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# RENTON SEWAGE TREATMENT PLANT PROJECT:

## Seahurst Baseline Study

by

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## Qualifier

This annual report includes preliminary data and associated analyses and is incomplete. Additional data will be included, subjected to additional analyses and interpretations in subsequent reports. This report therefore should only be used to guide the reader in the initial progress of this study.

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Approved:

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# 1.0 SUMMARY

This annual report provides a review and preliminary interpretation of the Seahurst Baseline Study findings from data collected and analyzed through the first nine months of Phase I. The total approved Baseline Study program will take 36 months to reach completion and is at this time, March 1983, approximately one-third completed. It must be stressed that these findings, results and conclusions are preliminary and may be subject to change following the analysis of additional data during the remainder of this study.

Expansion of the Renton Sewage Treatment Plant to meet the needs of a growing population in the Seattle Metropolitan area and the water quality requirements in the Duwamish River is designed to direct secondary treated sewage effluent from the Duwamish River to the south central Puget Sound basin at Seahurst. The Seahurst Baseline Study as a part of the expansion plan is designed to obtain pre-discharge ecological data in the marine environment in the East and Colvos Passage areas of Puget Sound. These data will be utilized to minimize potential impacts of design, to aid in ongoing planning efforts and to assess changes which may occur once effluent is discharged at the site.

The Seahurst Baseline Study has two broad objectives: (1) to collect, analyze and interpret the significance of physical, chemical and biological data around the proposed sewage treatment plant outfall at Seahurst to determine the properties and characteristics of the marine receiving environment; and (2) to recommend a post-effluent discharge monitoring plan that will effectively and efficiently determine if the presence of the new outfall significantly changes the receiving water environment described in the first objective.

This study is technically organized by task. The major tasks which have

been identified and which consistently interact have been grouped together under water column, environmental health, sediment investigations and chemistry. The studies of the water column include monitoring of the physical/chemical characteristics of the water and the indigenous pelagic biota. Sediment investigations include the ecological studies of the intertidal and subtidal benthic ecology and fishes. Environmental health includes monitoring and isolation of human pathogens (bacteria and viruses), fish pathology (fish health) and marine toxicology. The chemical analysis is focused on the presence of trace metals in water, biota and sediment, in addition to a variety of support analyses for the entire project. The organizational structure of this study has facilitated efficiency, interdiciplinary integration within and between tasks and ensured that the study scope and schedules are met in a timely manner. This report is similarly organized by task and only the most significant findings appear in this general summary.

Water Column: The analysis of data from the summer and autumn seasons of 1982 indicate the dissolved nutrient, chlorophyll, and zooplankton distributions exhibit large variations in concentration on the order of days to weeks. Temporal variation of these properties exceeds spatial variation among stations. The nearshore and offshore areas cannot be distinguished in terms of phytoplankton productivity. Concentrations of chlorophyll and nutrients in the surface water increase toward shore. The species of dominant phytoplankton and zooplankton change over the summer season and show differences between wide area and nearshore stations. Diatoms and herbivorous copepods are the common dominants. Commencement Bay is a significant source of ammonia and may contribute surface water to the East Passage area. No evidence of bottom water intrusion into the nearshore region at Seahurst was

found.

Nutrient limitation bioassays with endemic phytoplankton from the Seahurst water column stations demonstrated that nitrogen enrichment increased chlorophyll a levels above background at the offshore open water station. Samples nearshore were less influenced by nutrient addition. Further testing is required to elucidate the potential stimulatory effects of effluent discharge in Puget Sound.

Physical/Chemical Oceanography: Layers approximately 10 m thick in the water column with lower salinity and density and higher temperature and dissolved oxygen were evident off Browns Point as well as at mid-channel off Seahurst probably due to Puyallup River discharge. At the surface the water was approximately 0.3 C warmer nearshore when compared to mid-channel off Seahurst. A lens of warmer less saline water was found within the Seahurst Bight. The vertical oxygen profile indicated a tongue of highly oxygenated water at a depth of 5 m extended from the Bight (8 mg/l) toward mid-channel (7.5 mg/l). Below 30 m depth the Bight was less oxygenated than at mid-channel. A discontinuity near 50 m depth was found along the mid-channel within East Passage and may be associated with the sill between Blake and Vashon Islands which affects much of the flow exiting Colvos Passage. This discontinuity was not evident in Seahurst Bight suggesting that circulation dynamics in the Bight differ from mid-channel.

Dissolved oxygen data suggest that the water in Seahurst Bight is several weeks older than that at mid-channel. A water circulation pattern involving southward flow at mid-channel, some divergence of water from mid-channel towards shore and northward flow into Seahurst Bight has been suggested to explain the tongue of older water containing lower dissolved oxygen at about 90-100 m deep. No evidence of the intrusion and upwelling of bottom water

along shore at Seahurst was found.

Intertidal and Shallow Subtidal Ecology: Collections of macroalgae, eelgrass, small and large infauna were made at 30 intertidal sites located in major habitats on Vashon Island and the eastern shore of Puget Sound. This survey revealed the major habitats in the region were sand flats, eelgrass beds, mud flats and cobble fields. Six beaches (Seola, Seahurst Park, Normandy, Covenant, Tramp Harbor and Aquarium) were selected for intensive study of high and low intertidal cobble/sand, low intertidal and shallow subtidal sand and eelgrass habitats.

Sampling was performed to determine the number of replicates required to adequately sample target parameters within habitats. A high degree of spatial variability necessitated more samples than the originally proposed number of replicates. Nearshore water quality was monitored at each beach at two week intervals. Nutrients generally increased from summer to winter.

Significant declines in macroalgal standing stock occurred from summer to autumn. Algal species richness and diversity remained unchanged due to an increase in the number and kinds of small red and green algal species. Microalgae were abundant in sand flats and exhibited a bloom in mid November. This followed the October bloom of phytoplankton and indicated that sediment associated algae are low light adapted.

Eelgrass grows extensively in the low intertidal and shallow subtidal zones in the region. Eelgrass density decreased slightly from summer to autumn and leaf length decreased by approximately one-half during the same period. Eelgrass and bladed green algae in the drift line declined from summer to autumn.

Low littoral cobble habitats contained the highest abundance and biomass of small infauna during the summer and low intertidal sand habitats had the

lowest, however, the species diversity was similar among all habitats. Substantial populations of recreationally important clam species were found at all four sites sampled. Recreational clam digging has resulted in a decline in size and abundance of the butter clam at Seahurst Park beach. Total clam abundance was very similar among beaches and stable over time.

Macroalgae appear to be nutrient limited in the Seahurst Bight and additions of dilute effluent might stimulate productivity rates. Important and productive benthic biological resources exist in the Seahurst Bight. The Seahurst outfall should be sited so as to minimize the probability of effluent impingement upon the intertidal/shallow subtidal zone.

Subtidal Biology: Emphasis in Phase I was placed on the biological communities at water depths in excess of 185 m and on the physical and chemical properties of the sediments at all sampling depths. Physical and chemical data indicated that, in general, quantities of organics increase and the grain size decreases with an increase in depth with some exceptions in south central Puget Sound. Some seasonal cycling exists in the physical and chemical constituents of the sediments. The quantities of clay size particles and biological quality of the sediment organics is greater while percent water content is less in the West Point area than in the south central Puget Sound area.

Seasonal cyclings are identified in the abundance and number of species in major taxa groups in both the south central Puget Sound and in the West Point area. Polychaeta and arthropoda groups are more abundant during autumn months and mollusca during the summer periods in the south central Puget Sound area. Polychaeta are more abundant in the autumn periods off West Point. Mollusca are the most abundant species at depths greater than 185 m in both the south central Puget Sound and West Point areas. Long-term trends in

comparable data indicate a major change in the dominance of some species from 1969 to the present.

The regions in the vicinity of Three Tree Point in south central Puget Sound differ greatly from all other areas between Pt. Williams and Pt. Defiance. Significantly more species and individuals, as well as higher diversities and Infaunal Trophic Index values, exist at these stations than at any other stations from comparable depths. These trends in the data near Three Tree Point are also seen in the major taxa groups arthropoda, mollusca and polychaeta.

Commercial/Recreational Fisheries: Including the freshwater and marine habitats sampled at least 87 species of fishes have been found to occur in the Seahurst area. Numerous searun cutthroat trout have been sampled in the south stream at Seahurst Park. Striped seaperch, pile perch and copper rockfish are the predominant artifical reef (sunken barge) fishes. A pronounced increase of surfperch from spring-summer to fall-winter was observed on the reef.

The greatest number of species per sample occurred in the nearshore beach seine hauls. Seahurst had the largest average number of fish per haul (1591) and Pt. Pully the smallest (729). The mean number of fish per haul tended to increase from spring to autumn but the mean biomass per haul showed considerable fluctuation. The greatest average number of fish (2741) were sampled at Seahurst in autumn and the greatest biomass (over 68 kg) occurred at Pt. Pully in the spring. In general, Seahurst and Pt. Pully had the largest catches by weight. The abundance of juvenile fishes of several species indicates the importance of the nearshore areas as nursery grounds.

The total number of species of fishes in the offshore samples was greatest at the 50 m depths and lowest at the 200 m depths. The low fish species diversity and abundance at 200 m suggests that an outfall at this

depth would have the least impact on the fish populations.

The overall incidence of ectoparasites (Philometra) was 30-36% in rock sole, English sole, rex sole, and Dover sole. Parasite occurrence in November 1982 in rock and English sole was similar to November 1975 infestation levels.

Fish Health: Examination of the demersal and pelagic fish collected to date at Seahurst Park and Pt. Pully indicate the populations are relatively healthy. Most of the lesions found were of minimal significance to the health of the host and many represent traumatic injuries or normal physiological changes. The incidence of neoplasia has been quite low and limited to epidermal papillomas. No hepatic lesions of neoplastic appearance were noted.

Virology: At this time it is not possible to draw conclusions as to the extent of viral contamination of Puget Sound shellfish in the Seahurst area. The analysis of samples has lagged the collection to the extent that procedural corrections have not been possible and little data is available on which to draw conclusions.

Microbiology: Fecal coliforms, enterococci, Clostridium perfringens and Salmonella data indicate some relatively low pollution levels in intertidal water, shellfish and sediments at the sampling sites in East Passage. Yersinia enterocolitica and like species were found to increase seasonally during the colder months while Vibrio parahaemolyticus is more abundant during the warmer months. Indicator organisms were found in lower abundance at the water column stations due to increased distance from shore. Due to the variations in the environment and biological systems additional samples must be analyzed prior to development of final conclusions.

Marine Toxicology: The "background" toxicity associated with receiving water and sediment samples in the East Passage area was determined. Water column toxicity was monitored using standard 48 hr oyster embryo and 60-min

sand dollar sperm bioassays. Sediment toxicity was initiated using a 10-day amphipod bioassay which monitored survival and degree of inactivity (number moribund) as a sublethal indication of stress. Samples of Renton Treatment Plant sewage were tested with oyster embryo and sand dollar sperm bioassays to allow prediction of any possible post-discharge acute toxicity effects and/or "margins of safety."

