for Stations B-1, B-4, B-7, and B-8 Recalculated Using Log Base 2, and Revising Errors.
Table 2A.	Summary of Sampling Activity During Construction and Post-construction Engineering (Benthic Stations).
Table 2B.	Summary of Sampling Activity During Construction and Post-construction Engineering (Turbidity Stations).
Table 2C.	Station Locations.
Table 3.	Surface (Sur.) and Bottom (Bot.) Monthly Means of Temperatures, Salinity and Dissolved Oxygen Calculated from the Combined "B" and "T" Station Data Sets and Monthly Means of Total Solids and Turbidity Calculated from the "T" Station Data Set.
Table 4.	Probablity (p) Values Obtained from the Analysis of Variance.
Table 5.	Coefficients of Correlation (r) Between Total Solids and Turbidity Data.
Table 6.	Summary of Suspended Total Solids Values in mg/l.
Table 7.	River Dishcharge and Wind Speed and Direction Conditions During the collection of "T" Station Data.
Table 8A.	Summary of Sediment Characterization (Station B-1).
Table 8B.	Summary of Sediment Characterization (Station B-4).
Table 8C.	Summary of Sediment Characterization (Station B-8).
Table 9.	Summary of Construction [(N=60 vs. Post-construction (n=132) ANOVA] and Duncan's Multiple Range Test Means.
Table 10.	Summary of Station Interactions Using ANOVA and Duncan's Multiple Ranges Test of Means (N=132 and N=44 respectively).
Table 11.	Summary of ANOVA and Duncan's Multiple Range Test of Means (Construction: N=44).
Table 12.	Summary of ANOVA and Duncan's Multiple Range Test of Means (Post-Construction: N=24).
Table 13A.	Summary Biological Characterization, Station B-1.



Table 13B.	Summary Biological Characterization, Station B-4.
Table 13C.	Summary Biological Characterization, Station B-8.
Table 13D.	Summary Biological Characterization, Station B-7.
Table 14A.	Summary Polychaete Baseline Characterization, Station B-1.
Table 14B.	Summary Polychaete Baseline Characterization, Station B-4 and B-8.
Table 14C.	Summary Polychaete Baseline Characterization, Station B-7.
Table 15A.	Comparison of Community Indices: Baseline vs. Monitoring at Station B-4.
Table 15B.	Comparison of Community Indices: Baseline vs. Monitoring at Station B-8.
Table 16.	Correlation Matrix: Stations B-1, B-4, and B-8 Data Combined.

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We are grateful to them for their dedication to this Sea Lab effort.

## INTRODUCTION

### A. OVERVIEW

Mobile Bay is one of the major estuarine systems of the Gulf of Mexico. It may be characterized as a shallow semi-enclosed basin which receives large volumes of river water, has high levels of suspended solids, has a temperature range of approximately 25°C, and may undergo periods of severe dissolved oxygen depletion. Major port and industrial development is taking place along the western shore. To provide access to the new Theodore Industrial Park, the federal government authorized the construction of a 12 kilometer ship channel and an enlargement of the existing barge canal into the park itself (Fig. 1A) under Section 201 of Public Law 89-298.

The dredged material disposal plan called for the creation of a large island (approximately 5.2 km<sup>2</sup>) within the triangle that was to be created by the existing and new ship channels (Fig. 1A). The island was to be composed of approximately 2.4 x 10<sup>7</sup> m<sup>3</sup> of construction material, and accommodate approximately 1.5 x 10<sup>6</sup> m<sup>3</sup> of maintenance material annually (Crozier, 1979).

### B. SYNTHESIS OF KNOWLEDGE AND RECENT ADJUNCT STUDIES

A synthesis of data concerning the Mobile estuary was presented in 1979 and published in 1981 entitled "Symposium on the Natural Resources of the Mobile Estuary, Alabama." Although this symposium consolidates a lot of pertinent information, it does not answer the questions of environmental impacts resulting from spoil island construction.

#### 1. Hydrography

Under the auspices of the Coastal Area Board (CAB), the Dauphin Island Sea Lab (DISL) took monthly profile data at eight stations in Mobile Bay. CAB stations 6 and 7 were located approximately 2.75 km south and 10 km north of station B-7 respectively (Figure 1B). These stations were sampled fourteen times at approximately monthly intervals beginning in early April 1980 and concluding in late April 1981. Fourteen volumes of raw data (interim reports) are on file with the local Department of Environmental Management office and at the library of the Dauphin Island Sea Lab. Although the data have not been published, Ranasinghe (1983) has examined stations 6 and 7 data in relation to ACOE stations B-1, B-4, B-7 and B-8 established for this study (Figure 1B).

#### 2. Sediments and Sediment Quality

Isphording and Lamb (1979) analyzed 238 bottom sediment samples from Mobile Bay and developed a sediment texture map to update the work of Ryan



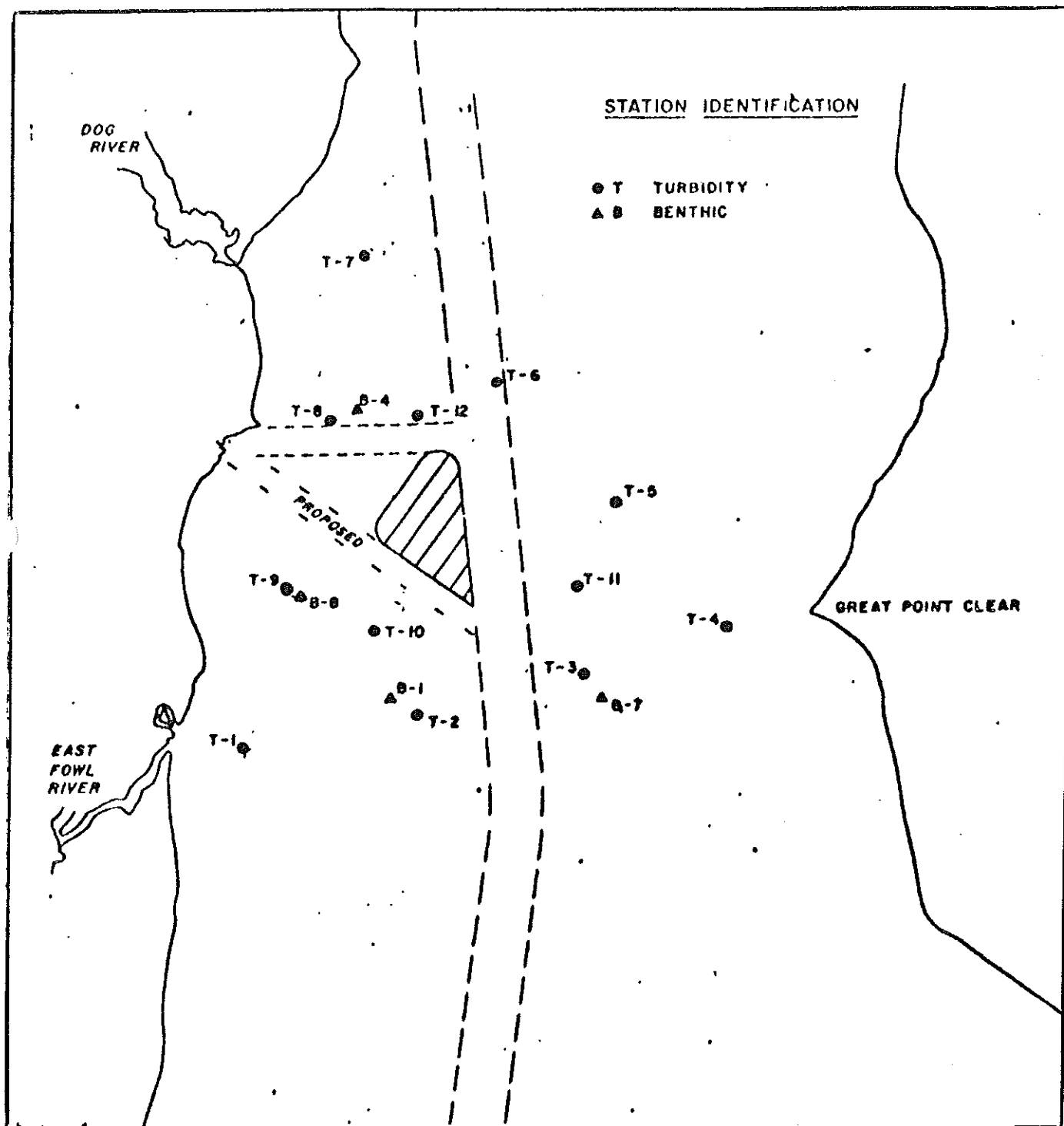


Figure 1B. Station Locality Map, Theodore Industrial Park Ship Channel Project, Mobile, Alabama.

(1969). Their map has classified the baseline and monitoring station areas as follows:

B-1 Clay to Silty Clay  
B-4 Clay  
B-7 Sandy Clay  
B-8 Clay

CAB stations 6 and 7 are classified as clay and silty clay respectively.

Ranasinghe (1983) has examined sediment data from stations B-1, B-4, and B-8 and from stations 6 and 7 of the CAB study. He regards the five stations as similar but notes these differences at the  $p = 0.05$  level:

(1) Station B-1 had significantly more clay than stations B-4, B-8 or CAB 6 which in turn had significantly more clay than CAB station 7.

(2) Stations B-4 and B-8 were significantly sandier than other stations.

(3) CAB station 7 was significantly siltier than station 6, which in turn was siltier than stations B-4, B-1 and B-8. (Station B-7 was un-analyze-able for silt and clay due to large percentages of shell and shell fragments of a crumbly nature).

(4) The median diameter of particles at CAB station 6 was significantly greater than at all other stations, and mean particle size at station B-1 was significantly smaller than at CAB stations 6 or 7.

(5) Total organic carbon was significantly higher at CAB stations 6 and 7 than at station B-1, B-4 or B-8 even though they had a coarser grain size structure. It might have been expected that high organic carbon would correlate with smaller grain size e.g. silts and clays.

### 3. Benthic Faunal Studies

Ranasinghe (1983) has examined faunal data from stations B-1, B-4, B-7 and B-8 in relation to CAB stations 6 and 7 using a variety of mathematical techniques. He concluded that "principal component ordination provided [him with] an objective and ecologically interpretable visualization of community structure, and stepwise multiple discriminant analysis provided an objective method for the comparison of communities." Unfortunately, Ranasinghe did not delineate the constituents of the community in a clear or concise manner.

## C. SYNOPSIS OF DREDGING AND DREDGE MATERIAL DISPOSAL CONCERNS IN ESTUARINE ENVIRONMENTS

### 1. Overview

In order for the lay-person to fully understand the rationale for USACOE sponsored environmental baseline and monitoring contracts, it is necessary to review and document the historical basis for concern about dredging and spoil disposal in an estuarine setting. Taylor and Saloman (1968) reported on some effects of hydraulic dredging in Boca Griga Bay, Florida. They suggested that an estuarine water acre (= one square acre of bay bottom plus overlying water column) had a value of \$988 per hectare (\$400/acre) per year.

We acknowledge that this study deals with bay bottoms to a large extent, but it is important to realize that activities at one place in the estuary may have effects at distant sites within the estuarine complex. It is necessary to think of the living components of the estuary as making 6 up "a living web", which like all of nature's webs is delicate. Figures 2 and 3 are presentations of food-webs that might exist in the Mobile Bay estuarine system.

This presentation discusses five subject areas of concern (Guillory, 1982) relative to the Theodore project (channel development using mechanical and hydraulic dredge devices accompanied by upland and bay bottom disposal). The five topical concerns are as follows:

- Water Quality
- Turbidity and Sedimentation
- Alteration in Hydrographic Regimes
- Saltwater Intrusion
- Physical Alteration in Habitats

We will deal with them in the order listed.

### 2. Water Quality

In order to understand how the disturbance of estuarine sediments can affect water quality, two points need to be established: (a) bay bottom sediments will typically have an oxidized surface layer of varying thickness resting on increasing thicknesses of reduced sediments, e.g. sediments which are devoid of oxygen and thus potentially high in oxygen demand and (b) sediments frequently are repositories for a variety of municipal and industrial wastes including but not limited to exotic organic compounds, oil and grease, Nitrogenous, Phosphorous, and Carbonaceous compounds, and heavy metals such as Cadmium, Chromium or Mercury. The level of any of these items may be extremely low, but, when re-released to the water column, they may recombine to form new compounds and act synergistically with low oxygen saturation levels or elevated temperatures to form an environment unacceptable to the normal estuarine fauna. For example, Pearce (1970) studied a designated "spoil disposal" site in the New York Bight and found contamination by heavy metals, pesticides, and petroleum derivatives. Closer to home, the Federal Water Pollution Control Agency (FWPCA 1970 a,b) found large areas of the bottoms of Perdido Bay (Alabama and Florida) and Escambia Bay, Florida, with sediments so heavily

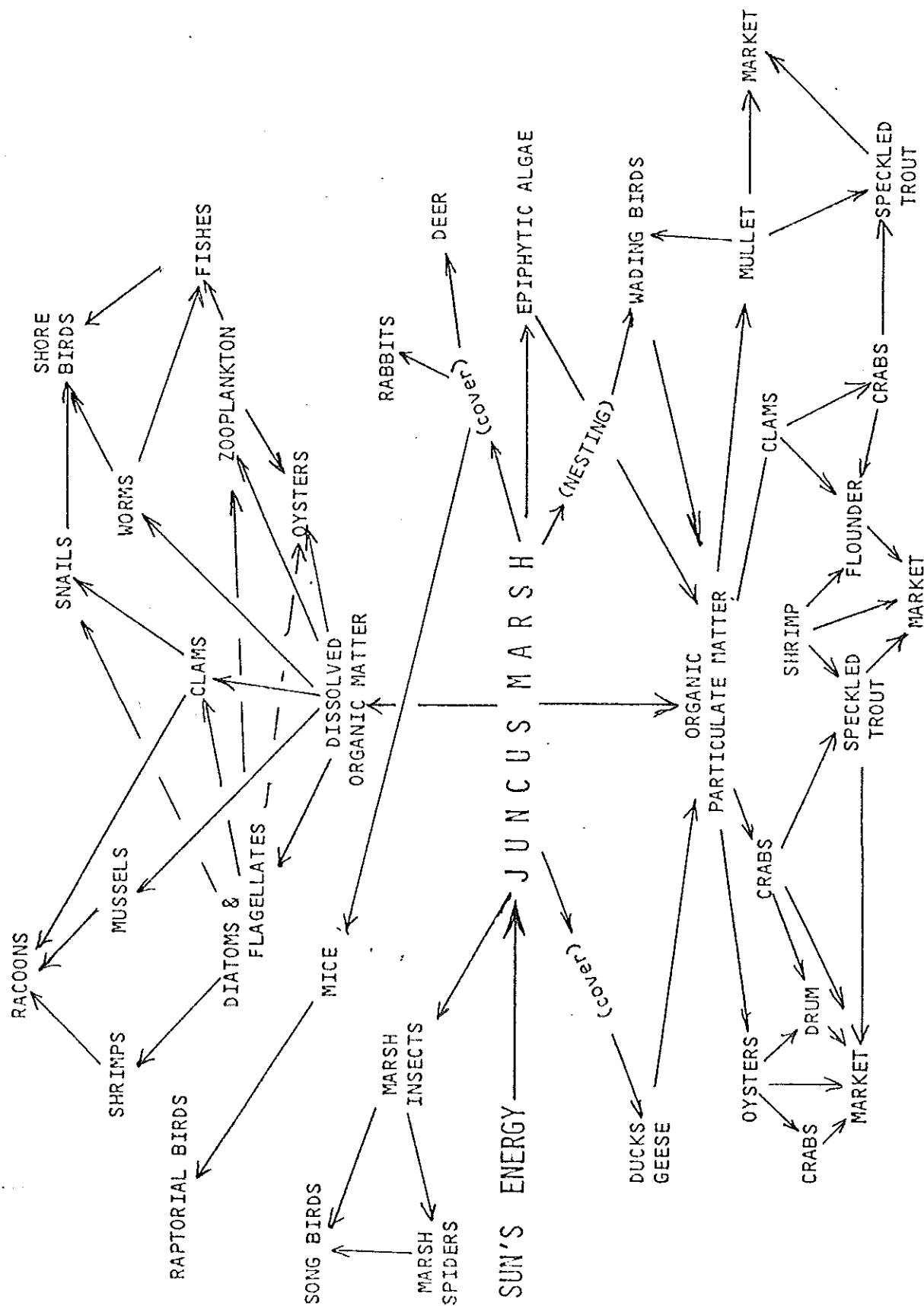


Figure 2. Theoretical Food Web in a Juncus marsh.



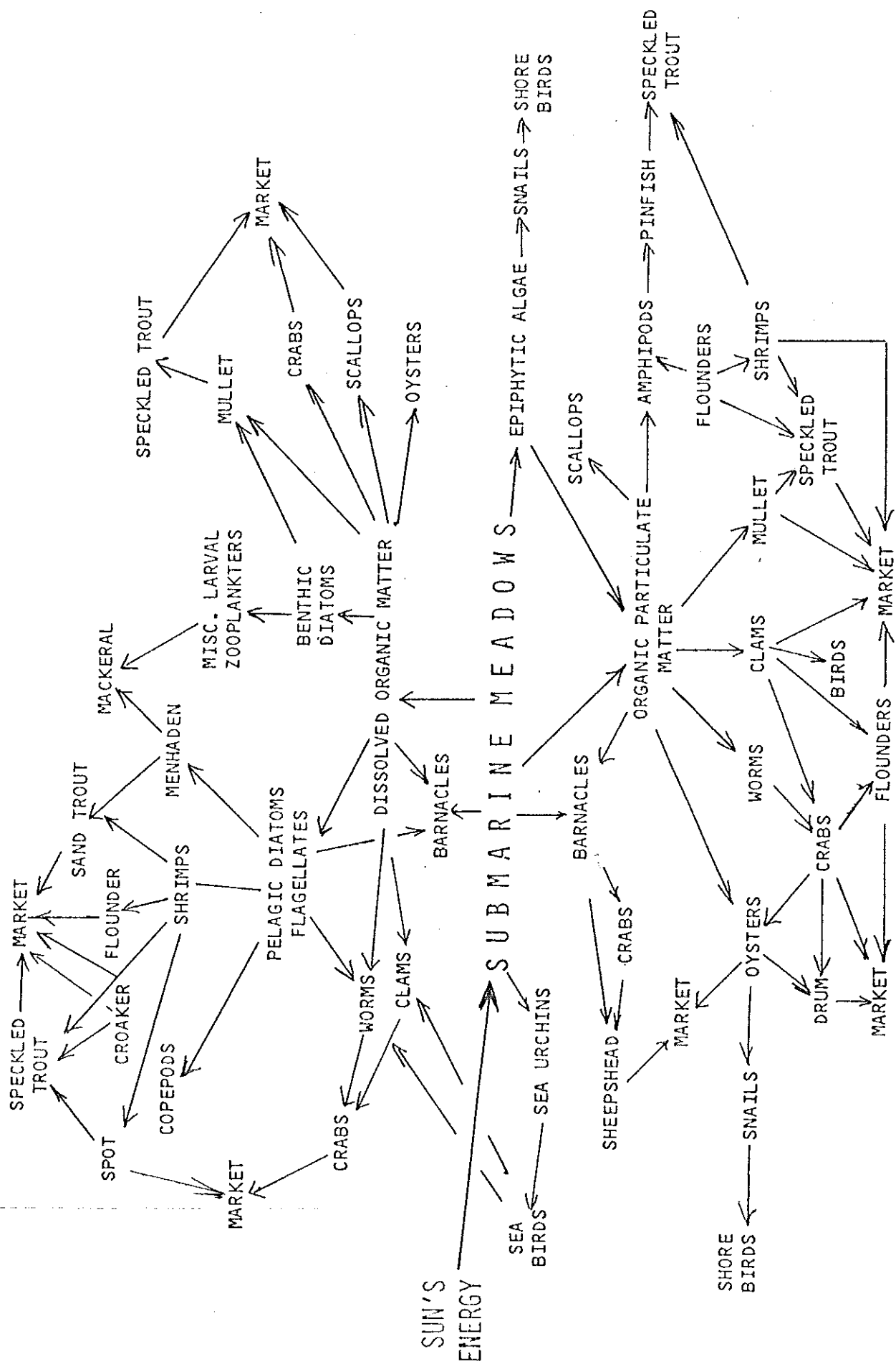


Figure 3. Theoretical Food Web in a Submarine Meadow e.g. Ruppia and Thalassia.

laden with potentially environmentally hazardous wastes of industrial and municipal origin that hydraulic or mechanical dredging, as a means of restoring the environments, was prohibited.

### 3. Turbidity and Sedimentation

Dredging and disposing of dredged material invariably produces the physical effect of discoloring the water and reducing light penetration by increasing the concentration of suspended sediments.

Although it is fairly easy to see how adverse water quality as discussed above could affect marine life, the case against turbidity and sedimentation in the estuarine environment is less easily defined and generally controversial. We can postulate that the combination of increased hydrologic volumes, storm events, and meteorological tides can act synergistically truly to muddy the waters of Mobile Bay. Some of the early investigators of the Gulf Coast's natural history argue that by their very nature the sediments delivered are historically responsible for a relatively constant level of turbidity in their study areas (Gunter, 1969; St. Amant, 1972).

Regardless of that origin, we do know that turbidity and sedimentation do play a role in the quality of estuarine life. For example, phytoplankton are affected by the reduction in quality and quantity of sunlight they need for photosynthesis. Furthermore, Stanet and Patrick (1952) report that suspended sediments can physically trap phytoplankton by flocculation and carry them to the sediments, and Hynes (1970) reports that suspended sediments can mechanically destroy cells (presumably by mechanical abrasion). With zooplankton, the evidence is difficult to interpret because of (a) the nature of zooplankters and (b) the experimental design of some of the studies. Increased sediment loading in the water column may affect zooplankters in the estuarine water column in two ways: (a) by entrapment (Simon and Dyer, 1972) and/or (b) by interference with feeding and respiration (Sullivan and Hancock, 1977). Thin layers of silts or clays will generally inhibit oyster spat attachment in areas where suitable substrates are otherwise available. (Personal Observation; TSH-Western end of Choctawhatchee Bay, Florida).

Adverse effects of resuspended material on seagrasses has been documented by Phillips (1960), Odum (1963), and Taylor and Soloman (1968). Godcharles (1971) and evidence from the Escambia Bay Recovery Study (EPA, 1975) indicate that re-establishment of seagrasses in dredged areas (Godcharles, 1971) and in the estuary in general is remarkably slow.

As for the benthic fauna, be it epifauna or infauna the evidence against increased sediment loading is substantial. There are at least four potential mechanisms:

- (1) High Biological Oxygen Demand (BOD) or Chemical Oxygen Demand (COD) reducing the oxygen available for life processes;

- (2) Interference with respiratory processes in filter feeding and mucous-food trapping organisms (e.g. clams, oysters, and certain polychaete worms);

(3) Direct burial, and

(4) Changing sediment texture.

#### 4. Alteration in Hydrographic Regimes

We can assume that the creation of the dredge material island and the newly created 12 kilometer channel will alter hydrographic patterns and sediment deposition/erosion patterns. Simmons (1965) reports that as a result of shipping channel construction in the Savannah River, there was a subsequent saltwater intrusion and predominantly landward sediment flow. Hargis (1966) noted that the current regime (not necessarily salinity values) was modified in the James River of Virginia subsequent to navigational improvements. May (1973) believes that "spoil islands" in the open bay have acted to reduce tidal exchange and therefore are a contributing mechanism to the extensive oxygen depletion occurring during summer months. Schroeder (1979a) questions the validity of May's conclusion, however, on the grounds that it is an opinion not supported by comprehensive field studies, i.e. there is not sufficient evidence in the article or in archived data files at the Alabama Department of Marine Resources to support such a definitive conclusion. Schroeder and Lysinger (1979) believe, however, that alterations in the bathymetry of the bay in certain localities should not be permitted because and they state "the greatest threat to the hydrographic and circulation regimes of Mobile Bay is alteration of its natural bathymetry".

#### 5. Salt Water Intrusion

We noted saltwater intrusion in the article of Simmons (1965), who reported the case for the Savannah River. Swingle (1971) reported that the construction of the Mobile Bay ship channel resulted in increased saltwater intrusion into the Mobile Delta. The ecological consequences of saltwater intrusion are considered to be complex and unpredictable. Biologically and commercially important species of shellfish such as shrimp and oysters have life cycles, habitat preferences, and predator control closely tied to salinity regimes. Therefore, a lethal increase in salinity, in a given area at a critical time of the shellfish's life cycle, could result in major reductions in catch-per-unit-effort. The channels themselves, however, may be beneficial for fish as the channels provide waters which cool more slowly and allow fish escape routes and refuge. Chapman (1968) reports that the 9 m deep Offats Bayou near Galveston Bay is noted for excellent sport fishing during and following winter storms. Saltwater intrusion can also be expected to affect rooted vegetation. Fresh water macrophytes with no history of saline exposure are likely to be replaced by hardy brackish and salt tolerant species, or not replaced at all, resulting in erosion of the non-vegetated sediment.

#### 6. Physical Alteration in Habitats

Physical alterations of habitat are usually irreversible in estuarine systems. The U.S. Fish and Wildlife Service (1967) have estimated that "dredging and filling" operations have destroyed more than 81,000 hectares (1ha.=2.47 acres) of shallow bay nursery areas in the Gulf and South Atlantic estuaries during the previous 20 years. Not only are organisms

removed, but as we have established (a) benthic organisms may be smothered, (b) the habitat can be made synergistically toxic, and (c) the sediment texture may be altered to such an extent that colonization is inhibited for a long period. Again, depending on the area, the activity and the season, the effects will vary. In some cases, recovery begins immediately with a new fauna (Sherk and Cronin, 1970) but it is also possible that the "new" habitat may be unsuitable for habitation (Taylor and Solomon, 1968).

#### D. INFORMATION REQUIREMENTS OF THIS STUDY

##### 1. Hydrography/Water Quality

We have seen earlier that dredging and dredge material island construction can have adverse effects in certain environments. In this study, we were required by the Waterways Experiment Station to collect salinity and temperature data by automated means for hydrodynamic modeling verification. We also had our own objective of trying to delineate the benthic fauna's hydrographic medium prior to and after channel dredging and dredged material island construction. Hydrographic data collection was designed to meet the modeling needs of the Waterways Experiment Station, and therefore was of limited value to the benthic faunal program.

We addressed one specific hydrographic question to the benthic faunal program: (1) In what way(s) will the hydrographic parameters at stations B-1, B-4 and B-8 be changed relative to "baseline" conditions? For example, will higher salinity bay water "pool" north of the constructed island? Will higher salinity water characteristic of the Mobile Ship Channel intrude up the Theodore Channel and then spill over to the south e.g. will station B-1 or B-8 develop new hydrographic signatures. Will opening the channel into the industrial canal reduce salinities at B-1 or B-8 due to increased run-off from land sources?

We have included water quality concerns in this hydrographic inquiry because the only two water quality parameters prescribed for the study were measurement of dissolved oxygen and turbidity and these two parameters usually correlate well with salinity.

Other questions addressed the fate of the living community:

(1) Will we find "stagnant" pools of water piling up above the newly constructed island?

(2) Will water from the industrial canal cut into the mainland have a low oxygen characteristic that will affect stations B-1 or B-8?

(3) Will oxygen depleted Mobile Ship Channel water intrude into the newly constructed channel and affect B-1 or B-8?

We ask several questions about turbidity:

(1). Would the dredging or the dredge material disposal system significantly elevate the turbidity in the study area?

(2). Would the island, as it took shape, and after it was built erode and significantly elevate turbidity in the study area?

(3). Will the industrial canal provide a significant elevation in turbidity in the study area as a result of erosion and flushing from heavy rains?

## 2. Sediments/Sediment Chemistry

The potential for change in surface sediments as a result of "mud flow" is very great in a project of this magnitude. Furthermore, if sediments are in fact redeposited, we should know their quality with respect to total organic content and their potential as reducing substances, e.g. whether they will exert excessive oxygen demands on the overlying surficial water. This will also dictate how well newly exposed sediments can be, or will be, colonized. Bear in mind certain polychaete worms such as Capitella capitata are valuable indicators of stress-related sediments (This worm thrives in silty sediments with low salinity and high organic carbon levels).

## 3. Benthic Fauna

The heart of our concern is the fauna (both kinds and numbers of animals) which live in the study area both during and after the engineering operation. We wanted to be able to answer these concerns:

(1) How has the composition (both kinds and numbers) of animals which inhabit the sediments of the study area changed with respect to the physical operations adjacent to them.

(2) If changes have occurred, were they in fact related to the operation or were they seasonal changes not related to the project?

(3) Was there any change in the biology of the oyster reef to the south of Station B-1 as seen by spat set count by the Alabama Department of Natural Resources?

(4) If changes occurred in (2) or (3) above were they in fact toward lesser faunal abundance or richness? Changes may have occurred for the better, and the animal community may have benefited from the activity and alterations.

## THE BASELINE STUDY

### A. SYNOPSIS OF BASELINE STUDY UNDER CONTRACT No.DACW01-78-C-0010.

#### 1. Overview

The Dauphin Island Sea Lab (DISL) at Dauphin Island, Alabama conducted a Baseline Data Collection Monitoring Program in the study area from November 1977 through October 1978 under the direction of the Mobile District Corps of Engineers. Final reports of this study involve Volume I - Text and Volume II - Tables and Figures. The Gulf Universities Research Consortium (GURC) of Houston, Texas subcontracted for computer analysis and evaluation of the MESC data. The GURC report consists of a "Final Report" ( 9 pp.), Appendix A: "Computer Output of Physical Data Analyses", and Appendix B: "Computer Displays-Assesment of Natural Variability in Benthic Faunal Data and Supporting Hydrographic and Sediment Data" dated April, 1980.

All of these reports are on file at the Mobile District Office, U.S. Army Corps of Engineers, and at the library of the Dauphin Island Sea Lab, Dauphin Island, Alabama. These documents are non-circulating.

#### 2. Hydrographic Characterization

The systematic evaluation of the physical/chemical data carried out by GURC indicates that a caveat must be recorded: There are serious shortcomings in the data base resulting from (a) the location of the ENDECO 101 salinity/temperature units in relation to the benthic stations and (b) the large amount of failure in the ENDECO 101 salinity mode. It also concludes that the benthic station data taken with the benthic grabs was insufficient for correlative analysis.

Schroeder, (1979b) analyzed the ENDECO 101 temperature data and was able to identify: (a) "Winter", a cold season of  $<12^{\circ}\text{C}$  involving December, 1977 and January, February, 1978; (b) "Spring", a cold to warm transition period where a large temperature increase of  $12-26^{\circ}\text{C}$  occurred between March and May, 1978; (c) "Summer" the hot season  $>26^{\circ}\text{C}$  from June to August, 1978; and (d) "Fall" the cooling period where temperatures dropped from  $>26^{\circ}\text{C}$  down to  $12^{\circ}\text{C}$  in September-October, 1978.

With respect to salinity, Schroeder (1979) concluded that salinity in the area does not follow a seasonal pattern with respect to monthly designation as did temperature, but is very strongly tied to Mobile River discharge. Data analysis reveals that river discharge data recorded by the U.S. Geological Survey for the Mobile River system should be extrapolated back 15 days from the bay observation data in order to allow for a travel time from the guage to the study site. That is, if the date of site sampling was 25 May 1978, for example, river discharge values for volumes on 9-11 May should be averaged and used.

During this study, January 22nd through February 11th, March 3rd through the 25th, and May 5th through June 3rd of 1978 were high river discharge periods (6000, 4000, and 4,500-6,500 m<sup>3</sup> sec<sup>-1</sup> respectively). Conversely lowest river discharge occurred from July 28th through October 28th of 1978 (mean value <500 m<sup>3</sup> sec<sup>-1</sup>).

With respect to dissolved oxygen, only the July 1978 survey revealed bottom waters with values less than 2.0 ppm of dissolved oxygen.

Turbidity and suspended solids (SPM) event monitoring were carried out under three of four scheduled conditions:

- Low wind-high discharge (>6000 m<sup>3</sup> sec<sup>-1</sup>) (Wind <10 kts.).
- Low wind-low discharge (<1000 m<sup>3</sup> sec<sup>-1</sup>) (Wind <10 kts.).
- High wind-low discharge (<1000 m<sup>3</sup> sec<sup>-1</sup>) (Wind >10 kts.).

The severity of high wind-high discharge bay conditions precluded measurements for that combination. For the former, the values recorded for (a) were  $37 \pm 5\%T$  and  $22 \pm 4$  mg/L; (b) were  $60 \pm 14\%T$  and  $6 \pm$  mg/L and (c) were  $29 \pm 5\%T$  and  $44 \pm 20$  mg/L. Crozier (1979) concluded that although the river discharge elevated SPM levels in the study area, wind induced re-suspension was a more significant cause of elevated turbidity, and that no evidence of seasonal trends in SPM other than a summer "calm" with low SPM was present.

### 3. Geological Characterization

The data characterizing sediment particle size was limited to quarterly collections during 1978. Hooks (DISL, 1979) points out that there was a wide range of variability between samples collected in Mobile Bay at the same time and locality, and enumerates three possible causes; and concludes that the sampling regime using a quarterly interval makes precise "baseline" determination of sediment distribution difficult.

The data reduction by GURC (1980) indicates the area can be described as low in sand, moderate in clay, and high in silt. The high levels of silt were prominent in April and July and may correspond to prior peak discharges of the Mobile River system. Coincidentally, the low levels of silt were found in quarters following lower levels of peak discharge.

### 4. Biological Characterization

Just as there are reservations with documentation in the validity of hydrographic and geological characterization, there are reservations and caveats to be exercised for the biological data. Aside from sampling frequency, which was quarterly at stations of critical interest, (a) the number of replicates, (b) the influence of simultaneous mud-shell dredging in the immediate area, and (c) the primitive navigation-station location procedure employed in the study are all sources for introducing error. Another problem encountered in the 1977-78 study was the omission of a data management and recording system by the contractor. As a result, it is very difficult to analyze the reported data in the DISL final report (DISL, 1979). GURC (1980) attempted to deal with this problem by reconstructing quarterly reports, however, the problem is also complicated by the fact that polychaetes were treated separately from "macroinfauna". Under the

current contract, these data were further scrutinized and put into formats presently in use.

Vittor (DISL, 1979) summarizes polychaete abundance, species number, average species diversity, and average species evenness for each of the eight stations surveyed. Those data for Stations B-1, B-4, B-7 and B-8 are found in Table 1A. Although the original table does not note it, Table 41 of the original report indicated that Vittor calculated  $H'$  and  $J'$  using log base 10; these values are not comparable to values we encounter in standard literature where log base 2 is used. Accordingly we have recalculated Vittor's observations using log base 2. These values are reported in Table 1B. Vittor (DISL, 1979) reported that "species diversity did not differ significantly ( $p > 0.10$ ) between stations, but did differ ( $p < 0.01$ ) with respect to season". Vittor (DISL, 1979 p.40) reports that Station B-1 exhibited generally low abundance and diversity while Station B-7 supported a more diverse but less abundant polychaete fauna.

The dominant species of polychaetes were Mediomastus californiensis (=ambiseta), Streblospio benedicti; Neanthes succinea, Parandalia (=Loandalia) americana, Polydora spp., and Paraprionospio pinnata. Vittor (op. cit., p.39) regards Mediomastus and Streblospio as opportunistic species indicative of systems rich in organic matter and marked by periodic oxygen depletion. Vittor suggests that Mediomastus dominates silt-clay habitats while the nereid, Neanthes succinea, was most abundant in silt-shell hash habitats.

Generally speaking the polychaete data suggests a summer seasonal low, with a late fall and early spring bloom of opportunistic species. Vittor (DISL, 1979, p.45) concluded before construction that "the project area is a high-stress benthic environment resulting in low polychaete diversity".



TABLE 1A. Vittor's MESC (1979) Table 39 Data for Stations B-1, B-4, B-7 and B-8.

DATE	STATION	AVERAGE ABUNDANCE PER 0.1 m	NUMBER OF SPECIES PER 0.4 m	AVERAGE NO. OF SPECIES PER 0.1 m	AVERAGE DIVERSITY AS H' <sup>*</sup>	AVERAGE EVENNESS AS J' <sup>*</sup>
Nov. 3-6, 1977	B-1	77**	10	7	0.52	0.69
	B-4	50	10	5	0.22	0.33
	B-7	68**	14**	6**	0.51	0.60
Jan. 27, 1978	B-1	59	12	7**	0.56	0.66
	B-4	98	7	5	0.32	0.47
	B-7	39	12**	8	0.70	0.77
	B-8	48	8	5	0.37	0.55
Mar. 29, 1978	B-1	161	13	10	0.32	0.33
	B-7	469	13	8	0.62	0.71
Apr. 14-19 1978	B-1	8	7	4	0.51	0.90
	B-4	18	12	5	0.42	0.67
	B-7	27**	13	6	0.58	0.74
	B-8	38	9	4	0.36	0.59
May 24, 1978	B-1	36	8**	4	0.23	0.40
	B-7	10	6	2	0.07	0.10
June 27, 1978	B-1	3	2	1	0.05	0.18
	B-7	14	6	4	0.39	0.77
July 15, 1978	B-1	15	4	2	0.32	0.99
	B-4	47	5	3	0.23	0.50
	B-7	6	2	1	0.06	0.19
	B-8	32	2	2	0.07	0.22
Aug. 23, 1978	B-1	2	2	1	0.07	0.22
	B-7	10	6	4	0.43	0.80
Sept. 15, 1978	B-1	0	0	0	0	0
	B-7	23	6	5	0.43	0.67
Oct. 5, 1978	B-1	3****	2*****	4***	0.03	0.06
	B-4	4****	3*****	67***	0.20	0.40
	B-7	6****	5*****	58***	0.26	0.38
	B-8	5****	3*****	45***	0.22	0.45

## Footnote:

\* Calculated using log base 10.

\*\* Apparent transcription error.

\*\*\* These values are actually average abundance per 0.1 m.

\*\*\*\* 3, 4, 6 and 5 respectively are actually number of species per 0.4 m.

\*\*\*\*\* 2, 3, 5 and 3 respectively are actually average no. of species per 0.1 m.

TABLE 1B. Vittor's MESC (1979) Table 39 Data for Stations B-1, B-4, B-7 and B-8, Recalculated Using Log Base 2, and Revising Errors.

DATE	STATION	AVERAGE ABUNDANCE PER 0.1 m	NUMBER OF SPECIES PER 0.4 m	AVERAGE NO. OF SPECIES PER 0.1 m	AVERAGE DIVERSITY AS H'	AVERAGE EVENNESS AS J'
Nov. 3-6, 1977	B-1	75	10	7	1.75	0.53
	B-4	50	10	5	1.49	0.47
	B-7	66	13	7	1.85	0.53
Jan. 27, 1978	B-1	59	12	8	1.92	0.56
	B-4	98	7	5	1.11	0.39
	B-7	39	10	8	2.61	0.79
	B-8	48	8	3	0.71	0.31
Mar. 29, 1978	B-1	161	13	10	1.08	0.29
	B-7	469	13	8	2.07	0.56
Apr. 14-19 1978	B-1	8	7	4	2.08	0.74
	B-4	18	12	5	1.73	0.48
	B-7	26	13	6	2.30	0.62
	B-8	38	9	4	1.33	0.42
May 24, 1978	B-1	36	7	4	0.71	0.25
	B-7	10	6	2	0.88	0.38
June 27, 1978	B-1	3	2	1	0.62	0.62
	B-7	14	6	4	1.48	0.57
July 15, 1978	B-1	15	4	2	0.46	0.23
	B-4	47	5	3	0.83	0.36
	B-7	6	2	1	0.74	0.74
	B-8	32	2	2	0.24	0.24
Aug. 23, 1978	B-1	2	2	1	0.92	0.92
	B-7	10	6	4	1.98	0.77
Sept. 15, 1978	B-1	0	0	0	0.00	0.00
	B-7	23	6	4	1.56	0.60
Oct. 5, 1978	B-1	4	3	2	0.69	0.44
	B-4	67	4	3	1.07	0.53
	B-7	58	6	5	1.04	0.40
	B-8	45	5	3	0.71	0.31

## METHODS AND MATERIALS

### A. OVERVIEW

The study described here involved monthly sampling for 30 consecutive months. The first 18 months have been designated as "construction" conditions. The last 12 months of the study involve "post-construction" monitoring. An overview of the sampling activity is provided in Tables 2A and B. Coordinates for station locations are found in Table 2C. For information purposes, stations B-2, B-3, B-5 and B-6 were occupied during some months of the baseline study but were not designated by the USACOE for occupation during this study.

### B. BAY WATER QUALITY STUDIES

#### 1. Continuous Recording Instruments

ENDECO 101 recording refractometer-thermographs were used to collect continuous salinity and temperature data. These units were deployed in near-bottom positions (0.5 to 1.0 m above the bottom) at stations B-1, B-4, B-7, and B-8 (Figure 1-B). The deployment schedule and relative success of data recovery from these units is displayed in Figure 4.

#### 2. Benthic Stations

Conductivity, temperature, and dissolved oxygen were measured at surface, middle, and bottom depths at each of the benthic macroinfauna stations, B-1, B-4, B-7, and B-8 (Figure 1B) using a Hydrolab Corporation 6-D surveyor water quality instrument. These measurements were taken concurrently with benthic macroinfaunal sampling exercises.

#### 3. Turbidity and Suspended Solids Stations

Turbidity was measured in situ at near-surface (0.5 to 1.0 m below the water surface) and near-bottom (0.5 to 1.0 m above the bottom) positions at stations T-1 through T-12 (Figure 1B). Sampling was carried out monthly using a Montedoro-Whitney TMU-1B Transmissometer/Nephelometer. In addition, a water sample was taken at the near-surface and near-bottom levels at each site by horizontal deployment of a Van Dorn water sampler. These water samples were subjected to both gravimetric and optical analysis. Total suspended solids were determined in the laboratory by 1) Millipore filtration of a known volume, 2) drying, and 3) gravimetric analysis on a precision balance (Accuracy  $\pm 0.01$  mg). Optical measurements were made with a Hach laboratory turbidimeter (Model 2100A).

In concurrence with turbidity measurements, conductivity, temperature, and dissolved oxygen were measured at surface, middle, and bottom depths at each turbidity station (T-1 through T-12) with the Hydrolab 6-D surveyor water quality instrument.

TABLE 2A. Summary of Sampling Activity During Construction and Post-construction Engineering (Benthic Stations).

S T A T I S T I C S	A M C O N S T R U C T I O N	M O N T H	1980												1981												1982																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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MONTH	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN

LEGEND

DO = Dissolved Oxygen  
S = Salinity  
T = Temperature  
P = Profile  
\* = Samples not Analyzed

SED CHAR = Particle size  
TOC = Total Organic Carbon  
TRS = Total Reducing Substance  
INFALNA = Peterson Samples  
Numbers = Numbers of Samples Taken

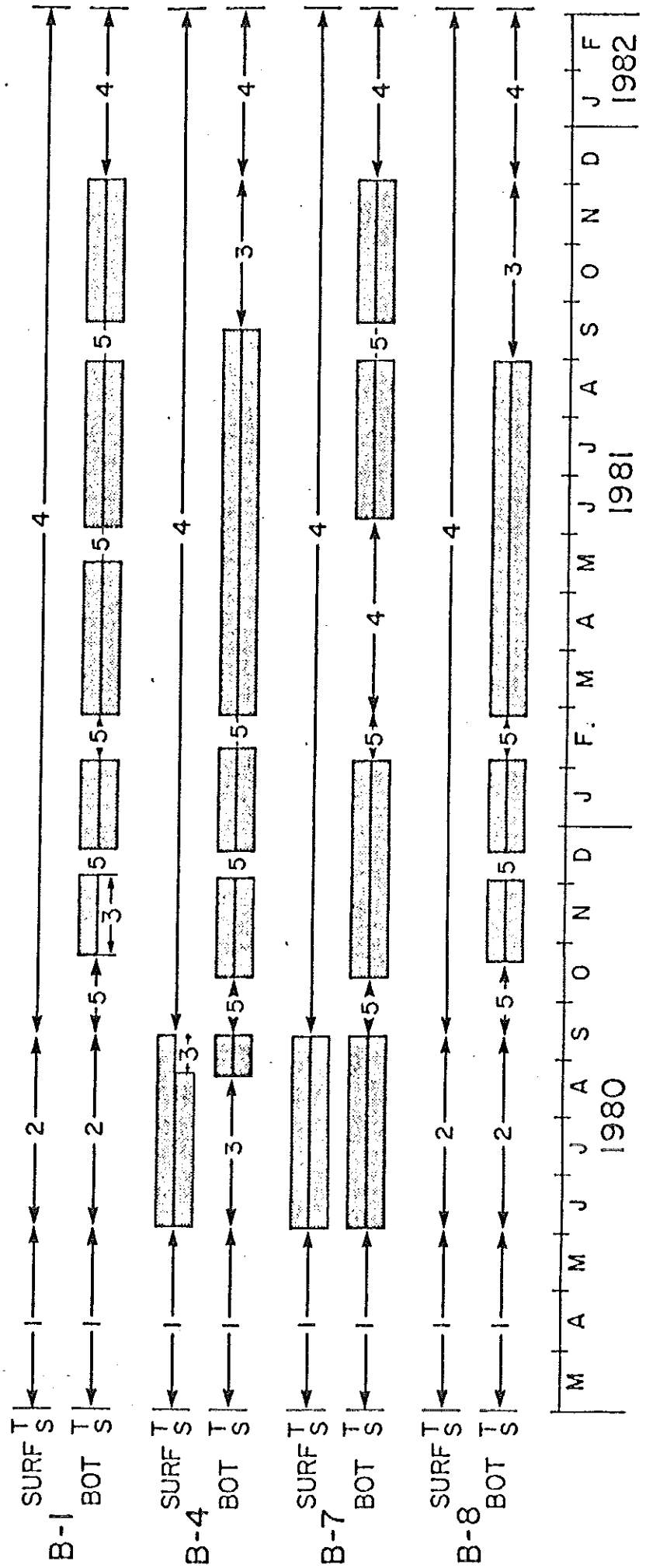


TABLE 2C. Station Locations.

STATION	LORAN C	LATITUDE NORTH	LONGITUDE WEST
T-1	12740.0; 47136.6	30°27.0'	88°05.05'
T-2	12767.3; 47140.0	30°27.65'	88°02.6'
T-3	12793.6; 47142.4	30°28.1'	88°00.05'
T-4	12821.8; 47145.8	30°28.65'	87°57.35'
T-5	12811.4; 47154.0	30°30.95'	87°58.6'
T-6	12785.0; 47157.7	30°32.1'	87°58.9'
T-7	12763.6; 47166.7	30°34.7'	88°03.5'
T-8	12765.0; 47155.6	30°31.85'	88°04.0'
T-9	12748.0; 47147.2	30°29.7'	88°04.5'
T-10	12760.1; 47142.8	30°28.45'	88°03.3'
T-11	12799.0; 47147.7	30°29.2'	87°59.35'
T-12	12774.7; 47156.1	39°31.85'	88°02.1'
B-1	12767.3; 47140.0	30°27.65'	88°02.6'
B-4	12764.2; 47156.5	30°32.05	88°03.05'
B-7	12802.4; 47140.9	30°27.55'	87°59.2'
B-8	12748.0; 47147.2	30°29.7'	88°04.5'

Figure 4. Chronology of Endeco 101 Refractometer-Thermograph Deployment (1980-1982).

SURF = Surface  
 BOT = Bottom  
 T = Temperature  
 S = Salinity  
 [Shaded Box] = Usable data obtained.  
 1 = Instruments not deployed during annual river flooding period.  
 2 = Instruments lost.  
 3 = Instrument malfunction.  
 4 = Instruments not available for deployment.  
 5 = Service period.



### C. BENTHIC MACROINFAUNA

At each of four stations (B-1, B-4, B-7, and B-8) seven replicate samples were obtained with a 0.1 m<sup>2</sup> Peterson Grab. Each sample was placed intact in a clean cloth bag, and the bag was placed in a plastic bucket for transfer to the laboratory. Within 24 hours of collection, all samples were individually and carefully sieved through a 500 micron screen to remove sediment particles < 500 microns. All fauna retained by the 500 micron screen were preserved in 5-10% formalin and stained with rose bengal. After at least 24 hours, the sample was rough sorted into the following groups: molluscs, polychaetes, crustacea, and other. "Other" was further broken down into Echinoderms, Insects, Coelenterates, and Nemertea (Rhynchocoels) when possible. All fauna so collected were then identified to the lowest possible identification level (LPIL).

Because of the paucity of material in each replicate, and the low sensitivity of the precision balance used (Accuracy  $\pm$  0.01 mg), we were unable to determine wet weight at sample collection time. Alternatively, we identified the dominant fifteen polychaete species, and using counted aliquots of these species we determined individual wet and dry weight biomass values, which were then factored back to station replicates. We did not attempt biomass measurements of mollusca or crustacea because of inherent errors introduced by shells and carapaces.

### D. SEDIMENTOLOGY

On each monthly cruise, two of the seven replicates of bottom sediments were subsampled for analysis of total organic carbon (TOC), total reducing substances (TRS), and sediment particle size (SPS).

#### 1. Total Organic Carbon (TOC)

Approximately 100 grams of sediment from the top five cm of two samples at each site were transferred to two jars using a teflon coated spatula. An aluminum foil lined cap was then screwed on each jar and the jar was sealed with vinyl tape. Samples were stored on ice and then frozen until analyzed.

#### 2. Total Reducing Substances (TRS)

Approximately 100 grams of sediment from various parts of each of two grabs were transferred as described above to 4 oz. screw capped jars. The jar and its aluminum foil cap were then placed in an inverted plastic bag and the bag purged with nitrogen gas to displace air. The cap was screwed on the jar in the inert nitrogen atmosphere. The jar was then sealed with tape and stored as described above.

Laboratory analysis of TOC and TRS was carried out by Vester J. Thompson, Inc. in accordance with the sub-contractor's proposal.

#### 3. Sediment Particle Size (SPS)

A 4 oz. jar was filled with sediment from a cross section of each of two grabs. The jar was capped, sealed and transported for shoreside analysis according to the Standard Method for Particle Size Analysis of



Soils, ASTM, D-422-63 (reapproved 1972) in the laboratory of Dr. Wayne Isphording in accordance with the sub-contractor's proposal.

#### E. WEATHER DATA

Daily weather data were collected and reported using the format described by Schroeder, Horton, and Lutz (1980). (See Figure 5 with explanatory notes).

#### F. STREAM FLOW

Mobile River System discharges were computed using U.S.G.S. Surface Water Records (Alabama) of the flows of the Tombigbee River at Coffeetown (02429761), Alabama, and the Alabama River at Claiborne (02429500), Alabama. To calculate the discharge of the system, the flows at these two gauging stations were added together and multiplied by 1.07, to account for additional downstream drainage areas. Because of the distance between Mobile Bay and these gauging stations a lag period for transit time of five to nine days was required when trying to predict the flow into Mobile Bay.

#### G. DATA MANAGEMENT

Data collected by MESC was entered into the data base using an IBM 3774-P2 remote batch communication terminal and was stored locally on magnetic diskettes. Individual diskettes were used for different data types to insure the fidelity of the data base and to allow for flexible archiving procedures. Data were written onto the diskette in Extended Binary Coded Decimal Interchange Code (EBCDIC) in the Basic Exchange Diskette format. Editing of the data was accomplished locally using the 3774 terminal. Listings of the raw data can also be obtained locally.

Once the diskettes were filled with data, they were transmitted to a central data processor for analysis. Several remote processing centers (hosts) are accessible by the DISL terminal: the University of Alabama in Birmingham (RUST Computer Center), the University of Florida (Northeast Regional Data Center), the University of South Alabama, and the Boeing Computer Service. High speed output can be routed to either the DISL office or the Mobile Districts' ADP center (presently from UF and Boeing only). All processing centers use IBM's operating system OS/MVS JES2 or CP/CMS. In addition to the remote batch facilities, programs and/or data can be entered and retrieved via low speed ASCII terminals in a time share mode. These facilities allow for more efficient program editing via CRT displays and retrieval of hardcopy output of graphics displays.

A flow diagram of the use of the the data management system is presented in Figure 6. Data were transmitted to the host center and stored on an operating system (OS) disk file. Applications programs were then transmitted which read the data from the disk (host) system, performed the necessary analyses, and routed the output to the MESC/RJE retrieval. Once the analyses were completed, the data were scratched from the host system to achieve maximum economy. All data were archived on nine track tapes in both labeled and non-labeled formats.

# METEOROLOGICAL DATA COLUMN EXPLANATIONS

The Dauphin Island Meteorological Station is located on the east end of Dauphin Island, Alabama at Latitude 30° 14' 57" N and Longitude 88° 04' 38" W. The elevation is approximately 2.45 m above mean sea level.

## Column

- (1) Date.
- (2) Daily maximum air temperature (°C), based on 24 hourly readings from 0100 to 0000. \* = Extremes for the month: first occurrence.
- (3) Daily minimum air temperature (°C), based on 24 hourly readings from 0100 to 0000. \* = Extremes for the month: first occurrence.
- (4) Daily mean air temperature (°C), based on 12 hourly readings from 0100 to 0000.
- (5) Water temperature (°C), observed twice daily at specified times (0800 and 1300).
- (6) Type of weather, weather conditions observed, usually during regular observation periods (0800 and 1300). A blank in this column indicates that none of the weather conditions listed below were observed.

Code	Weather Condition	Code	Weather Condition
1	Water Spout	9	Hail
2	Squall	10	Snow Pellets
3	Thunder Storm	11	Snow
4	Freezing Rain	12	Rain
5	Freezing Drizzle	13	Drizzle
6	Fog	14	Haze
7	Snow Shower	15	Smoke
8	Rain Shower		

- (7) Precipitation (mm), measured once daily at 0800. Precipitation may have actually occurred the preceeding day after the 0800 reading (check column 6). T = Trace Amount.
- (8) Pressure (millibars) 24 hourly readings taken and averaged.
- (9) Sky Cover, observed daily at two specified observation periods (0800 and 1300). 0 to 20% = Clear (C); 30 to 70% = Partly Cloudy (PC); 80 to 100% = Cloudy (CY); OBS = Visibility Obstructed.
- (10) Wind direction and speed (° mag/knots), observed daily at two specified observation periods (0800 and 1300). Variable = Var.

Figure 5. Meteorological Data Column Explanations/Daily Weather Observation Form.

## DAILY WEATHER OBSERVATIONS

DATE

LOCATION

[illegible]

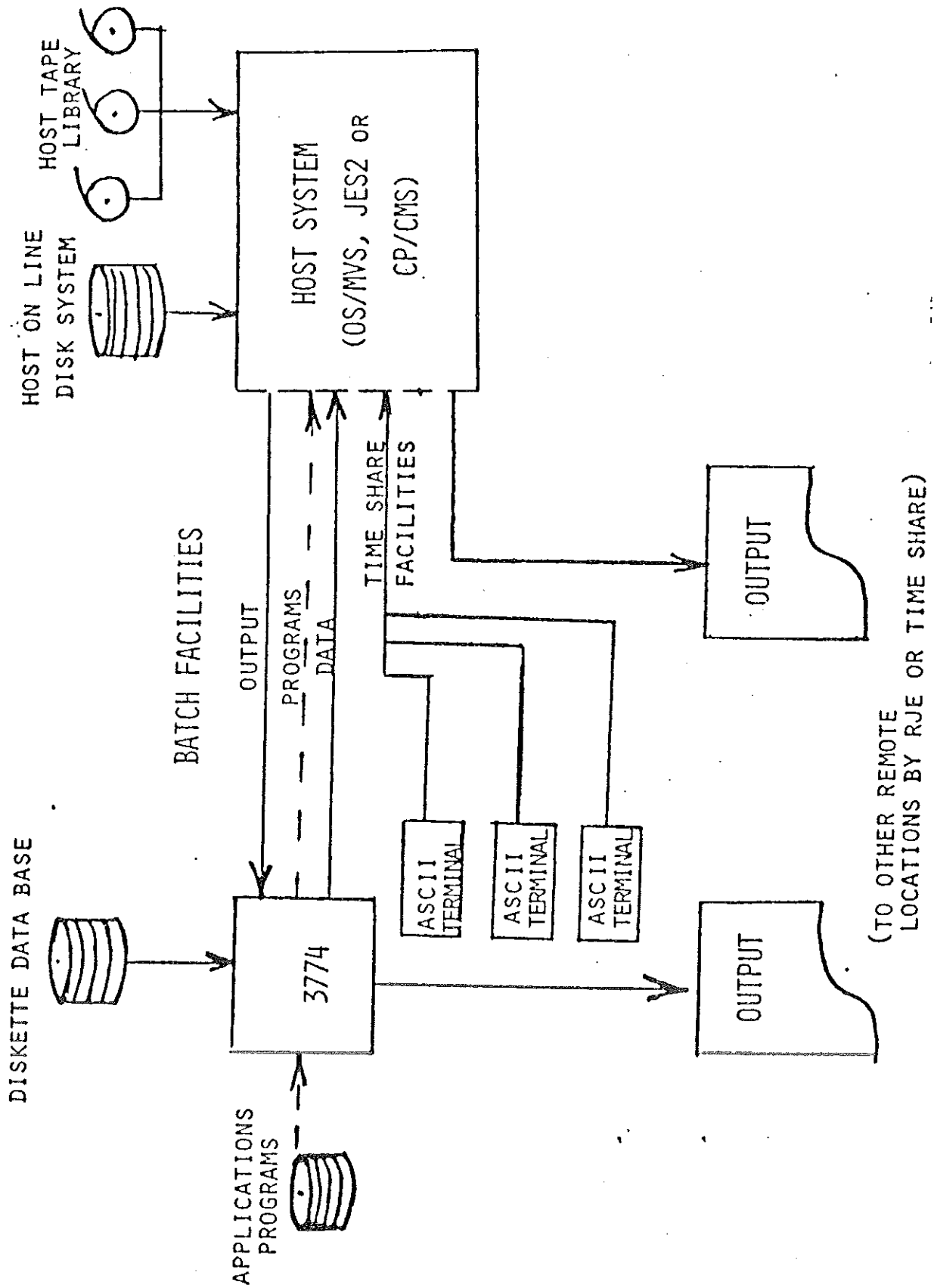


Figure 6. Flow Diagram Illustrating Information Flow Through the Data Management System.

## RESULTS AND DISCUSSION

### A. HYDROGRAPHY

#### 1. Overview

In order to best understand the results and discussion, the reader should review section D.2. of the Introduction (Specific Requirements by Category; pp. 9-10 deal with hydrography). Using these as guidelines, the author (Dr. W. W. Schroeder) has developed a scenario that specifically addresses the impact of island construction on hydrography at stations B-1, B-4, B-7 and B-8 in middle Mobile Bay.

#### 2. Continuously Recorded Data

Continuously recorded data were obtained on U.S. Army Corps of Engineers (Mobile District) owned ENDECO 101 recording refractometer-thermographs. These data were collected for the purposes of this study and in support of the modeling efforts at the U.S. Army Engineer Waterways Experiment Station on a deployment site and time schedule provided by the contractor. All of the collected data are available in computerized format, and were provided to the contractor on schedule.

#### 3. Monthly Collected Data

Monthly hydrographic and water quality measurements were taken at both Benthic (B-1, B-4, B-7 and B-8) and Turbidity and Suspended Solids (T-1 through T-12) stations (Fig. 1B). These measurements consisted of temperature, salinity and dissolved oxygen at both the "B" and "T" stations and gravimetric and optical measurements of suspended solids at the "T" stations.

The most complete picture of the monthly hydrographic conditions is produced by combining the measurements taken at the "B" and "T" stations. Although both surface and bottom observations were taken and are reported herein, emphasis will be placed on the analysis and discussion of the bottom observations in support of the benthic biology.

Table 3 presents surface and bottom monthly means of temperature, salinity and dissolved oxygen calculated from the combined "B" and "T" station data sets and monthly means of total solids and turbidity from the "T" stations.

##### a. Temperature:

The mean monthly temperature values (Table 3) for the 12 month post-construction period of September, 1981 to August, 1982 indicate that the annual thermal regime structure, for both the surface and bottom waters, was:

- (1) A four month cooling season of September, October, November and December;

TABLE 3. Surface (Sur.) and Bottom (Bot.) Monthly Means of Temperature, Salinity and Dissolved Oxygen Calculated from the Combined "B" and "T" Station Data Sets and Monthly Means of Total Solids and Turbidity Calculated from the "T" Station Data Set.

	TEMPERATURE (°C)		SALINITY (PPT)		DISSOLVED OXYGEN (% SATURATION)		TOTAL SOLIDS (Mg/l)		TURBIDITY (NTU/% TRANS)	
	SUR.	BOT.	SUR.	BOT.	SUR.	BOT.	SUR.	BOT.	SUR.	BOT.
<u>1977</u>										
November	19.6	20.4	4.1	10.0	101	80	8	10	ND/43	ND/50
December	ND	ND	ND	ND	ND	ND	ND	ND	ND/ND	ND/ND
<u>1978</u>										
January	6.7	6.8	1.8	3.7	92	96	44	29	ND/29	ND/29
February	ND	ND	ND	ND	ND	ND	ND	ND	ND/ND	ND/ND
March	16.7	15.5	2.0	4.8	ND	ND	15	15	ND/36	ND/38
April	22.4	21.6	3.9	4.9	97	95	8	13	ND/44	ND/49
May	26.0	24.8	<1.0	<1.0	96	64	22	26	ND/37	ND/32
June	30.2	28.4	4.2	10.4	116	22	ND	ND	ND/ND	ND/ND
July	31.2	30.3	8.2	12.7	115	21	6	7	6/60	6/50
August	30.5	29.7	7.5	13.3	97	47	4	10	3/68	5/61
September	28.1	28.3	12.9	14.7	101	81	ND	ND	ND/ND	ND/ND
October	26.0	25.5	10.9	15.7	121	82	3	3	3/ND	3/ND
<u>1980</u>										
March	17.0	15.3	2.2	9.4	102	75	17	15	16/ND	12/ND
April	18.5	17.9	<1.0	<1.0	81	78	45	51	59/7	61/7
May	24.4	24.3	2.3	2.4	84	84	26	24	29/30	29/26
June	26.5	25.7	1.7	3.2	86	73	15	20	16/53	19/46
July	31.1	29.1	6.3	12.6	72	36	6	12	5/98	10/85
August	31.0	30.5	9.3	12.3	61	40	3	8	2/73	3/65
September	29.5	29.4	12.7	18.8	69	52	3	5	2/78	3/77
October	22.1	22.5	9.1	15.9	93	74	4	8	3/79	5/66
November	18.8	18.0	6.8	16.4	91	77	7	7	6/65	5/66
December	14.5	14.2	6.1	13.9	94	89	6	5	8/67	5/76
<u>1981</u>										
January	11.1	10.1	15.0	22.7	108	78	2	3	2/78	3/78
February	12.7	11.7	5.6	10.4	93	80	27	21	28/28	20/53
March	15.0	14.8	8.8	11.8	107	97	17	15	18/50	14/57
April	24.1	23.1	1.7	3.1	70	67	26	32	32/24	34/23
May	22.6	22.5	10.7	12.1	92	83	7	8	7/67	8/53
June	26.3	25.8	9.8	10.2	74	70	13	11	11/46	10/39
July	27.2	26.8	15.6	16.1	51	44	10	14	7/45	8/41
August	31.6	31.3	15.0	18.0	73	32	4	5	3/48	5/47
September	24.0	24.0	17.6	19.3	107	96	8	14	6/63	9/51
October	24.6	24.2	19.4	19.7	105	87	5	8	4/66	5/46
November	19.3	18.9	19.6	20.5	101	90	5	7	5/74	6/61
December	19.6	19.4	20.6	22.3	127	127	6	10	5/67	7/62
<u>1982</u>										
January	12.8	12.8	8.3	10.8	101	107	14	14	11/47	12/36
February	13.2	12.5	1.4	2.8	72	70	18	17	36/20	31/23
March	13.5	13.5	2.7	9.0	93	89	12	10	21/39	12/53
April	23.4	23.3	4.8	5.0	89	86	20	25	19/ND	22/ND
May	26.5	25.9	2.3	6.8	68	69	10	9	10/57	9/58
June	28.3	27.6	5.5	6.5	65	63	10	13	9/52	11/49
July	28.8	28.1	8.9	15.8	69	37	4	7	4/67	5/65
August	30.4	30.1	9.3	14.7	63	26	6	7	5/65	5/63

(2) A three month cold season of January, February and March;

(3) A two month warming season of April and May; and

(4) A three month hot season of June, July and August.

When this thermal regime structure is compared to both the 12 month baseline period of November, 1977 to October 1978 and the 18 months construction period of March, 1980 to August, 1981 the following relationships are observed:

(1) The warming seasons of the baseline (March, April and May, 1978) and construction (March, April, May and June, 1980 and March, April, May and June, 1981) periods were longer, by one to two months, than during the post-construction period;

(2) The hot seasons of the baseline (June, July and August, 1978) and construction (July, August and September, 1980 and June, July and August, 1981) periods were the same length, three months, or one month shorter than during the post-construction period;

(3) The cooling season of the construction period (October and November, 1980) was shorter, by one month, than during the post-construction period, no comparison is made with the baseline period because of the incomplete sampling schedule; and

(4) The cold season of the construction period (December, 1980 and January and February, 1981) was the same length, three months, as during the post-construction period, no comparison is made with the baseline period because of the incomplete sampling schedule.

Although there are differences in both the numbers of months and the specific individual months that make up the seasonal structure of the thermal regime during these three time periods, the overall general thermal regime structures produce a remarkably uniform annual pattern. Figure 7 presents the average monthly bottom temperature values from combined "B" and "T" station data sets. The monthly symbols are different for each of the years in which data were collected, and these monthly values are connected chronologically by different types of lines representing the three sampling periods of (a) baseline, (b) construction, and (c) post-construction. A close examination of Figure 7 leads to the following observations:

(1) A more severe cold season was experienced during the baseline period wherein the average bottom temperature was  $6.8^{\circ}\text{C}$  in January, 1978;

(2) The mildest cold season occurred during the post-construction period when average bottom temperatures did not go below  $12.0^{\circ}\text{C}$ ;

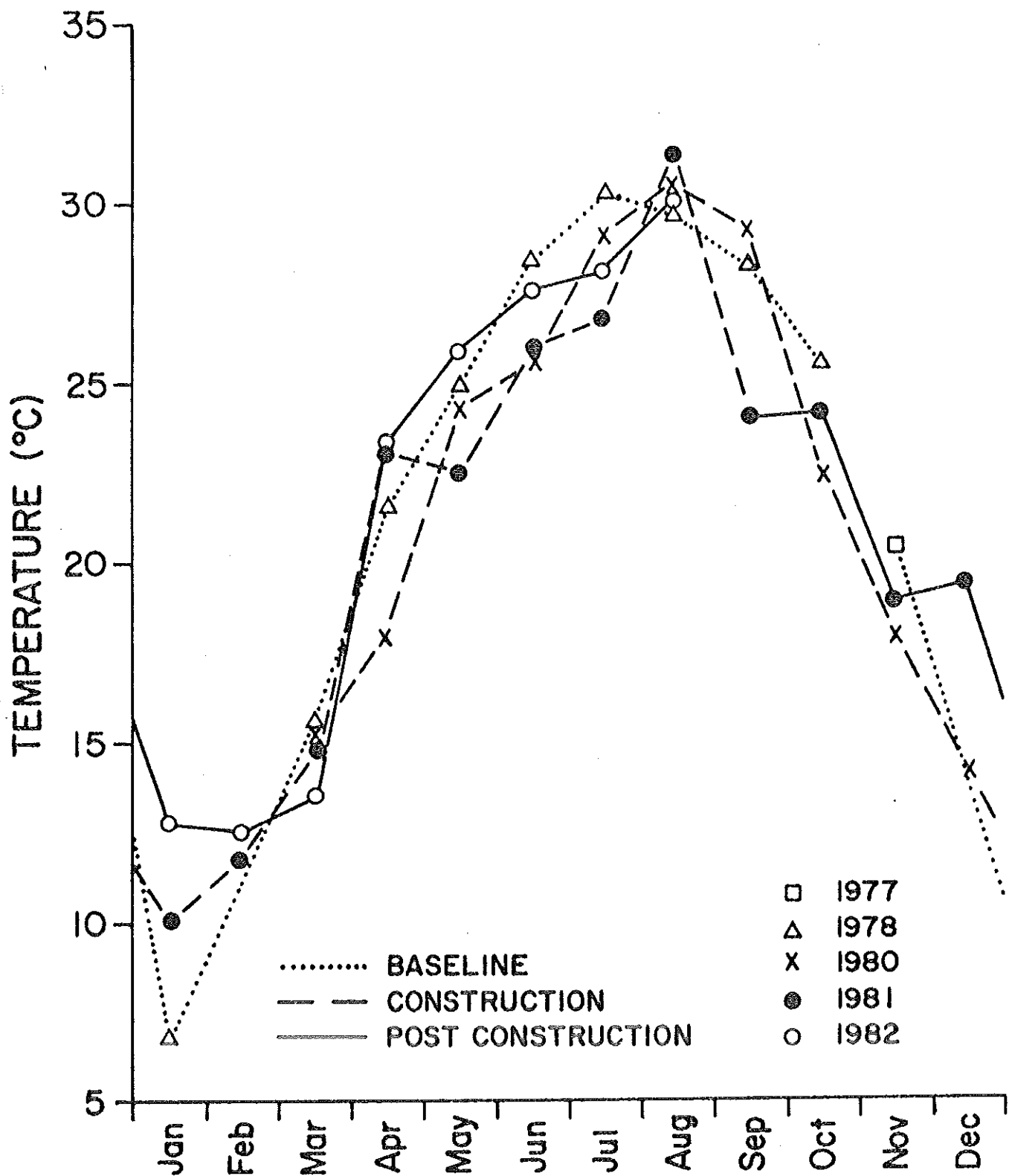


Figure 7. Mean Monthly Bottom Temperature Values , in °C, Calculated from the Combined "B" and "T" Station Data Sets.