Water column toxicity was highly variable depending on a variety of factors. The oyster embryo mortality index was generally highest in water from surface samples and within the Seahurst Bight, probably due to the presence of phytoplankton metabolites. The oyster embryo abnormality index showed highest responses in deeper water and in water outside the Seahurst Bight. The responses of the sperm assay were generally intermediate between the two oyster indices.

Results of Renton sewage bioassays suggest that no direct water column toxicity should be observed after initial dilution with the discharge of either unchlorinated or dechlorinated secondary effluent. Toxicity may be detectable outside the zone of initial dilution if chlorinated effluent is discharged, but the "non-conservative" nature of chlorine in seawater may serve to mitigate this source of toxicity.

The stimulation of "indirect" water column toxicity must be considered if the effluent discharge serves to cause greater than normal phytoplankton production. Increased algae growth could produce additional metabolites which might add to the present levels of "background" water toxicity.

Amphipod survival was generally high in the Seahurst area sediment samples. However, trends toward higher mortality were suggested for samples taken along transects ("C"), which crossed areas of sediment deposition. Amphipod test results must be viewed with caution since several confounding

factors (i.e., sediment anoxia, sediment grain size differences and the possible generation of biological metabolites) may have played an interactive role in some of the tests. A refined flow-through sediment bioassay system has been designed and tested to minimize these problems in future tests.

The biological implications of the proposed sewage discharge are discussed in relation to the test results and data generated by other studies with suggestions for outfall siting to help mitigate future biological effects.

Marine Chemistry: The biogeochemistry of trace metals in surface sediments, sediment cores and biological samples was determined. The sediment cores were $^{210}Pb$ dated. The top portion of six cores showed an almost constant concentration of $^{210}Pb$. This could be due to a very rapid sediment accumulation, bioturbation or physical mixing by other processes.

Two general types of trace metal profiles were found. Profiles of metals such as cadmium show constant concentration from top to bottom of the core indicating no significant anthropogenic input has changed its natural background. On the other hand, metals such as Pb, Cu and Hg show significant increase over the natural background, indicating strong anthropogenic input.

Results from the analysis of biological tissues for trace metals are not available at this time. Numerous additional samples have been analyzed for sediment grain size, total sulfide, biochemical oxygen demand, percent volatile solids, organic carbon and nitrogen, dissolved oxygen, salinity, and nutrients which have been analyzed in other tasks.

General Conclusions: Preliminary analysis of the physical, chemical and biological data in the Seahurst Bight and the East Passage area to date (March 1983) are summarized by the following statements:

- Circulation is weak in the northern sector of Seahurst Bight.

- Chlorophyll concentrations are higher in the surface waters of the Seahurst Bight than at mid-channel.
- Intertidal habitats and associated organisms in the Seahurst Bight are similar to other parts of east passage with harvestable hard shell clam and seaweed populations.
- Zones of sediment deposition and seasonal and long-term changes in subtidal benthic indices are becoming defined.
- The fish fauna is concentrated in the nearshore nursery area and least abundant offshore.
- Demersal and pelagic fish fauna appear healthy.
- The levels of bacterial contamination exceed the standards for shellfish consumption and swimming.
- Background toxicity was generally highest in surface samples in the Seahurst Bight.
- Chlorinated secondary effluent is most toxic to marine organisms.
- Sediment core analysis indicates significant accumulations of Pb, Cu and Hg.
- Potential ecological and health effects will be minimized by discharge of the effluent west of the Seahurst Bight in water depths of 600 ft.

# 2.0 INTRODUCTION

Expansion of the Renton Sewage Treatment Plant to meet the needs of a growing population in the Seattle metropolitan area and the water quality requirements in the Duwamish River is designed to direct secondary treated sewage effluent from the Duwamish River to the south central Puget Sound basin at Seahurst. The Seahurst Baseline Study as a part of the expansion plan is designed to obtain pre-discharge ecological data in the marine environment in the East and Colvos Passage areas of Puget Sound (Figure 2.1). Although facility planning by METRO and an environmental impact statement by the U.S. Environmental Protection Agency predicted no water quality problems are likely to occur as a result of the proposed discharge, the Seahurst Baseline Study was initiated to carefully document a comprehensive and integrated understanding of the marine ecological conditions in the receiving waters. These data will be utilized to minimize potential impacts of the design, to aid in ongoing planning efforts and to assess changes which may occur once effluent is discharged at the site. The principal purpose for this effort is to establish environmental conditions, organism assemblages and predictive water quality information prior to a planned event using appropriate scientific procedures which can be repeated during later monitoring efforts.

The Seahurst Baseline Study has three broad objectives: (1) to collect, analyze and interpret the significance of physical, chemical and biological data around the proposed sewage treatment plant outfall at Seahurst to determine the properties and characteristics of the receiving environment; (2) to utilize the information obtained to aid in the siting and design of the outfall pipe and diffuser; and (3) to recommend a post-effluent discharge monitoring plan that will effectively and efficiently determine if the

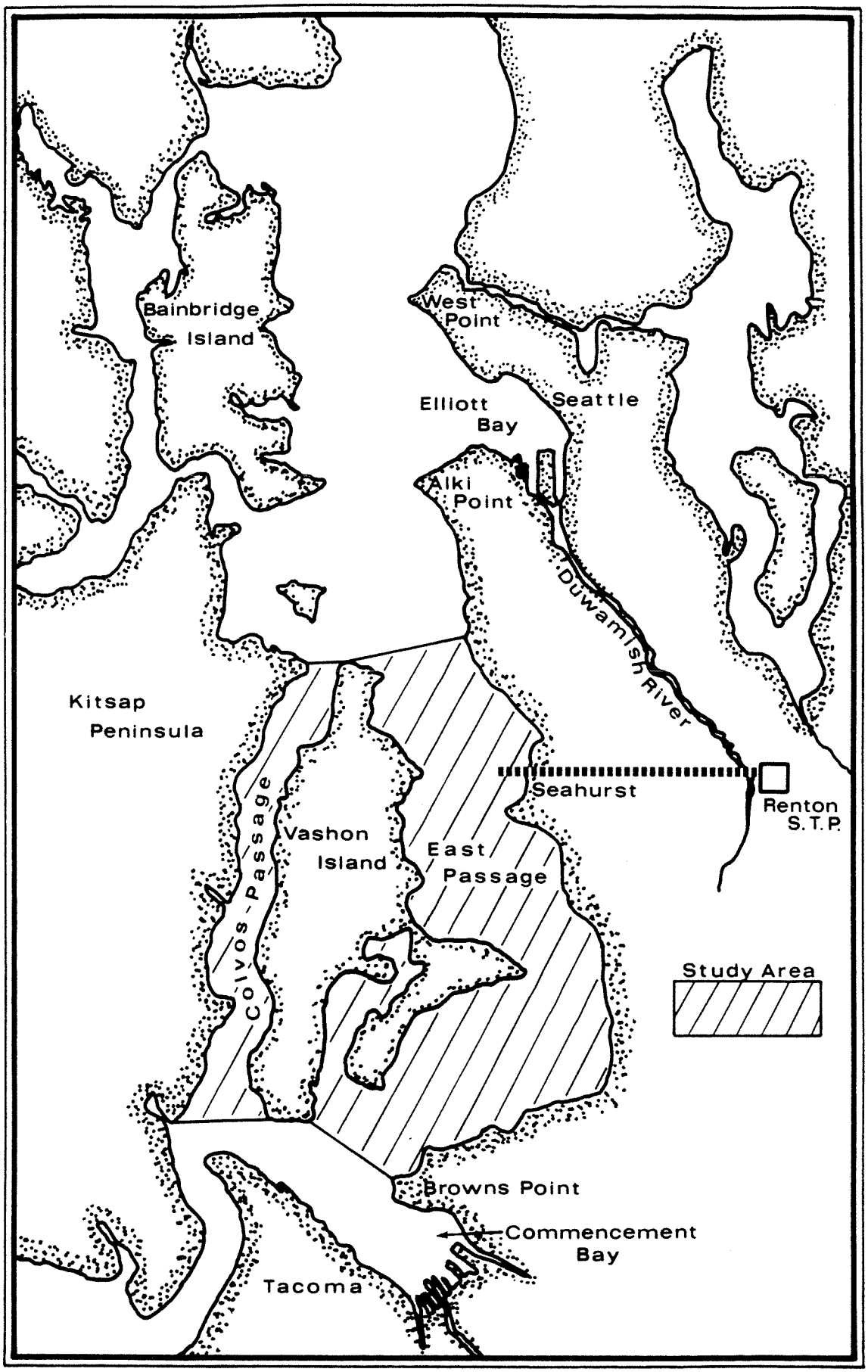



Figure 2.1. The Central Puget Sound basin showing the location of the Renton Sewage Treatment Plant and the study area in the south central basin

presence of the new outfall significantly changes the receiving water environment described in the first objective.

This report contains the scientific results of the ecological studies conducted during the first nine months of the Seahurst Baseline Study and constitutes the first annual progress report. The purpose of this report is to present the data collected during the initial nine months of the study along with preliminary analyses and interpretations of these data.

# 3.0 PROJECT MANAGEMENT

Q. J. Stober, L. Conquest, K. K. Chew

The technical organization of this study is illustrated in Figure 3.1. The major tasks which have been identified and which consistently interact have been grouped together under water column, environmental health, sediment investigations and chemistry. The studies of the water column include monitoring of the physical/chemical characteristics of the water and the indigenous pelagic biota. Sediment investigations include the ecological studies of the intertidal and subtidal benthos and fishes. Environmental health includes the monitoring and isolation of human pathogens (bacteria and viruses), fish pathology (fish health) and marine toxicology. The chemical analysis is focused on the presence of trace metals in water, biota and sediment, in addition to a variety of support services to the entire project. The organizational structure of this study has facilitated efficiency, interdisciplinary integration within and between tasks and ensured that the study scope and schedules can be met in a timely manner. This report is similarly organized by task.

Statistical expertise has been provided by Dr. L. Conquest on a regular basis to faculty, staff and students associated with the project. Preliminary requirements for sample sizes in the Intertidal Study were estimated. Later, some of these sample sizes were reduced due to low values of the coefficient of variation (standard deviation/mean) for certain variables. These sample sizes also hold for doing nonparametric tests (such as rank tests), which do not require the usual normal distribution assumptions.