(3) Generally the hot season patterns were uniform in temperature and in time of occurrence ( $\pm$  one month), the one possible exception is the 1981 construction period hot season when average bottom temperatures were above 27.0 °C only in the month of August, at which time the highest recorded average bottom temperature (31.3°C) for the entire data collection period was recorded.

(4) Both the warming and cooling seasons had similarly consistent patterns over the entire study period.

Analysis of variance (ANOVA) calculations (Table 4) show that there is a very highly significant difference between monthly temperatures in both the surface ( $p = 0.0001$ ) and bottom ( $p = 0.0001$ ) regimes. The major contributing factor to the month-to-month variability that leads to these "highly significant" differences is the response of the water to the range of air temperatures (-5.0 to 33.3 °C), over the study periods. ANOVA calculations (Table 4) also show that on an individual monthly basis there are very highly significant differences between stations in both the surface ( $p = 0.001$ ) and bottom ( $p = 0.0021$ ) regimes. However, an examination of the absolute temperature values at both the "B" and "T" stations show that the monthly average differences between surface stations was 1.3 °C (absolute range 0.2 to 2.7 °C) and between bottom stations was 1.4 °C (absolute range 0.2 to 3.5 °C). The larger absolute differences (e.g. those greater than 1.5°C) can be accounted for by the following natural processes:

(1) In the surface regime, daily fluctuations resulting from the diel (24 hour) heating-cooling cycle and the time that is required (three to five hours) to complete the monthly field sampling; and

(2) In the bottom regime, the simultaneous presence, in the study area, of different water masses that have various temperature and salinity combinations.

Although there are differences between some of the individual values of the three study periods, none of the study periods are shown to be significantly different from the other two study periods when the monthly means from all three periods are subjected to a Duncan's Multiple Range Test. Therefore, based on the data presented in this report, it is concluded that the basic characteristics of the thermal regime were not altered by the construction activities.

#### b. Salinity:

The mean monthly salinity values (Table 3) for the 12 month post-construction period of September, 1981 to August, 1982 indicate that both the surface and bottom regimes were:

(1) generally under the influence of low (1.0 to 7.9 ppt) salinity waters (salinity grouping will follow the convention set forth by Schroeder, 1979) during the months of February, 1982 (surface = 1.4 ppt, bottom = 2.6 ppt), March, 1982 (surface = 2.7 ppt, bottom = 9.0 ppt), April, 1982 (surface = 4.8 ppt, bottom =

5.0 ppt), May, 1982 (surface = 2.3 ppt, bottom = 6.6) and June, 1982 (surface = 5.5 ppt, bottom = 6.5 ppt);

(2) generally under the influence of moderately-low (8.0 to 14.9 ppt) salinity waters during the months of January, 1982 (surface = 8.3 ppt, bottom = 10.6 ppt), July, 1982 (surface = 8.9 ppt, bottom = 15.8 ppt) and August, 1982 (surface = 9.3 ppt, bottom = 14.7 ppt); and

(3) generally under the influence of moderate (15.0 to 21.9 ppt) salinity waters during the month of September, 1981 (surface = 17.6 ppt, bottom = 19.3 ppt), October, 1981 (surface = 19.4 ppt, bottom = 19.7 ppt), November, 1981 (surface = 19.6 ppt, bottom = 20.5 ppt) and December, 1981 (surface = 20.6, bottom = 22.3 ppt).

When the mean monthly salinity values for the surface and bottom regimes (Table 3) of both the 12 month baseline period of November, 1977 to October, 1978 and the 18 month construction period of March, 1980 to August, 1981 are characterized using the salinity groups of Schroeder, 1979 the following observations can be made:

(1) the study area was under the influence of river water (salinities less than 1.0 ppt) during the baseline month of May and the construction month of April, 1980;

(2) low (1.0 to 7.9 ppt) salinity waters generally occurred during the baseline months of January, 1978 (surface = 1.8 ppt, bottom = 3.7 ppt), March, 1978 (surface = 2.0 ppt, bottom = 4.8 ppt), and April, 1978 (surface = 3.9 ppt, bottom = 4.9 ppt) and during the construction months of March, 1980 (surface = 2.2 ppt, bottom = 9.4 ppt), May, 1980 (surface = 2.3 ppt, bottom = 2.4 ppt), June, 1980 (surface = 1.7 ppt, bottom = 3.2 ppt) and April, 1981 (surface = 1.7 ppt, bottom = 3.1 ppt);

(3) mixed low (1.0 to 7.9 ppt) and moderately low (8.0 to 14.9 ppt) salinity waters occurred during the baseline months of November, 1977 (surface = 4.1 ppt, bottom = 10.0 ppt) and June, 1978 (surface = 4.2 ppt, bottom = 10.4 ppt) and during the construction month of February, 1981 (surface = 5.6 ppt, bottom = 10.4 ppt);

(4) moderately-low (8.0 to 14.9 ppt) salinity waters generally occurred during the baseline months of July, 1978 (surface = 8.2 ppt, bottom = 12.7 ppt), August, 1978 (surface = 7.5 ppt, bottom = 13.3 ppt), September, 1978 (surface = 12.9 ppt, bottom = 14.7 ppt) and October, 1978 (surface = 10.9 ppt, bottom = 15.7 ppt) and during the construction months of July, 1980 (surface = 6.3 ppt, bottom = 12.6 ppt), August, 1980 (surface = 9.3 ppt, bottom = 12.3 ppt), October, 1980 (surface = 9.1 ppt, bottom = 15.9 ppt), November, 1980 (surface = 6.8 ppt, bottom = 16.4 ppt), December, 1980 (surface = 6.1 ppt, bottom = 13.9 ppt), March, 1981 (surface = 8.8 ppt, bottom = 11.8 ppt), May, 1981 (surface = 10.7 ppt, bottom = 12.1 ppt) and June, 1981 (surface = 9.8 ppt, bottom = 10.2 ppt); and

(5) Moderate (15.0 to 21.9 ppt) salinity waters generally occurred only in the baseline month of October, 1978 in the bottom regime (15.7 ppt) and during the construction months of September, 1980 (surface = 12.7 ppt, bottom = 18.8 ppt), January, 1981 (surface = 15.0 ppt, bottom = 22.7 ppt), July, 1981 (surface = 15.6 ppt, bottom = 16.1 ppt) and August, 1981 (surface = 15.0 ppt, bottom = 18.0 ppt).

At first glance a comparison of the categorical breakdown of the salinity regimes observed during the three study periods (baseline, construction and post-construction) does not result in a very uniform pattern. This is particularly true of the bottom regime, and because of the bottom regime's importance relative to benthic biology, the following discussion will be centered around it. In order to determine whether or not there were any similarities in the bottom regimes of the three study periods, the mean monthly values from the combined "B" and "T" station data sets have been plotted in Figure 8. The monthly symbols are different for each of the years in which data were collected, and these monthly values are connected chronologically by different types of lines representing the three study periods. Year-to-year and study period-to-study period differences can plainly be seen, however, a rather consistent annual pattern is apparent.

The obvious differences and similarities that can be seen in Figure 8 are:

(1) The baseline period has the lowest overall bottom salinity regime conditions;

(2) The post-construction period has the highest overall bottom salinity regime conditions (however, at times, portions of the construction period were very high);

(3) The lowest individual monthly averages (less than 1.0 ppt) for the bottom regime occurred during both the baseline period (May, 1978) and the construction period (April, 1980);

(4) The highest individual monthly averages for the bottom regime occurred during both the construction period (22.7 ppt, January 1981) and post-construction period (22.3 ppt, December, 1981); and

(5) Overall there is a strong similarity in the annual cyclic nature of the bottom regimes (i.e. the lowest mean monthly salinities, less than 7.9 ppt, generally occurred in April, May and June but as early as January and is the highest mean monthly salinities, greater than 15.0 ppt, generally occurred in September, October and November but as early as July and as late as December and January.

ANOVA calculations (Table 4) show that there is a very highly significant difference between monthly salinity values in both the surface ( $p = 0.0001$ ) and bottom ( $p = 0.0001$ ) regimes. The major contributing factor to the month-to-month variability that leads to these "very highly

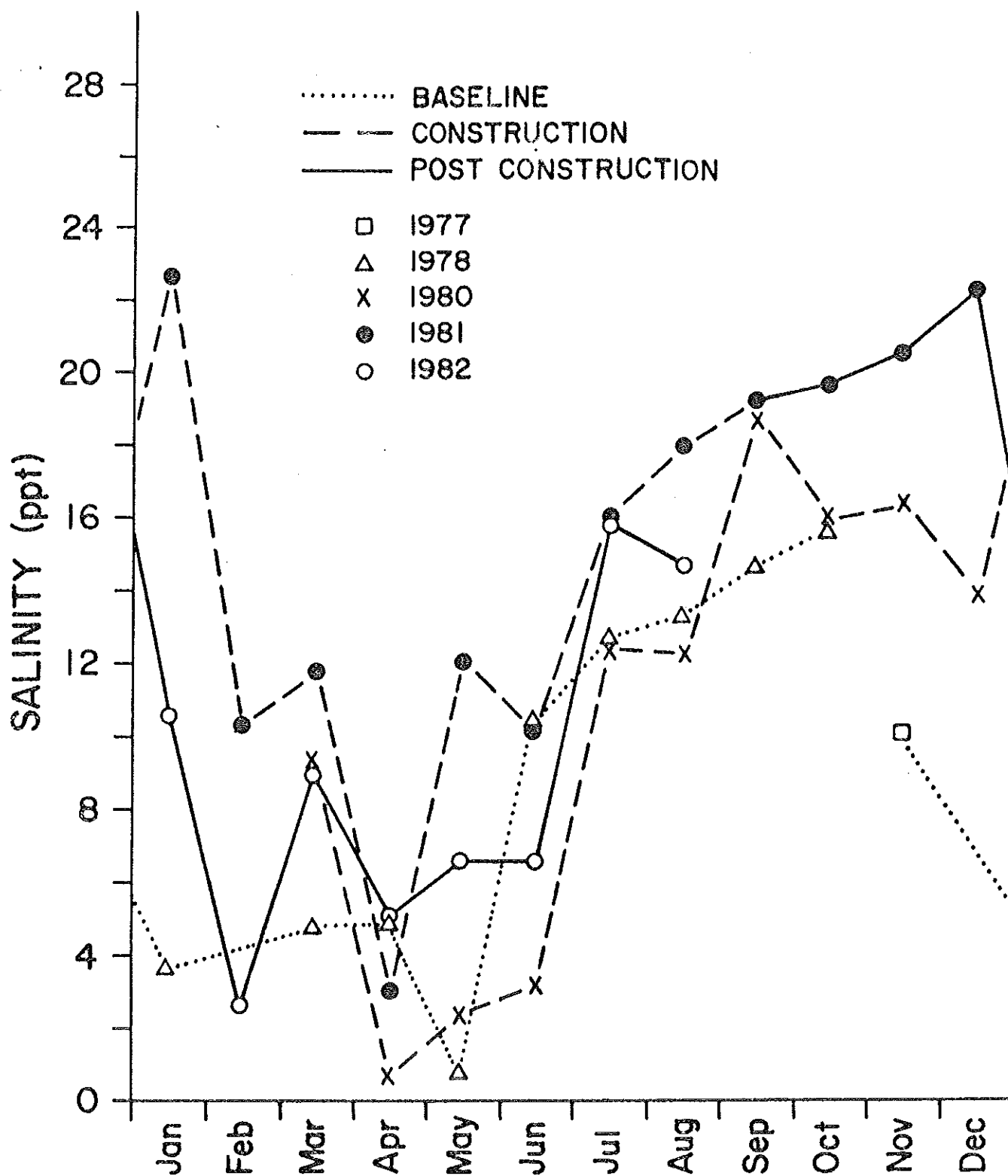


Figure 8. Mean Monthly Bottom Salinity Values, in ppt, Calculated from the Combined "B" and "T" Station Data Sets.

TABLE 4. Probability (p) Values Obtained from the Analysis of Variances. Values of  $p < 0.05$  Indicate Significant Differences.

	MONTH TO MONTH		STATION TO STATION	
	SURFACE	BOTTOM	SURFACE	BOTTOM
Temperature (°C)	0.0001	0.0001	0.0001	0.01
Salinity (ppt)	0.0001	0.0001	0.0001	0.0001
Dissolved Oxygen (% Saturation)	0.0001	0.0001	0.0001	0.0001
Total Solids (mg/l)	0.0001	0.0001		
Turbidity (NTU)	0.0001	0.0001		
Turbidity (% Transmission)	0.0001	0.0001		

significant" differences is the response of the salinity regime to the range of river discharge values (275 to 12,956 m<sup>3</sup>/sec) over the study periods. ANOVA calculations (Table 4) also show that on an individual monthly basis there are very highly significant differences between stations in both the surface (p = 0.0001) and bottom (p = 0.0001) regimes. The principal contributing factor to the station-to-station variability that leads to these "very highly significant" differences is the natural lateral variability that exists in the salinity regime as a function of (1) river discharge, (2) tidal and wind effects, and (3) the bathymetric differences associated with the station sites.

Although there are differences between some of the individual values of the three study periods, none of the study periods are shown to be significantly different from the other two study periods when the monthly means from all three periods are subjected to a Duncan's Multiple Range Test. Therefore, based on the data presented in this report, it is concluded that the basic characteristics of the salinity regime were not altered by the construction activities.

#### c. Dissolved Oxygen:

The solubility of oxygen in water is primarily a function of the water temperature and the concentration of dissolved salts. Therefore, in environments that have large annual temperature ranges and undergo seasonal and/or periodic salinity fluctuations, such as Mobile Bay, the actual measured concentrations (e.g. ppm or mg/l amounts) of dissolved oxygen (D.O.) may not accurately reflect whether there are high or low concentrations relative to what could be present under fully saturated conditions. On the other hand, percent saturation (% Sat.) calculations,

$$\% \text{ Sat.} = \frac{(O_2)}{2} \frac{(O_2) \text{ Sat}}{2}$$

where (O<sub>2</sub>) is the measured concentration of D.O. and (O<sub>2</sub>) Sat. is the D.O. saturation concentration for the observed values of temperature and salinity of the sampled water parcel, provide a means of quantitatively characterizing D.O. levels over any combination of temperature and salinity values. For comparative purposes, percent saturation values will be utilized in this report.

Average monthly percent saturation values of D.O. (Table 3) for the 12 month post-construction period of September, 1981 to August, 1982 indicate that the D.O. regime had the following structure:

- 1) the mean monthly surface values were either equal to or greater than the mean monthly bottom values except during January, 1982 when the average surface D.O. = 101% Sat. and the average bottom D.O. = 107% Sat.;

- 2) the mean monthly surface values were all greater than 65% Sat. and had a maximum value of 127% Sat. during December 1981; and

3) the mean monthly bottom values were all greater than 63% Sat., except during July, 1982 (37% Sat.) and August, 1982 (26% Sat.), and had a maximum value of 127% Sat. during December, 1981.

When this D.O. regime structure is compared to both the 12 month baseline period of November, 1977 to October, 1978 and the 18 month construction period of March, 1980 to August, 1981 the following relationships are observed:

(1) the mean monthly surface values for the baseline and construction periods were also either equal to or greater than the average monthly bottom values except in January, 1978, during baseline, when the average surface D.O. = 92% Sat. and the average bottom D.O. = 96% Sat.;

(2) the mean monthly surface values for the baseline period were all greater than 92% Sat. and had a maximum value of 121% Sat. during October, 1978 (overall, baseline and values were higher than the post-construction values);

(3) The average monthly surface values for the construction period were all greater than 61% Sat. and had a maximum value of 108% Sat. during January, 1981 (overall, these values are lower than the post-construction values);

(4) The mean monthly bottom values for the baseline period were all greater than 47% Sat., except during June, 1978 (22% Sat.) and July, 1978 (21% Sat.), and they had a maximum value of 96% Sat. during January, 1978, (overall, these values are slightly lower than the post-construction values; and

(5) The mean monthly bottom values for the construction period were all greater than 44% Sat., except during July, 1981 (36% Sat.), August, 1981 (40% Sat.) and August, 1982 (32% Sat.) and had a maximum value of 97% Sat. in March, 1981, overall, these values were very similar to the post-construction values.

Figure 9 presents the mean monthly bottom D.O. values from the combined "B" and "T" station data sets. The monthly symbols are different for each of the years in which data were collected, and these monthly values are connected chronologically by different types of lines representing the three sampling periods of baseline, construction and post-construction. From Figure 9, the following observations can be made:

(1) all of the data support the existence of a strong annual cycle for the percent saturation of D.O., where the highest values generally occur during January through May and September through December, while the lowest values generally occur during June, July and August with a very short to no transition period between the extremes;

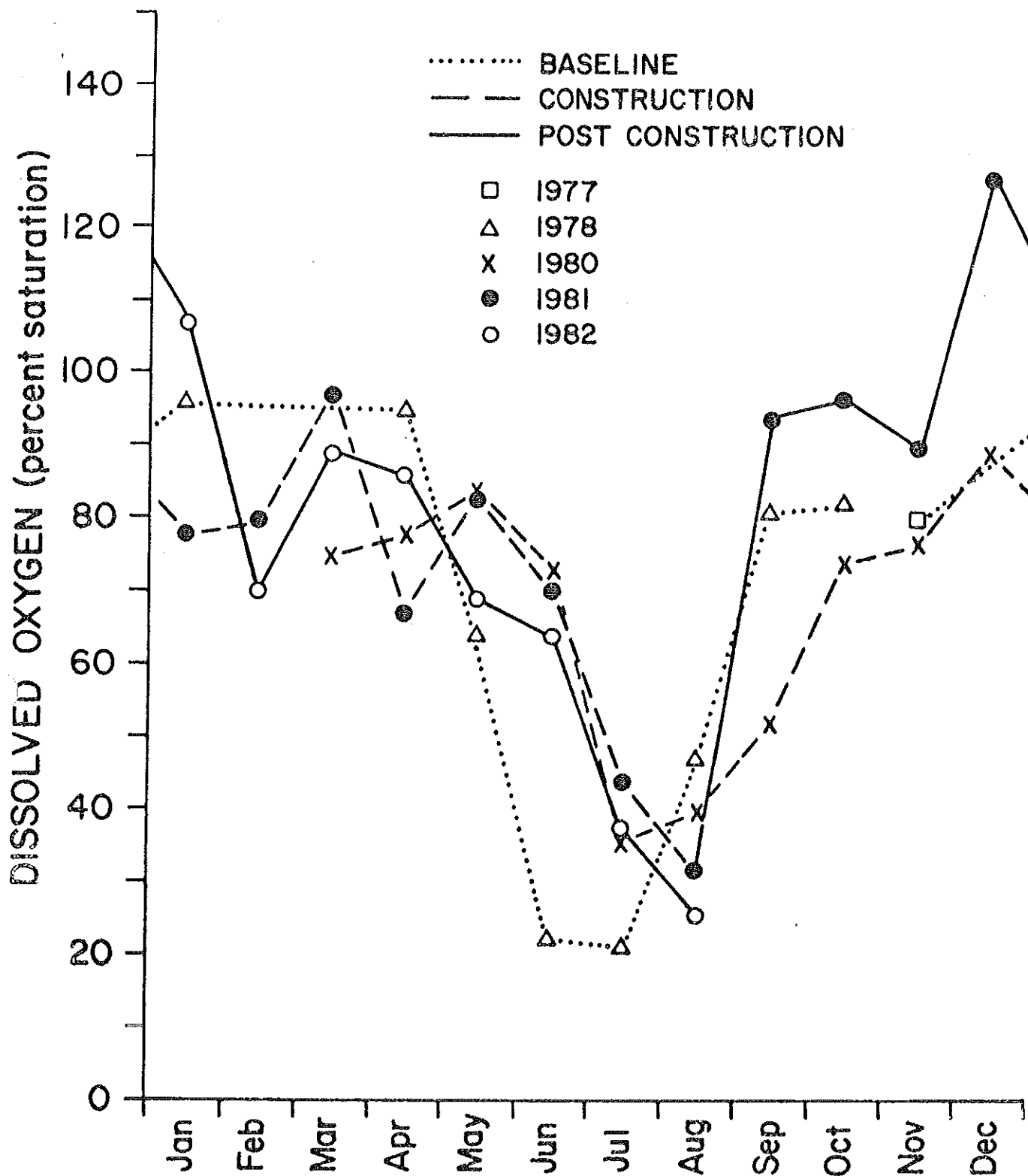


Figure 9. Mean Monthly Bottom Dissolved Oxygen Values, in percent Saturation, Calculated from the Combined "B" and "T" Station Data Sets.



(2) the most severe period of depressed D.O. percent saturation conditions occurred during baseline (June and July, 1978) when the mean values approached 20% Sat. (lowest absolute concentrations of less than 1.0 ppm resulted in percent saturation values of less than 14% Sat. during both months); and

(3) the highest mean monthly values occurred during the post-construction months of December, 1981 and January, 1982.

ANOVA calculations (Table 4) show that there is a very highly significant difference between monthly D.O. percent saturation values in both the surface ( $p = 0.0001$ ) and bottom ( $p = 0.0001$ ) regimes, and also show that on an individual monthly basis there are very highly significant differences between stations in both the surface ( $p = 0.0001$ ) and bottom ( $p = 0.0001$ ) regimes. These month-to-month between station differences occur during all three study periods (baseline, construction and post-construction) at similar magnitudes. They result from a combination of highly variable oxygen producing and oxygen consuming processes found in estuaries, and differences in the temperature and salinity properties of the various water masses that can be simultaneously present in the Bay. Although there are differences between some of the individual values of the three study periods, none of the study periods are shown to be significantly different from the other two study periods when the monthly means from all three periods are subjected to a Duncan's Multiple Range Test. Therefore, based on the data presented in this report, it is concluded that the basic characteristics of the dissolved oxygen regime were not altered by the construction activities.

#### d. Total Solids and Turbidity:

All of the total suspended solids, laboratory nephelometry and field transmissometry data obtained from the "T" stations were subjected to a correlation analysis. The results produced high to very high coefficients of correlation (Table 5). Total suspended solids data were very highly positively correlated with the laboratory nephelometry data,  $r = 0.92$  ( $n = 792$ ), and highly negatively correlated with field transmissometry data,  $r = -0.72$  ( $n = 763$ ).

The difference between the coefficients of correlation for the two turbidity measurements, relative to the total suspended solids, is a function of the optical physics of the two measuring instruments. The nephelometry measurements are a function of the light scattering properties of a volume of water, and therefore, are measurements that are in direct proportion to the concentration of total suspended solids. Thus, a very high correlation can exist between nephelometric and total suspended solids data. On the other hand, transmissometry measurements are a function of both the light scattering and absorptive properties of a volume of water. Therefore, they are measurements of the concentrations of both the total suspended solids and dissolved substances. Consequently, whenever high concentrations of dissolved substances are present in the water, a reduced correlation relationship is possible between the transmissometer measurements and the concentrations of total suspended solids.

The mean monthly total solid and turbidity (laboratory nephelometry in NTU's and field transmissometry in percent transmission) values for the

TABLE 5. Coefficients of Correlation (r) Between Total Solids and Turbidity Data. Number of Pairs of Observations in Parenthesis.

	LABORATORY NEPHELOMETRY (NTU)	FIELD TRANSMISSOMETRY (% TRANSMISSION)
Total Solids (mg/l)	0.92 (792)	-0.72 (763)

entire study period are presented in Table 3. Because of the high correlative relationship that exists between these three variables, and the importance of the actual loading of suspended solid material in the water column, this section will center around a discussion of the total solids data.

The total solids values (Tables 3 and 6 and Figure 10) for the 12 month post-construction period of September, 1981 to August, 1982 indicate the following:

(1) The mean and absolute range of the total solids values (Table 6) were 10 mg/l and 1 to 39 mg/l for the surface and 12 mg/l and 1 to 59 mg/l for the bottom; and

(2) The mean monthly values (Table 3), for both the surface and bottom regimes, were 15 mg/l or less for all months except February, 1982 (surface = 18 mg/l, bottom = 17 mg/l) and April (surface = 20 mg/l, bottom = 25 mg/l).

The above average monthly (Table 7) values for February, 1982 are likely accounted for by high (5178 m<sup>3</sup>/sec) river discharge, while the values for April, 1982 are possibly linked to high (10k) winds (Table 7).

When these post-construction period results are compared to both the 12 month baseline period of November, 1977 to October, 1978 and the 18 month construction period of March, 1980 to August, 1981 (Tables 3 and 6 and Figure 10). The following relationships are observed:

(1) The mean and absolute range values (Table 6) for both the baseline (surface 14 mg/l and 1 to 78 mg/l and bottom 14 mg/l and 1 to 77 mg/l) and construction (surface 13 mg/l and 1 to 114 mg/l and bottom 15 mg/l and 1 to 124 mg/l) periods were higher than during post-construction period;

(2) The baseline prior mean monthly values (Table 3), for both the surface and bottom regimes, were 15 mg/l or less for all months except January, 1978 (surface = 44 mg/l, bottom = 29 mg/l) and May, 1978 (surface = 22 mg/l, bottom = 26 g/l); and

(3) The construction period average monthly values (Table 3), for both the surface and bottom regimes, were 15 mg/l or less for all months except March 1980 (surface = 17 mg/l), April, 1980 (surface = 45 mg/l, bottom = 51 mg/l), May, 1980 (surface = 26 mg/l, bottom = 24 mg/l), June, 1980 (bottom = 20 mg/l), February, 1981 (surface = 27 mg/l, bottom = 21 mg/l), March, 1981 (surface = 17 mg/l) and April, 1981 (surface = 26 mg/l, bottom = 32 mg/l); and

The mean monthly values greater than 15 mg/l noted in items 2) and 3) above that are likely accounted for by river discharge and/or wind events (Table 7) are May, 1978 (high river discharge of 5523 m<sup>3</sup>/sec), April 1980 (flooding river discharge of 12,956 m<sup>3</sup>/sec) May, 1980 (high river discharge of 3326 m<sup>3</sup>/sec), June, 1980 (high winds of 13 to 16 k), March, 1981 (high winds of 9 to 14 k) and January, 1978 (moderate river discharge of 2794 m<sup>3</sup>/sec and high winds of 14 k). Those months, with mean values greater

TABLE 6. Summary of Suspended Total Solids Values in mg/l.

PERIOD	DEPTH	MEAN	ABSOLUTE RANGE	RANGE OF MONTHLY MEANS
Baseline (11/77 to 10/78)	Surface	14	1 to 78	3 to 44
	Bottom	14	1 to 77	3 to 29
Construction (3/80 to 8/81)	Surface	13	1 to 114	2 to 45
	Bottom	15	1 to 124	3 to 51
Post-Construction (1/81 to 8/82)	Surface	10	1 to 39	4 to 20
	Bottom	12	1 to 59	7 to 25
Overall	Surface	12	1 to 114	2 to 45
	Bottom	14	1 to 124	3 to 51

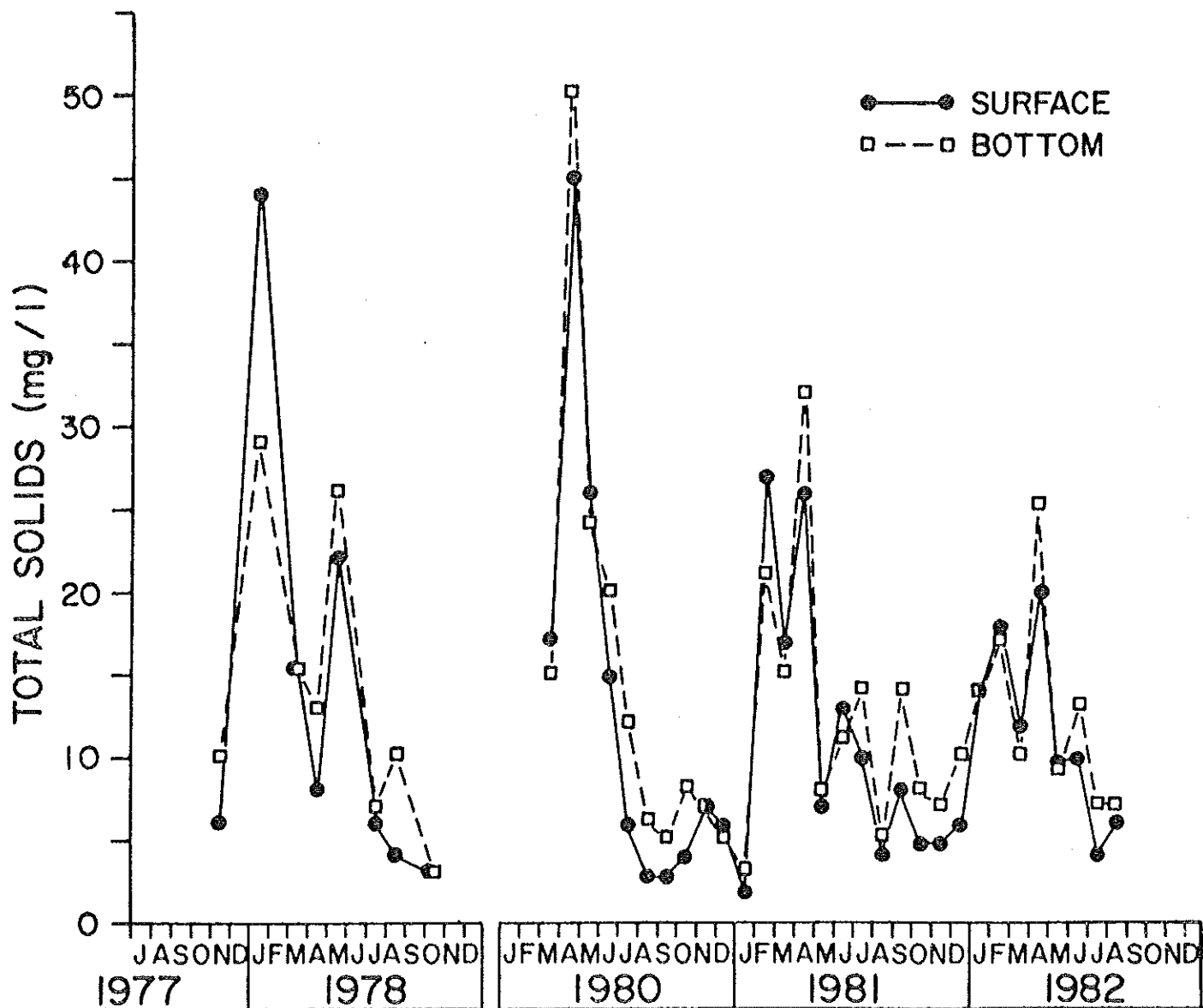


Figure 10. Mean Monthly Surface and Bottom Total Solids Values, in mg/l, Calculated from the "T" Station Data Set.

than 15 mg/l, that are only possibly linked to river discharge and/or wind events (Table 7) are March, 1980 (moderate river discharge of 1445 m<sup>3</sup>/sec) and February, 1981 (winds of 10 k).

ANOVA calculations (Table 4) show that there is a highly significant difference between monthly total solid values in both the surface ( $p = 0.001$ ) and bottom ( $p = 0.0001$ ) regimes. Two of the major contributing factors to the month-to-month variability that leads to these "very highly significant" differences are the variability of both the river discharge and wind events over the study periods. ANOVA calculations (Table 4) also show that there are no significant differences between stations in either the surface or the bottom regimes. Although there are differences between some of the individual values of the three study periods, none of the study periods are shown to be significantly different from the other two study periods when the monthly means from all three periods are subjected to a Duncan's Multiple Range Test. Therefore, based on the data presented in this report, it is concluded that the loading of suspended solid material into the water column was not altered by the construction activities.

## B. SEDIMENTS/SEDIMENT CHEMISTRY

### 1. Overview

In accordance with the guidelines for interpreting sediments and sediment chemistry results stated in the introduction (page 1), we have developed a scenario that specifically addresses the impact of island construction on sediment parameters at stations B-1, B-4, B-7 and B-8 in middle Mobile Bay.

### 2. Data Collection

Data were collected quarterly (April, July, October and January) during the first twelve months, and monthly during the last six months of the construction period. Data were collected monthly during the twelve month post-construction period.

### 3. Sediment Analysis and Characterization

#### a. Sediment Analysis:

Analysis was carried out according to the methods under section II.D.3. Sediments from station B-7 were continually excepted by the sub-contractor because the shell fragment component was too large to yield to standard methods.

#### b. Sediment Characterization:

Tables 8 A, B, and C summarize monthly means for the given parameters by month and period. Table 9 examines variance and mean differences during the construction and the post construction periods without regard to station interactions. The table clearly indicates where there are significant differences in the selected parameters and the directions of the resultant means during post-construction monitoring. Table 10 examines station interactions during the construction and post-construction period

TABLE 7. River Discharge and Wind Speed and Direction Conditions During the Collection of "T" Station Data.