As part of the Water Column Study, probability distributions (notably the

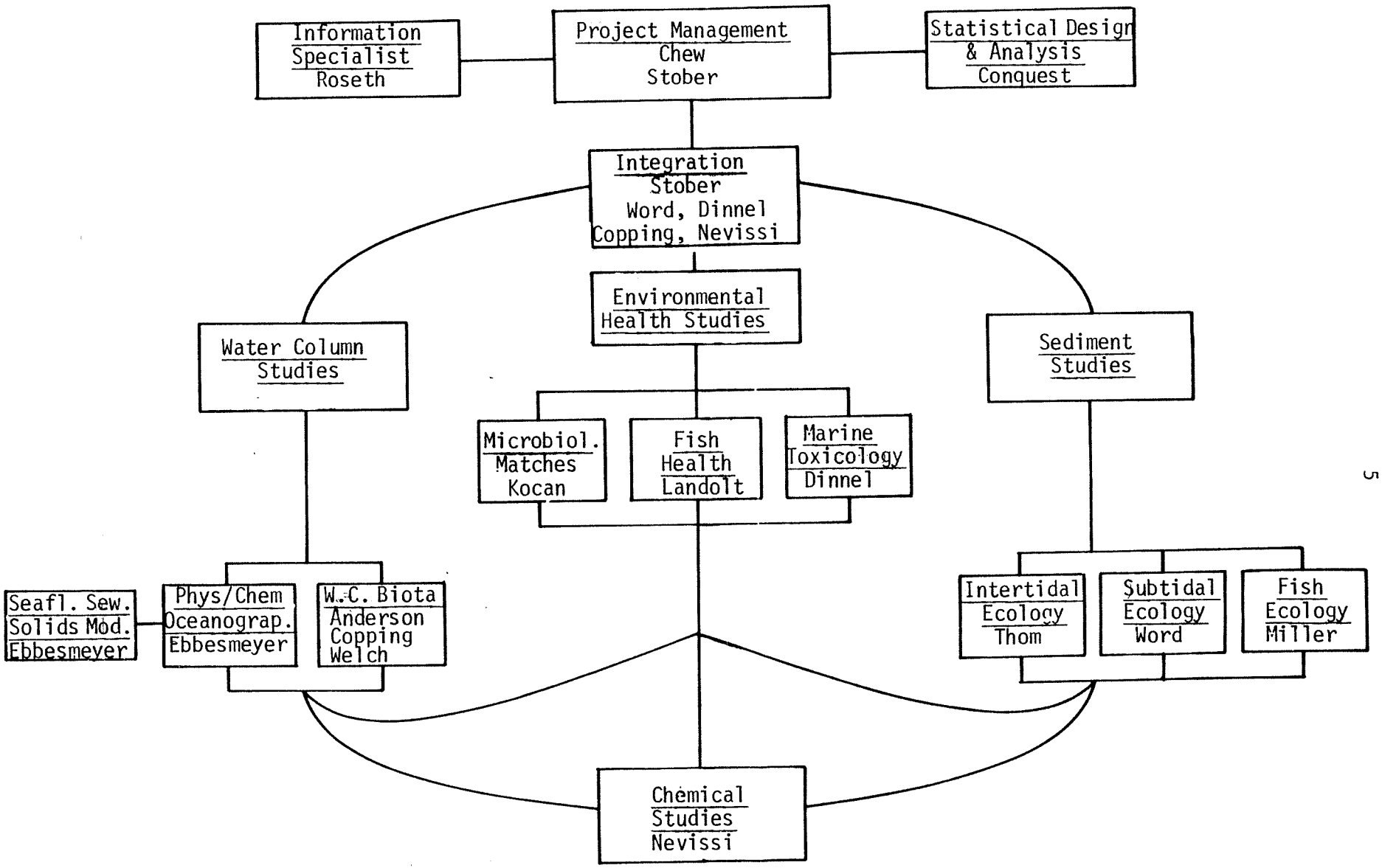



Figure 3.1. Organization of the Renton Sewage Treatment Plant Project, Seahurst baseline study indicating major project divisions, specific tasks, and responsibilities of selected personnel.

gamma) were used to describe the behavior of certain parameters (e.g., phaeopigments, chlorophyll). Both simple and analytically complicated estimates of distribution constants were computed from available data sets. The two groups of estimates were similar, although confidence intervals were available only for the more "complicated" set. The normal, log-normal, and gamma distribution seem to be doing a sufficient job of describing these parameters.

The computational procedures in the Geological Oceanography Laboratory Manual were reviewed to determine basic validity from a statistical point of view. These concerned the methods for determining mean and median particle grain size. The methods and the original principles from which derivation was made were found to be valid.

Other areas of statistical advice included critical values for tests comparing a single control group to many treatment groups (e.g., more than 20) in the sediment toxicty bioassays to allow computation of new values to extend the existing statistical tables. Estimates on inherent variability on trace organics expected to come from another METRO Study on Toxicant Pretreatment Planning may allow determination of the amount of statistical power associated with a given experimental design and sample sizes. Trace organics are known to be associated with high natural variability, so required sample sizes may be higher than those associated with parameters for the Intertidal Study.

Organizational and coordination meetings have been held routinely throughout the year within and between task groups to plan sampling and analytical activities and to discuss preliminary interpretations of the data. The Principal Investigators and Project Leaders have been in daily contact with METRO staff throughout the year in an effort to find solutions to problems and to ensure the maximum performance of all investigators during this study.

# 4.0 WATER COLUMN

J. Anderson, A. Copping, T. Jagielo, J. Postel, W. Peterson,
B. Dumbauld, G. Heron, R. Hood, M. Strom

## 4.1 Introduction

Natural daily and seasonal fluctuations in the Puget Sound marine environment can produce extremely high and low levels of chemical and biological properties in the water column and nearshore environment. At this time, the consensus of scientific opinion is that the discharge of treated effluent at depth will have a small impact on the average conditions and the levels and frequency of the extreme fluctuations in the receiving water properties in the Sound. The natural daily and seasonal fluctuations might easily be misinterpreted as due to the effects of effluent without prior documentation. On the other hand, the long term changes that might occur to the environment by the continuous discharge of effluent into the Sound are of vital importance to everyone. Thus, the overall purpose of the water column study is to provide a baseline of the physical, chemical and biological properties which will be of use in the post effluent discharge monitoring effort and contribute a statistically meaningful baseline from which long term changes in the Puget Sound environment can be assessed.

### 4.1.1 Purpose and Scope

The purpose of the study is to focus on the key water column chemical and biological properties that are directly affected by effluent. These properties include nutrients, phytoplankton, zooplankton, and particulate material. These observations are collected in statistically significant quantities so the probabilities of observing different levels of the properties can be assessed. In addition, the sampling scheme is designed to

identify possible specific impacts and assess their significance. The study is focused on the following tasks:

1. To determine the presence and possible effects of Commencement Bay water in East Passage.
2. To define the oceanographic differences in the water column among East Passage, Brown's Point, Colvos Passage, and West Point.
3. To determine the probability of high plankton levels in East Passage before the construction of an outfall at Seahurst Park.
4. To document the seasonal changes in plankton biomass and nutrient concentrations in the very nearshore area of Seahurst Park.
5. To determine the possibility of an onshore bottom flow of water at Seahurst Park.
6. To determine the quantity and quality of sediment loading in the Seahurst/East Passage area.

Wide area studies and underway mapping aid in obtaining information on Commencement Bay water and the oceanographic difference among areas in the south central basin of Puget Sound. Probability levels of plankton in East Passage will be determined by discrete stations occupied during the nearshore studies and by underway mapping in the Seahurst Bight. Studies carried out in the Seahurst inshore area will document changes in plankton biomass and nutrient concentration close to the Seahurst beach, and to investigate the possibility of deep water flowing along the sea bottom towards shore at Seahurst Park. Sediment trap studies will examine sediment loading in the nearshore area of Seahurst/East Passage.

### 4.1.2 Description of Study Area and Station Locations

Six discrete water column stations, numbered five through ten were chosen in the nearshore region of Seahurst Park in order to determine physical and

chemical parameters and their spatial variability in the area. Plankton populations in the water column move with water currents and thus spatial variability in a small area is difficult to document. Levels of zooplankton and phytoplankton biomass can be recorded and probability distributions of their abundance constructed for comparison with those generated post-discharge. A seventh station in the center of East Passage (Station 4) was added to the nearshore discrete stations as a link to the environment of the open waters of Puget Sound. Table 4.1 provides the locations and bottom depths for the discrete stations. The map in Figure 4.1 locates them in the Seahurst/East Passage area.

The discrete sampling stations chosen to answer questions regarding a wider area in the south central basin of Puget Sound are located at West Point (Station 1), chosen as an historical station occupied in previous METRO studies (Campbell et al. 1977). Brown's Point (Station 3), chosen to represent the environment of Commencement Bay, Colvos Passage (Station 2), chosen as a "clean" control station, and East Passage (Station 4), chosen to represent the study area. See Table 4.1 and Figure 4.1 for details.

Cruise tracks for underway mapping were chosen as midchannel representations of the areas linking the wide area stations; that is, from West Point heading south, around Vashon Island and back to West Point. Figure 4.1 shows this transect which was generally run in a clockwise manner, weather permitting. The inshore transect at Seahurst Park was designed to examine, in detail, surface parameters close to shore from south of Point Pully to Brace Point (see Figure 4.1).

The Seahurst inshore studies have their basis in a sampling station of opportunity. Students at the Occupational Skills Center marine facility have collected samples for chlorophyll and nutrient analysis from the beach

Table 4.1. Location of discrete sampling stations and bottom depths (see also Figure 4.1).

| Station No. | Latitude | Longitude | Bottom depth (m) | Location |
|---|---|---|---|---|
| 1 | 47°39.6'N | 122°28.8'W | 220 | West Point |
| 2 | 47°29.9'N | 122°29.5'W | 100 | Colvos Passage |
| 3 | 47°19.1'N | 122°28.3'W | 170 | Commencement Bay |
| 4 | 47°28.8'N | 122°24.7'W | 180 | East Passage |
| 5 | 47°28.3'N | 122°22.7'W | 110 | Seahurst |
| 6 | 47°29.3'N | 122°22.3'W | 110 | Seahurst |
| 7 | 47°28.8'N | 122°22.3'W | 100 | Seahurst |
| 8 | 47°28.8'N | 122°22.2'W | 60 | Seahurst |
| 9 | 47°28.8'N | 122°22.0'W | 30 | Seahurst |
| 10 | 47°28.7'N | 122°21.9'W | 10 | Seahurst |

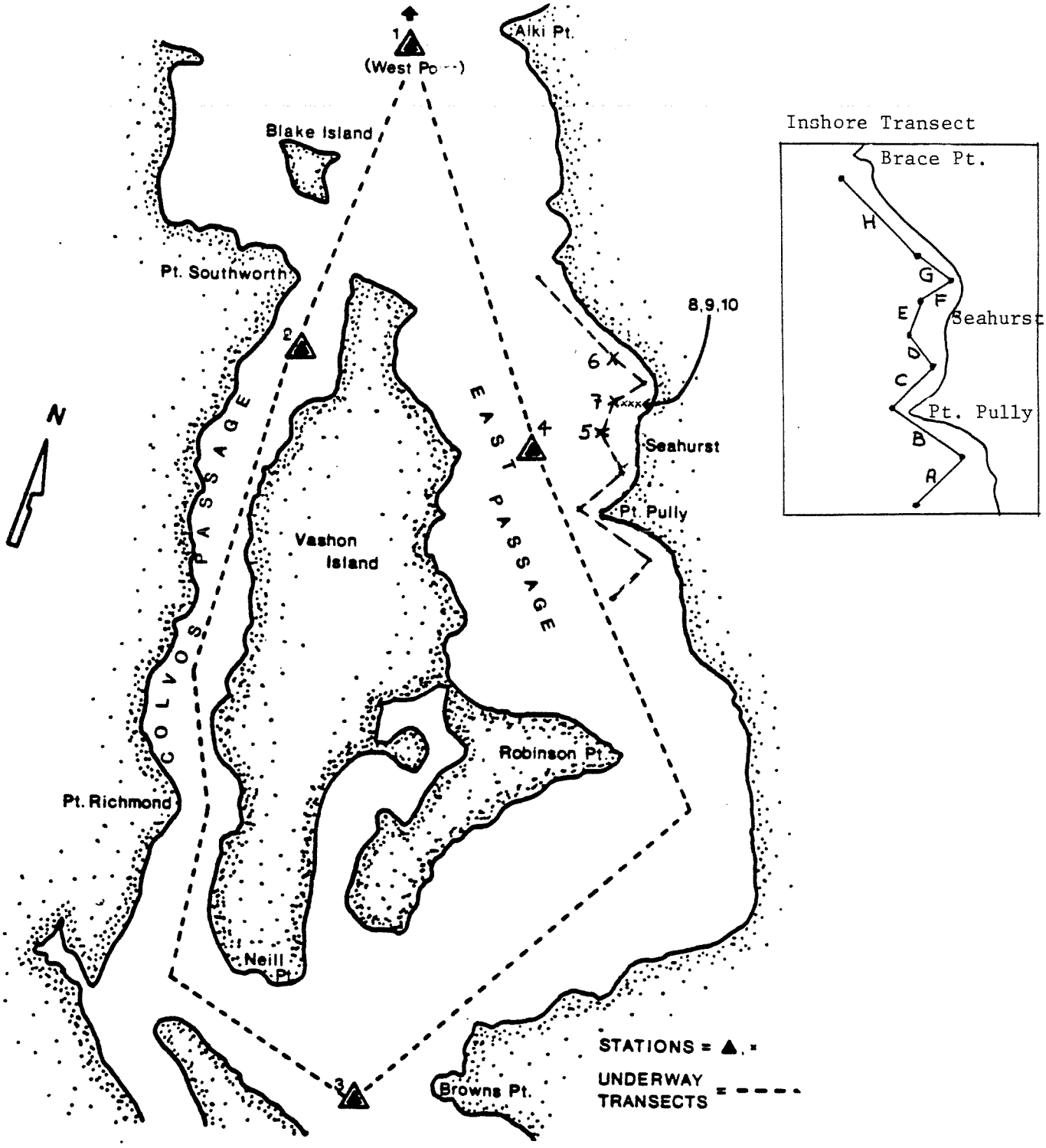



Figure 4.1. Map of discrete sampling stations (1-10) and wide area and inshore surface mapping transects.

directly in front of the lab. Incident radiation was collected by an instrument mounted on a lamp post in front of the lab building, and zooplankton hauls were taken about 500 meters offshore of the facility. Salinometer surface mapping transects are perpendicular to the shore, and separated from one another by approximately 200 meters. This scheme covers the entire length of the shoreline of Seahurst Park. Figure 4.2 pinpoints these locations.

A location for sediment trap deployment was chosen at 47°27.9'N latitude, 122°22.9'W longitude. This spot is within half a mile of shore, south of Seahurst Park. The bathymetry of the Seahurst bight is so steep that this location represents the only flat spot capable of holding a mooring, close to shore. The water depth is approximately 65 m.

## 4.2 METHODS AND MATERIALS

### 4.2.1 Wide Area Studies

Wide area stations were occupied on a biweekly basis throughout the summer and fall of 1982, and once every three weeks during the winter of 1982-1983. During the same cruises, underway surface mapping was carried out from Shilshole Bay south through East Passage and around Vashon Island, in order to determine the presence and possible effects of Commencement Bay water in East Passage. The underway sampling system measures at 1 m depth, water properties using the seawater system onboard the R/V Liberty. Continuous measurement of ammonia and *in vivo* fluorescence follows that of Strickland and Parsons (1971). Temperature and salinity are measured by an Ocean Data Equipment instrument. Chlorophyll is measured on a Sequoia-Turner model 111 fluorometer equipped with a flow-through sampling cell. Particle scattering is measured

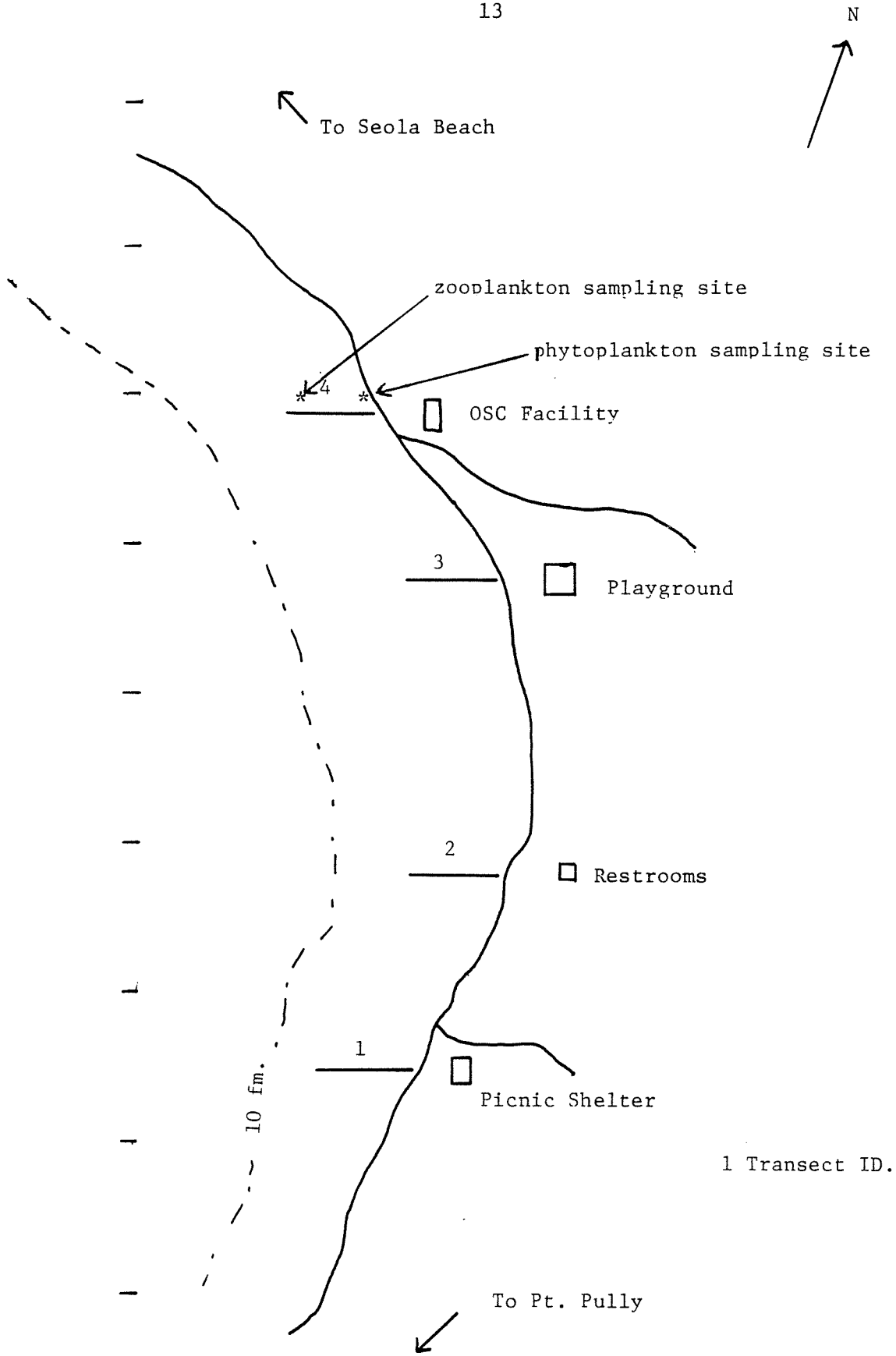



Figure 4.2. Study area for onshore bottom flow of water.

using a Monitek model 31 continuous-flow nephelometer. All instruments are calibrated and checked for drift frequently. All sensors are computer-compatible and are monitored with an HP-41CV programmable calculator and interface loop, controlling a data acquisition system.

Underway measurements of temperature, salinity, turbidity, ammonia and in vivo chlorophyll were gathered in order to trace the distribution of surface water masses from Commencement Bay. In addition, measurement of chlorophyll and ammonia aid in evaluating the impact of this water on the biological communities. Surface ammonia and chlorophyll samples from discrete water column stations were regularly compared with results of underway analysis in the same area. The results were similar, within the limits of experimental error.

Oceanographic differences among East Passage, West Point, Brown's Point and Colvos Passage have been determined by discrete vertical sampling at stations 1 through 4. Standard depths were sampled to evaluate seasonal changes in phytoplankton biomass and the accompanying chemical and physical environments.

Water samples were collected with a General Oceanics Rosette containing eleven 5-liter Niskin bottles, one of which was equipped with reversing thermometer racks. Temperature, conductivity, depth and dissolved oxygen were measured by METRO's Interocean CTD sensor on each cast. Calibration samples for temperature, determined using duplicate reversing thermometers, salinity, collected in standard salinity bottles, and dissolved oxygen, collected in Carpenter oxygen bottles, treated according to Carpenter (1964) and the samples kept cool and dark until analysis, are collected at intermediate and/or bottom sampling depths. Table 4.2 summarizes the depths that are routinely sampled at each station.

Table 4.2. Sampling depths and water bottle analysis. n = nutrients and chlorophyll; o = oxygen, salinity, and temperature; P = phytoplankton; c = carbon-14. The first five sampling depths are light depths, or standard depths, as shown. The last depth will be at the bottom. Wide area stations (1-4) will be sampled 23 times per year, near field stations (4-10) 41 times per year. Carbon-14 stations have percent incident radiation levels used for the first 5 sampling depths. All other stations use standard depths.

| % incident surface radiation | Standard Depth (m) | Station No. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Sample total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100% | 0 | n P | n | n | n P c | n | n | n P c | | | n P c | |
| 50% | 3 | n P | n | n | n P c | n | n | n P c | | | n P c | |
| 25% | 5 | n P | n | n | n P c | n | n | n P c | | | n | |
| 10% | 10 | n P | n | n | n P c | n | n | n P c | | | | |
| 1% | 20 | n P | n | n | n P c | n | n | n P c | | | | |
| | 50 | n | n | n | n | n | n | n | | | | |
| (effluent | 75 | n | n | n | n | n | n | n o | n o | n o | | |
| depth) | 100 | n | n o | n | n | n o | n o | | | | | |
| | 150 | n | | n o | n o | | | | | | | |
| | 200 | n o | | | | | | | | | | |
| | | 10 n | 8 n | 9 n | 9 n | 8 n | 8 n | 7 n | 1 n | 1 n | 3 n | 2138 n |
| | | 1 o | 1 o | 1 o | 1 o | 1 o | 1 o | 1 o | 1 o | 1 o | | 315 o |
| | | 5 P | | | 5 P | | | 5 P | | | 2 P | 607 P |
| | | | | | 5 c | | | 5 c | | | 2 c | 492 c |

Nutrient samples were collected in acid-washed 250 ml plastic bottles and frozen immediately on board. Chlorophyll was collected at each depth and 280 ml routinely filtered over glass-fiber filters. Water column particulates have been collected quarterly since the fall of 1982 for CHN analysis, at stations 7 and 10. Up to one liter was filtered through pre-combusted silver filters.