DATE	RIVER DISCHARGE <sup>1, 2</sup> (m <sup>3</sup> /sec)	WIND <sup>3</sup> SPEED (k)/DIRECTION(MAG)			
		8AM <sup>4</sup>	1PM <sup>4</sup>	8AM <sup>5</sup>	1PM <sup>5</sup>
<u>BASELINE</u>					
11/07/77	1305 - MODERATE	5/WNW	5/WSW	1/W	6/SSW
01/28/78	2794 - MODERATE	8/NNW	CALM	14/N	5/N
03/29/78	1220 - MODERATE	6/NE	7/S	7/N	CALM
04/17/78	736 - MODERATE	2/E	2/SE	5/SSE	12/ESE
05/22/78	5523 - HIGH	2/N	5/S	CALM	CALM
07/10/78	558 - MODERATE	4/NE	CALM	1/NE	CALM
08/21/78	743 - MODERATE	2/SSW	4/NW	5/N	2/N
10/04/78	357 - LOW	3/N	2/NE	4/NNW	4/ENE
<u>CONSTRUCTION</u>					
03/11/80	1445 - MODERATE	7/W	4/E	2/E	5/SSE
04/09/80	12956 - FLOODING	8/E	6/WSW	2/N	6/WSW
05/13/80	3326 - HIGH	5/S	5/SSE	4/SSE	7/SSE
06/10/80	1974 - MODERATE	13/N	15/N	16/NNE	2/N
07/10/80	959 - MODERATE	2/ESE	2/SE	2/N	2/S
08/05/80	380 - LOW	3/WSW	4/S	4/SSE	5/SE
09/09/80	318 - LOW	8/NNW	6/SSE	7/NE	4/E
10/09/80	913 - MODERATE	6/N	5/N	4/NNW	CALM
11/03/80	532 - MODERATE	8/NNE	CALM	4/N	3/N
12/02/80	1072 - MODERATE	3/E	3/SE	5/ESE	3/SSW
01/27/81	625 - MODERATE	CALM	4/SSE	2/SSE	3/S
02/24/81	436 - LOW	7/ENE	10/SSW	7/WNW	5/SSW
03/20/81	1463 - MODERATE	14/NNW	9/WNW	8/NW	6/SW
04/15/81	7211 - FLOODING	7/NNE	4/N	9/N	5/S
05/14/81	415 - LOW	5/NE	5/S	3/SW	14/S
06/02/81	483 - LOW	6/S	7/S	1/S	2/S
07/07/81	354 - LOW	10/SSW	10/S	2/SSE	3/E
08/04/81	297 - LOW	CALM	4/SSE	2/NNW	6/ESE
<u>POST-CONSTRUCTION</u>					
09/22/81	376 - LOW	6/ENE	2/ESE	8/N	N.D.
10/09/81	283 - LOW	13/NNE	10/NE	8/NE	N.D.
11/03/81	275 - LOW	14/NE	11/ENE	9/ENE	8/E
12/01/81	316 - LOW	4/S	4/S	5/WNW	N.D.
01/05/82	997 - MODERATE	11/NW	8/N	12/ENE	8/ESE
02/18/82	5178 - HIGH	8/W	N.D.	CALM	N.D.
03/02/82	3803 - HIGH	8/NNW	10/N	2/E	4/WSW
04/20/82	1261 - MODERATE	5/SSW	6/SSE	10/E	N.D.
05/19/82	1555 - MODERATE	3/E	N.D.	3/E	N.D.
06/01/82	572 - MODERATE	14/SE	8/S	2/SSW	6/SSW
07/06/82	396 - LOW	2/NNW	5/SW	2/NW	2/N
08/25/82	717 - MODERATE	3/WNW	8/SW	7/WNW	7/SW

N.D. = No Data

<sup>1</sup>River discharge values are calculated using U.S.G.S. surface water records by the method employed by Schroeder, 1979.

<sup>2</sup>River discharge rate categories follow the convention set by Schroeder, 1978.

<sup>3</sup>Wind observations are the meteorology station data of the Dauphin Island Sea Lab.

<sup>4</sup>Observations from the day before sampling.

<sup>5</sup>Observations from the sampling day.

TABLE 8A. Summary of Sediment Characterization (Station B-1).

SEDIMENT DESCRIPTION	CONSTRUCTION												POST-CONSTRUCTION											
	APR. 80	JULY 80	OCT. 80	JAN. 81	MAR. 81	APR. 81	MAY 81	JUNE 81	JULY 81	AUG. 81			SEP. 81	OCT. 81	NOV. 81	DEC. 81	JAN. 82	FEB. 82	MAR. 82	APR. 82	MAY 82	JUNE 82	JULY 82	AUG. 82
Percent Composition																								
Shell	0.15	0.00	0.01	0.00	0.00	0.01	0.00	0.10	0.26	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	0.68	0.66	0.92	0.00	0.13	0.76	2.39	0.72	2.05	0.97			3.19	1.40	1.47	1.32	0.65	0.26	0.79	0.64	0.66	0.37	0.49	1.22
Silt	26.19	14.68	19.52	22.50	23.21	27.50	29.20	25.86	20.71	20.46			24.33	34.42	24.49	23.46	13.88	22.63	21.93	15.11	15.03	38.99	22.05	30.52
Clay	72.87	84.85	79.53	77.50	75.75	71.71	68.41	73.32	76.98	78.56			72.47	64.17	74.04	75.21	85.47	77.08	77.27	84.24	84.30	60.64	77.45	68.25
USACE Textural Descrip.	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY			CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY/ SILTY-CLAY	CLAY	CLAY
Median Diameter	10.363	10.614	10.071	10.003	10.186	10.006	10.095	9.808	10.086	10.644			10.327	9.006	9.977	10.175	12.558	10.753	10.468	11.114	12.228	8.610	9.893	9.872
Mean Diameter	9.464	9.953	9.525	9.437	9.438	9.246	9.295	9.147	9.503	9.898			9.489	8.443	9.302	9.431	11.606	9.958	9.773	10.412	11.284	8.725	9.334	9.114
Sorting Coefficient	2.427	2.043	1.759	1.700	2.139	2.351	2.617	2.099	2.574	2.338			2.786	2.190	2.104	2.343	2.985	2.490	2.186	2.213	3.097	3.074	1.756	2.625
Skewness	-0.935	-1.32	-1.35	-1.16	-1.01	-0.814	-0.716	-1.19	-1.14	-1.07			-0.823	-0.765	-1.15	-0.968	-1.07	-0.923	-1.03	-1.32	-0.978	-0.265	-1.27	-0.890
Kurtosis	1.073	1.498	1.614	1.061	1.049	0.892	0.792	1.415	1.366	1.072			0.901	0.888	1.172	0.973	1.063	0.902	1.084	1.301	1.023	0.746	1.245	0.756
Mean Organic C in g/kg	12.68	15.15	14.57	17.68	13.35	13.75	13.50	15.85	11.65	12.85			11.20	12.00	8.47	9.74	12.30	13.03	13.92	13.70	11.85	13.32	15.36	13.89
Mean Reducing Substances in ug O <sub>2</sub> /g	2133	2417	2037	2542	1998	1804	1767	2651	1835	2700			1477	2115	2093	1080	1853	1883	2023	1847	1627	1720	1533	1660



TABLE 88. Summary of Sediment Characterization (Station 8-4).

SEDIMENT DESCRIPTION	CONSTRUCTION												POST-CONSTRUCTION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
	APR. 80		JULY 80		OCT. 80		JAN. 81		MAR. 81		APR. 81		MAY 81		JUNE 81		JULY 81		AUG. 81		SEP. 81		OCT. 81		NOV. 81		DEC. 81		JAN. 82		FEB. 82		MAR. 82		APR. 82		MAY 82		JUNE 82		JULY 82		AUG. 82																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															

TABLE 8C. Summary of Sediment Characterization (Station 8-B).

SEDIMENT DESCRIPTION	CONSTRUCTION												POST-CONSTRUCTION											
	APR. 80	JULY 80	OCT. 80	JAN. 81	FEB. 81	APR. 81	MAY 81	JUNE 81	JULY 81	AUG. 81			SEP. 81	OCT. 81	NOV. 81	DEC. 81	JAN. 82	FEB. 82	MAR. 82	APR. 82	MAY 82	JUNE 82	JULY 82	AUG. 82
Percent Composition																								
Shell	0.00	0.01	0.01	0.00	0.54	0.18	0.00	0.02	0.00	0.00			0.05	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	12.98	7.17	7.94	8.63	8.17	11.30	9.89	9.10	11.13	8.32			4.39	11.24	1.04	3.86	1.86	9.39	5.64	1.83	3.81	7.34	14.02	7.65
Silt	32.62	14.96	19.55	22.90	22.60	22.71	28.85	23.41	30.94	30.05			22.99	31.49	17.43	24.34	17.24	21.14	17.84	15.96	21.87	25.43	20.59	31.39
Clay	54.39	77.85	72.49	68.46	68.69	65.81	61.21	67.45	57.92	51.62			72.55	57.26	81.49	71.79	81.10	69.46	76.51	82.21	74.32	67.22	65.88	60.96
USACOE Textural Descrip.	SILTY CLAY/CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY			CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY	CLAY
Median Diameter	9.192	10.497	10.304	10.094	9.925	9.762	9.835	10.085	9.410	9.597			10.645	8.773	10.373	10.052	11.087	10.909	11.151	11.577	10.094	9.954	10.159	9.641
Mean Diameter	9.016	9.612	9.404	9.168	8.960	8.733	8.771	9.121	8.439	9.241			9.705	8.037	9.753	9.237	10.255	9.761	10.181	10.729	9.319	8.637	9.323	8.847
Sorting Coefficient	4.470	2.707	2.738	2.960	2.955	2.985	3.320	3.166	3.219	3.189			3.085	2.975	1.960	2.633	2.583	3.626	3.096	2.644	2.406	2.475	3.739	3.390
Skewness	0.023	-1.29	-1.24	-0.957	-1.07	-0.861	-0.471	-0.811	-0.500	-0.555			-0.842	-0.539	-1.500	-0.891	-1.13	-0.872	-1.05	-1.21	-1.17	-1.02	-0.556	-0.399
Kurtosis	0.528	1.365	1.283	0.920	1.189	0.916	0.658	0.863	0.680	0.696			0.984	0.709	1.670	0.923	1.150	0.752	1.088	1.237	1.222	1.070	0.740	0.611
Mean Organic C in g/kg	13.46	24.10	13.68	17.81	16.05	13.55	12.80	14.20	12.90	12.80			12.80	11.55	12.39	10.75	13.55	12.69	14.73	14.81	12.45	13.27	19.36	14.02
Mean Reducing Substance in ug O2/g	2783	2393	2240	2412	2050	1740	1868	2670	2180	3062			2045	2617	2758	1438	2428	2162	2825	2612	2332	2038	2395	2045

TABLE 9. Summary of construction [(N = 60 vs. Post construction (n = 132) ANOVA] and Duncan's Multiple Range Test Means.

COMPARISON/TEST	% SAND	% SILT	% CLAY	MEAN DIAM. PHI	SORT. COEF.	SKEWNESS	KURTOSIS	MEAN ORG. C	MEAN REDUC. SUB.
ANOVA	>.001	NS	>0.05	>0.05	NS	NS	NS	>0.005	NS
DUNCAN'S	1 $\bar{x} \downarrow$	S	2 $\bar{x} \uparrow$	3 $\bar{x} \uparrow$	S	S	S	4 $\bar{x} \downarrow$	S

Explanatory Notes:

$\bar{x}$  = Mean Decreased Post Construction Period

$\bar{x}$  = Mean Increased Post Construction Period

S = Means are in same "family" e.g. not separable.

1 = % Sand = X construction 6.79% vs. post-construction 4.12%; D = -2.672%

2 = % Clay = X construction 69.18% vs. post-construction 72.23%; D = +3.041%

3 = Mean Diameter phi-construction = 9.945 vs. post-construction = 10.267; D = +0.341

4 = Mean Organic carbon-construction = 14.374 vs. post-construction = 12.610; D = -1.564 g/kg

(April, 1980 through August, 1982). Not surprisingly, it reveals that there was significant variance in nearly all the parameters examined, the Duncan's Multiple Range Test results indicate how the stations interacted, and gives their resultant direction. Table 10 suggests that we need to look farther into the time frame of the study by asking if the variance is due to construction, or results from it. Table 11 examines variance and means during the construction period (April, 1980 to August, 1981) and reveals which of the parameters were affected by construction and in what manner. Table 12 is perhaps the most important analysis of all because it examines the post-construction period (September, 1981 to August, 1982) and thus more accurately addresses the question of construction effects.

Our major concerns are (a) changes in sediment texture and (b) changes in sediment quality. The data indicate that following construction Station B-1 contained significantly less sand (approximately 4% less sand). The data also indicate that Station B-4 and B-8 contain significantly higher amounts of reducing substances than they did during construction and probably baseline investigation.

A cursory look at the baseline levels of percent sand at B-1 indicates a mean of 2.62 (N = 8). It should also be noted that 7 of the 8 values lay between 1 and 3 inclusive, with one value of 8%. In general then, we conclude that a mean value of 1.043 is probably not a serious decrease from baseline conditions, and does not really change the textural description of the site.

The same cannot be said for the post-construction levels of total reducing substances at stations B-4 and B-8, which are apparently being affected by high levels of oxygen-consuming inorganic materials. We say inorganic materials because there is no significant increase in organic carbon and they are in effect negatively correlated. Since neither channel dredging nor island construction generate or sustain high levels of inorganic substances, and since we cannot correlate these high levels with any other measured parameter, we conclude that the source of these substances is very likely the specific industries the new canal serves. The NPDES permits for the effluents associated with the canal have been reviewed and there is no readily apparent contributor to the measureable Total Reducing Substances.

## C. BENTHIC FAUNA

### 1. Overview

This section will be organized in such a way as to generally characterize the habitat of the benthic macroinfauna at stations B-1, B-4, B-7, and B-8. The characterization will be by station for the 30-month period, however, the time frame will be divided into an 18-month "Construction Period" and a 12-month "Post-construction Period." Emphasis will be placed on standard measures of community composition so as to delineate dominant organisms and changing seasonal abundance. The ecological indices, Diversity (H'), Evenness (J') and Richness (R) have been calculated for each month. (See Volume II for more information on these indices).

TABLE 10. Summary of Station Interactions using ANOVA and Duncan's Multiple Range Test of Means (N = 132 and N = 44 respectively).

COMPARISON/TEST	% SAND	% SILT	% CLAY	MEAN DTAM, PHI	SORT. COEF.	SKWENESS	KURTOSIS	MEAN ORG. C	MEAN REDUC. SUB.
ANOVA	>0.0001	NS	>0.0001	NS	>0.0001	>0.05	>0.05	NS	>0.005
Duncan's	4 = 8	NS	4 = 8		4 = 8	4 = 8	1 = 8 H		8 ≠ 1 H
	1 ≠ 4		1 ≠ 4		1 ≠ 4	1 ≠ 4	4 ≠ 8		8 ≠ 4
	L	S	H	S	L	H	1 ≠ 4 H	S	1 = 4
	1 ≠ 8		1 ≠ 8		1 ≠ 8	1 ≠ 8			

Explanatory Notes

- 1 ≠ 4 H Means at 1 were not same as 4 and 8; 1 was highest.  
1 ≠ 8 L Means at 1 were not same as 4 and 8; 1 was lowest.  
1 ≠ 4  
1 ≠ 8  
1 = 8 H = 1 and 8 were high.  
4 = 8 = 4 and 8 not separable  
1 ≠ 4 H = 1 higher than 4  
8 ≠ 1 H means at 8 were not same as 1 or 4; 8 was highest  
8 ≠ 4  
1 = 4 = 1 and 4 not separable  
S = Means are in same family e.g. not separable

TABLE 11. Summary of ANOVA and Duncan's Multiple Range Test of Means (Constructions: N = 44).

COMPARISON/TEST	% SAND	% SILT	% CLAY	MEAN DIAM. PHI	SURT. COEF.	SKEWNESS	KURTOSIS	MEAN DRG. C	MEAN REDUC. SUB.
ANOVA	>0.0001	NS	>0.0001	NS	>0.0001	>0.05	>0.05	NS	NS
Duncan's	4 = 8 1 ≠ 4	NS	4 = 8 1 ≠ 4		4 = 8 1 ≠ 4	4 = 8 1 ≠ 4	4 = 8 1 ≠ 4		
	L 1 ≠ 8	S	H 1 ≠ 8	S	L 1 ≠ 8	H 1 ≠ 8	H 1 ≠ 8	S	S

Explanatory Notes:

1 ≠ 4

H Means at 1 were not same as 4 and 8; 1 was highest.

1 ≠ 8

1 ≠ 4

L Means at 1 were not same as 4 and 8; 1 was lowest.

1 ≠ 8

4 = 8 Means at 4 and 8 not separable.

S = Means are in same family c.o. not separable.

TABLE 12. Summary of ANOVA and Duncan's Multiple Range Test of Means (Post-construction: N = 24).

COMPARISON/TEST	% SAND	% SILT	% CLAY	MEAN DIAM. PHU	SORT. COEF.	SKEWNESS	KURTOSIS	MEAN DIF. C	MEAN REDUC. SUB.
ANOVA	>0.0001	NS	NS	NS	NS	NS	NS	NS	>0.0001
Duncan's	1 # 4 1 # 8	L NS	NS	NS	NS	NS	NS	NS	1 # 4 L 1 # 8

1 # 4  
1 # 8  
L Means at 1 were not same as 4 and 8; 1 was lowest.

4 = 8  
Means at 4 and 8 were not separable.

1.  $\bar{X}$   
 $\bar{X}$   
 $\bar{X}$   
B-4 = 5.892  
B-8 = 5.378  
B-1 = 1.043

2.  $\bar{X}$   
 $\bar{X}$   
 $\bar{X}$   
B-4 = 2174.7  
B-8 = 2302.8  
B-1 = 1746.2

Having developed a scenario which describes the study area for the 30 month period, we will compare the community as seen by baseline investigation to the community as seen at monitoring.

After developing comparisons, the resultant community or communities will be examined in relation to the requisite physical parameters.

Lastly we will call attention to any evidence of community change which can be positively linked to the construction activity.

## 2. Station Characterization

### a. Station B-1:

This station is located due south of the proposed island and canal. The sediments at the site were predominantly clay with varying mixtures of silt and minor amounts of sand. When plotted on Isphording's (1979) sediment map, the station falls on a boundary line between clay and silty clay. There were essentially no shell or shell fragments found in the samples during the study. No plant life was found in association with this substrate. Consequently we conclude that "cover" was very minimal to non-existent at the site. Again referring to Isphording's (1979) map, we suggest that this habitat covers a minimum of one square kilometer and the community is not complex in the absence of habitat irregularity.

### b. Station B-4:

This station is located northwest of the proposed island and canal. The sediments at the site were much as described for station B-1. When plotted on Isphording's (1979) map, the station falls in a clay area just south of a small oyster reef or shell deposit. The latter materials were taken in small quantities (< 1%) during 1980-81, but not in 1982. Isphording (1979) classifies the substrate as clay. The minimal amount of shell encountered, and the absence of attached plant life suggests that cover is minimal but may exist in the northwest quadrant as oyster shell. The remaining three quadrants of a one-kilometer square would suggest a non-complex community. Since we have no actual data for the suggested substrate in the northwest quadrant, we cannot delineate complexity in that direction.

### c. Station B-7:

This station lies across the ship channel in a southwesterly direction from the spoil island in line with the proposed dredge cut into Deer River. The sediments at the site were always found to contain large amounts of aged and eroded oyster shell. So much so that the subcontractors could not reliably delineate their percent composition or carry out accurate measurements of total organic carbon or total reducing substances. When plotted on Isphording's (1979) map, it falls in a region labeled Sandy-Clay. On his map however, we note with interest that there is a long narrow deposit of oyster shell stretching from a point just east-south-east of Station B-7 toward the eastern shore. Station B-7 appears to be related to this structural feature.



Because of the size and amount of shell fragments, there is "cover" and the habitat should be considered complex by comparison. Areal coverage cannot be predicted accurately in as much as the substrate in the area departs so markedly from the Isphording proposal.

d. Station B-8:

This station lies southwest of the proposed island and canal and northwest of station B-1. The sediments at the site were characteristically dominated by clay with lesser amounts of silt and then sand. Shell was virtually absent. On Isphording's map, the station falls into an area labeled clay and is bordered on either side, northwest by sand clay, and southeast by silty-clay. We suggest that the areal extent is at least a square kilometer and cover and complexity are minimal.

3. Community Structure

a. Station B-1:

1) Overview - Table 13A summarizes the biological characterization data for site B-1 during construction and post-construction periods. This table contains data for all organisms from March 1980 through August 1982. During selected months, data for polychaetes only has been tabulated to show year to year fluctuations in this dominant group of macroinfaunal invertebrates.

2) Construction -

General Abundance/Dominance - Of the 6,254 organisms collected at station B-1, 4,821 were collected during the 18-month construction phase. This accounts for 77.0% of the total organisms. Of the 4,821 organisms collected, the bivalve Mulinia lateralis totaled 1,868 (38.8%) and was followed in abundance by the polychaete Mediomastus ambiseta, which totaled 975 individuals (20.2%). The third ranking dominant organism was the bivalve Macoma sp. A with 297 individuals (6.2%) of the total organisms collected. In summary, three organisms, two bivalve species and one polychaete species, accounted for 3,140 individuals (65.2%) taken during construction months.

By examining Table 13A, we can see an organismal peak in April of 1980 dominated by polychaetes followed by declining numbers of these organisms until November of 1980 when a non-polychaete proliferation is evident and maintained until June of 1981.

Diversity, Evenness, and Richness - These indicators of community structure and well-being at station B-1 are plotted in figures 11A through 13A. The data for polychaetes only at station B-1 are plotted in figures 14A through 16A. It should be noted that data for post-construction and baseline also appear on these figures, and their relationships will be discussed as appropriate in subsequent interpretation.

Figure 11A indicates macroinvertebrate diversity has a bimodal distribution during construction with peaks in the late months of 1980 and again in June 1981. Figure 14A indicates polychaete diversity generally

TABLE 13A. Summary Biological Characterization, Station B-1.

NOTES: YEAR:	CONSTRUCTION																POST-CONSTRUCTION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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- 1 = Organisms/7 grabs  
2 = Polychaete/7 grabs  
3 = Mean No. Organisms Per 0.1 Meter Square  
4 = Species/7 grabs  
5 = Polychaete Species/7 grabs  
6 = Mean No. Species Per 0.1 Meter Square  
7 = Diversity as H'  
8 = Polychaete Diversity  
9 = Evenness as J'  
10 = Polychaete Evenness  
11 = Richness as R  
12 = Polychaete Richness  
( ) = Polychaete Only Data

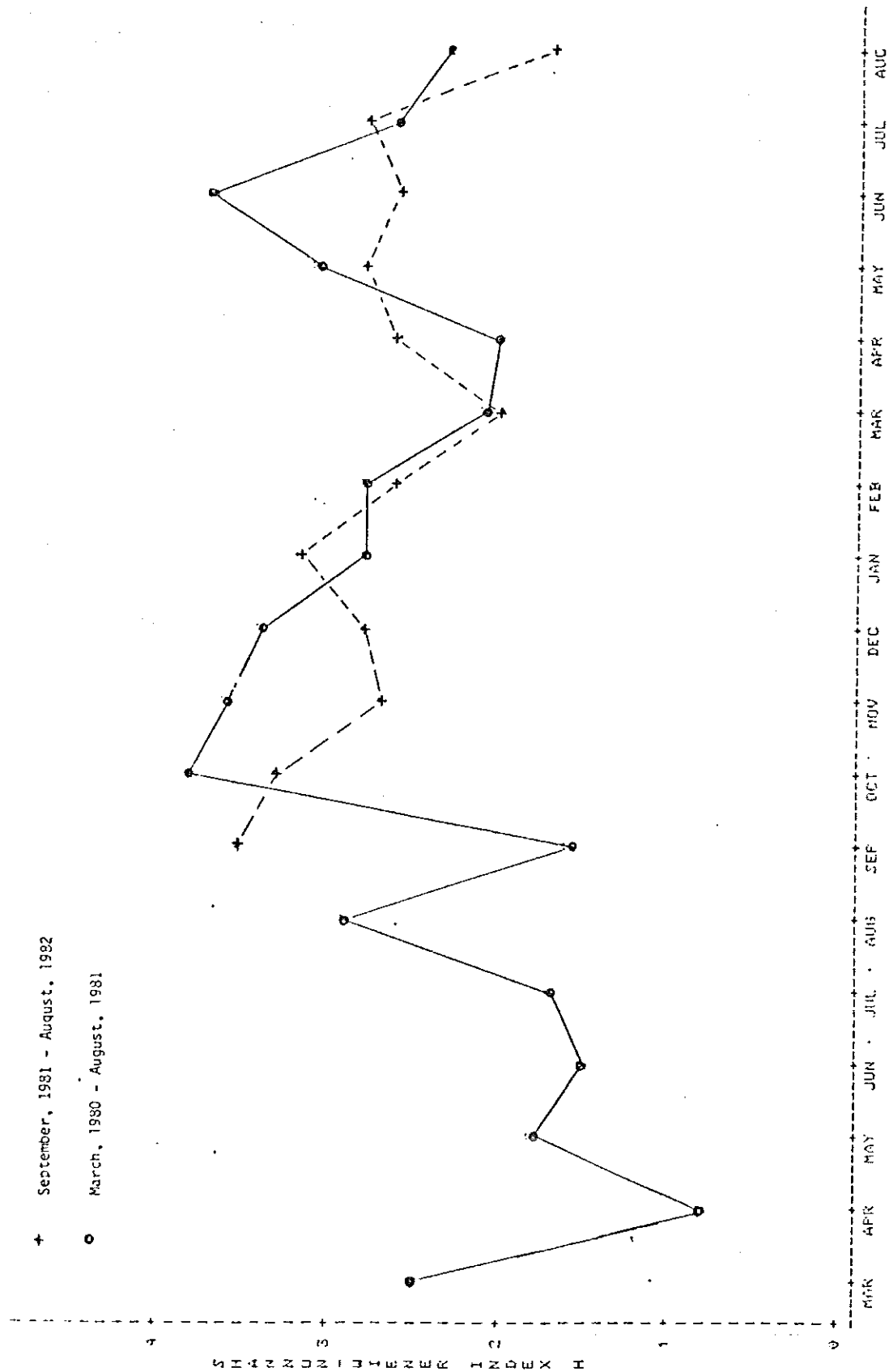


Figure 11A. Graph of Macroinvertebrate Diversity (H') at Station B-1.

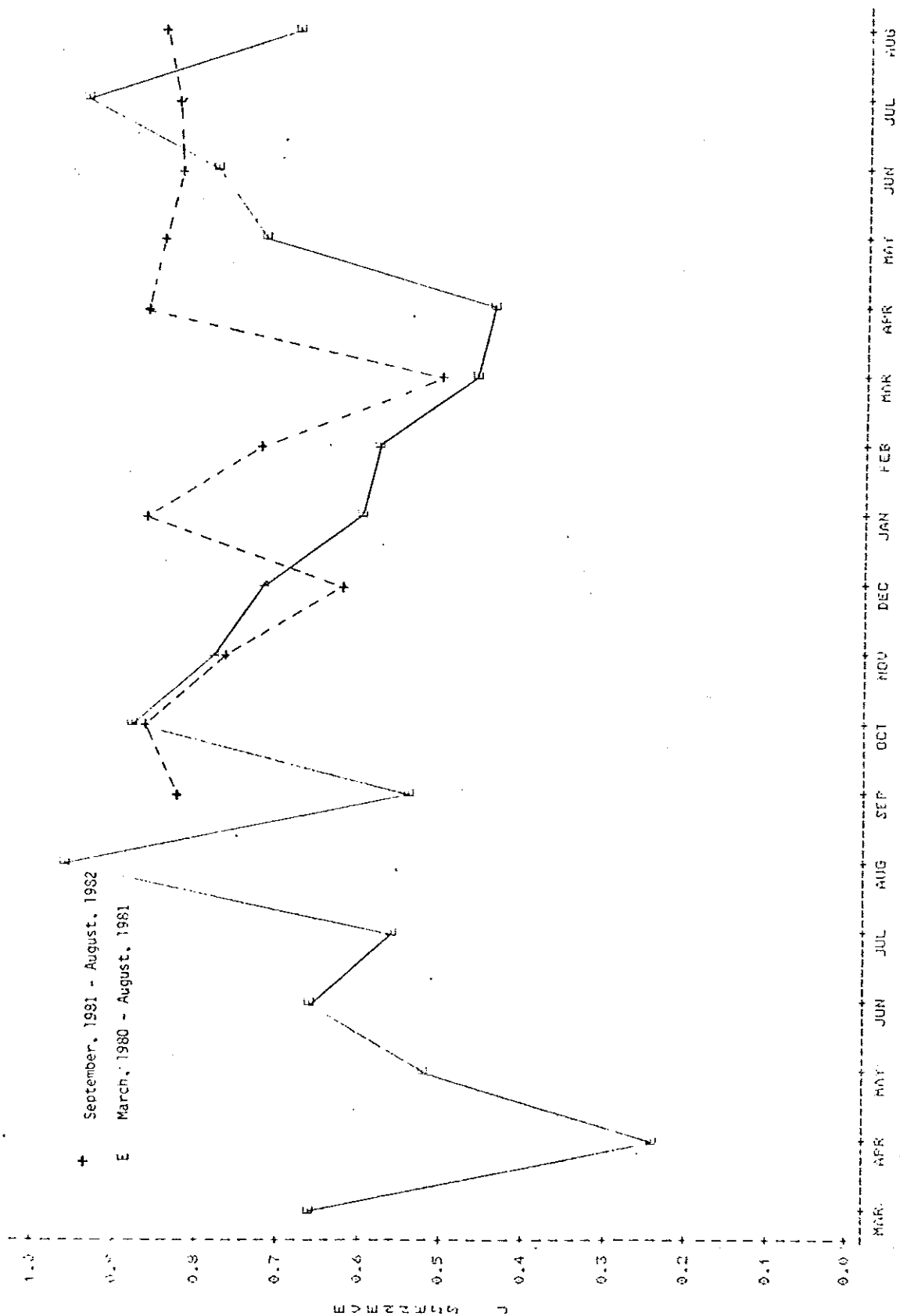


Figure 12A. Graph of Macroinvertebrate Evenness (J') at Station B-1.

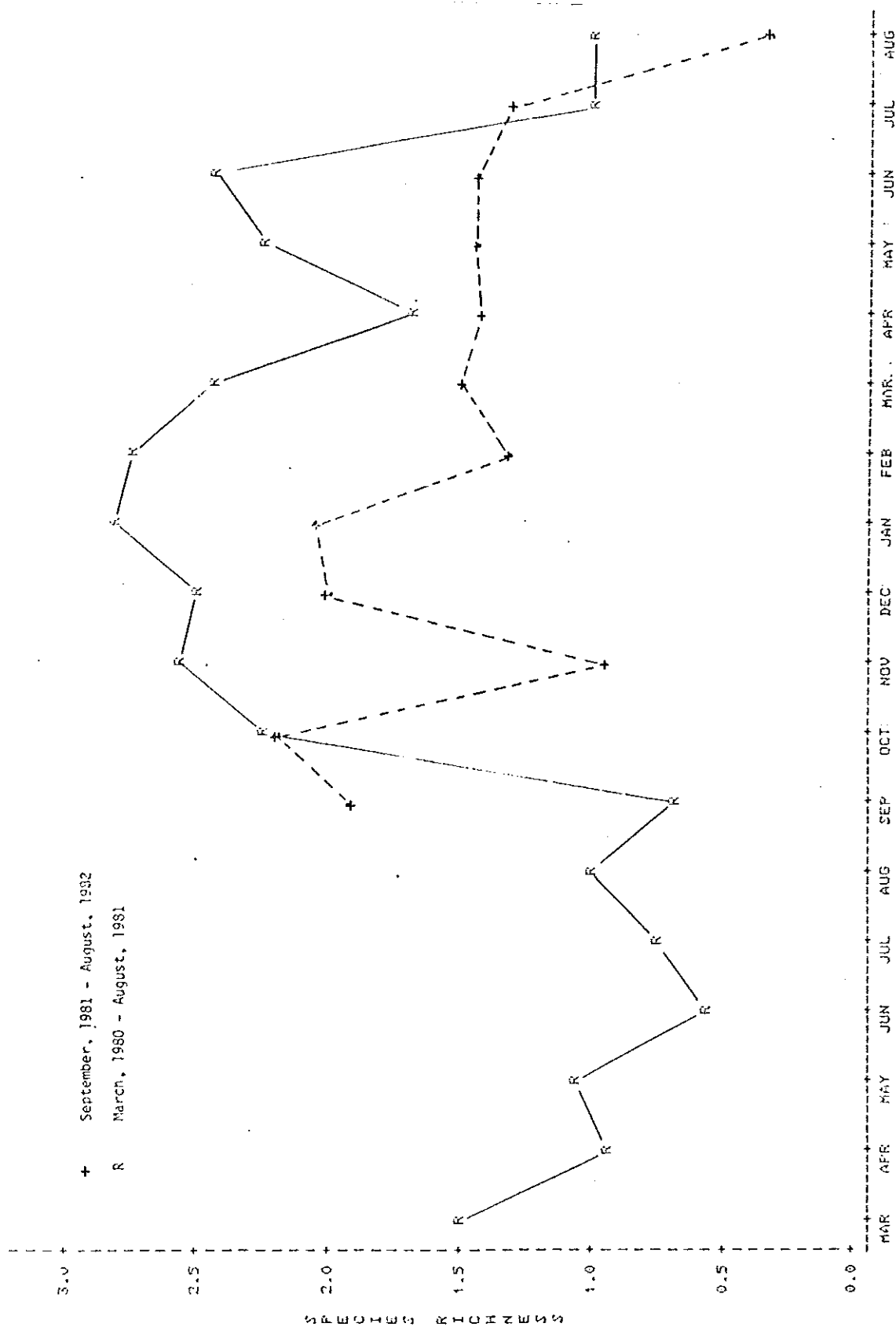


Figure 13A. Graph of Macroinvertebrate Richness (R) at Station B-1.

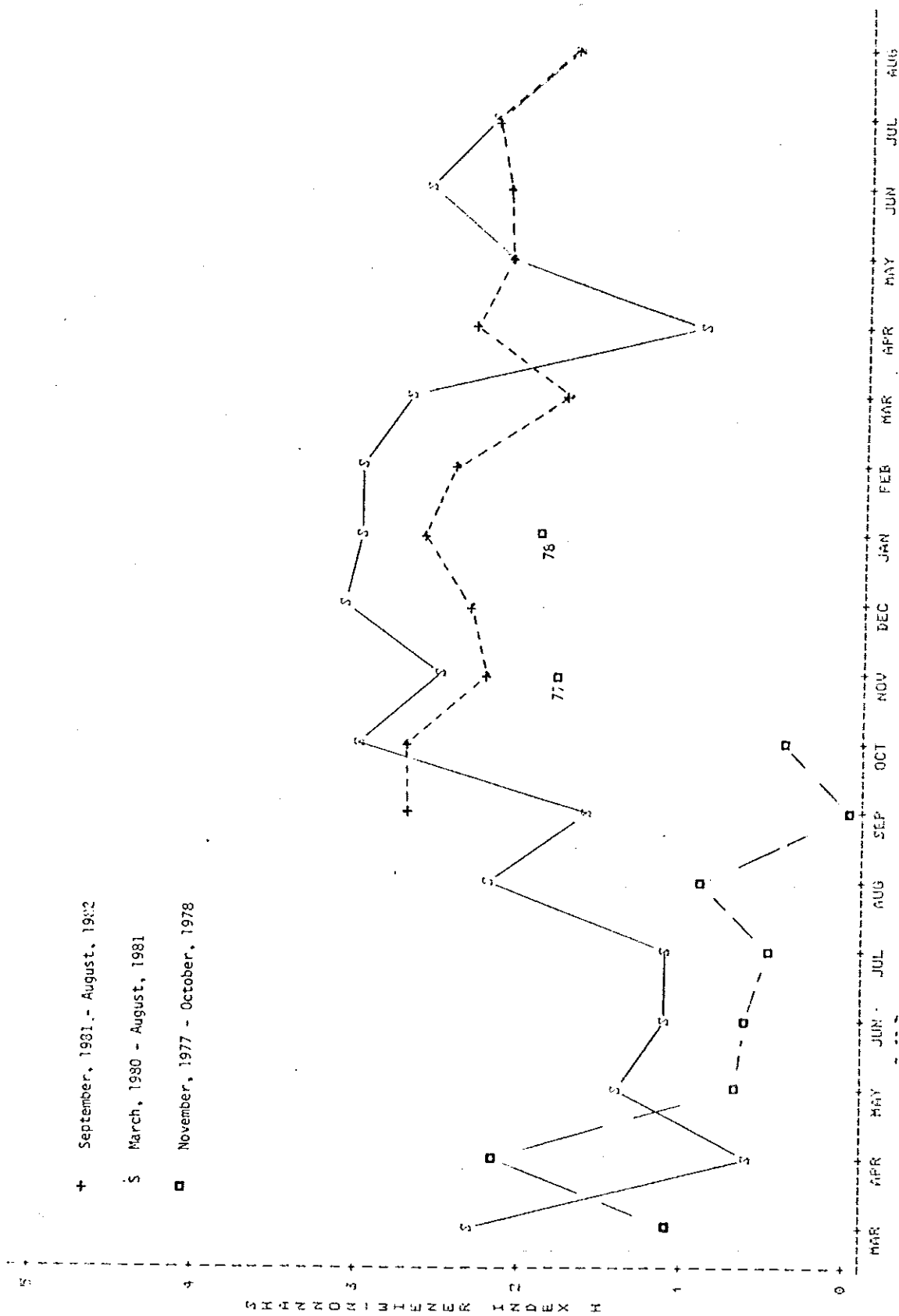


Figure 14A. Graph of Polychaete Diversity ( $H'$ ) at Station B-1.

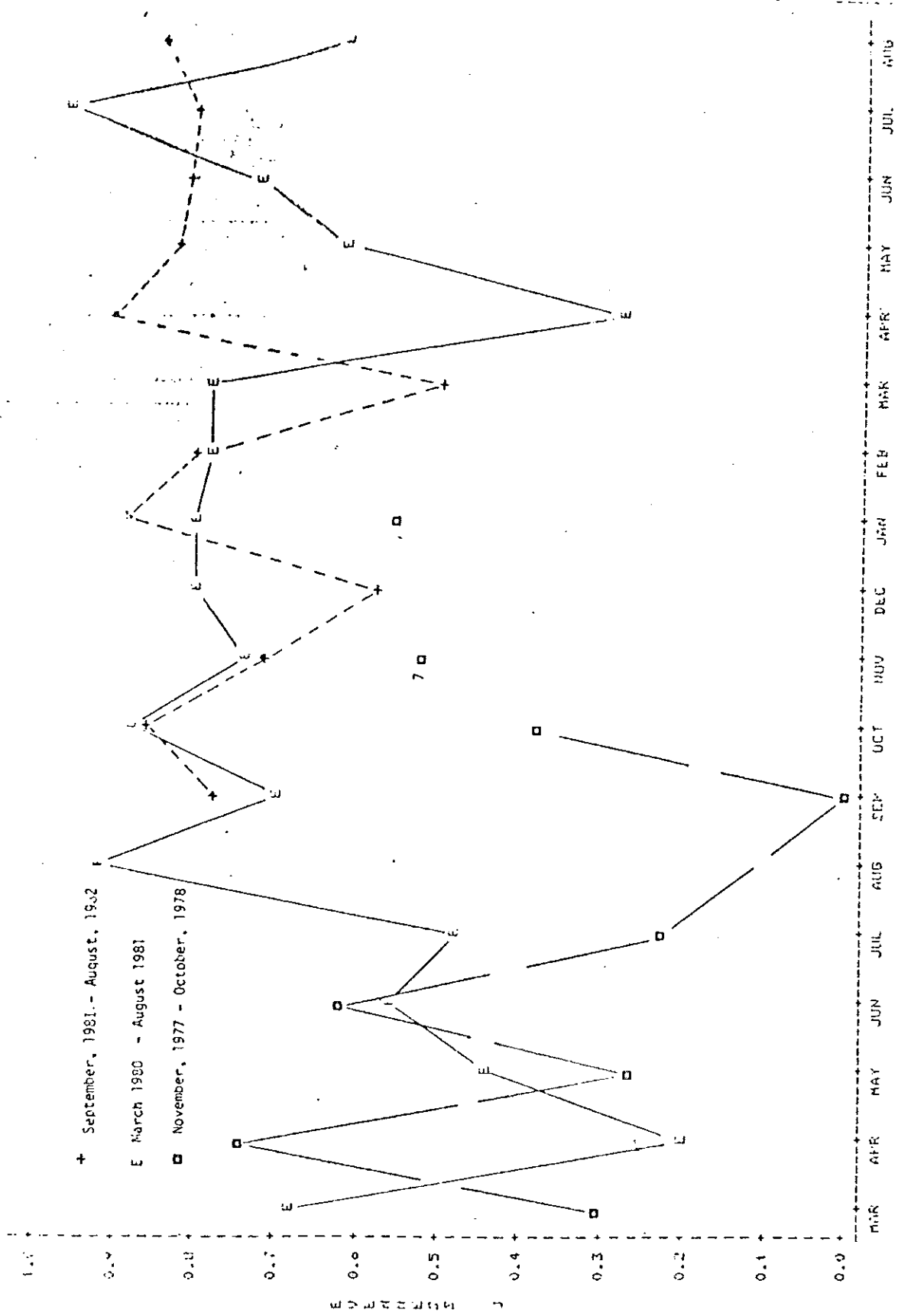


Figure 15A. Graph of Polychaete Evenness (J') at Station B-1.

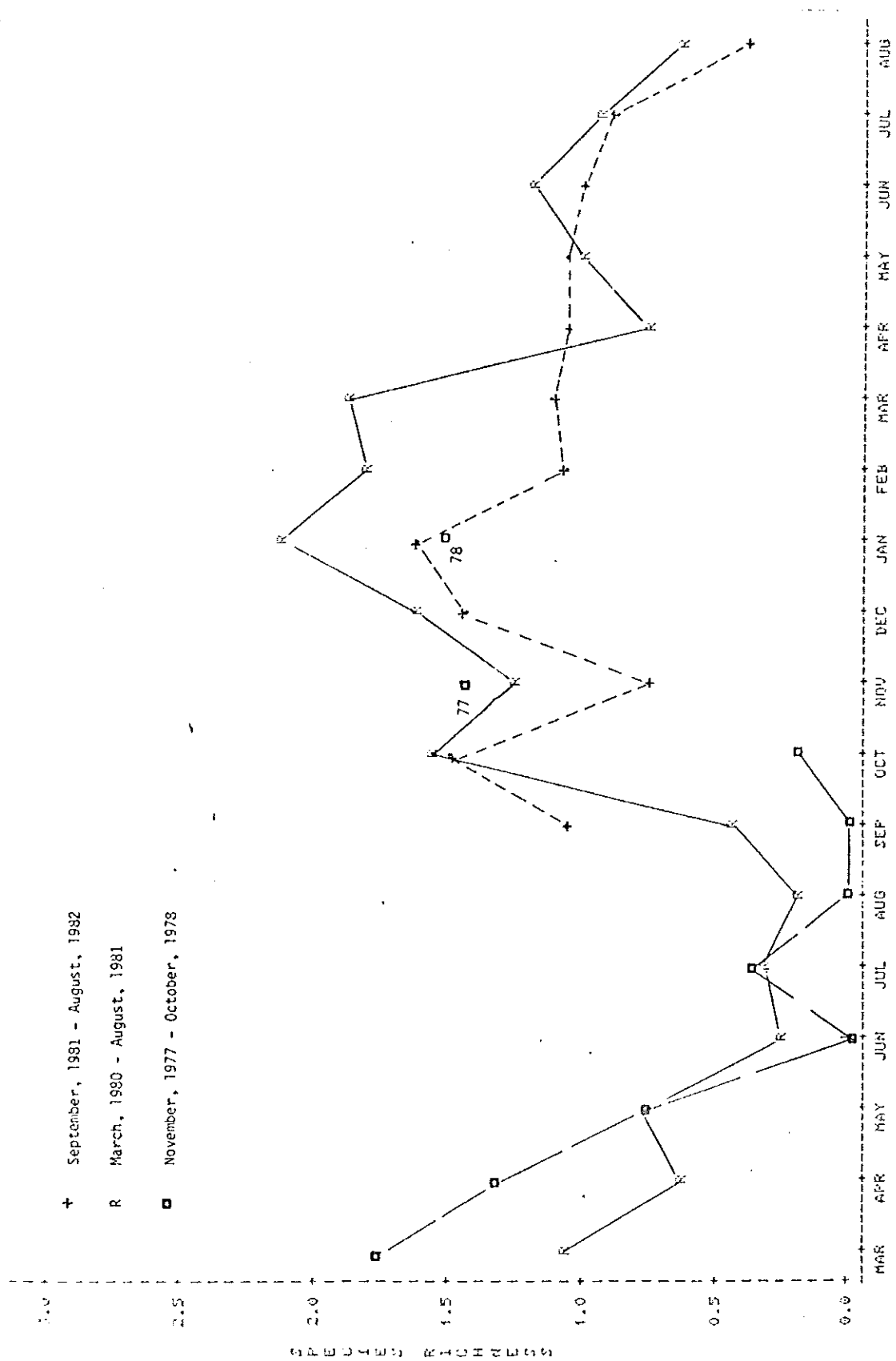


Figure 16A. Graph of Polychaete Richness (R) at Station B-1.



follows the same trend at a slightly lower level. Figures 12A indicates a bimodal distribution of evenness in macroinvertebrates with peaks in the early fall of 1980 and again in mid-summer of 1981 (July). In contrast, polychaete evenness (Figure 15A) stays generally consistent throughout the construction period with repeated dips in April of 1980 and April of 1981. The relatively high values of polychaete evenness indicate stability in the polychaete community at station B-1 during construction. Figures 13A and 15A show macroinvertebrate and polychaete richness respectively. Richness generally parallels diversity in both cases with seasonal peaks in January and June 1981 respectively.

### 3) Post-construction -

General Abundance/Dominance - During the 12 months of post-construction 1,433 organisms were collected at station B-1. Of this number Mediomastus ambiseta accounted for 572(39.9%) of the organisms taken and Sigambra sp.A totaled 15.8% (226) indicating a dominance of two polychaete species over Mulinia lateralis which was not recorded, and Macoma sp. A which accounted for only 3.3% (47 individuals) of the collected organisms. Clearly, polychaetes were dominant during post-construction.

Diversity, Evenness, and Richness - Figures 11A-13A and 14A-16A reflect these indices during the post-construction months at station B-1. Whereas the construction period displayed fairly sharp peaks in diversity during 1980 and 1981, the peaks are less pronounced for macroinvertebrates (Figure 11A) during late 1981 and the winter to summer of 1982. Diversity is remarkably uniform during the 12-month construction period. Polychaete diversity mirrors macroinvertebrate diversity at a lower level (about 2.5 on the scale). Macroinvertebrate and polychaete evenness were markedly consistent and high during post-construction (Figure 12A and 15A respectively). Noticeable dips in this index were recorded in both figures during December 1981 and again in March 1982. An inspection of richness during the post-construction months, found in figures 13A and 16A, show parallel trends for macroinvertebrates and polychaetes. Overall richness was lower in 1982 than in 1981, but the spring of 1982 was higher than the same period in 1980.

### 4) Monitoring Period Overall -

The data generally indicate that there were fluctuations in dominance and numerical indices over the 30-month period, but these fluctuations are apparently annual variations with seasonal trends and do not appear to be related to construction. This conclusion is supported by comparing post-construction to construction data from the Duncan's Multiple Range Test for mean number of organisms and mean number of species per replicate at station B-1. The results indicate no significant difference at the 0.05 level.

#### b. Station B-4:

1) Overview - Table 13B summarizes the biological characterization data for site B-4 during construction and post-construction months. This table contains data for all organisms from March 1980 through August of

TABLE 136. Summary Biological Characterization, Station B-4.

PERIOD:		CONSTRUCTION												POST-CONSTRUCTION																	
MONTH:	YEAR:	APR 80	MAY 80	JUN 80	JUL 80	AUG 80	SEP 80	OCT 80	NOV 80	DEC 80	JAN 81	FEB 81	MAR 81	APR 81	MAY 81	JUN 81	JUL 81	AUG 81	SEP 81	OCT 81	NOV 81	DEC 81	JAN 82	FEB 82	MAR 82	APR 82	MAY 82	JUN 82	JUL 82	AUG 82	
1		162	464	156	256	204	133	86	222	362	335	2120	373	538	477	463	344	7	130	891	249	126	249	39	121	162	270	110	84	43	15
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- 1 = Organisms/7 grabs
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- 3 = Mean No. Organisms Per 0.1 Meter Square
- 4 = Species/7 grabs
- 5 = Polychaete Species/7 grabs
- 6 = Mean No. Species Per 0.1 Meter Square
- 7 = Diversity as H'
- 8 = Polychaete Diversity
- 9 = Evenness as J'
- 10 = Polychaete Evenness
- 11 = Richness as R
- 12 = Polychaete Richness

( ) = Polychaete Only Data

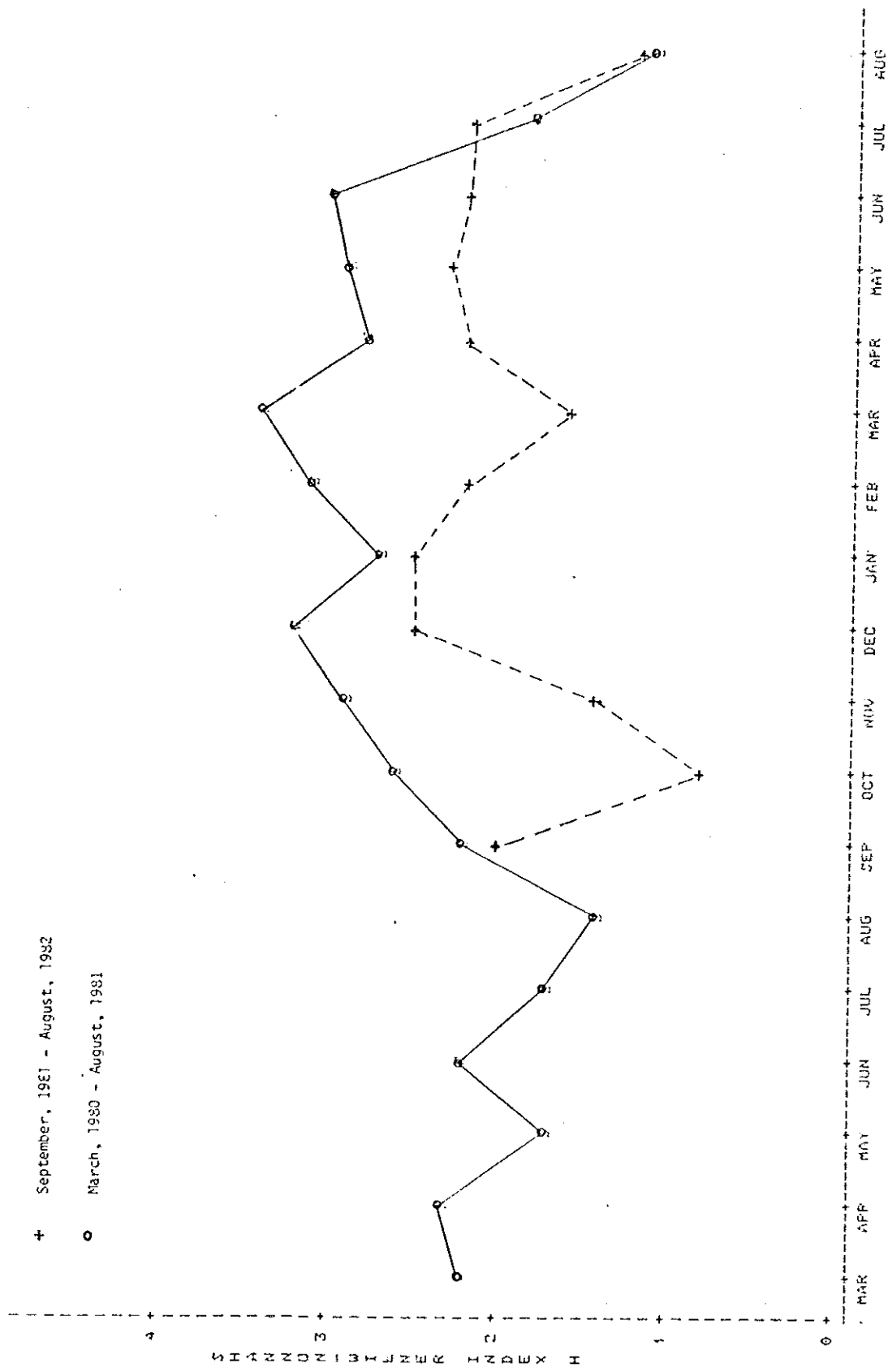


Figure 11B. Graph of Macroinvertebrate Diversity (H') at Station B-4.

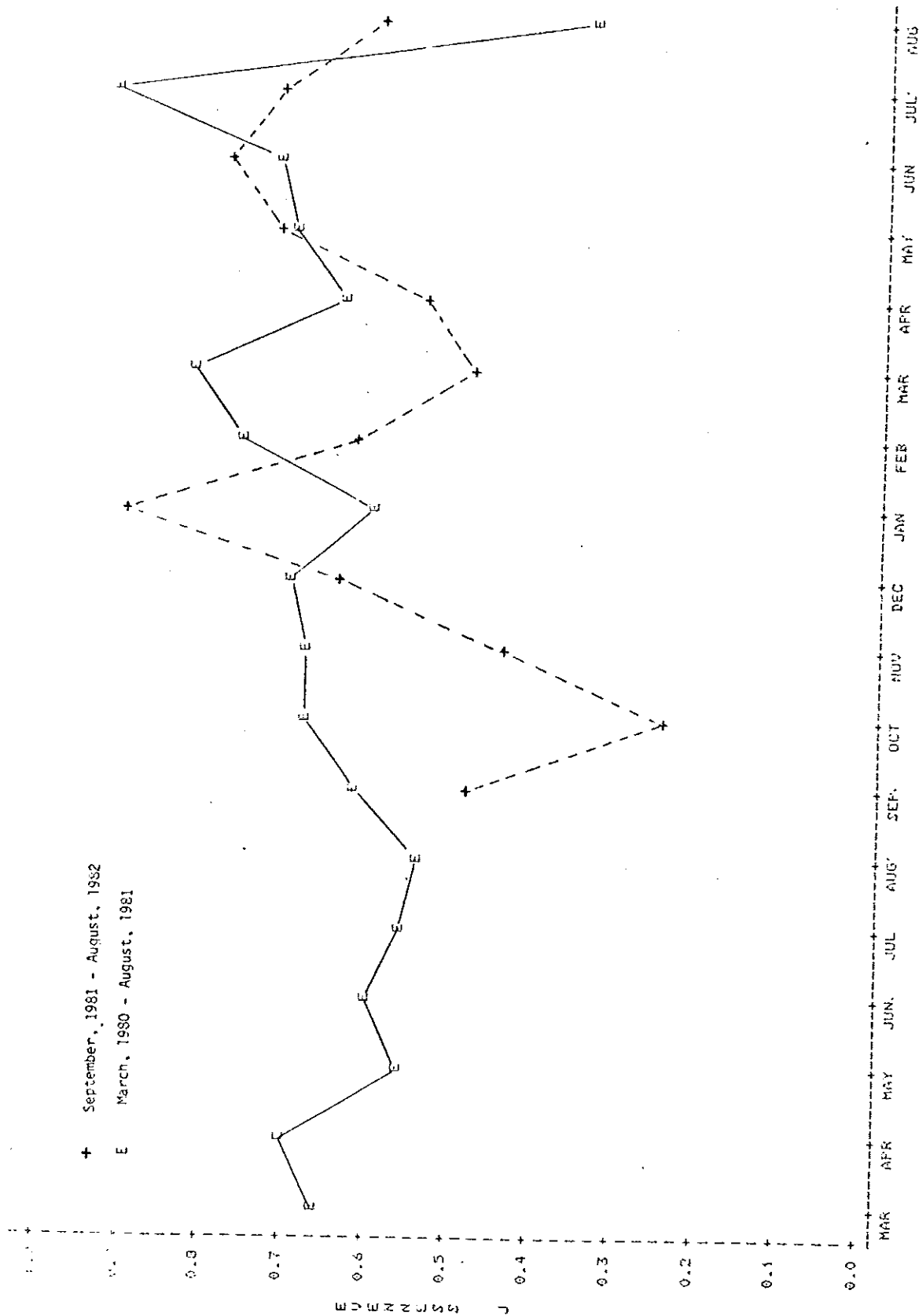


Figure 12B. Graph of Macroinvertebrate Evenness (J') at Station B-4.

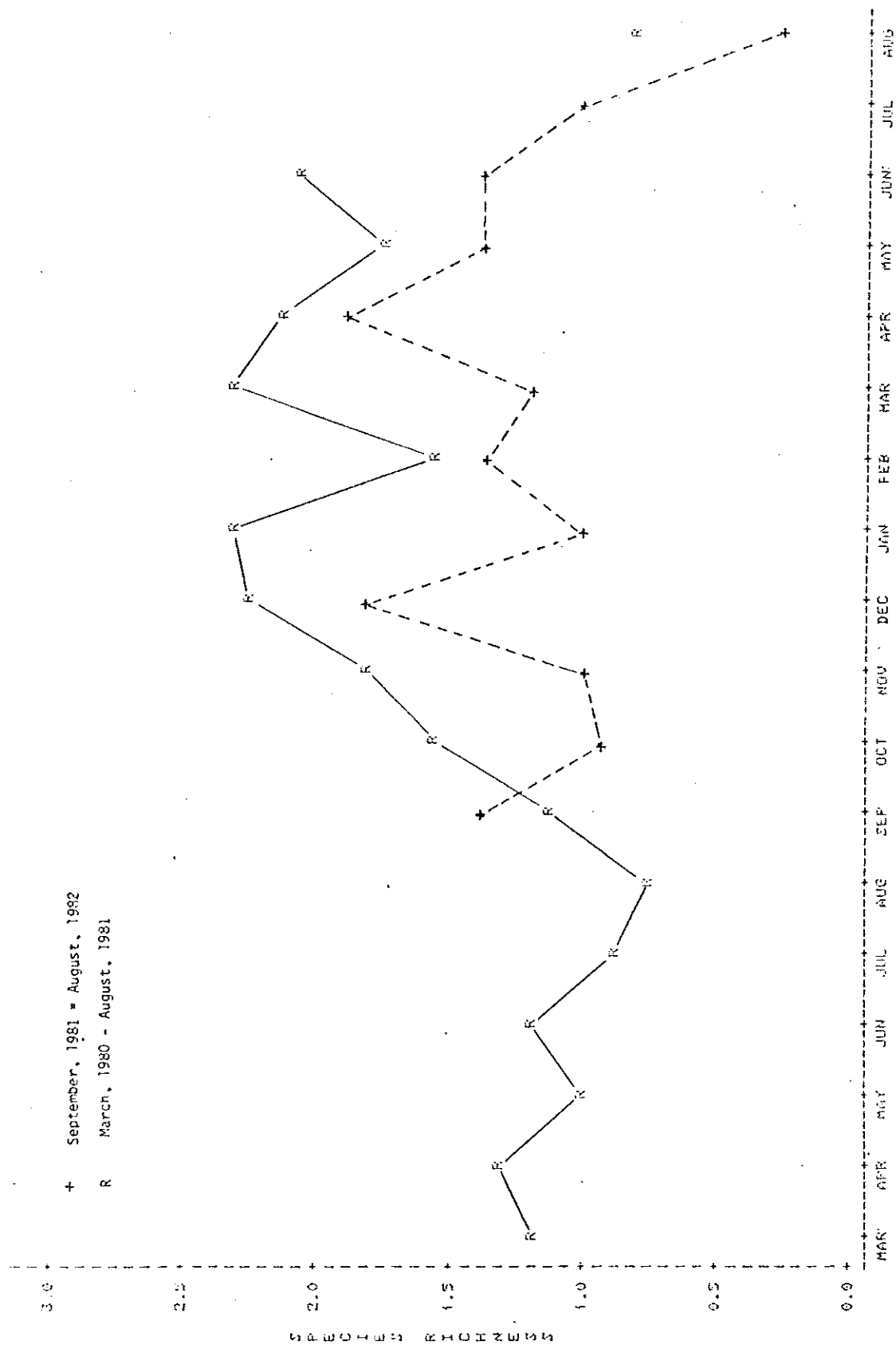


Figure 13B. Graph of Macroinvertebrate Richness (R) at Station B-4.

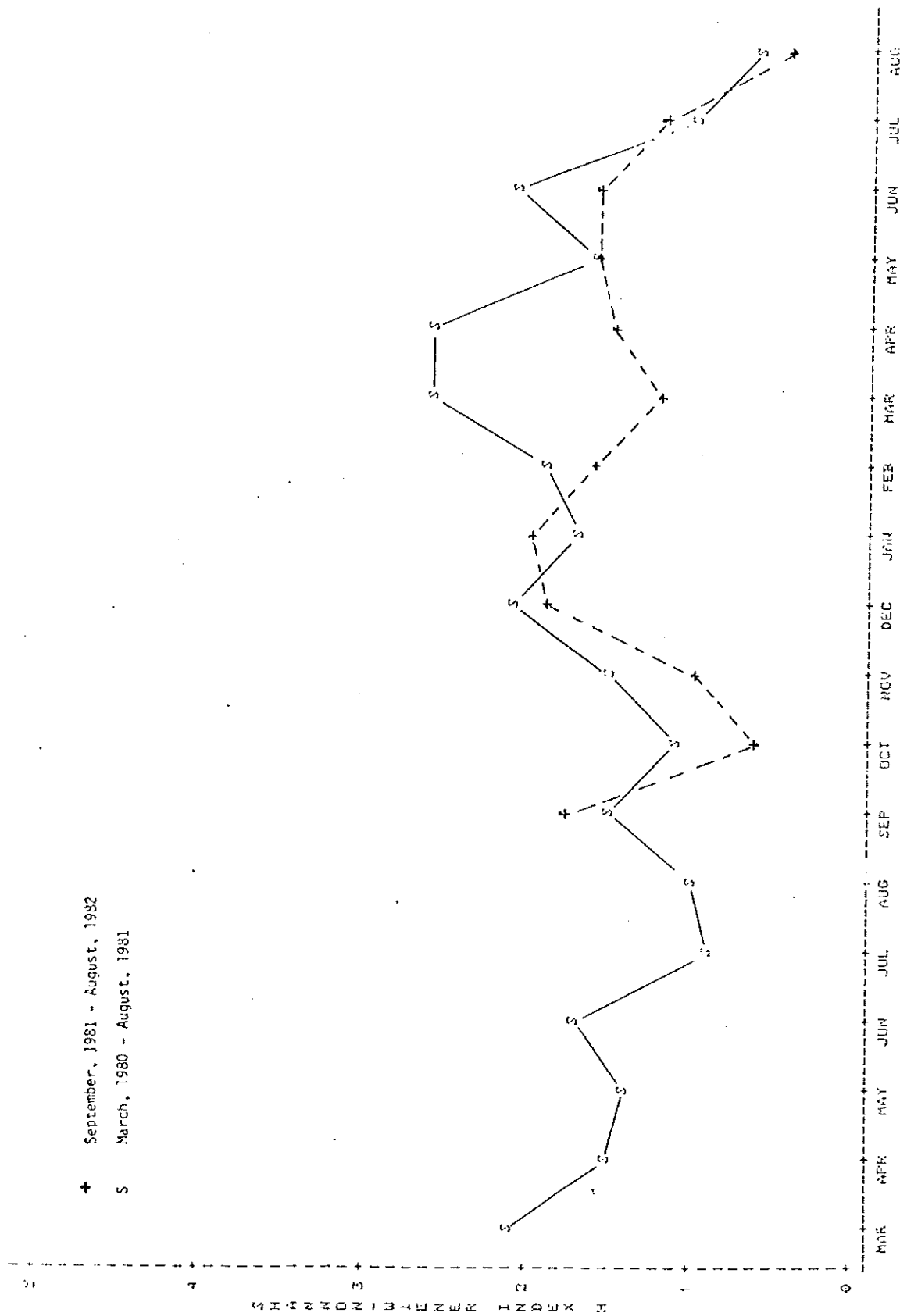


Figure 14B. Graph of Polychaete Diversity ( $H'$ ) at Station B-4.

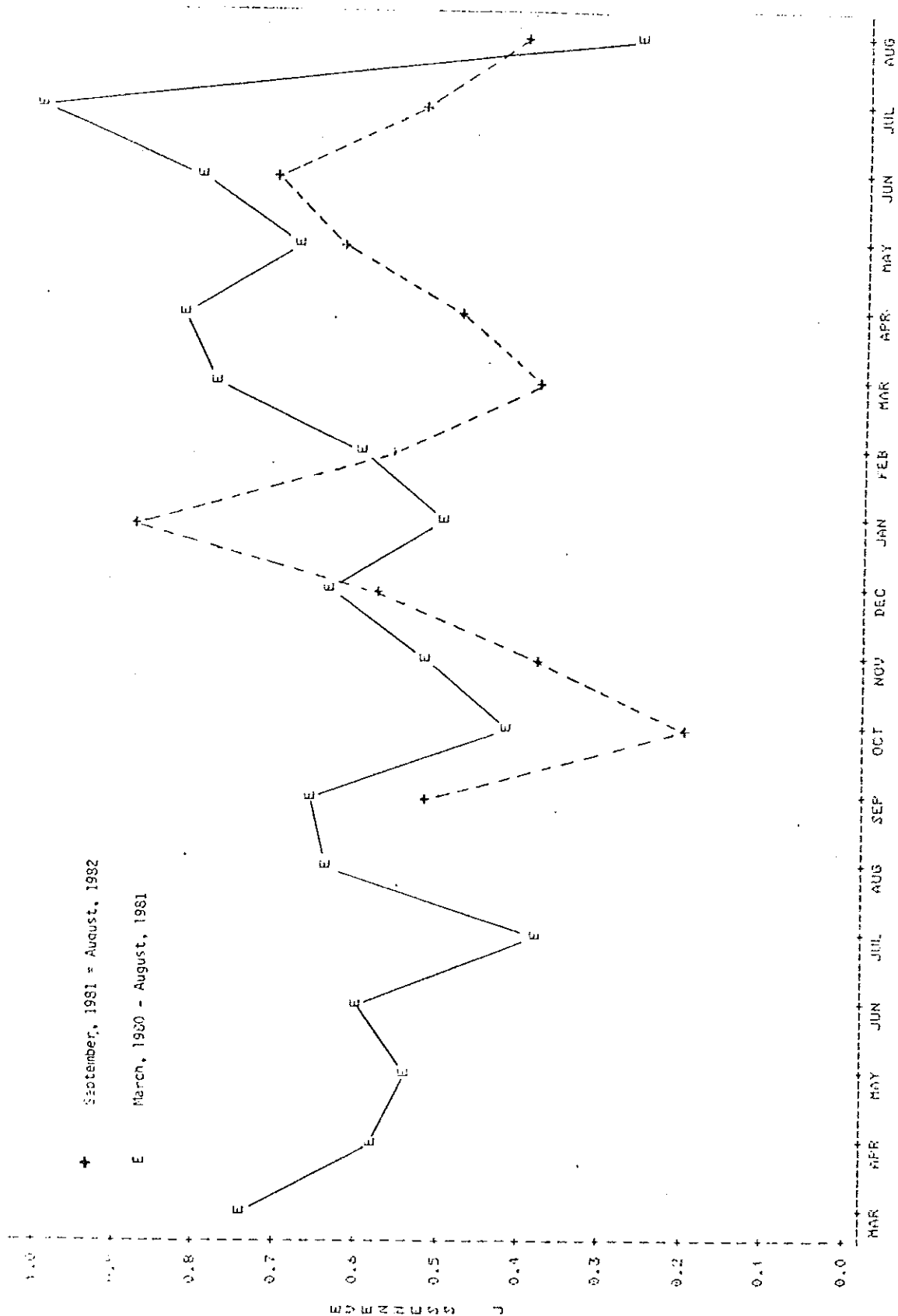


Figure 15B. Graph of Polychaete Evenness (J') at Station B-4.