Zooplankton net hauls were performed to determine the changes found in zooplankton species and biomass. All hauls were vertical and adhered to the sampling scheme seen in Table 4.3. A 1/2 meter, 209 μm mesh Puget Sound closing net was used. Hauls were split with a Folsom splitter. One half was preserved with formalin for species analysis and the other half (until August 1982) was preserved for displacement (wet) volume analysis. After August 1982, the second half of the sample was filtered over a pre-weighed glass-fiber filter and dessicated for dry weight analysis.

4.2.2 Nearshore and East Passage Areas

The nearshore area was sampled at weekly intervals throughout the summer and fall of 1982 and at three week intervals during the winter of 1982-1983. Seven stations (4-10) were occupied, representing a continuum from the offshore (station 4) to the nearshore (station 10) environment. Discrete water samples for chlorophyll analysis and zooplankton net hauls for volume and dry weight analysis were taken at each station, as outlined for the wide area stations, to determine the probability of observing extremely high or low levels of plankton occurring naturally in the East Passage/Seahurst area. Similarly, construction of probability distributions for dissolved nutrients is possible with the results of nutrient analyses from discrete samples, taken as for wide area stations. Additional chlorophyll and ammonia data in surface waters was obtained by underway mapping, as outlined previously.

Table 4.3. Schedule of zooplankton net hauls for wide area stations (1-3), and nearshore stations (4-10). Biomass is expressed as volume or dry weight.

| | Station Number | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Totals |
| Cruises/year | 23 | 23 | 23 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 356 |
| Hauls/cruise | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 356 |
| Biomass analysis per cruise | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 356 |
| Species analysis per cruise | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 356 |
| Archieved samples per cruise | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 356 |

Primary productivity experiments were carried out weekly at stations 4, 7 and 10 to determine phytoplankton growth. Samples were taken from five light depths (as determined by secchi disc), inoculated with carbon-14 and the uptake method outlined in Strickland and Parsons (1972) was followed. Simulated in situ incubations were carried out on deck using neutral density filters from local apparent noon to sunset. Correlation of primary productivity with nutrient availability and physical parameters provide information about the effect of the environment on living populations. Additionally, changes in zooplankton and species composition were examined in terms of changing physical and chemical properties. Zooplankton species composition samples were taken as outlined for wide area stations. Phytoplankton species composition samples were taken from rosette bottles and preserved with buffered formalin, to a final solution of 4% formalin.

4.2.3 Seahurst Inshore Studies

Chlorophyll and nutrient samples have been collected daily since June of 1982 from the beach area off the marine laboratories at Seahurst Park. A clean bucket was used to sample and approximately 300 ml of water was filtered for chlorophyll analysis. Additional unfiltered water was frozen for nutrient analysis. All analysis was carried out at the University.

Vertical net hauls for zooplankton were taken several times a week beginning in October of 1982 at a fixed station off Seahurst Park. A 1/4 m 73 micrometer mesh zooplankton net was towed from the bottom (approximately 11-16 meters) to the surface. Samples were preserved with formalin. Samples are being analyzed for species identification, and trends of distribution noted on a weekly and seasonal basis.

Physical oceanographic data has been collected along four transects in the Seahurst Park area in order to investigate the existence of an onshore

movement of bottom water, from October 1982 until January 1983. Sampling occurred at one week to one month intervals. The transects were perpendicular to the shoreline and consist of four stations apiece, with bottom depths of approximately 3, 5, 7 and 10 meters, respectively. Conductivity, temperature and salinity have been measured at one meter intervals from the bottom, using a Beckman RS5-3 Induction Salinometer.

4.2.4 Sediment Trap Studies

In November of 1982, a sediment trap array was deployed in the Seahurst area in order to examine sediment loading in the area. A baseline of data will be compiled to quantify the following:

1. Organic fallout from the water column.
2. Sedimentation of terrigenous material, and
3. Rate of incorporation of organic material into the sediments.

The array was deployed in approximately 65 m of water south of Seahurst Park. The array consisted of a pair of sediment traps placed below the photic zone which are closed electronically, after the design of Lorenzen et al. (1981). The mooring has subsurface flotation and is released by electronically-triggered explosive devices. Ground lines improve the chances of recovery. The University of Washington research vessel ONAR has been used to deploy and recover the sediment trap arrays. The deployment site for the array is 47°17.9'N 122°22.9'W with the flotation at 10 m depth.

Table 4.4 summarizes the type of samples which have been taken for analysis from the sediment traps, the reasons for the analysis and which group will be carrying out each analysis. Chlorophyll, phaeopigment, dry weight and CHN sampling was carried out as indicated for wide area discrete samples. Lead-210 samples were placed in pre-washed 2 liter jugs and returned to the University for analysis in order to calibrate the rate of sedimentation in the

Table 4.4. Analysis of Sediment Trap Samples.

| Type | Reason | Analysis By |
|---|---|---|
| Chlorophyll and Phaeopigments | organic matter fallout and passage through zooplankton trophic level | Water Column Group |
| CHN | total organics | Water Column Group |
| Dry Weight | sedimentation rate of inorganic portion | Water Column Group |
| Microscopic Analysis | characterization of living/dead material | Water Column Group and/or Sediment Fingerprint Group |
| Lead-210 | sedimentation rate | Chemistry Group |

sediment traps versus that occurring on the sea floor. Samples for microscopic analysis are preserved as phytoplankton species analysis samples.

4.2.5 Laboratory Analysis

4.2.5.1 Chemical Analyses

Dissolved nutrients (nitrate, nitrite, ammonia, phosphate and silicate) have been analyzed as soon as was practicable after each cruise. Analysis was performed by the routine chemistry laboratory of the School of Oceanography using the methods of Strickland and Parsons (1972). The AutoAnalyser was standardized every four hours with standards made with low nutrient North Pacific Ocean water. Unknown standards were included with the analysis to maintain additional checks on the data quality.

Dissolved oxygen has been analyzed by the Fisheries Research water quality laboratory (Carpenter, 1964).

Salinity samples were analyzed on the University of Washington conductance salinometer. Each batch run was standardized using Copenhagen standard sea water.

Carbon, hydrogen and nitrogen (CHN) content of particulate materials was determined using a Carlo-Erba Elemental Analyser available through the School of Oceanography, after the methods of (Pella and Columbo, 1964).

4.2.5.2 Biological Parameters

Chlorophyll was analyzed by the fluorometric technique (Strickland and Parsons, 1972).

Zooplankton biomass was determined by the displacement volume method of Wickstead (1965), from the start of Phase I through the end of the 1982 growing season (October). Additionally zooplankton biomass was measured by dry weight analysis (adapted from the methods of Lovegrove, 1966). It was determined that the dry weight data provided better estimates for biomass and

thus volume analysis was discontinued after October 1982.

Zooplankton were identified to species (whenever possible) and the dominant species counted. After September 1982, copepods were further subdivided into life stages. Gayle Heron of the School of Oceanography carried out the analysis.

Phytoplanton species were identified and counted using an inverted microscope after the methods of Lund et al. (1958). James Postel of the School of Oceanography performed the analyses.

Carbon-14 activity was measured using a Packard Tricarb Liquid Spectrometer. The data analysis was carried out by Willis Peterson of the School of Oceanography. Surface incident radiation was measured initially using a Belfort Pyroheliometer and later with a Licor Quantum meter throughout each incubation day.

4.2.6 Data Management

4.2.6.1 Underway Surface Mapping

Underway data has been recorded on cassette tape through a data acquisition system controlled by an Hewlett Packard-41CV calculator. Discrete water samples were analyzed to provide calibration points for the underway data. The data has been transferred to data files on the Hewlett Packard-87 microcomputer. Calibration and interpretation of the data has taken place on the HP-87.

4.2.6.2 Discrete Sampling

Measurements from discrete water samples have been checked for quality by trend analysis. Data from discrete water samples and zooplankton hauls have been entered, analyzed and interpreted on the microcomputer. Results of species analysis for plankton have also been placed in the computer and are graphically displayed.

4.2.6.3. CTD Data

The data obtained from the Interocean CTD sensors has been collected onboard ship by the Superbrain microcomputer, operated by a METRO technician. The water column group has supplied calibration samples for temperature, salinity, and dissolved oxygen from one to two depths in each cast. Bias calibrations using this data have been made on a weekly basis with advice from Evans-Hamilton, Inc. This calculation has been performed on the METRO PRIME minicomputer. The data has been assessed and analyzed by Evans-Hamilton. Temperature, salinity, sigma-t and dissolved oxygen data has been provided to the water column group for the discrete sampling stations.

4.2.6.4 Data Grouping for Analysis

In this report the data was grouped in order to illustrate first order spatial and temporal patterns. Statistical analyses were not preformed because of the limited number of observations available. These analysis will be presented in future reports.

Stations 1-4 were grouped to study water column characteristics over the wide area and stations 4-10 were grouped to study the nearshore region. Station 4 is near mid-channel. The reason for including Station 4 in the nearshore group was to determine if the nearshore and offshore regions could be distinguished. From our limited analysis the regions are essentially the same.

The data have been grouped from the upper 10 m of the water column for each station. This interval covers the majority of the euphotic zone and generally includes four sampling depths.

## 4.3 RESULTS AND DISCUSSION

### 4.3.1 Wide Area Chlorophyll and Nutrients

A time series analysis of chlorophyll for the upper 10 m of the water column has been prepared for the wide area stations (1 to 4), and is shown in Figure 4.3. Chlorophyll is measured in µg/1.

Wide area stations one through four showed significant changes in algal biomass throughout the summer and fall of 1982. Additionally, significant differences among stations are noted. The highest chlorophyll levels are seen in July and early August at station 4 (East Passage) and station 3 (Brown's Point). Vestiges of an earlier summer bloom sampled in late May indicate that West Point (station 1) had a large standing stock of phytoplankton at that time. Throughout the summer and fall, station 2 (Colvos Passage) maintains the lowest level of chlorophyll in the surface layers, due to vertical mixing on the water column. Stations 1, 3, and 4 all develop surface (or slightly subsurface) chlorophyll maxima similar to those shown in Figures 4.4 and 4.5. The fall die off of phytoplankton due to light limitation begins in October at all stations and continues to decrease throughout November. While mean chlorophyll levels are high, the variance is also high, and decreases with decreasing fall chlorophyll values.

Time series plots for the nitrogen sources which are of importance for phytoplankton growth, nitrate and ammonia, are presented in Figures 4.6 and 4.7. Wide area stations 1 to 4 are shown in different symbols, with data averaged from the upper 10 m. Both nitrate and ammonia are measured in g-at/1.