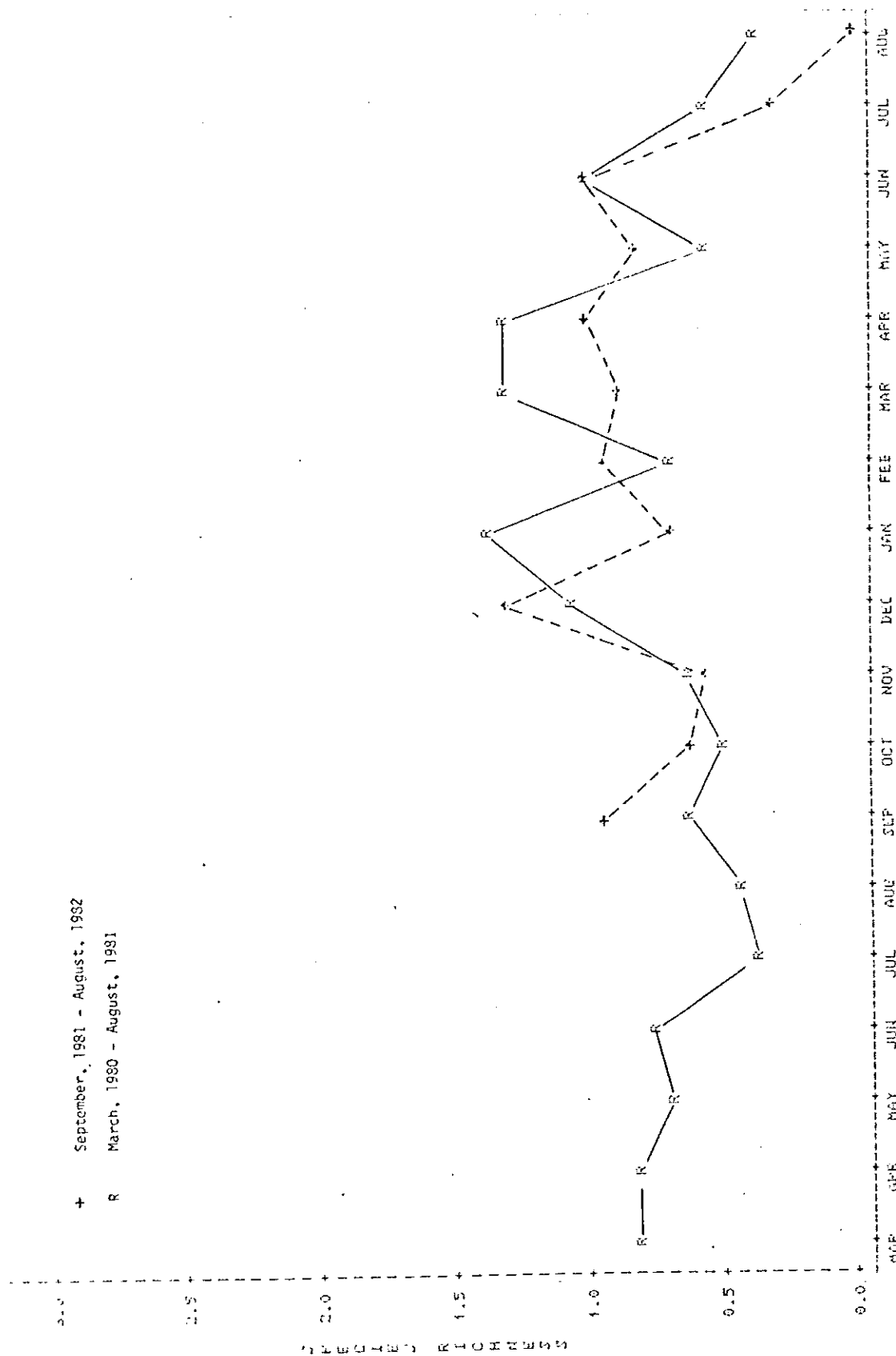


Figure 16B. Graph of Polychaete Richness (R) at Station B-4.



1982. Data for polychaetes only has been tabulated during selected months to show year to year fluctuations in this dominant group of macroinfaunal invertebrates.

## 2) Construction -

General Abundance/Dominance - Of the 9,192 organisms collected at station B-4, 6,832 were collected during the 18-month construction phase. This accounts for 74.3% of the total organisms. Of the 6,832 organisms taken, the bivalve Mulinia lateralis totaled 1,514 (22.2%) and was followed in abundance by a second bivalve, Macoma sp.A with 20.3% (1,387 individuals). The third ranking dominant organism was Mediomastus ambiseta, a polychaete, at 19.5% (1,330 individuals). In summary, three organisms, two bivalve species and one polychaete species, accounted for 4,231 individuals (62.0%) taken during construction months.

By examining Table 13B, we can see an organismal peak in April 1980 which was generally maintained for two months by polychaetes. In November of 1980, molluscs begin to proliferate and peak in January, however, they remained dominant overall.

Diversity, Evenness, and Richness - These indicators of community structure and well-being at station B-4 are plotted in figures 11B through 13B. The data for polychaetes only at station B-4 are plotted in figures 14B through 16B. As in the case of station B-1, post-construction and baseline data are also present on these figures where available.

Figure 11B shows the diversity pattern for macroinvertebrates at station B-4 during the construction period. Generally speaking it mirrors station B-1, but at a lower level, e.g. peaks are not as high and the data spread is more uniform on either side of about 2.5 on the  $H'$  index. Polychaete diversity (Figure 14B) follows figure 11B very closely. Turning to evenness, figure 12B shows distinct differences from figure 12A in terms of scatter on either side of a line through 0.65 on the index. Polychaete evenness at station B-4 (Figure 15B) is also more tightly grouped around a line through 0.65 with smaller upper and lower excursions than at station B-1 (Figure 15A). Turning to richness (Figure 13B) in macroinvertebrates, we see generally low values until August of 1980 and peaking in the winter and falling below scale in July of 1981. Station B-1 did not fall below scale in July of 1981. Polychaete richness, figure 16B, at station B-4 had a distribution similar to but below station B-1 (Figure 11B).

## 3) Post-construction -

General Abundance/Dominance - During the 12 months of post-construction 2,360 organisms were collected at station B-4. Of this number, Mediomastus ambiseta, a polychaete, accounted for 1,182 individuals (50.1% of the total). The second most abundant species was Sigambra sp.A, another polychaete at 6.1% (145 individuals) much as at station B-1 during this period. As at station B-1, the bivalves Mulinia and Macoma are at less than 1% each.

Diversity, Evenness, and Richness- Figures 11B-13B and 14B-16B reflect these indices during post-construction at B-4. The general trend of diversity at B-4 is similar to B-1 but at a lower level, e.g. around 2.0 at

B-4 and near 3.0 at B-1. B-4 has a low period during the first three months which differ from B-1, but has dips in March and August 1982 which correspond to dips at station B-1. Post-construction polychaete diversity follows macroinvertebrate diversity more closely at B-4 and is more erratic and at a lower level (around 1.5) than at station B-1.

Macroinvertebrate evenness during post-construction monitoring is displayed in figure 12B and figure 15B for polychaetes only. Evenness is bimodal with peaks in January and June 1982. This pattern is less evident at station B-1 (Figure 11B). Polychaete evenness mirrors macroinvertebrates at station B-4 (Figure 15B).

The displays for richness are found in figure 13B and figure 16B. Post-construction richness of macroinvertebrates ranges around 1.25 for the first 11 months, but falls to a distinct low in August of 1982. This low was also seen at station B-1 in August of 1982. Polychaete richness generally follows the macroinvertebrate trend, but at about 0.90 on the scalar index. (See Station B-1, Figure 11B).

#### 4) Monitoring Period Overall -

Just as we saw at station B-1, there were distinct changes in dominance by organisms at station B-4. Molluscs gave way to polychaetes during the post-construction phase, however, the Duncan's Multiple Range Test for mean number of organisms and mean number of species per replicate at station B-4 indicated no significant differences when the two periods were compared at the 0.05 level.

#### c. Station B-8:

1) Overview - Table 13C summarizes the biological characterization data for site B-8 for construction and post-construction months. A review of this table reveals data for all organisms from March 1980 through August 1982. Data for polychaetes only has been tabulated during selected months, to show year to year fluctuations in this dominant group of macroinfaunal invertebrates.

#### 2) Construction -

General Abundance/Dominance - Of the 12,501 organisms collected at station B-8, 9,574 were collected during the 18-month construction phase. This accounts for 76.6% of the total organisms taken. Of the 9,574 organisms examined, the bivalve Mulinia lateralis totaled 3,006 (31.4%) and was followed by another bivalve, Macoma sp.A which totaled 1,782 individuals (18.6%). The third ranking dominant organism was the polychaete, Mediomastus ambiseta totalling 1,730 individuals and accounting for 18.1% of the collected organisms. In summary, two bivalve species and one polychaete species accounted for 6,518 individuals (68.1%) taken during construction months.

Diversity, Evenness, and Richness - These indicators of community structure and well being at station B-8 are plotted in figures 11C through 13C. The data for polychaetes only at station B-8 are plotted in figures 14C through 16C. As in the case of station B-1 and B-4, post-construction and baseline data are also present on these figures where available.

TABLE 13C. Summary Biological Characterization, Station B-8.

PERIOD:		CONSTRUCTION												POST-CONSTRUCTION																	
MONTH:	YEAR:	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
		80	80	80	80	80	80	80	80	80	80	81	81	81	81	81	81	81	81	81	81	81	81	82	82	82	82	82	82	82	82
1		305	401	257	180	122	117	126	172	519	1310	2215	502	2209	271	451	223	14	80	358	437	455	525	113	97	457	200	132	51	88	12
2		(222)	(334)	(243)	(149)	(86)				(131)	(602)	(431)	(161)	(269)	(69)	(145)	(69)			(350)	(431)	(450)	(500)			(452)	(176)	(118)			
3		43.6	57.3	36.7	25.7	17.4	16.7	21.0	28.7	74.1	187.1	316.4	86.0	315.6	38.7	64.4	31.9	2.8	16.0	51.1	62.4	55.1	73.7	16.1	13.9	65.3	28.6	19.9	8.7	12.6	2.0
4		10	10	5	11	9	9	9	17	21	29	24	21	23	15	20	21	5	7	12	10	9	9	9	12	9	10	10	6	6	4
5		(4)	(6)	(3)	(4)	(5)														(8)	(8)	(7)	(6)			(7)	(7)	(5)			
6		6.1	5.6	3.6	5.0	4.1	4.7	2.6	6.6	9.7	16.1	15.3	13.0	15.3	7.4	11.7	9.6	1.4	1.6	5.0	4.9	4.4	5.6	4.6	5.1	4.1	6.0	3.9	3.9	2.6	1.3
7		2.35	2.07	0.87	2.00	2.02	2.24	1.10	3.17	3.09	3.62	2.61	3.33	3.12	3.12	3.20	3.49	1.81	0.98	1.07	1.12	0.91	1.24	2.23	2.72	1.05	2.02	1.48	2.04	1.21	1.78
8		(1.60)	(1.45)	(0.55)	(1.11)	(1.23)				(2.19)	(2.56)	(2.16)	(2.74)	(2.58)	(2.03)	(2.28)	(2.30)			(0.69)	(1.02)	(0.61)	(1.03)			(0.96)	(1.49)	(0.89)			
9		0.71	0.62	0.38	0.58	0.64	0.71	0.35	0.78	0.70	0.74	0.57	0.76	0.69	0.80	0.74	0.79	0.78	0.35	0.30	0.34	0.29	0.39	0.70	0.76	0.33	0.61	0.45	0.79	0.47	0.89
10		(0.80)	(0.56)	(0.35)	(0.55)	(0.53)				(0.69)	(0.66)	(0.57)	(0.76)	(0.75)	(0.72)	(0.72)	(0.77)			(0.30)	(0.34)	(0.29)	(0.40)			(0.34)	(0.53)	(0.38)			
11		1.36	1.13	0.71	1.23	1.10	1.32	0.52	1.66	2.02	2.89	2.48	2.69	2.48	1.76	2.57	2.48	0.42	0.21	1.02	0.53	0.62	1.06	1.28	1.58	0.75	1.49	0.57	1.32	0.62	0.41
12		(0.62)	(0.57)	(0.36)	(0.51)	(0.51)				(1.22)	(1.73)	(1.66)	(1.59)	(1.53)	(0.79)	(1.40)	(1.07)			(0.73)	(0.73)	(0.62)	(0.80)			(0.62)	(0.53)	(0.46)			
1		1 = Organisms/7 grabs																													
2		2 = Polychaete/7 grabs																													
3		3 = Mean No. Organisms Per 0.1 Meter Square																													
4		4 = Species/7 grabs																													
5		5 = Polychaete Species/7 grabs																													
6		6 = Mean No. Species Per 0.1 Meter Square																													
7		7 = Diversity as H'																													
8		8 = Polychaete Diversity																													
9		9 = Evenness as J'																													
10		10 = Polychaete Evenness																													
11		11 = Richness as R																													
12		12 = Polychaete Richness																													
		13 = Polychaete Only Data																													

- 1 = Organisms/7 grabs  
2 = Polychaete/7 grabs  
3 = Mean No. Organisms Per 0.1 Meter Square  
4 = Species/7 grabs  
5 = Polychaete Species/7 grabs  
6 = Mean No. Species Per 0.1 Meter Square  
7 = Diversity as H'  
8 = Polychaete Diversity  
9 = Evenness as J'  
10 = Polychaete Evenness  
11 = Richness as R  
12 = Polychaete Richness  
( ) = Polychaete Only Data

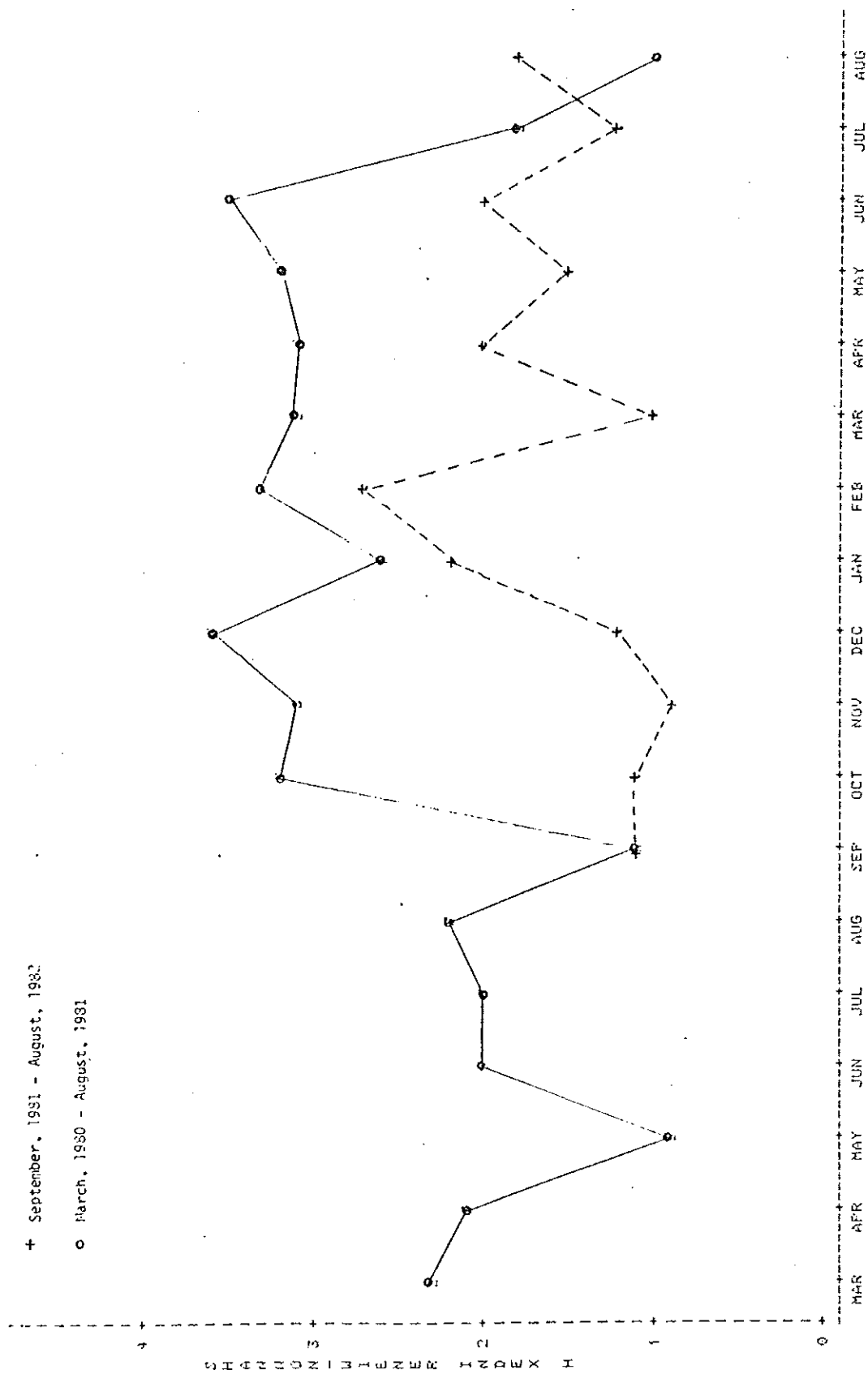


Figure 11C. Graph of Macroinvertebrate Diversity ( $H'$ ) at Station B-8.

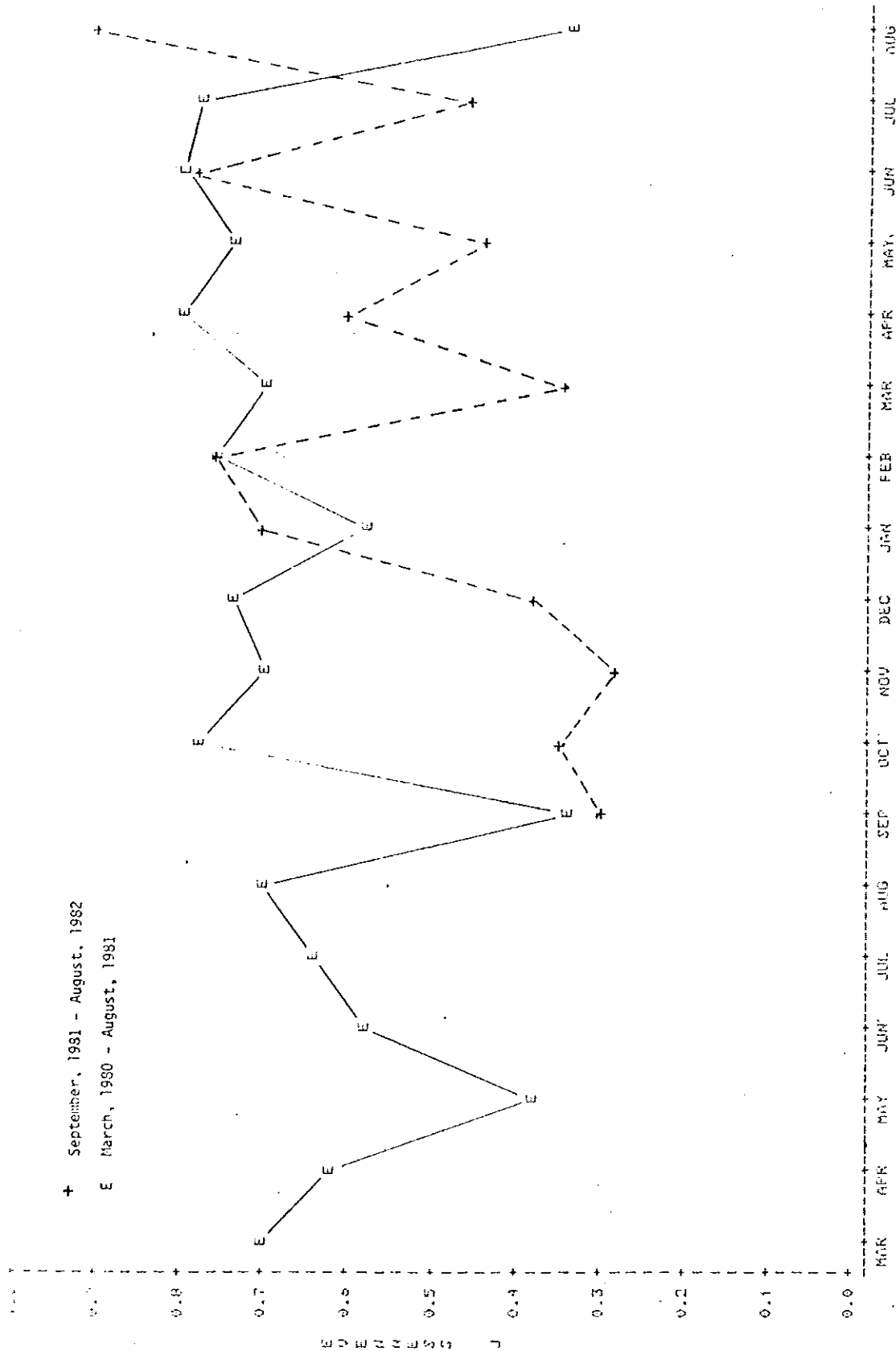


Figure 12C. Graph of Macroinvertebrate Evenness (J\*) at Station B-8.

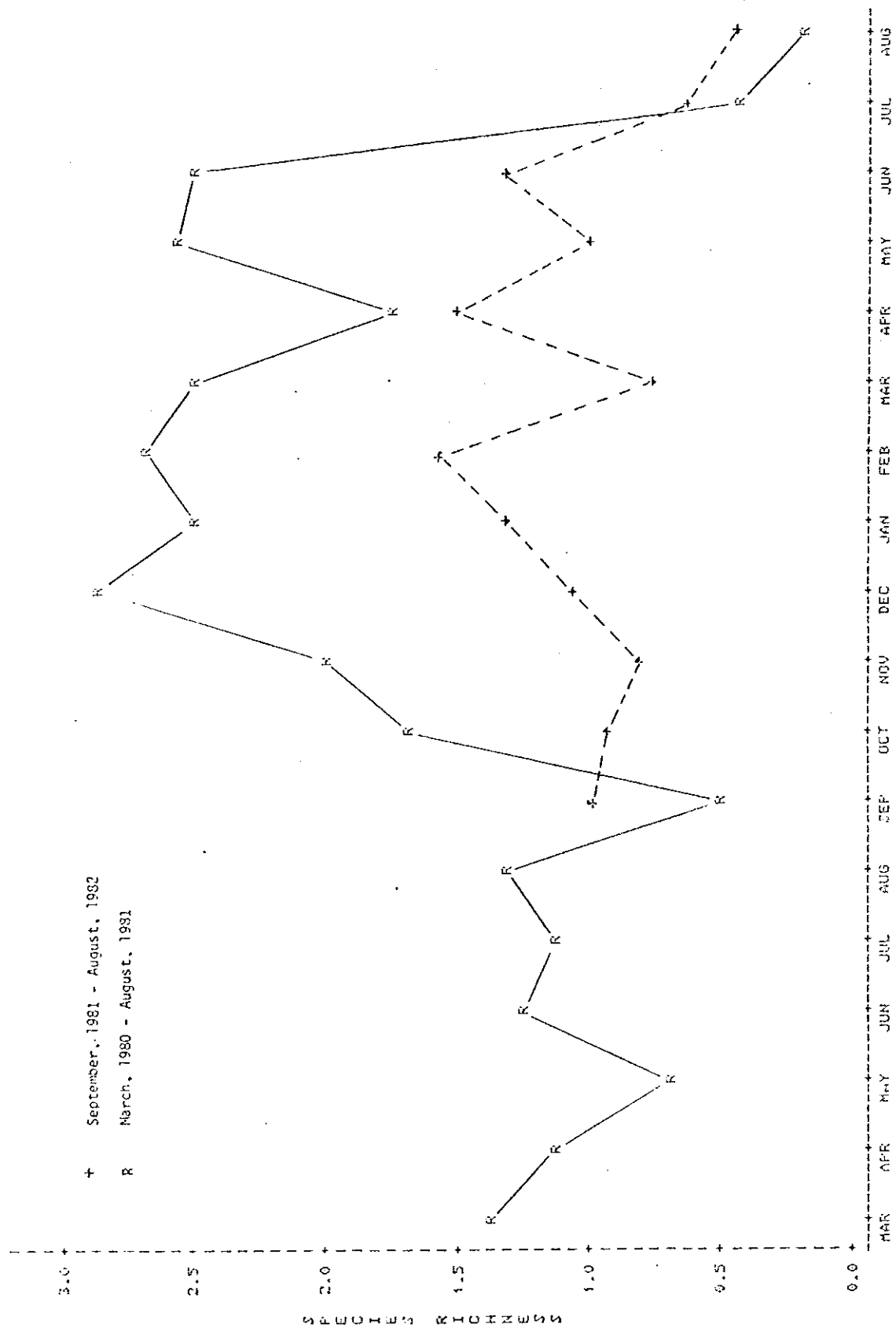


Figure 13C. Graph of Macroinvertebrate Richness (R) at Station B-8.

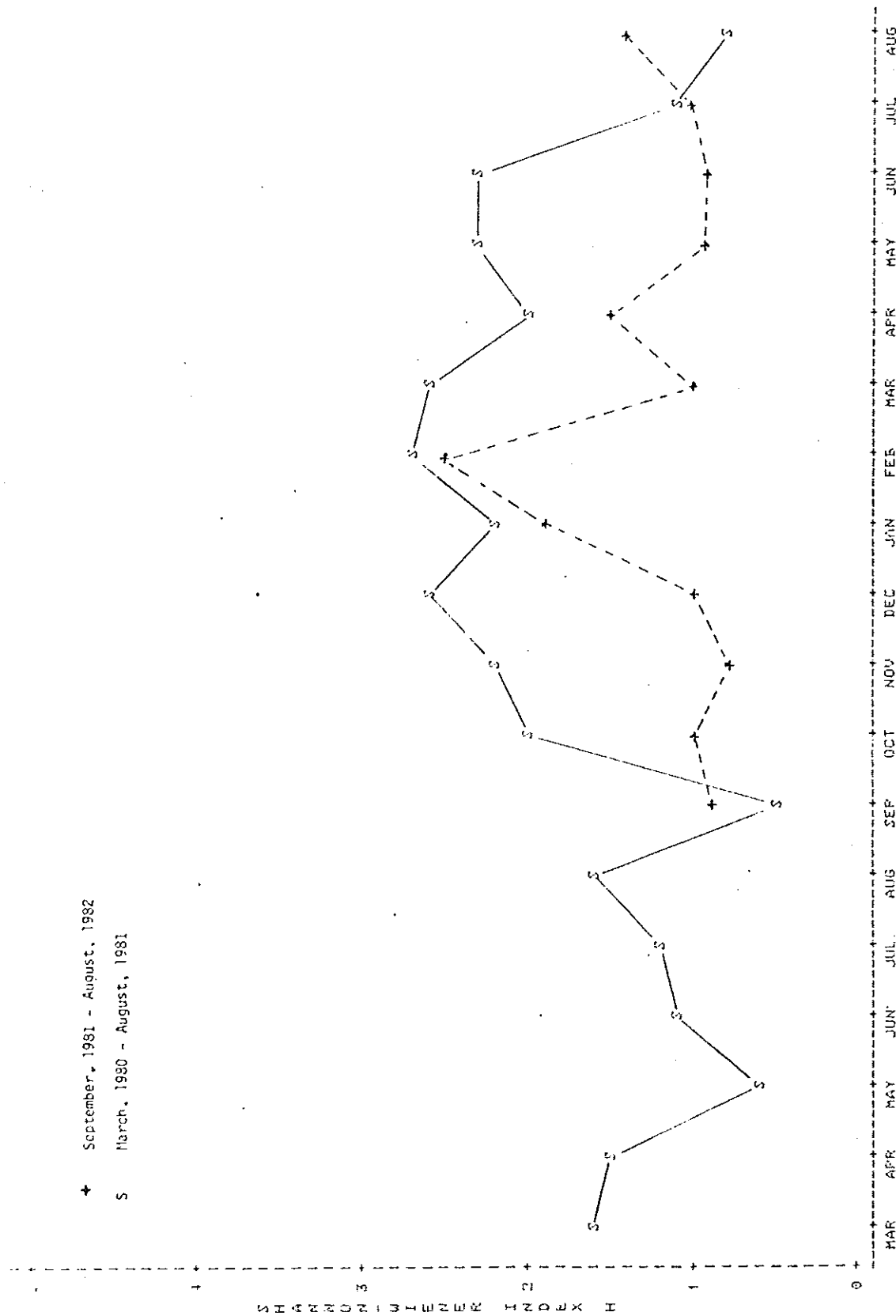


Figure 14C. Graph of Polychaete Diversity (H') at Station B-8.

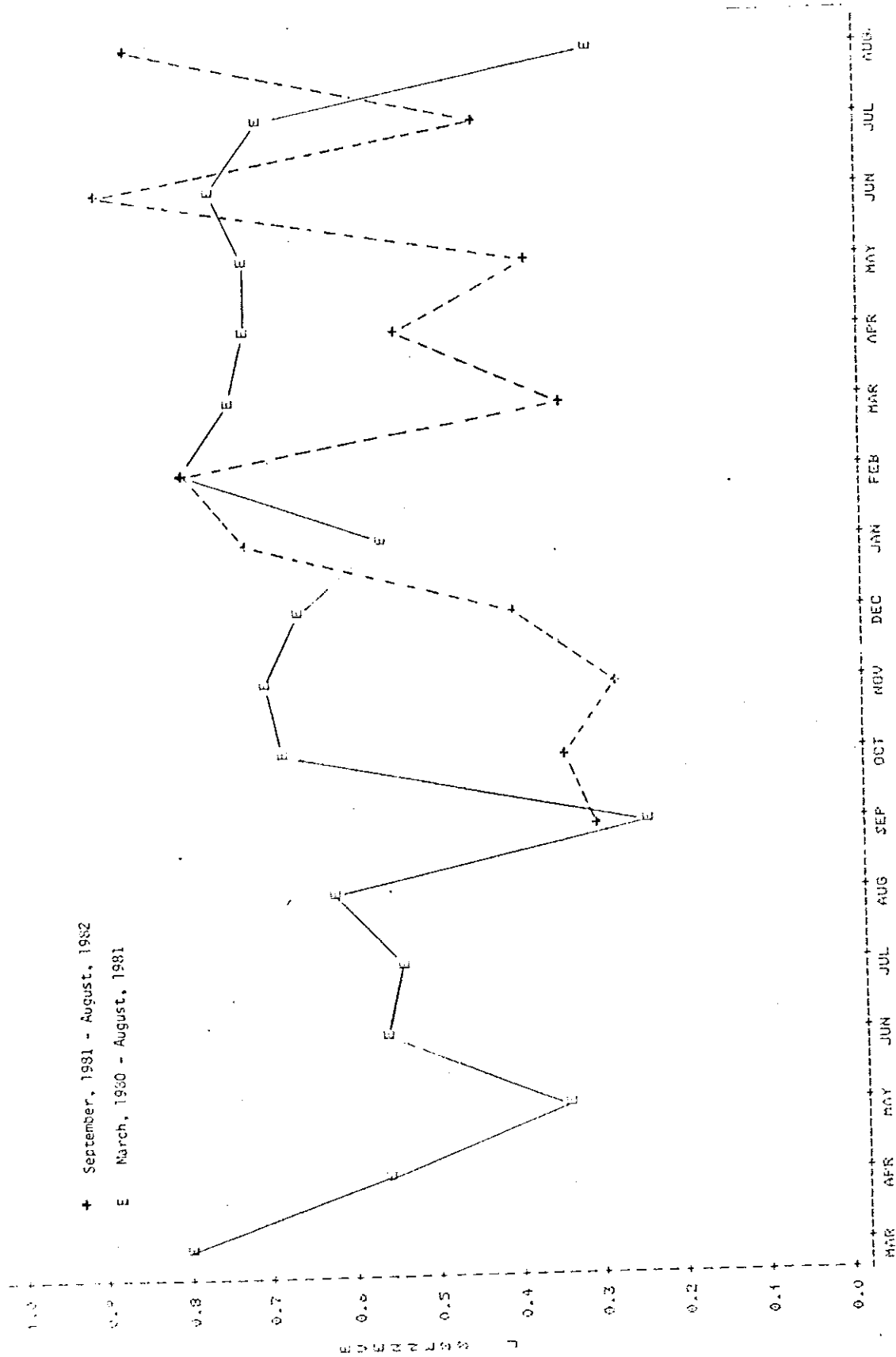


Figure 15C. Graph of Polychaete Evenness (J') at Station B-8.