Ammonia and nitrate are the nitrogen sources most readily availabile for phytoplankton growth in the area. The trends observed in Phase I indicate

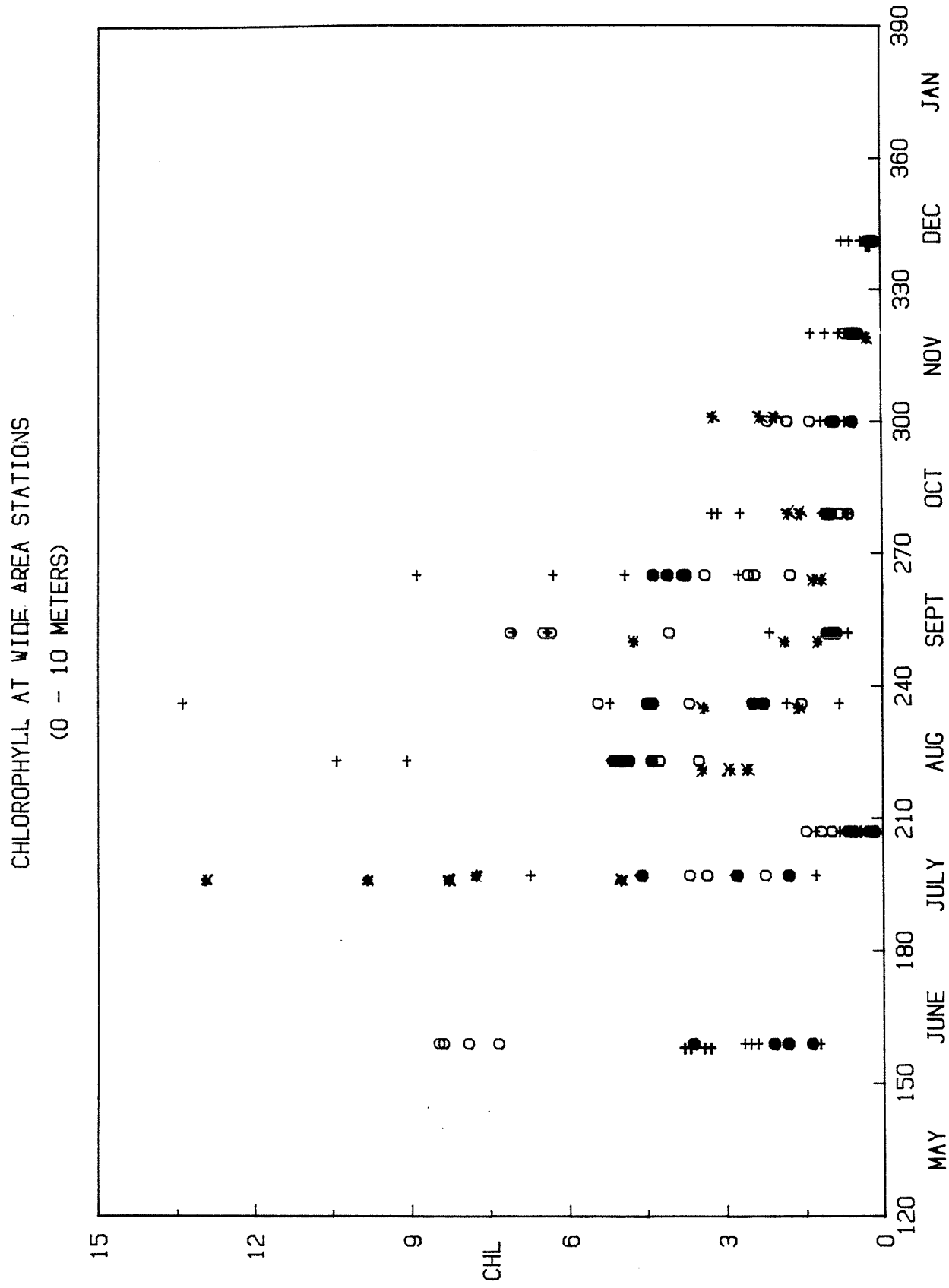



Figure 4.3. Time series of chlorophyll for the upper 10 meters at wide area stations (1-4). Chlorophyll is in µg/l. Time is in Julian days. Station 1 data is represented by the open circles (o), station 2 by closed circles (●), station 3 by crosses (+) and

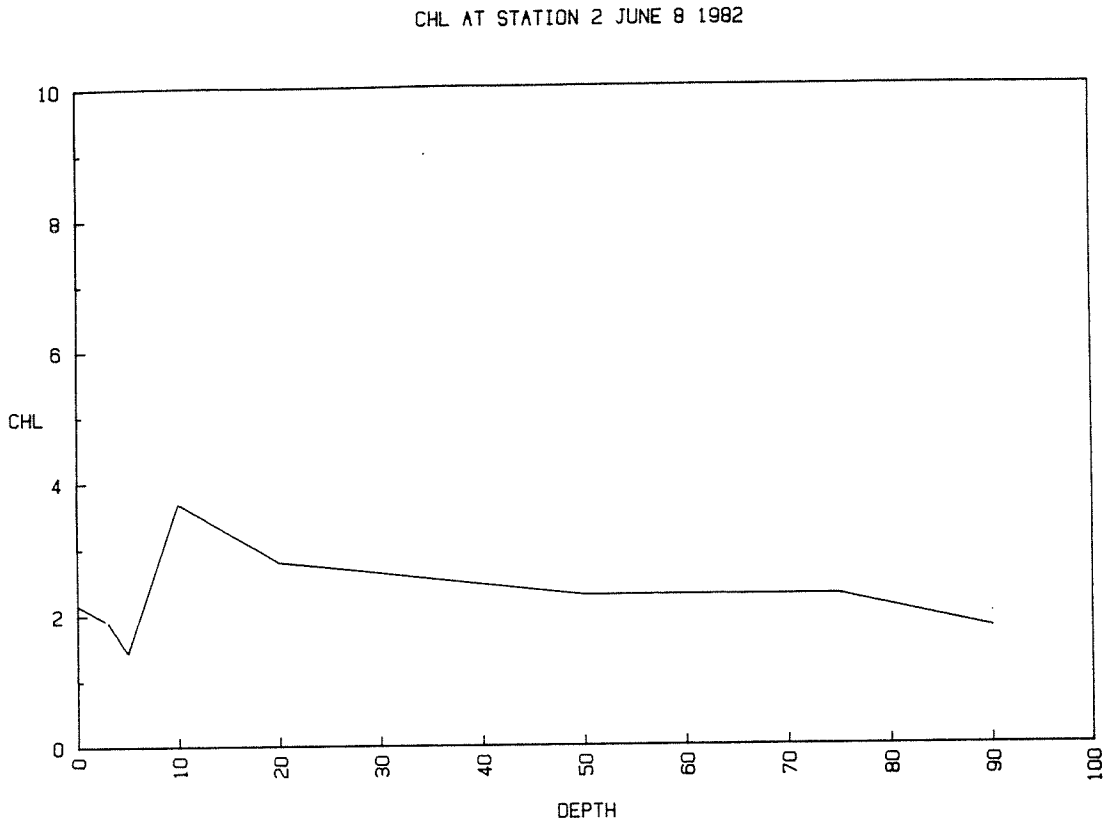



Figure 4.4. Vertical profile of chlorophyll at Station 2 (Colvos Passage) in June, 1982. Chlorophyll is in µg/l.

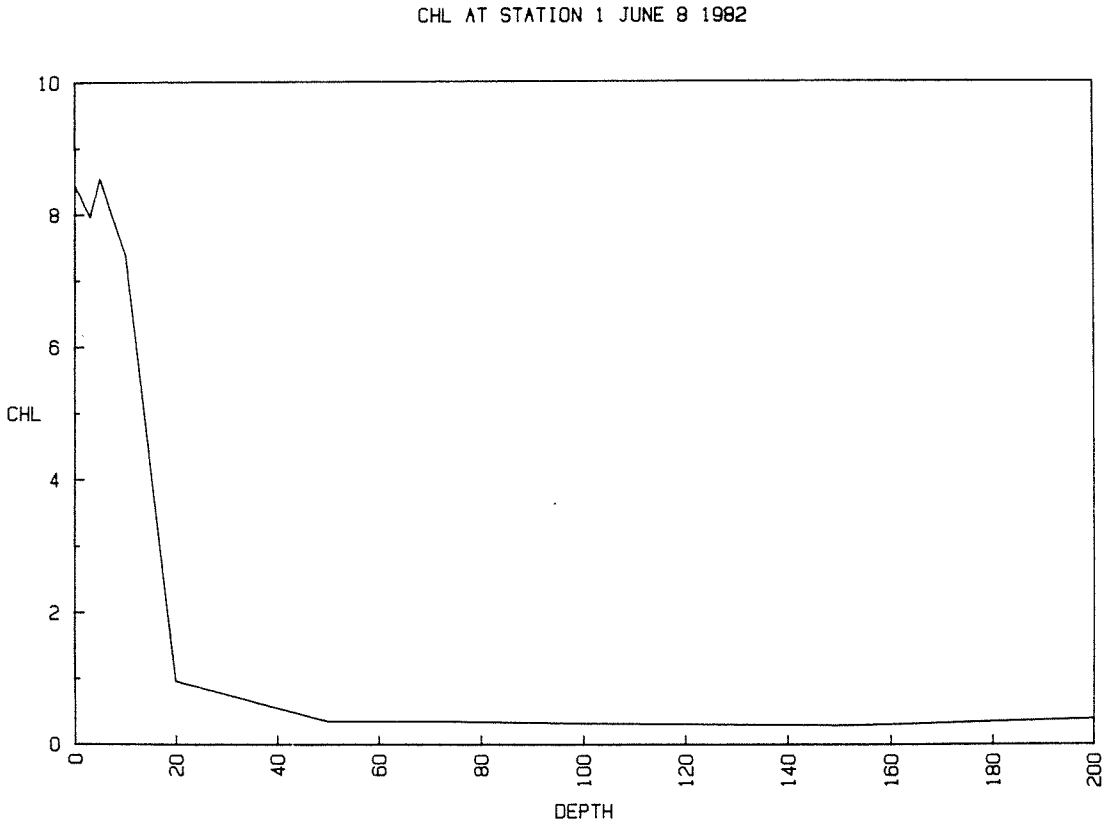



Figure 4.5. Vertical profile of chlorophyll at Station 1 (West Point in June. 1982. Chlorophyll is in µg/l.