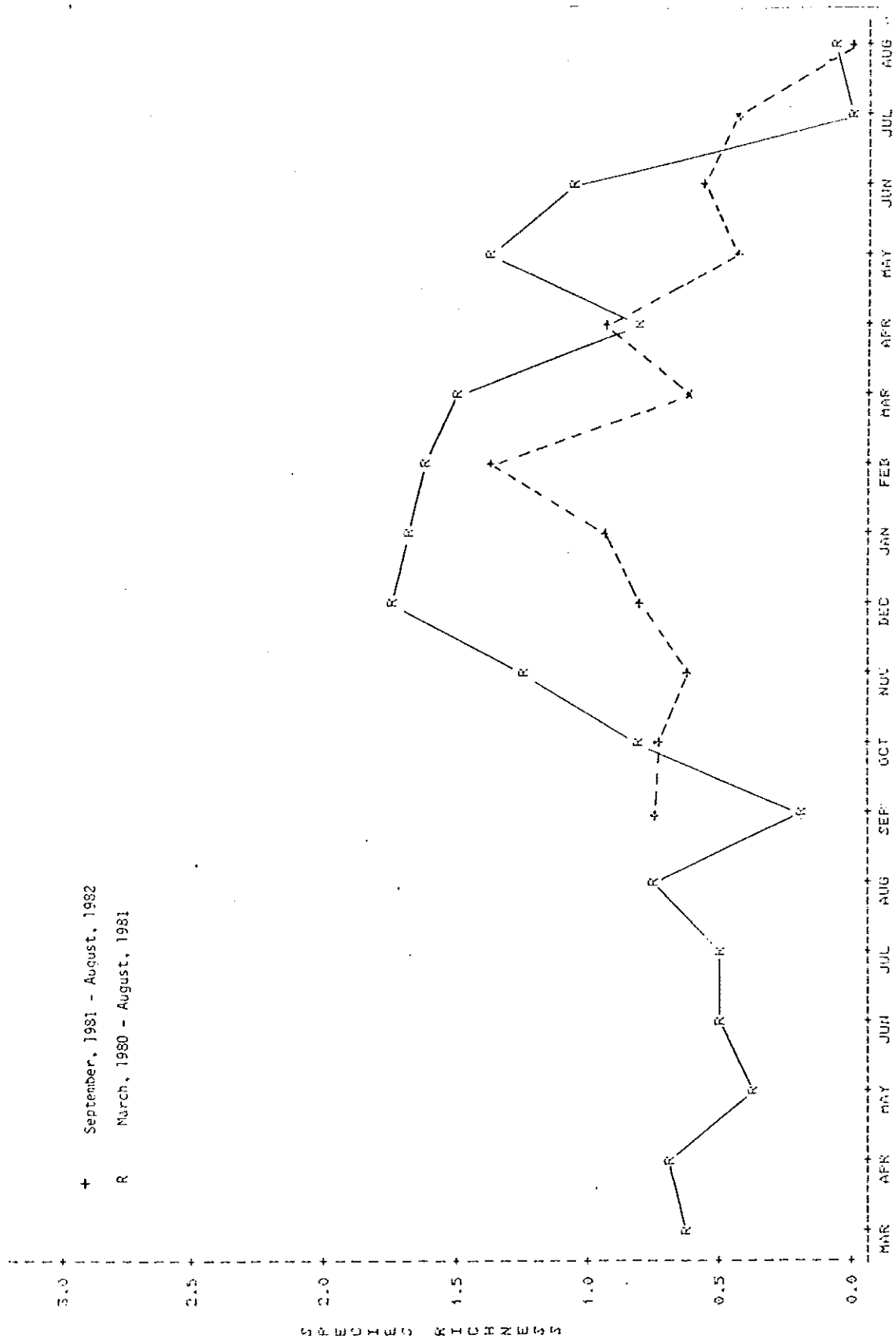


Figure 16C. Graph of Polychaete Richness (R) at Station B-8.

Figure 11C shows the diversity pattern for macroinvertebrates at station B-8 during the construction period. During March through October 1980, station B-8 showed patterns for these animals like those of station B-1 for that period. After October 1980, the graph of diversity becomes more similar to station B-4. In contrast, polychaete diversity does not appear to follow the trends at station B-4 or B-8 during the period listed. For example, polychaete diversity fell sharply at station B-8 during May and September of 1980. This did not occur at station B-1 or B-4 during and B-8 are remarkably similar in July and August 1981.

Turning to macroinvertebrate evenness, figure 12C indicates that station B-8 maintained a relatively high index of evenness (around 0.70) with three low months May and September 1980, and August 1981. Station B-1 has no apparent commonality with station B-8, however, data for station B-4 is similar to that of B-1 by August of 1981. Figure 15C displays polychaete evenness and station B-8 has some commonality with station B-4 during 1980, but not with station B-1 during this period. During 1981, only August has commonality at stations B-4 and B-8. No common features are evident at B-1 (Figure 15A). As a descriptor, polychaete evenness at B-8 is generally around 0.65 (as it was at station B-4).

Richness (Figure 13C) in macroinvertebrates at station B-8 is not comparable to station B-1 or B-4. Each of the stations display trends peculiarly erratic unto themselves. Polychaete richness (Figure 16C) at station B-8 during 1980 shows trends similar to those seen at stations B-1 (Figure 16A) and B-4 (Figure 16B), however, during 1981 richness at station B-8 maintains a relatively high and even level until July and August where it falls below that of both stations B-1 and B-4.

### 3) Post-construction -

General Abundance/Dominance - During the 12 months post-construction, 2,927 organisms were collected at station B-8. Of this number, the polychaete, Mediomastus ambiseta, totaled 2,183 individuals (74.6%). The second most abundant species was Paraprionospio pinnata (259;8.8%) and close behind at 224(7.6%) was Sigambra sp. A third polychaete. As was the case at B-1 and B-4, molluscan species were barely represented. (Macoma mulinia totaled less than 1% each).

Diversity, Evenness, and Richness - Figures 11-13C and 14-16C reflect these indices for station B-8 during post-construction monitoring. The plot of post-construction diversity at station B-8 (Figure 11C) is not similar to Figure 11A or 11B (Stations B-1 and B-4). Overall, diversity at station B-8 is lower, and only in January and February does it rise much above 2.0. By comparison, diversity at station B-1 ranks higher than at station B-4, which is more diverse than station B-8 overall. Polychaete diversity (Figure 14C) reflects the same story.

With respect to evenness (Figure 12C) station B-8 shows even greater irregularity than station B-4 (Figure 12B). This erratic pattern is maintained in the comparison of polychaete evenness (Figure 15C) at station B-8 with station B-1 (Figure 15A) or station B-4 (Figure 15B).

Macroinvertebrate richness at station B-8 (Figure 13C) is generally lower by comparison with station B-1 or B-4 (Figure 13A and 13B). This lower trend is maintained in polychaete richness at station B-8 (Figure 16C).

#### 4) Monitoring Period Overall

Just as at stations B-1 and B-4, there were distinct changes in dominance by organisms at station B-8. Molluscs gave way to polychaetes during the post-construction phase, however, the Duncan's Multiple Range Test for mean number of organisms and mean number of species per replicate at station B-8 indicated no significant differences when the two periods were compared. Using community indices, station B-8 is of lesser quality than station B-1 or B-4, but not significantly so during this study.

##### d. Station B-7:

1) Overview - Table 13D summarizes the biological characterizations data for site B-7 during construction and post-construction monitoring. This table contains data for all organisms from March 1980 through August 1982. Data for polychaetes only has been tabulated during selected months to show year to year fluctuations in this dominant group of macroinfaunal invertebrates.

##### 2) Construction -

General Abundance/Dominance - Of the 28,368 organisms collected at station B-7, 15,032 were collected during the 18-month construction phase. This accounts for 53.0% of the total organisms. Of the 15,032 organisms taken, the polychaetes Mediomastus ambiseta and Streblospio benedicti contributed 3,916 (26.0%) and 2,705 (18.0%) respectively to the total. Another polychaete, Neanthes succinea ranked third with 1,933 (12.9%). Macoma sp. A was scarce, with only 60 individuals, and Mulinia lateralis contributed only 604 individuals (4.0%). In summary, station B-7 was dominated by polychaetes with three species contributing 56.9% of the population (8,554 individuals). In abundance and dominance alone, we can see that station B-7 on the east side of the main channel is not similar to stations B-1, B-4, or B-8 on the west side. We will see this fact demonstrated repeatedly with community indices.

Diversity, Evenness, and Richness - These indicators of community structure and well-being at station B-7 are plotted in figures 11D through 13D. The data for polychaetes only at station B-7 are plotted in figures 14D through 16D. It should be noted that data for post-construction and baseline investigation also appears on these figures, and their relationships will be discussed as appropriate in subsequent interpretation.

Figure 11D indicates macroinvertebrate diversity has a bimodal distribution with peaks occurring in October-November, 1980 and again in February-March of 1981. Figure 14D is not surprising in that this station dominated by polychaetes shows polychaete diversity mirroring the station trend. Of note is the fact that the December drop in diversity seen on Figure 11D is not reflected by polychaetes.

TABLE 120. Summary Biological Characterization, Station 8-7.

PERIOD:	CONSTRUCTION												POST-CONSTRUCTION																		
	MAR 80	APR 80	MAY 80	JUN 80	JUL 80	AUG 80	SEP 80	OCT 80	NOV 80	DEC 80	JAN 81	FEB 81	MAR 81	APR 81	MAY 81	JUN 81	JUL 81	AUG 81	SEP 81	OCT 81	NOV 81	DEC 81	JAN 82	FEB 82	MAR 82	APR 82	MAY 82	JUN 82	JUL 82	AUG 82	
1	395	470	543	2591	400	207	802	125	234	964	337	625	1089	84	1875	2516	257	1447	570	1133	593	467	695	469	3077	4606	249	687	753	37	
2	(366)	(130)	(540)	(1905)	(342)			(135)	(297)	(191)	(355)	(730)	(1769)	(2355)	(242)	(1309)	(444)	(944)	(487)	(245)	(520)	(416)	(2953)	(462)	(524)	(521)					
3	55.0	67.1	134.2	327.3	57.1	29.6	114.5	19.0	33.4	137.7	48.1	89.3	152.7	12.0	267.9	359.4	36.7	206.7	81.4	161.9	84.7	66.7	99.3	67.0	439.5	659.0	35.6	96.1	107.6	9.2	
4	15	13	17	25	16	13	46	28	32	29	39	47	56	14	33	33	15	29	29	35	27	35	32	20	26	29	16	18	23	11	
5	(10)	(7)	(10)	(14)	(11)	(17)	(16)	(21)	(20)	(22)	(16)	(14)	(9)	(15)	(17)	(17)	(15)	(16)	(13)	(11)	(15)	(15)									
6	4.9	5.3	9.0	12.6	7.7	5.0	15.7	8.4	10.1	14.7	13.4	20.3	23.6	3.4	14.9	13.6	6.4	14.9	12.0	18.6	13.6	18.4	15.6	9.6	13.9	15.3	7.6	10.6	12.4	3.3	
7	1.05	2.10	2.18	2.55	2.82	2.16	3.14	3.91	3.81	2.77	4.15	4.22	3.95	1.66	2.49	2.19	2.07	3.02	2.91	3.16	3.18	4.21	3.52	1.91	1.48	1.45	2.79	2.99	3.17	2.76	
8	(0.71)	(1.54)	(1.21)	(2.05)	(2.40)	(2.77)	(2.94)	(3.23)	(3.09)	(2.92)	(2.10)	(1.78)	(1.73)	(2.58)	(2.06)	(2.42)	(2.59)	(3.17)	(2.70)	(1.23)	(1.30)	(1.20)									
9	0.27	0.57	0.53	0.55	0.71	0.59	0.56	0.81	0.75	0.57	0.79	0.75	0.68	0.44	0.49	0.43	0.53	0.62	0.60	0.61	0.67	0.62	0.70	0.44	0.31	0.30	0.70	0.72	0.70	0.80	
10	(0.21)	(0.55)	(0.37)	(0.54)	(0.69)	(0.68)	(0.74)	(0.74)	(0.71)	(0.65)	(0.52)	(0.47)	(0.55)	(0.66)	(0.50)	(0.59)	(0.65)	(0.79)	(0.73)	(0.37)	(0.30)	(0.31)									
11	0.96	1.02	1.63	2.00	1.66	1.18	3.10	2.57	2.61	2.78	3.21	4.29	4.49	0.99	2.48	2.14	1.51	2.60	2.50	3.45	2.83	4.15	3.17	2.04	2.11	2.20	1.84	2.09	2.44	1.26	
12	(0.65)	(0.70)	(1.05)	(1.25)	(1.21)	(1.53)	(1.87)	(1.81)	(2.22)	(2.43)	(1.37)	(0.91)	(1.09)	(1.61)	(1.55)	(1.88)	(1.95)	(2.45)	(1.86)	(1.15)	(1.39)	(1.31)									

- 1 = Organisms/7 grabs
- 2 = Polychaete/7 grabs
- 3 = Mean No. Organisms Per 0.1 Meter Square
- 4 = Species/7 grabs
- 5 = Polychaete Species/7 grabs
- 6 = Mean No. Species Per 0.1 Meter Square
- 7 = Diversity as H'
- 8 = Polychaete Diversity
- 9 = Evenness as J'
- 10 = Polychaete Evenness
- 11 = Richness as R
- 12 = Polychaete Richness
- ( ) = Polychaete Only Data

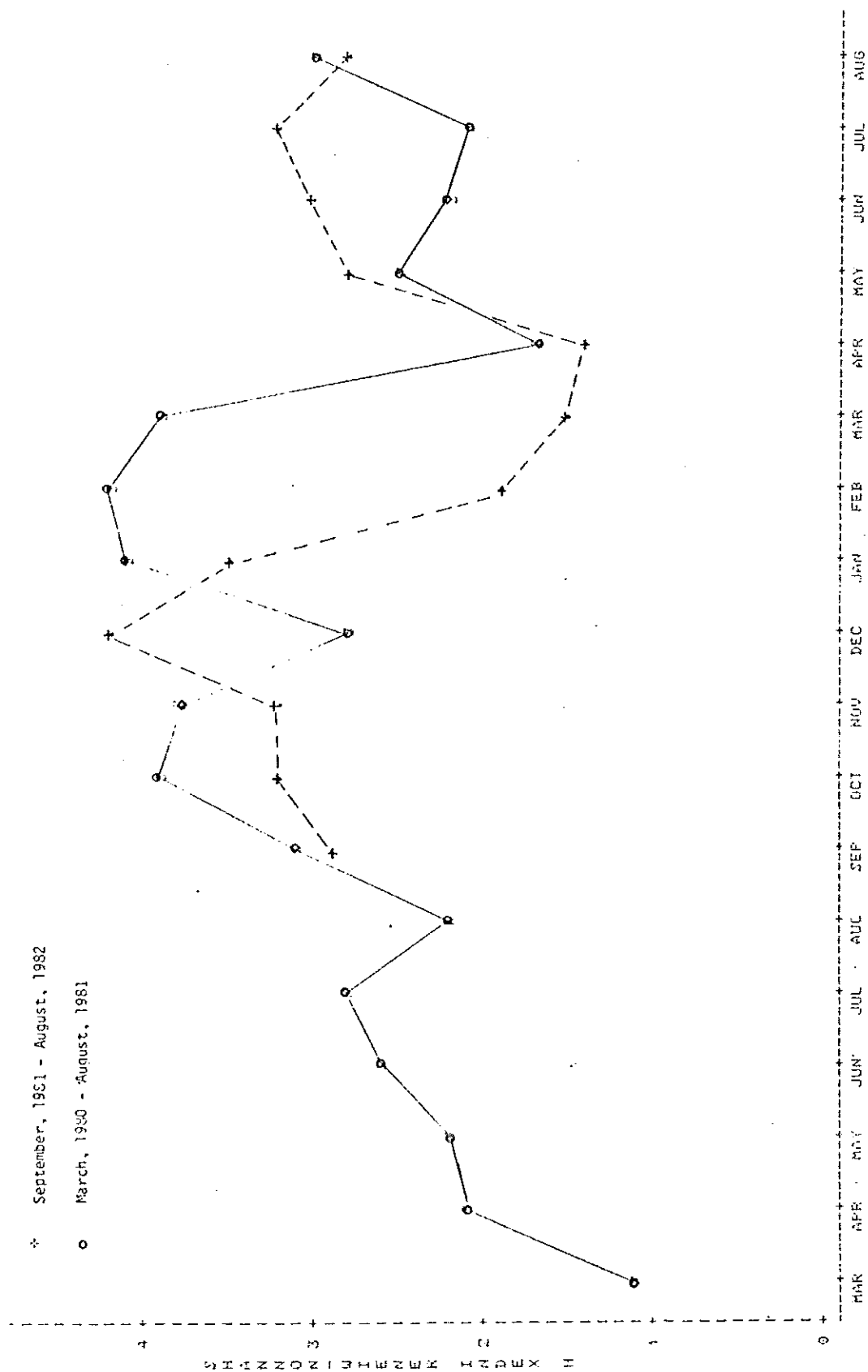


Figure 11D. Graph of Macroinvertebrate Diversity (H') at Station B-7.

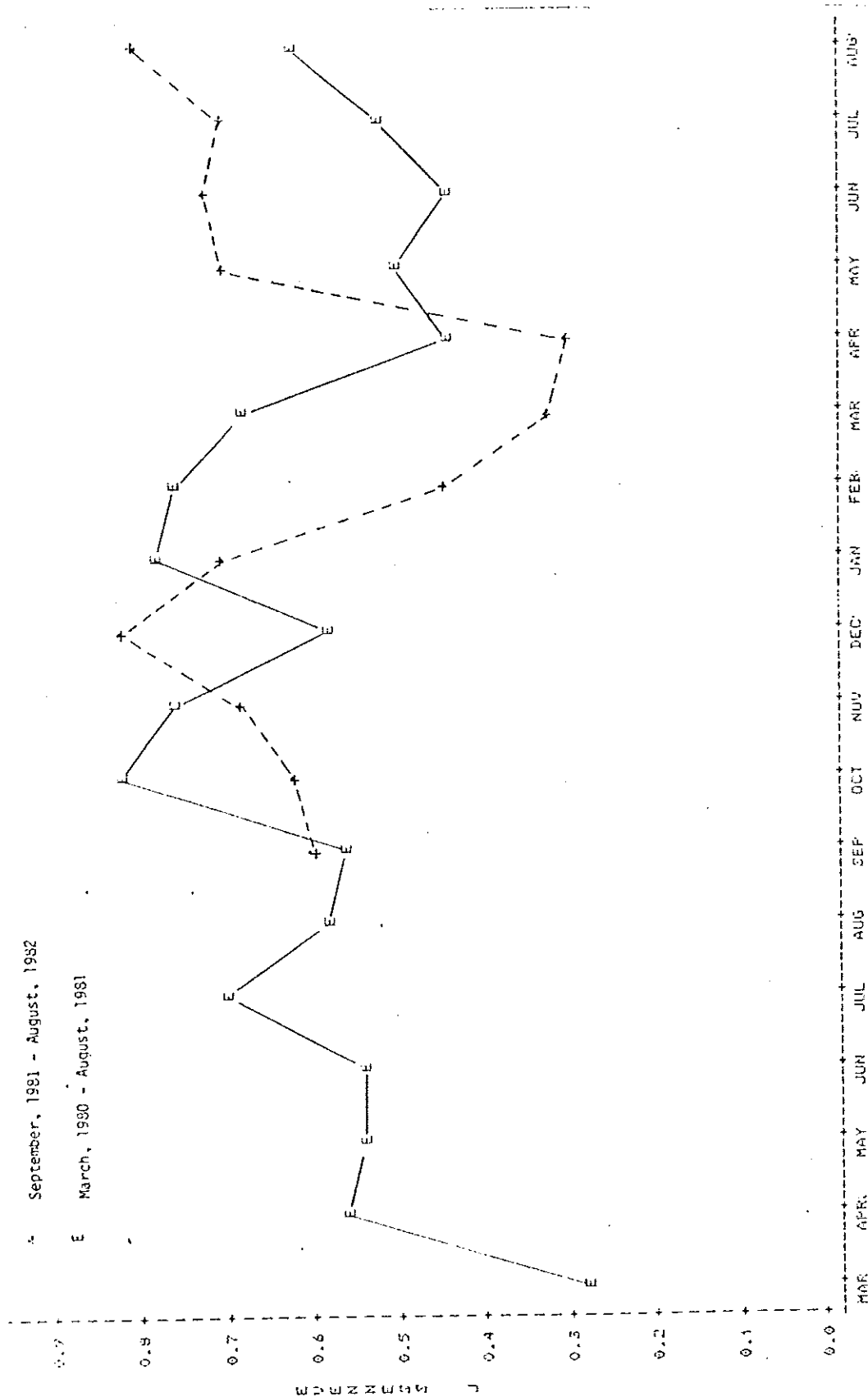


Figure 12D. Graph of Macroinvertebrate Evenness (J') at Station B-7.

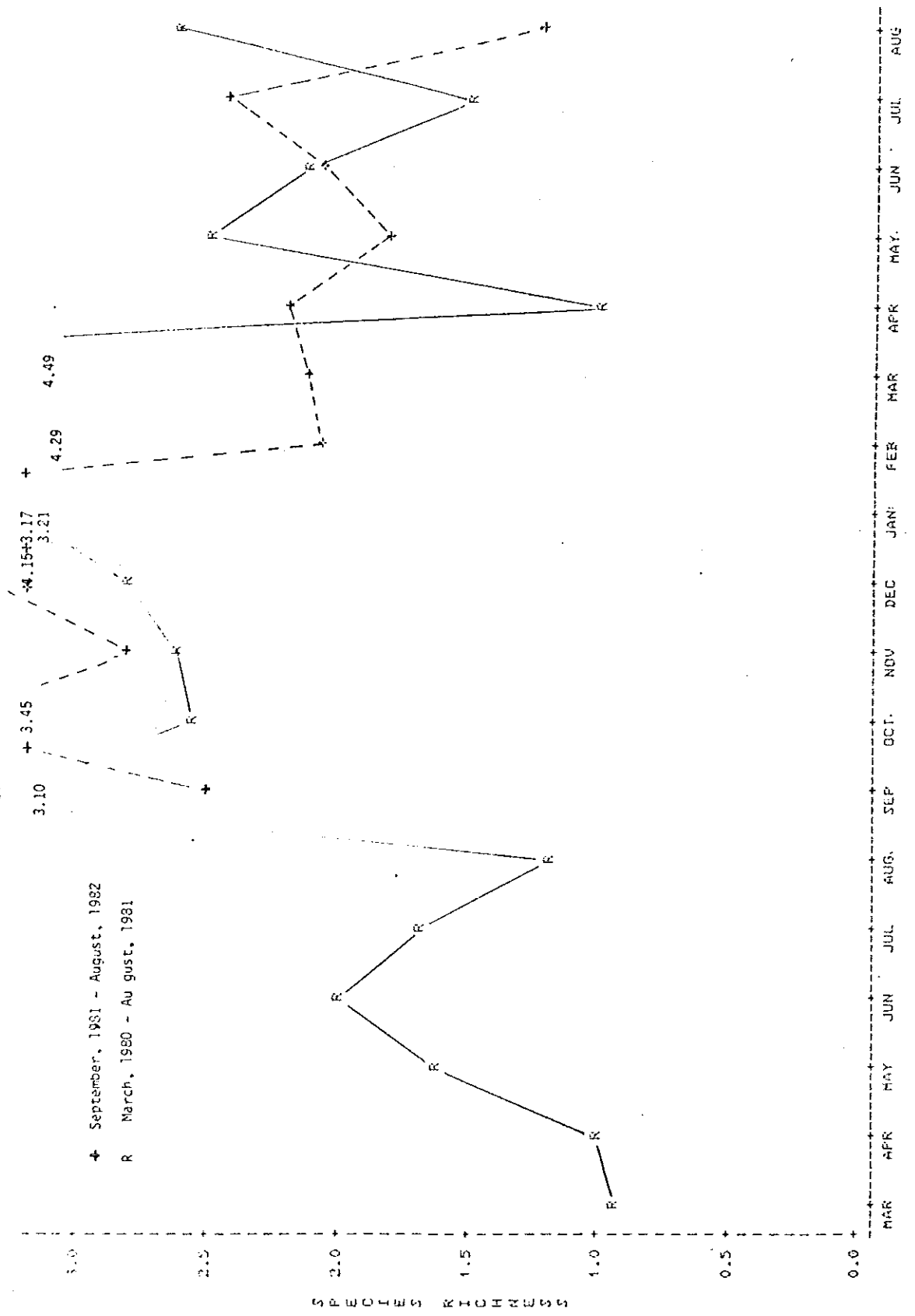


Figure 130. Graph of Macroinvertebrate Richness (R) at Station B-7.

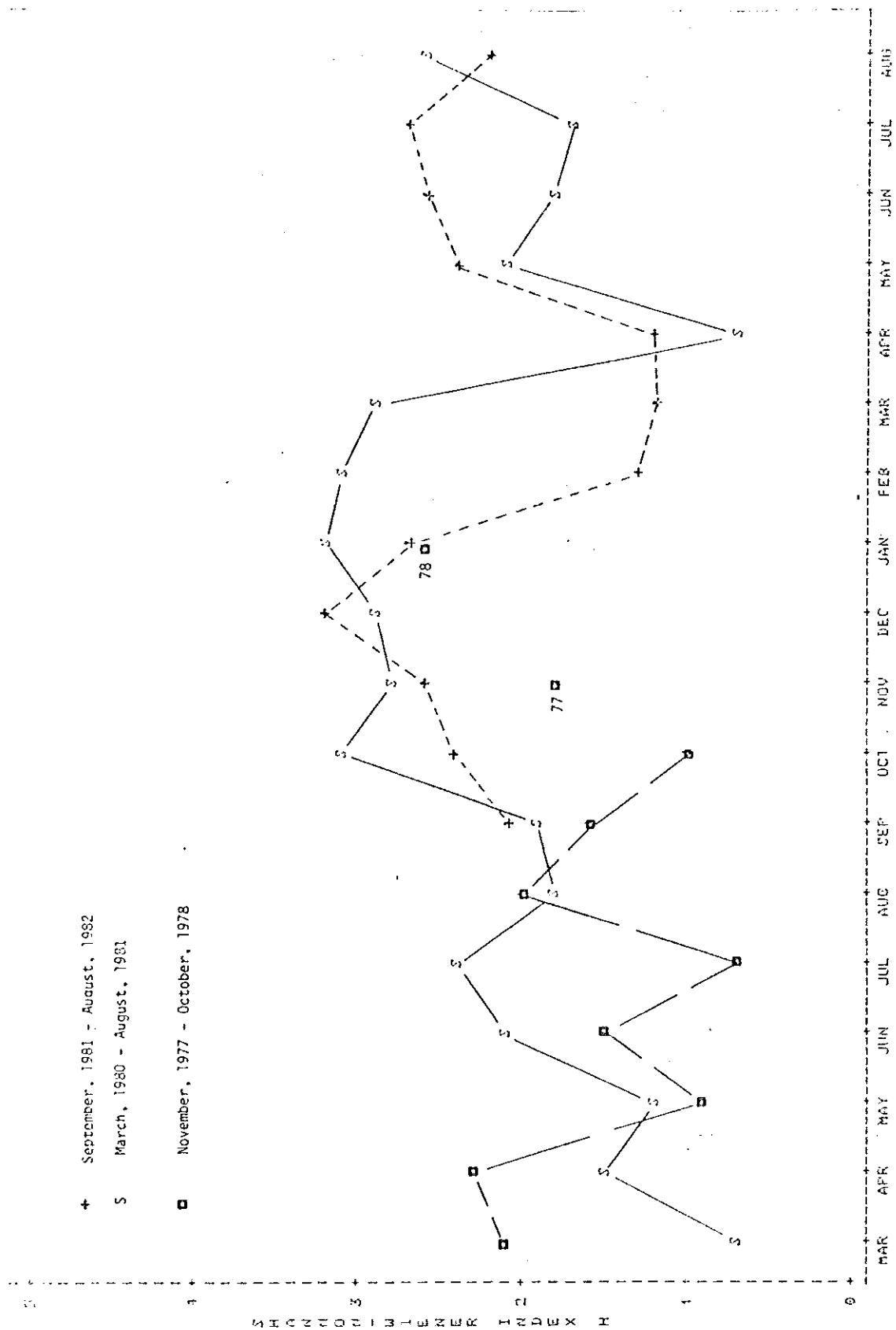


Figure 14D. Graph of Polychaete Diversity ( $H'$ ) at Station B-7.



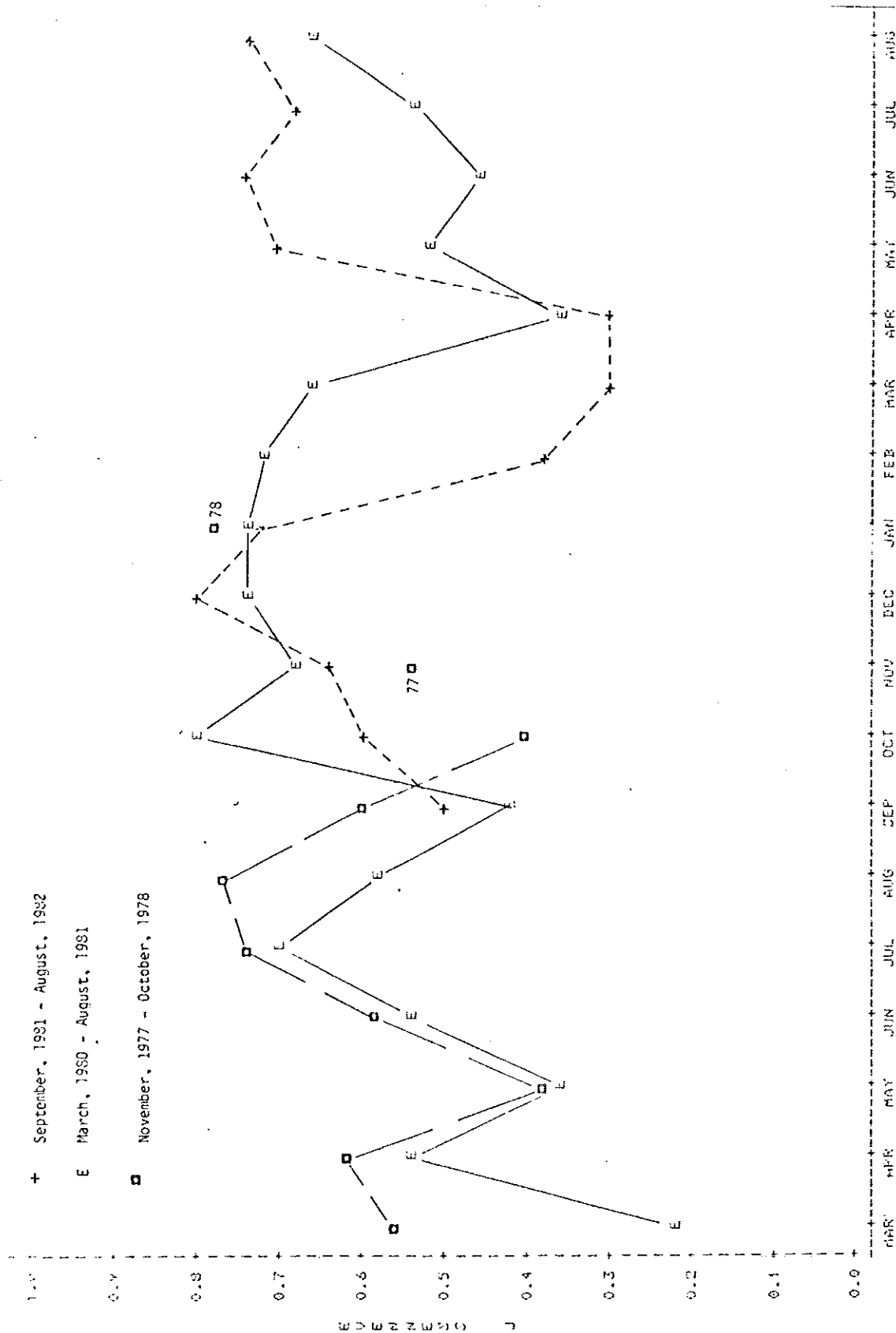


Figure 15D. Graph of Polychaete Evenness (J') at Station R-7.

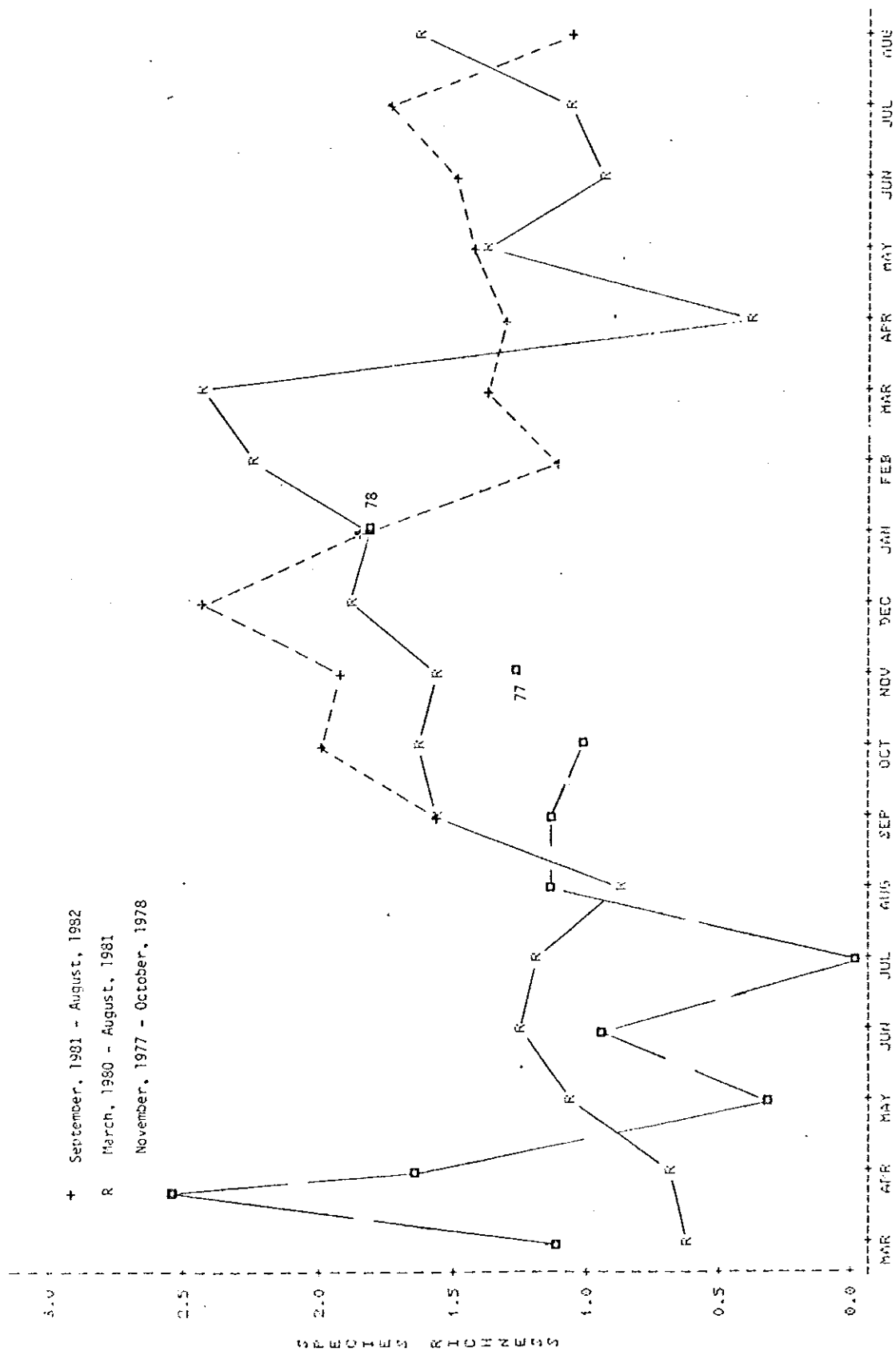


Figure 16D. Graph of Polychaete Richness (R) at Station B-7.

Figure 12D shows a relatively stable pattern of evenness with only March of 1980 being well away from a trend line at 0.6 - 0.65. Compared to station B-4 (Figure 12B), we conclude that station B-7 had more stability. With respect to polychaete evenness, (Figure 15D), this index is less stable, e.g. more erratic than was the macroinvertebrate evenness during March through September of 1980. After this, the data generally mirror the total macroinfaunal trend.

Figure 13D reflects macroinvertebrate richness at station B-7, and as with other indices there is little similarity to data from stations B-1, B-4, or B-8. We note with interest that this index went off scale, 3.21, 4.29, and 4.49, for January-March 1981 before plummeting in April of that year. Again, the polychaetes by comparison were more conservative, yet mirrored the overall trend at station B-7 (Figure 16D).

### 3) Post-construction -

General Abundance/Dominance - During the 12 months of post-construction sampling, 13,336 organisms were collected at station B-7. Of this number, 6,672 (50.0%) belong to a polydorid species complex that erupted in March and April of 1982. No such eruption took place at stations B-1, B-4, or B-8. Mediomastus ambiseta was the second ranked polychaete with 1,914 individuals (14.35%) and Neanthes succinia followed with 914 (6.85%). Clearly polychaetes continued to dominate in the post-construction months.

Diversity, Evenness, and Richness - Figures 11D-13D and 14D-16D reflect these indices during post-construction sampling at station B-7.

Macroinvertebrate diversity (Figure 11D) was generally high during the 12 months post-construction. It fell to low levels from March to April of 1982. The domination by polydorid species of polychaetes is reflected during these months (Figure 14-D) and contributes to the low diversity levels.

Macroinvertebrate evenness (Figure 12D) also reflects the impact of polydorid species as does polychaete evenness (Figure 15D).

Macroinvertebrate and polychaete richness (Figures 13D and 16D) do not reflect the polydorid eruption in the spring of 1982.

### 4. Baseline-Monitoring Comparison

#### a. Overview:

We have addressed baseline shortcomings elsewhere. Specifically they entail (1) an apparent insufficiency in number of replicates at a station/month, (2) problems in station location repeatability, (3) an insufficiency of number of months sampled at stations B-4 and B-8, (4) an incompleteness in the non-polychaete macroinfaunal data, and (5) the fact that shell dredging was being carried on in the study area during the study period. Never-the-less, we have inventoried and corrected errors in the polychaete data base and have tabulated and graphed the data so comparisons can be made.

Baseline data for polychaetes only are found in Table 14 A, B, and C. Data for diversity, evenness, and richness are graphed in figures 14-16 A and D for stations B-1 and B-7.

b. Station B-1:

General Abundance/Dominance- Of the 1,446 polychaetes collected at station B-1 during the baseline study (November, 1977 - October 1978), 1104 individuals (76.6%) were assigned to Mediomastus ambiseta. The second and third ranked polychaetes were Paraprionospio pinnata and Glycinde solitaria whose numbers accounted for 9.1% (131) and 3.1% (45) respectively. Inspection of the construction period data reveals that this 18 month study produced 634 Mediomastus ambiseta (46% of the polychaetes), 131 Paraprionospio pinnata (9.5% of the polychaetes), and 33 Glycinde solitaria (2.4% of the polychaetes). Neanthes succinea accounted for 12.7% (175) of the construction phase polychaetes, and at least four other species:

<u>Pseudeurythae ambigua</u>	84-6.1%
<u>Scoloplos robustus</u>	56-4.1%
<u>Sigambra bassi</u>	85-6.2%
<u>Sigambra sp.A</u>	55-4.0%

were dominant to G. solitaria. Inspection of post-construction data at station B-1 reveals that during this 12 month period Mediomastus ambiseta totaled 403 (51.5%) of the polychaetes, Paraprionospio pinnata totaled 58 (7.4%) of the polychaetes, and Glycinde solitaria contributed 26 (3.3%) of the polychaetes only. Other significant contributors were:

<u>Podarke obscura</u>	34 (4.3%)
<u>Pseudeurythoe ambigua</u>	40 (5.1%)
<u>Scoloplos robustus</u>	33 (4.2%)
<u>Sigambra sp.A</u>	146 (18.6%)

Overall, the numbers of Mediomastus/replicate during construction was about five. During baseline, however, they numbered about 27/replicate. The decrease in pure numbers of Mediomastus after baseline is more than offset by the increases in other species. Overall, the baseline yielded 36 individuals/replicate whereas construction yielded 11 individuals/replicate and post-construction yielded 9 individuals/replicate.

Diversity, Evenness, and Richness- These indicators of community health and well being are graphically portrayed for station B-1 in comparison to construction and post-construction data in figures 14-16A. Diversity is clearly lower, evenness is distinctly erratic (no stability), and richness declined steadily from March of 1978 through October of that year. The conclusion that we draw from these graphics is that, overall, station B-1 was not in good health during the baseline study, but it is considerably more healthy during 1980-1982. Furthermore, engineering activities have not affected station B-1 adversely.

Conclusions- If we compare baseline data to post-construction data, and use mean number of polychaete species or mean number of polychaetes per 0.1m square, we find no significant differences in these data by ANOVA and the Duncan's Multiple Range Test of Means. We conclude

TABLE 14A. Summary Polychaete Baseline Characterization, Station B-1

PERIOD:	BASELINE									
MONTH	NOV	JAN	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
YEAR:	77	78	78	78	78	78	78	78	78	78
Polychaetes/4 grabs	299	235	643	33	144	13	59	6	0	15
Mean No. Polychaetes per 0.1 m sq.	75	59	161	8	36	3	15	2	0	4
Polychaete Species per 4 grabs	10	12	13	7	7	2	4	2	0	3
Mean No. Polychaetes per 0.1 m sq.	7	8	10	4	4	1	2	1	0	2
Polychaete Diversity as $H'$	1.75	1.92	1.08	2.08	0.71	0.62	0.46	0.92	0.00	0.69
Polychaete Evenness as $J'$	0.53	0.56	0.29	0.74	0.25	0.62	0.23	0.92	0.00	0.44
Polychaete Richness as $R$	1.45	1.47	1.72	1.30	0.77	0.00	0.37	0.00	0.00	0.87

TABLE 14B. Summary Polychaete Baseline Characterization, Station B-4 and B-8.

PERIOD:	B-4 BASELINE					B-8 BASELINE			
MONTH	NOV	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT
YEAR:	77	78	78	78	78	78	78	78	78
Polychaetes/4 grabs	202	392	73	188	268	192	152	126	181
Mean No. Polychaetes per 0.1 m sq.	50	98	18	47	67	48	38	32	45
Polychaete Species per 4 grabs	10	7	12	5	4	8	9	2	5
Mean No. Polychaetes per 0.1 m sq.	5	5	5	3	3	5	4	2	3
Polychaete Diversity as $H'$	1.49	1.11	1.73	0.83	1.07	1.27	1.33	0.24	0.71
Polychaete Evenness as $J'$	0.47	0.39	0.48	0.36	0.53	0.42	0.42	0.24	0.31
Polychaete Richness as $R$	0.96	0.82	1.29	0.58	0.54	1.03	0.89	0.22	0.59

TABLE 14C. Summary Polychaete Baseline Characterization, Station B-7.

PERIOD:	BASELINE									
MONTH	NOV	JAN	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
YEAR:	77	78	78	78	78	78	78	78	78	78
Polychaetes/4 grabs	363	156	1877	106	41	55	24	39	91	231
Mean No. Polychaetes per 0.1 m sq.	66	39	469	26	10	14	6	10	23	58
Polychaete Species per 4 grabs	7	8	8	6	2	4	1	4	4	5
Mean No. Polychaetes per 0.1 m sq.	13	10	13	13	5	6	2	6	6	6
Polychaete Diversity as $H'$	1.85	2.61	2.07	2.30	0.88	1.48	0.74	1.98	1.56	1.04
Polychaete Evenness as $J'$	0.53	0.79	0.56	0.62	0.38	0.57	0.74	0.77	0.60	0.40
Polychaete Richness as $R$	1.25	1.84	1.10	1.60	0.29	0.95	-0.10	1.10	1.12	0.99

that no significant changes have taken place in the polychaete community at station B-1 as a result of the Theodore Project.

c. Station B-4:

General Abundance/Dominance- Of the 1,123 polychaetes collected at station B-4 during the baseline study (November, 1977-October 1978), 826 (74.0%) were assigned to Mediomastus ambiseta. The second and third ranked polychaetes were, Hobsonia florida (26;2.3%) and Capitella capitata (24;2.1%). Inspection of construction period data shows that Mediomastus ambiseta accounted for 60.2% of the population (1,043 of 1,734 individuals), Parandalia americana ranked second with 337 individuals (19.4%), and Capitella capitata ranked third with 9.3% (161 individuals). Hobsonia florida was represented by 46 individuals (2.6%). The post construction period data shows that Mediomastus ambiseta accounted for 53.4% (857 of 1,605 individuals), Streblospio benedicti was second at 448 individuals (27.9%) and Sigambra sp.A was third at 5.7% (91 individuals). P. americana contributed 3.4% but H. florida was only 0.2% (4 individuals).

Diversity, Evenness and Richness- These data are found in table 14B. For comparative purposes table 15A compares monthly data for baseline to comparable months during the monitoring study.

Conclusions- Table 15A data may be a cause for concern, but if we compare baseline data to post-construction data and use mean number of polychaete species or mean number of polychaetes per 0.1 m square, we find no significant differences in these data by ANOVA and the Duncan's Multiple Range Test of Means. We conclude that month to month comparisons show differences, but overall, no significant changes have taken place in the polychaete community at station B-4 as a result of the Theodore Project.

d. Station B-8:

General Abundance/Dominance- Of the 651 polychaetes collected at station B-8 during the baseline study (November, 1977 - October, 1978), 428 (65.8%) were assigned to Mediomastus ambiseta. The second and third ranked polychaetes were Streblospio benedicti (119;18.3%) and Capitella capitata (34;5.2%). Inspection of construction period data shows that Mediomastus ambiseta accounted for 52.4% (1,154 of 2203 individuals) Parandalia americana ranked second with 300 individuals (13.6%) and C. capitata was third with 10.4% (229 individuals). Streblospio benedicti ranked fifth with 3.4% (75 individuals). The post-construction period data shows that Mediomastus ambiseta accounted for 79.3% of the 1,606 polychaetes (M. ambiseta = 1,274). Second and third ranked polychaetes were Paraprionospio pinnata (126;7.8%) and Sigambra sp.A (124;7.7%). Capitella capitata, Parandalia americana, and Streblospio benedicti were all 1.0% or less (0.68, 1.0, and 0.62 respectively).

Diversity, Evenness and Richness - These data are found in table 14B. For comparative purposes, table 15B compares monthly data for baseline to comparable months during the monitoring study.

Conclusions - Table 15A data may be a cause for concern, but if we compare baseline data to post-construction data and use mean number of polychaete species or mean number of polychaetes per 0.1 m square, we find



TABLE 15A. Comparison of Community Indices: Baseline vs. Monitoring at Station B-4.

STATION B-4					
	JAN	APR	JUL	OCT	NOV
DIVERSITY ( $H'$ )					
<u>Baseline</u>					
1977	-	-	-	-	1.49
1978	1.11	1.73	0.83	1.07	-
<u>Monitoring</u>					
1980	-	1.50	0.86	1.10	1.47
1981	1.70	2.59	1.00	0.56	0.96
1982	2.04	1.53	1.21	-	-
EVENNESS ( $J'$ )					
<u>Baseline</u>					
1977	-	-	-	-	0.47
1978	0.39	0.48	0.36	0.53	-
<u>Monitoring</u>					
1980	-	0.58	0.37	0.43	0.52
1981	0.49	0.82	1.00	0.20	0.37
1982	0.88	0.48	0.52	-	-
RICHNESS ( $R$ )					
<u>Baseline</u>					
1977	-	-	-	-	0.96
1978	0.82	1.29	0.58	0.54	-
<u>Monitoring</u>					
1980	-	0.84	0.36	0.53	0.61
1981	1.35	1.33	0.57	0.61	0.56
1982	0.67	0.98	0.29	-	-

TABLE 15B. Comparison of Community Indices: Baseline vs. Monitoring at Station B-8.

STATION B-8				
	JAN	APR	JUL	OCT
DIVERSITY (H')				
<u>Baseline</u>				
1978	1.27	1.33	0.24	0.71
<u>Monitoring</u>				
1980	-	1.45	1.23	2.03
1981	2.16	2.03	1.10	1.02
1982	1.86	1.49	1.03	-
EVENNESS (J')				
<u>Baseline</u>				
1978	0.42	0.42	0.24	0.31
<u>Monitoring</u>				
1980	-	0.56	0.53	0.68
1981	0.57	0.72	0.69	0.34
1982	0.72	0.53	0.44	-
RICHNESS (R)				
<u>Baseline</u>				
1978	1.03	0.89	0.22	0.59
<u>Monitoring</u>				
1980	-	0.67	0.51	0.81
1981	1.66	0.79	0.00	0.73
1982	0.91	0.93	0.46	-

no significant differences in these data by ANOVA and the Duncan's Multiple Range Test of Means. We conclude that month to month comparisons show differences, but overall, no significant changes have taken place in the polychaete community at station B-8 as a result of the Theodore Project.

e. Station B-7:

General Abundance/Dominance - Of the 2,883 polychaetes collected at station B-7 during the baseline study (November, 1977-October, 1978), 952 (33.0%) were assigned to Mediomastus ambiseta. The second and third ranked polychaetes were Streblospio benedicti and Polydora ligni whose numbers accounted for 22.3% (643 individuals) and 21.8% (630 individuals) respectively. Inspection of the construction period data reveals that this 18 month study period produced 7,596 polychaetes. Of these, M. ambiseta accounted for 1,978 individuals (26.0%). The first and third ranked polychaetes were Streblospio benedicti with 2,135 (28.1%) and Neanthes succinea with 1,383 (18.3%). Polydora ligni contributed 12.2% (923 individuals). During the 12 months of post-construction, station B-7 yielded 9,081 polychaetes of which polydorid species (including P. ligni) contributed 60.5% (8,441 individuals). M. ambiseta contributed 14.4% (1,312) and S. benedicti; 5.5% (500).

Basically, the same polychaetes were predominant, but their dominance position changed. Additionally, more species were encountered during the monitoring period.

Diversity, Evenness, and Richness - These indicators of community health and well being during baseline are graphically portrayed against monitoring months in figures 14-16D. Polychaete diversity during baseline was generally lower than monitoring during 1980 and 1981 and the majority of comparable months during 1982. Evenness (Figure 15D) was comparable between baseline and monitoring in 1980, but not comparable in 1982. This is probably due to the polydorid eruption in 1982. Baseline richness (Figure 16D) was generally lower and more erratic during baseline compared to 1980, 1981, and 1982 monitoring. This may be accounted for by the larger number of species encountered during the monitoring exercise.

Conclusions - If we compare baseline data to post-construction data, and the mean number of polychaete species or mean number of polychaetes per 0.1 m square, we find there were no significant differences in the mean number of polychaetes per 0.1 meter square by ANOVA and the Duncan's Multiple Range Test of Means. However, when we examine the mean number of species per 0.1 m square we do find significant differences by ANOVA and the Duncan's Test at the  $p = >0.05$  level.

We submit, however, that such differences are not related to the Theodore Project. It should be noted that the mean number of polychaete species per 0.1 m square during post-construction was eight (8). This mean is greater than the baseline period at station B-7 ( $X = 4.7$ ). We attribute the larger mean to several factors: (a) higher shell content of substrate, (b) greater number of replicates (4 during baseline vs. 7 during post-construction), and (c) generally higher salinity during the post-construction months.

## 5. Correlative Relationships

### a. Overview:

We have established that stations B-1, B-4, and B-8 all have similar communities, and that these communities remain unaltered by the construction activity. Furthermore, they are not significantly different in nature during March 1980- August 1982 when compared to a period of November, 1977 through October, 1978. There remains one major task, and that task is to discover what measureable driving forces e.g. temperature, salinity, sediment character etc. demonstrably control the organisms or community structure [as seen by diversity ( $H'$ ), Evenness ( $J'$ ), and Richness ( $R$ )].

To carry out this task, we developed a matrix which correlated the following biological categorical data:

1. Diversity ( $H'$ )
2. Evenness ( $J'$ )
3. Richness ( $R$ )
4. Total Organisms at a Station
5. Total Species at a Station
6. Mean No. of Organisms per 0.1m sq.
7. Mean No. of Species per 0.1m sq.

to a collection of chemical, geological, hydrographical, hydrological, and physical parameters collected over the 30 months.

These categorical data were:

1. Mean Total Organic Carbon
2. Mean Total Reducing Substances
3. Mean % Oyster Shell
4. Mean % Sand
5. Mean % Salt
6. Mean % Clay
7. Mean Median Diatmeter in Phi
8. Sorting Coefficient
9. Salinity in ppt.
10. Dissolved Oxygen in mg/l
11. Percent Saturation of Oxygen
12. River Flow
13. Field Measured Turbidity in NTUS
14. Percent Transmittance of Light

Furthermore, we used all the available 30 month data set for stations B-1, B-4, and B-8 to develop community correlations.

### b. Results and Conclusion:

The significant data for the correlation matrix are presented in table 16. Parameters not listed were not significant nor were correlations with blanks under their column heading.

TABLE 16. Correlation Matrix: Stations B-1, B-4 and B-8 Data Combined.

BIOLOGICAL	PHYSICAL/GEOLOGICAL						
	TEMP.	D.O.	% SAT. D.O.	TRS	% TRANS.	FLD. TURB.	FLOW 10
Diversity H'	->0.05	+>0.01	+>0.01	->0.05	+>0.05	->0.05	->0.05
Evenness J'	-	-	-	-	-	+>0.05	-
Richness R	->0.0001	+>0.0001	+>0.0001	->0.05	-	-	-
Total Organisms/ Station	->0.0001	+>0.0001	+>0.0001	-	-	-	-
Total Species/ Station	->0.0001	+>0.0001	+>0.0001	->0.05	-	-	-
Organisms/ 0.1 m sq.	->0.0001	+>0.0001	+>0.0001	-	-	-	-
Species/0.1 m sq.	->0.0001	+>0.0001	+>0.0001	-	-	-	-

We are able to see that the major consistent driving forces are temperature, dissolved oxygen and percent oxygen saturation. We might have expected salinity or river flow (Flow 10) to play a role. The fact that they do not suggests a community structure very tolerant of fluctuations in salt balance (a euryhaline community).

We must make note of the fact that Total Reducing Substances (TRS) have a negative impact on diversity and richness (leading indicators of community structure) and on species numbers in the study area. We also note that the project itself did not generate the TRS. However, it must be realized that TRS from outside sources could be or is building up in the study area as a result of the changes in bathymetry. For this reason, we will recommend a monitoring program that should be implemented by July 1, 1983. (See Section E below).

#### D. OYSTER REEFS

##### 1. Overview

Data on oyster reefs and their biology was obtained from the Alabama Department of Conservation and Natural Resources, Marine Resources Division at Dauphin Island, Alabama. The data provided are contained in two documents:

Completion Report, Project No. 2-230-R, Segment No. 3 covering 1 October 1978 through 30 September 1981, and

Completion Report, Project No. 3-380-R, Segment No. 1 covering 1 January 1982 through 30 September 1982.

##### 2. The Data Base

For the period 1 October 1978 through 30 September 1981, the data base for Whitehouse reef, immediately south of station B-1, consists of these data:

	<u>Oysters</u>	<u>Spat</u>	<u>Boxes</u>	<u>Half-shells</u>	<u>Oyster Drills</u>
Whitehouse					
Aug.-Sept. 1977	55	243,568	28	30,421	6,810
Nov. 1978	290	15,972	484	31,363	290
Aug. 1980	0	437,360	0	52,800	0
July 1981	2,606	34,252	2,358	35,990	0
Change	-	-92.2%	-	-31.8%	0%

Furthermore, it included figure 17 which is figure 17 in this report. In the second referenced report [(b) above], Table 9 of that report gives an estimate of the number of oysters per acre on Whitehouse reef as follows:

	<u>Oysters</u>	<u>Spat</u>	<u>Boxes</u>	<u>Half-shells</u>	<u>Oyster Drills</u>
August 1980	0	437,360	0	52,800	0
July 1981	2,606	34,252	2,358	35,990	0
September 1982	0	81,312	32,186	13,794	21

Table 10 of the referenced report provides an estimate of the oyster population at Whitehouse reef in 1980-81 and 1981-82 as follows:

#### NUMBER OF OYSTERS PER REEF

<u>Reef</u>	<u>1980-81</u>	<u>1981-82</u>	<u>Numerical Change</u>	<u>Percent Change</u>
Whitehouse	1,102,077	0	-1,102,077	-

Table 11 of the referenced report provides an estimate of oyster spat for Whitehouse Reef, 1980-81 and 1981-82.

#### NUMBER OF SPAT PER REEF

<u>Reef</u>	<u>1980-81</u>	<u>1981-82</u>	<u>Numerical Change</u>	<u>Percent Change</u>
Whitehouse	14,485,171	34,386,845	+19,901,674	+137

Table 12 of the referenced report estimated oyster drill abundance on Whitehouse Reef, 1980-81 and 1981-82.

<u>Reef</u>	<u>1980-81</u>	<u>1981-82</u>	<u>Numerical Change</u>	<u>Percent Change</u>
Whitehouse	0	51,171	+51,171	-

Page 30 of the referenced report for 1982 states that Whitehouse reef, with a 137% increase in net spat abundance, was the only reef where spat set gained. It further states, however, that "it hasn't been commercially productive since 1967." Page 34 of the report suggests that "Shell loss on Shellbank and Whitehouse reefs can likely be attributed to shrimp trawls."

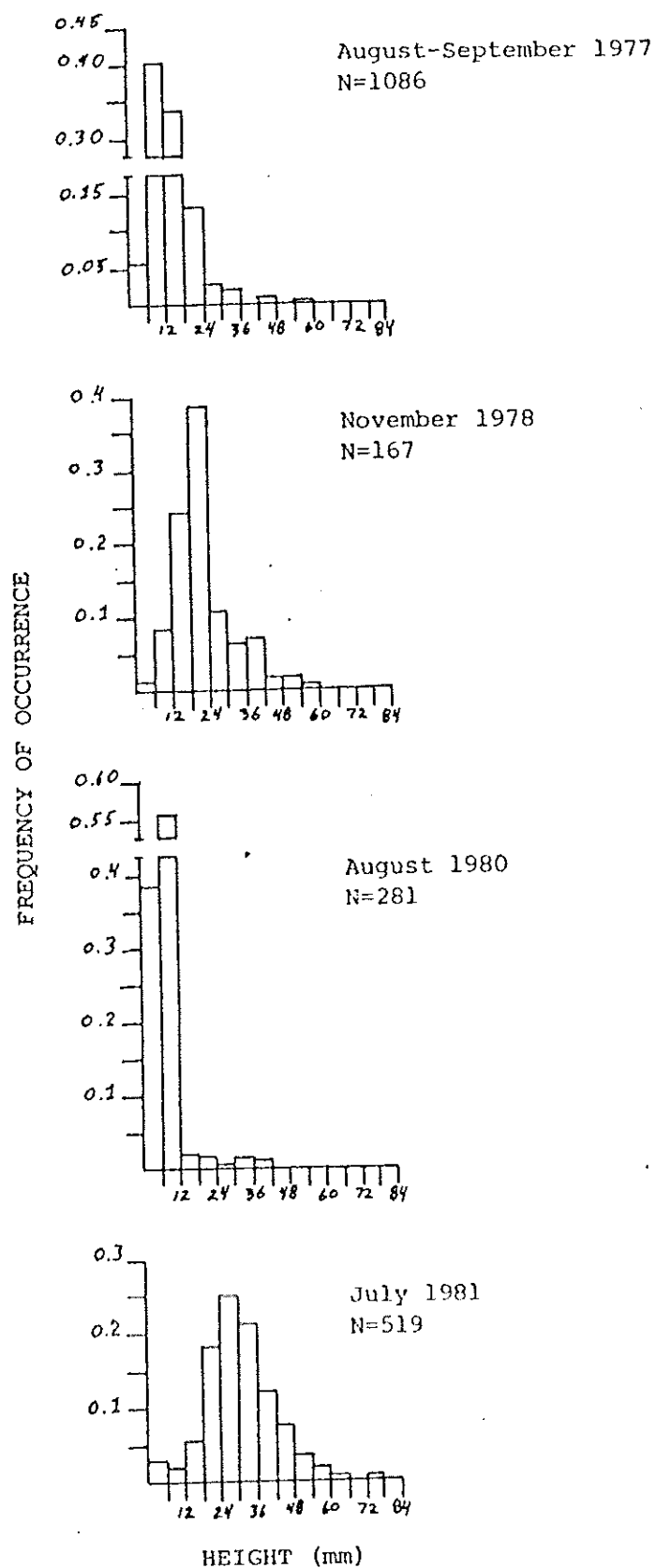


Figure 17. Height frequency Distributions of Oysters and Oyster Spat on Whitehouse Reef.



### 3. Conclusions

Review of the ADNR reports lead to the conclusion that the Theodore Project had no documented effects on the oyster population at Whitehouse reef. We conclude that what changes have occurred are most likely attributed to shrimpers in the area, and are coupled with oyster drill abundance in 1982.

#### E. RECOMMENDATIONS FOR FURTHER STUDIES

##### 1. Needs Not Addressed in Present Study

The resulting water and sediment quality of the newly formed channel was not adequately addressed in the post-construction phase of the project. The program manager suggests that the water quality (salinity, temperature, and dissolved oxygen) and the sediment quality [TOC, TRS, toxic trace metals (Ba, Cd, Cr, Hg, and Pb), oil and grease, and chlorinated hydrocarbons] of this bathymetric alteration should have been characterized.

Rationale - There is reasonable evidence that channels in estuarine systems act as reservoirs and subaquatic canyons for the distribution of high density and sometimes oxygen depleted water. It would seem prudent to examine the newly constructed Theodore Canal in relation to both its source of run-off and its source of Gulf water. Twice monthly observations of dissolved oxygen, salinity and temperature at three localities on the new canal would fill this information need. Monthly sample replicates of sediment at each of the three locations in quantities of sufficient size to accomplish the analytical aim should be taken and analyzed as appropriate for the parameter.

##### 2. Needs Apparent as a Result of Present Study

The study results suggest a concern for the quality of the environment at station B-8. There were indications that Total Reducing Substances (TRS) at this station were elevated, but they were unrelated to the construction activity per se. The program manager suggests that water quality, sediment quality, and the kinds and amounts of infauna be examined at stations B-1 and B-8 on a monthly basis. This sampling program would be carried out in conjunction with the channel study described above.

Rationale - The newly formed channel may be a "pipeline" for industrial activities at its source. It would seem prudent to monitor the environmental quality of stations B-1 and B-8 with no less than seven biological replicates and two sediment/sedimentary replicates per month for at least two years. This study would be interfaced with the channel study suggested above, and would further define the source of TRS sediments at station B-8 and provide predictive information for station B-1 which may be affected in time.

This program should be implemented by July 1, 1983 and be conducted for a minimum of two years.

## REFERENCES

- Chapman, C. 1968. Channelization and spoiling in Gulf Coast and South Atlantic estuaries. IN: Marsh and Estuary Management Symposium, La. St. Univ., pp. 93-106.
- Crozier, G. F. 1979. From the "Introduction." IN: Final Report Baseline Data Collection, Environmental Monitoring Program, Theodore ship Channel and Barge Channel Extension, Mobile Bay, Alabama. Mobile District, Corps of Engineers Contract No. DACW01-78-C-0010. p. 1-3.
- Environmental Protection Agency (EPA). 1975. Environmental and Recovery Studies of Escambia Bay and the Pensacola Bay System. EPA 904/9-76-016.
- Federal Water Pollution Control Administration (FWPCA) 1970a. Effects of Pollution on Water Quality, Escambia River and Bay, Florida. U.S. Department of Interior, Athens, GA 63 pp.
- Federal Water Pollution Control Administration (FWPCA) 1970b. Effects of Pollution on Water Quality in Perdido Bay and its Tributaries, Alabama and Florida. U.S. department of Interior, Athens, GA 283 pp.
- Godcharles, M. 1971. A study of the effects of a commercial hydraulic clam dredge on benthic communities in estuarine areas. Fla. Dept. Nat. Res. Mar. Lab. Tech. Ser. 65, 51 pp.
- Guillory, V. 1982. Environmental effects of estuarine dredging and spoil disposal, a literature review. Tech. Bull. 35., Mar. Res. Lab., La. Dept. Wildl. and Fish., p. 37-61.
- Gunter, G. 1969. Reef shell or mud shell dredging in coastal bays and its effects upon the environment. Trans. N. Amer. Wildl. Conf. 34: 51-74.
- Gulf Universities Research Corporation (GURC). 1980. Final Report, "Systemization and Evaluation of USACE Benthic Baseline Data (1977-78) Theodore Industrial Park Ship Channel and Spoil Island, Mobile Bay, Alabama. Contract No. DACW01-78-C-0010 ammended. Nine pages plus Appendix A - Computer Output of Physical Data Analyses" and Appendix B - Computer Displays - Assessment of Natural Variability in Benthic Faunal Data and Supporting Hydrographic and Sediment Data.
- Hargis, W. 1966. Research on the tidal Potomac. IN: Water management in the Potomac estuary, Interstate Comm. Potomac River Basin, pp. 38-44.

- Hooks, W. G. 1979. From "Sedimentology" IN: Final Report Baseline Data Collection, Environmental Monitoring Program, Theodore Ship Channel and Barge Channel Extension, Mobile Bay, Alabama. Mobile District, Corps of Engineers Contract No. DAWW01-78-C-0010. p. 11-14.
- Hynes, H. 1970. The ecology of running waters. Univ. Toronto Press. Ontario, Canada, 553 p.
- Isphording, W. D. and G. M. Lamb. 1980. The Sediments of Mobile Bay. Tech. Rpt. 80-002, Dauphin Island Sea Lab. 24 p.
- May, E. B. 1973. Extensive oxygen depletion in Mobile Bay, AL. Limnol. Oceanogr. 18(3): 353-366.
- Odum, H. 1963. Productivity measurements in Texas turtle grass and the effects of dredging in intercoastal channel. Publ. Inst. Mar. Sci. Univ. Tex., 9: 48-58.
- Pearce, J. 1970. The effects of waste disposal in New York Bight-Interim report to January 1, 1970. IN: Waste disposal in the coastal waters of New York Harbor. pp. 54-80.
- Phillips, R. 1960. Observations on the ecology and distribution of the Florida seagrasses. Fla. St. Bd. Conser., Mar. Res. Lab., Prof. Pap. Ser. 2, 27 p.
- Ranasinghe, J. A. 1983. A comparison of techniques to characterize benthic macroinfaunal communities of middle Mobile Bay, AL. A report, Plan II M.S. degree. Univ. of AL. 91 pp.
- Ryan, J. J. 1969. A sedimentologic study of Mobile Bay, AL. Sed. Res. Lab., Dept. Geol., Fl. State Univ. Cont. no. 30, 110 p.
- Schroeder, W. W. 1979a. The dissolved oxygen puzzle of the Mobile Bay estuary. IN: Symposium on the Natural Resources of the Mobile Bay Estuary, Alabama. H. A. Loyacono and J. P. Smith, eds. USACE, Mobile District. p. 25-30.
- Schroeder, W. W. 1979b. From "Hydrography". IN: Final Report Baseline Data Collection, Environmental Monitoring Program, Theodore Ship Channel and Barge Channel Extension, Mobile Bay, Alabama. Mobile District, Corps of Engineers Contract No. DACW01-78-C-0100 p. 4-10.
- Schroeder, W. W. and W. R. Lysinger. 1979. Hydrography and circulation of Mobile Bay. IN: Symposium on the Natural Resources of the Mobile Bay Estuary, Alabama. H. A. Loyacono and J. P. Smith, eds. USACE, Mobile District. p. 75-94.
- Sherk, J. and L. Cronin. 1970. The effects of suspended and deposited sediments on estuarine organisms. An annotated bibliography of selected references. Ches. Biol. Lab., Ref. No. 70-19, 73 pp.

- Simmons, H. B. 1965. Channel depth as a factor in estuarine sedimentation. IN: Proceedings of the 1963 Federal Inter-Agency Sedimentation Conference. U.S.D.A. Misc. Publ. 970, pp. 673-690.
- Simon, J. and J. Dyer. 1972. An evaluation of siltation created by Bay dredging and Construction Co. during oyster shell dredging operations in Tampa Bay, Florida, Jan. 1, 1972 to March 31, 1972. Univ. South Fla. Dept. Biol., Final Res. Rept. 60 pp.
- St. Amant, L. 1972. A discussion of the effects of shell dredging on the ecosystems of northern Gulf of Mexico embayments. La. Wildl. Fish. Comm., Memo. Rpt., 10 pp.
- Sullivan, B. K. and D. Hancock. 1977. Zooplankton and dredging: Research perspectives from a critical review. Water Resour. Bull., 13(3): 461-468.
- Swingle, H. 1971. Biology of Alabama estuarine areas cooperative Gulf of Mexico Estuarine Inventory. Ala. Mar. Resour. Bull., 5: 1-123.
- Taylor, J. L. and C. H. Saloman. 1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. Fish. Bull. U.S. Fish. Wildl. Ser., 67: 213-42.
- U.S. Fish and Wildlife Service. 1967. Hearing on estuarine areas, House merchant marine and fisheries subcommittee on fisheries and wildlife conservation, March 6, 8, 9, 1967. Cons. Found. Letter, May 2, 1967, 8 pp.
- Vittor, B. A. 1979. "Benthic Polychaetes" IN: Final Report Baseline Data Collection, Environmental Monitoring Program, Theodore Ship Channel and Barge Channel Extension, Mobile Bay, Alabama. Mobile District, Corps of Engineers Contract No. DACW01-78-C-0010. p. 37-45.