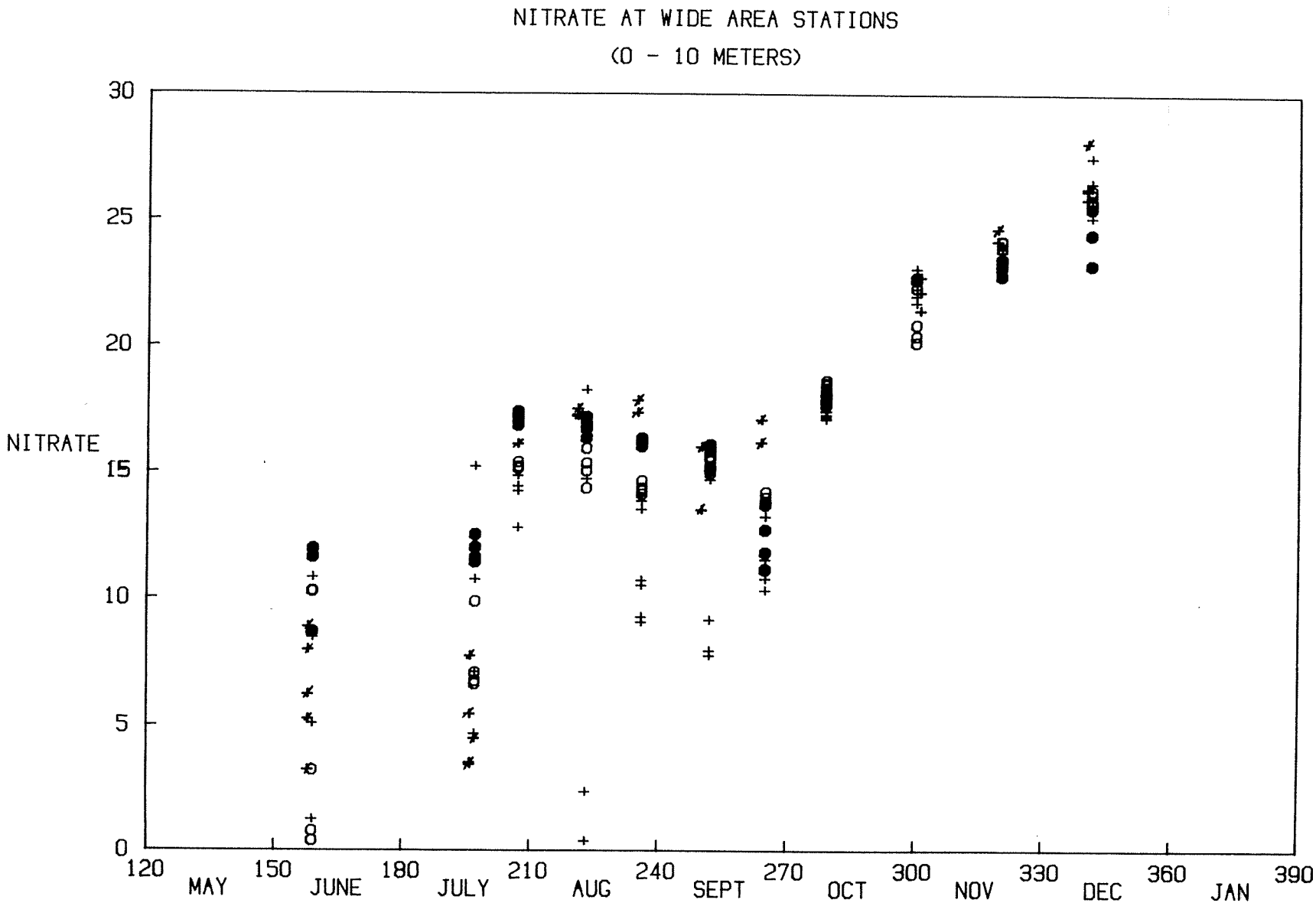



Figure 4.6. Time series of nitrate for the upper 10 meters at wide area stations (1-4). Nitrate is in µg-at/l. Time is in Julian days. Station 1 data are in open circles (o), station 2 in closed circles (•), station 3 in crosses (+) and station 4 in stars (*).

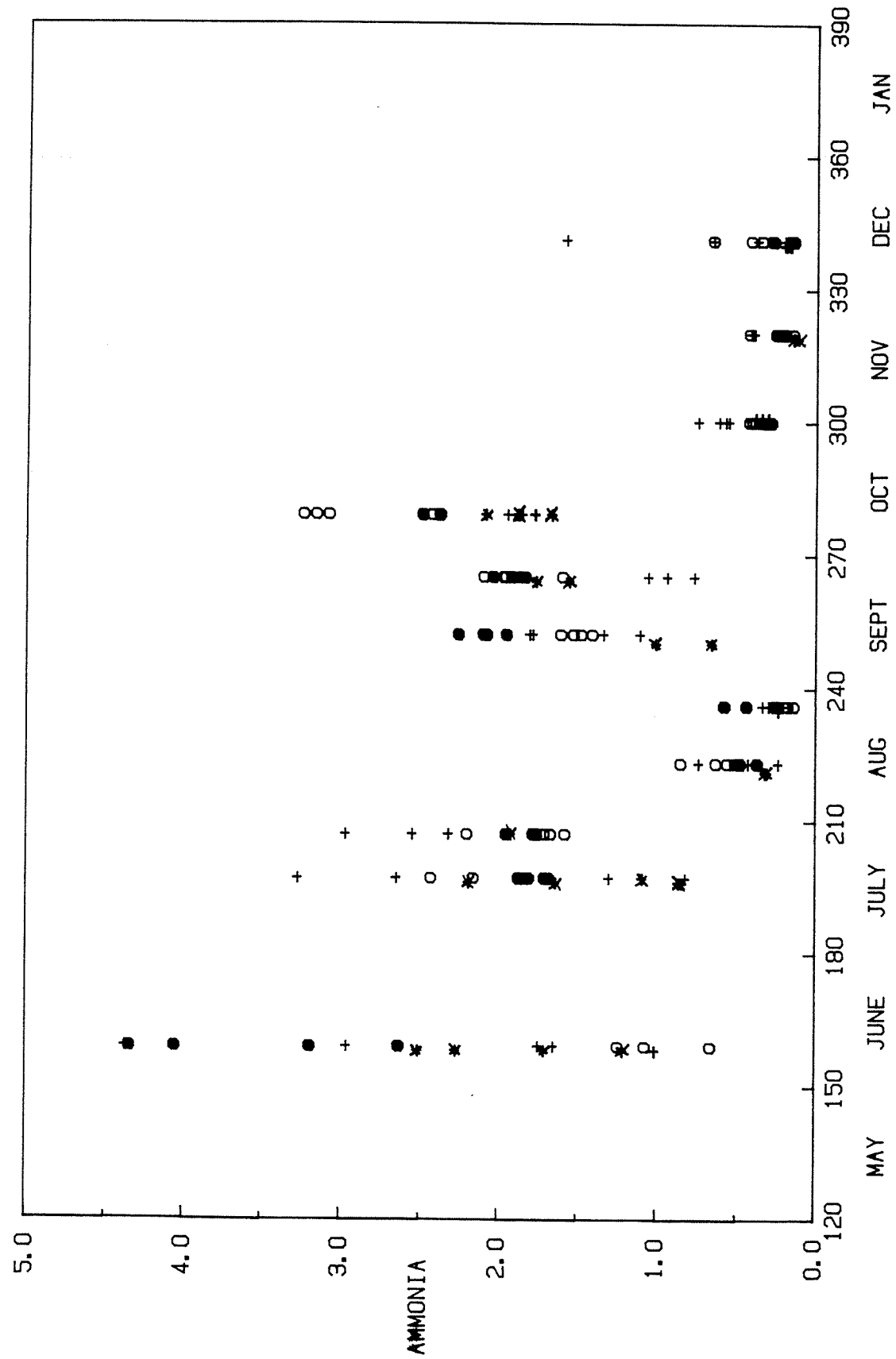



Figure 4.7. Time series of ammonia for the upper 10 meters at wide area stations (1-4). Ammonia is in µg-at/l. Time is in Julian days. Station 1 data are in open circles (o), station 2 in closed circles (•), station 3 in crosses (+) and station 4 in stars (*).

that a seasonal cycle exists for each nutrient. Ammonia, the preferred algal nutrient (Dugdale and Goering, 1967), shows a low in August, at the time of the highest chlorophyll levels, and relative highs preceding the midsummer bloom (July) and again after it (September). Midwinter low levels of ammonia are reached by the beginning of November. Nitrate displays a seasonal cycle which oscillates from relative highs to lows similar to that of ammonia, with an approximate four week lag. This results in a case where ammonia is increasing while nitrate decreases and vice versa.

The correspondance of midsummer lows in ammonia with highs in chlorophyll indicate that the phytoplankton population has a significant effect on the concentration of dissolved nutrient in the water column.

Ammonia levels observed in surface waters during this study are higher than those expected for temperate summer waters and may reflect addition of ammonia by external sources into the system. Conversely, the apparent midwinter low of ammonia may indicate a complex coupling of nitrate and ammonia utilization by phytoplankton. Further study in Phase 2 will complete the seasonal cycle and should elucidate this problem.

4.3.2 Nearshore Chlorophyll, Nutrients, Primary Production and Zooplankton Biomass

Chlorophyll samples from the upper 10 meters of the water column have been analyzed over time for the nearshore stations (5-10). This time series appears in Figure 4.8. Chlorophyll is measured in ug/1. Probability distributions for the occurrence of chlorophyll have been calculated. The data in Figure 4.8 has been divided into two different distributions to represent the summer/fall phytoplankton population and the winter population, that is, from May to September 1982, and October 1982 to January 1983. Figures 4.9 and 4.10 summarize this data.

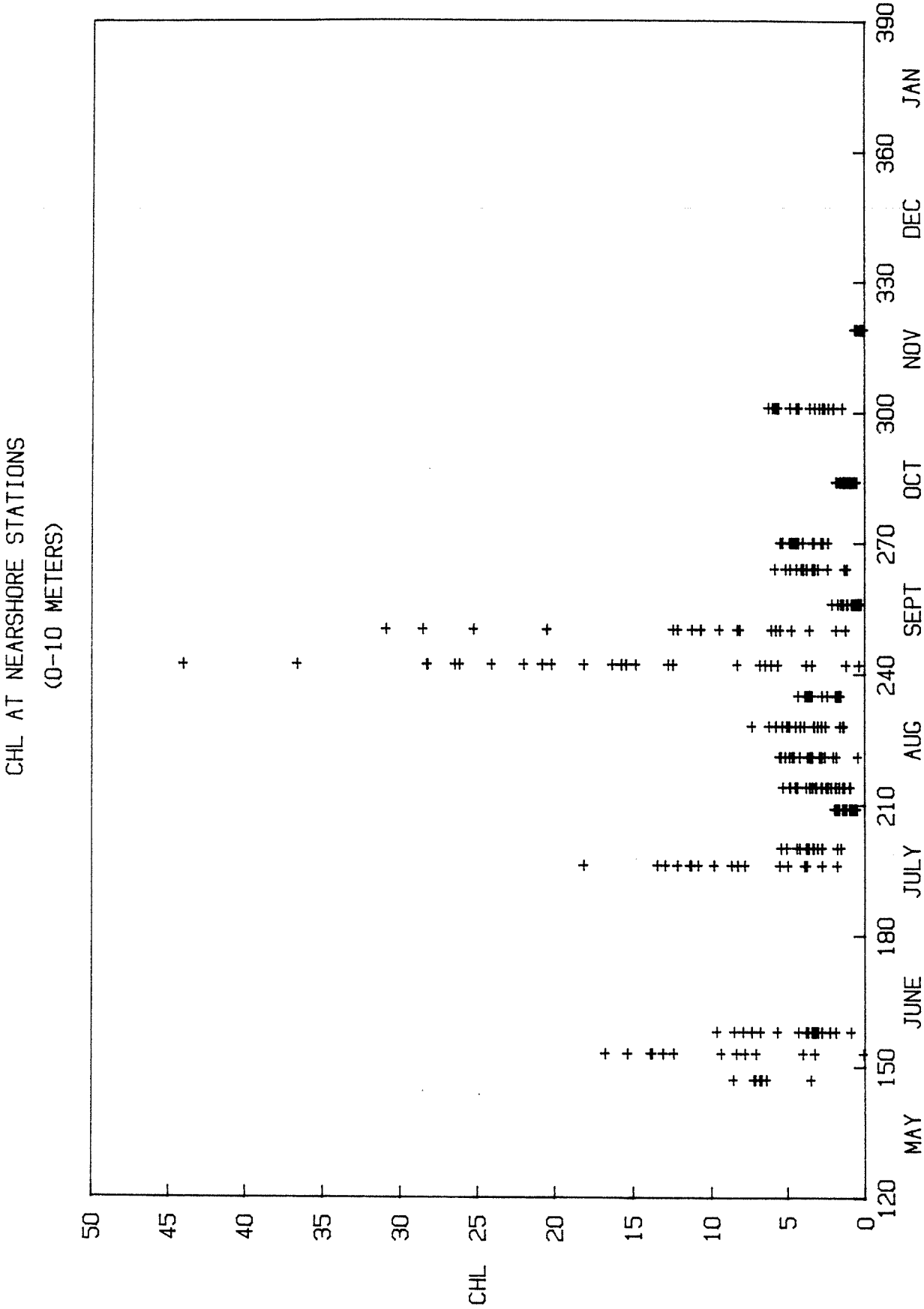



Figure 4.8. Time series of chlorophyll for the upper 10 meters at nearshore stations (5-10). Chlorophyll is in µg/l.

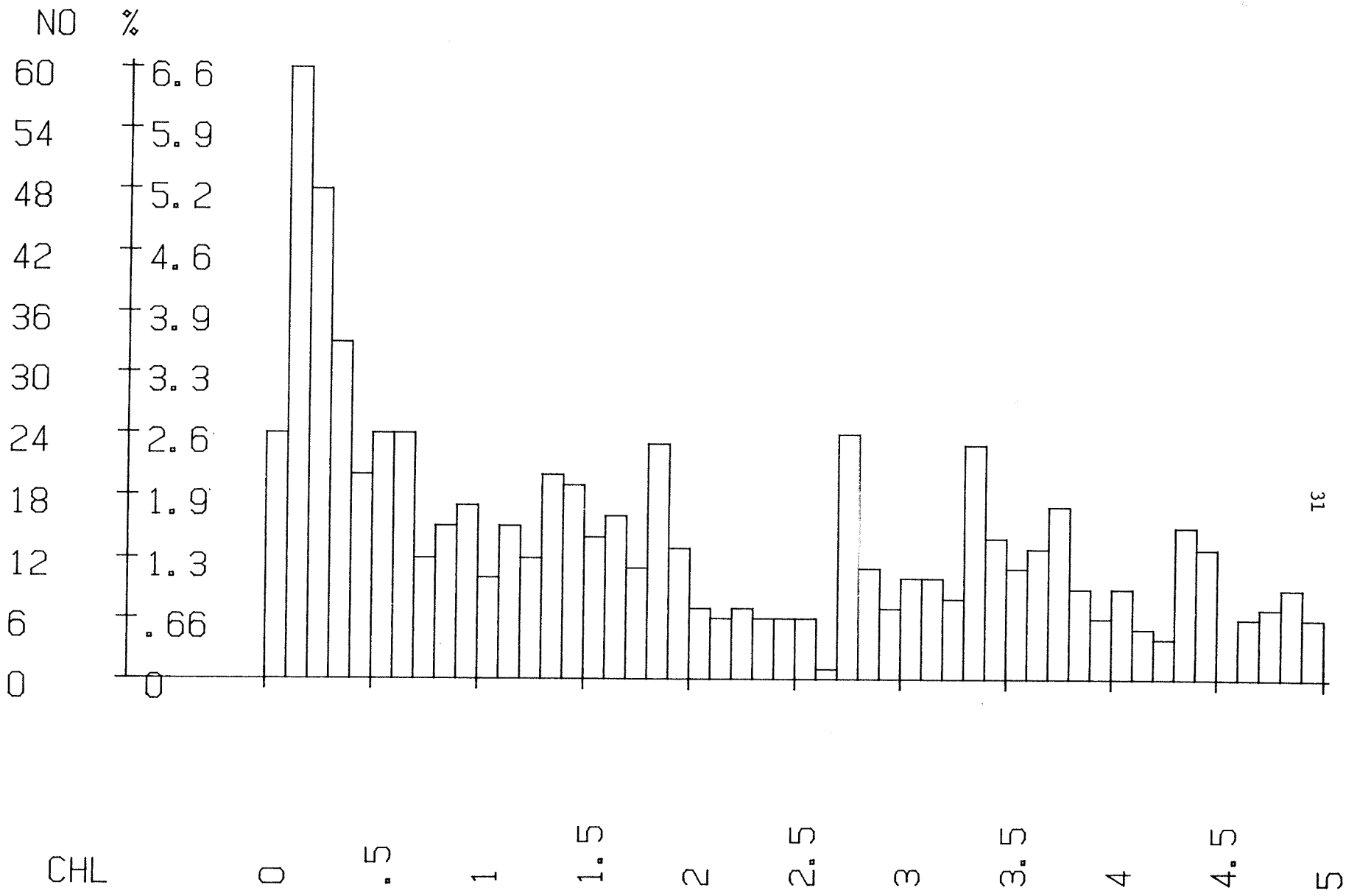



Figure 4.9. Probability distribution of chlorophyll in the upper 10 meters at nearshore stations (5-10) for the time period May-September, 1982. Chlorophyll is in µg/l.

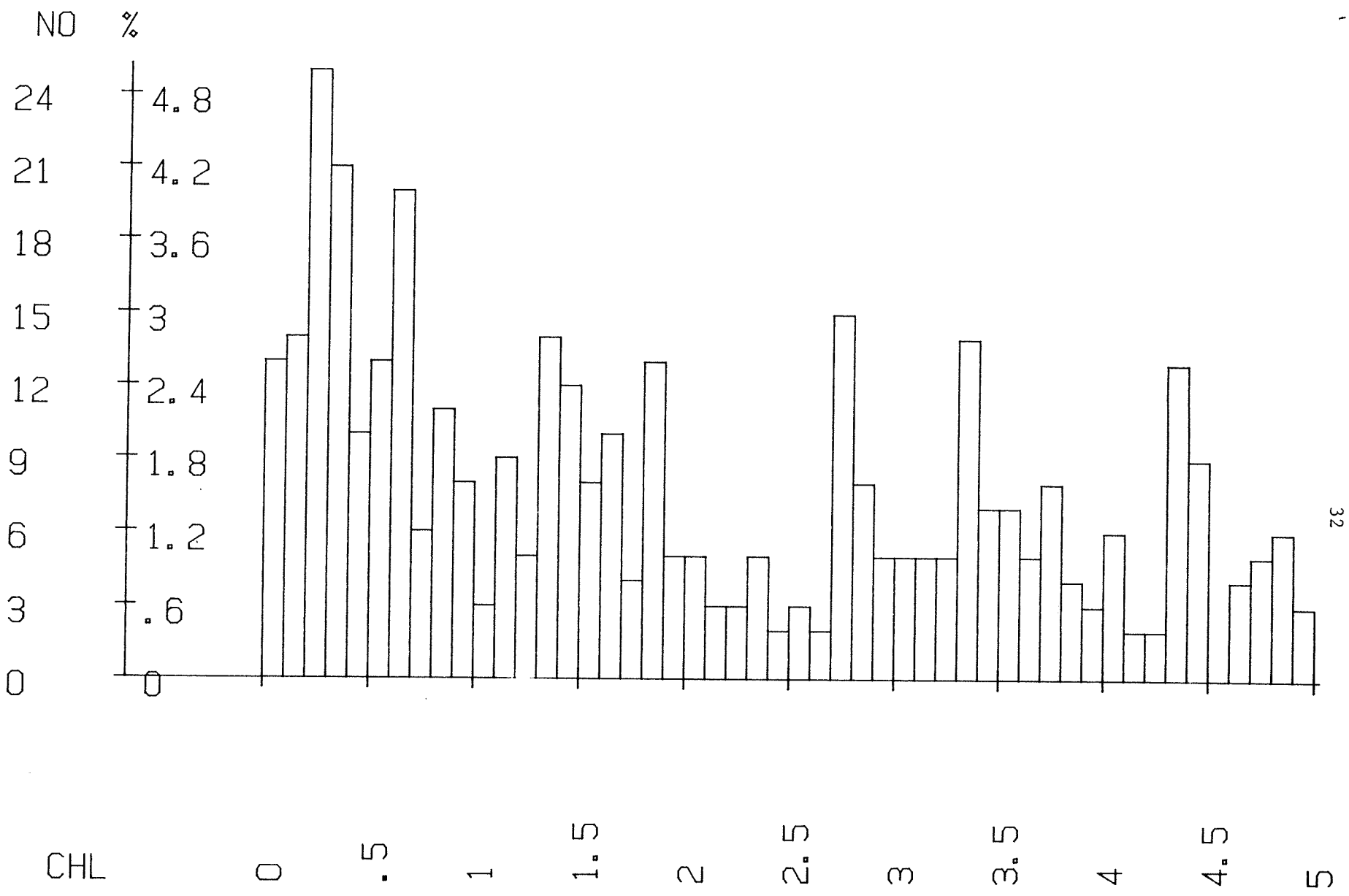



Figure 4.10. Probability distribution of chlorophyll in the upper 10 meters at nearshore stations (5-10) for the period October, 1982-January, 1983. Chlorophyll is in µg/l.

In examining the probability distributions, some interpretation of the results is necessary. Figure 4.9 will be used as an example. The y-axis consists of two scales; the number of observations (NO) which occur at each chlorophyll level, and the percentage (%) of the total observations which correspond to that number. Each bar represents the number of observations (or percent of total observations) which occurred within an interval of chlorophyll. For example, approximately 24 observations (2.6%) fell between 0 and 0.1 µg/l of chlorophyll during the period May to September 1982; 60 obervations (6.6%) occurred within the interval 0.1 to 0.2 µg/l chlorophyll.

Phytoplankton biomass in terms of chlorophyll at the nearshore stations follows a classical buildup to a midsummer high in August and a decrease to midwinter levels in late October. Evidence of a spring bloom is seen in the scanty data from May and June. It is possible that the spring bloom was larger than that occurring in August-September, a detail of the seasonal cycle which will be clarified in the second phase of work.

Probability distributions for chlorophyll have been divided into two time periods: from April until the end of September and from October to the end of the year, representing typical summer and winter populations. Surprisingly enough, the two distributions are very similar, with the mean chlorophyll value for the upper 10 m being 4.16 µg/1 for the summer, and 4.12 µg/1 for the winter period. These distributions favor the occurrence of chlorophyll levels of less than 1 µg/1 but show a strong likelihood of naturally occurring levels of up to 5 µg/1 in the nearshore area (Appendix 4A). Comparisons of these results with those obtained post-discharge should yield an indication of the impact of effluent on the phytoplankton population.

Time series for nitrate and ammonia from the upper 10 m for the nearshore stations five throughout ten are plotted in Figures 4.11 and 4.12. Both

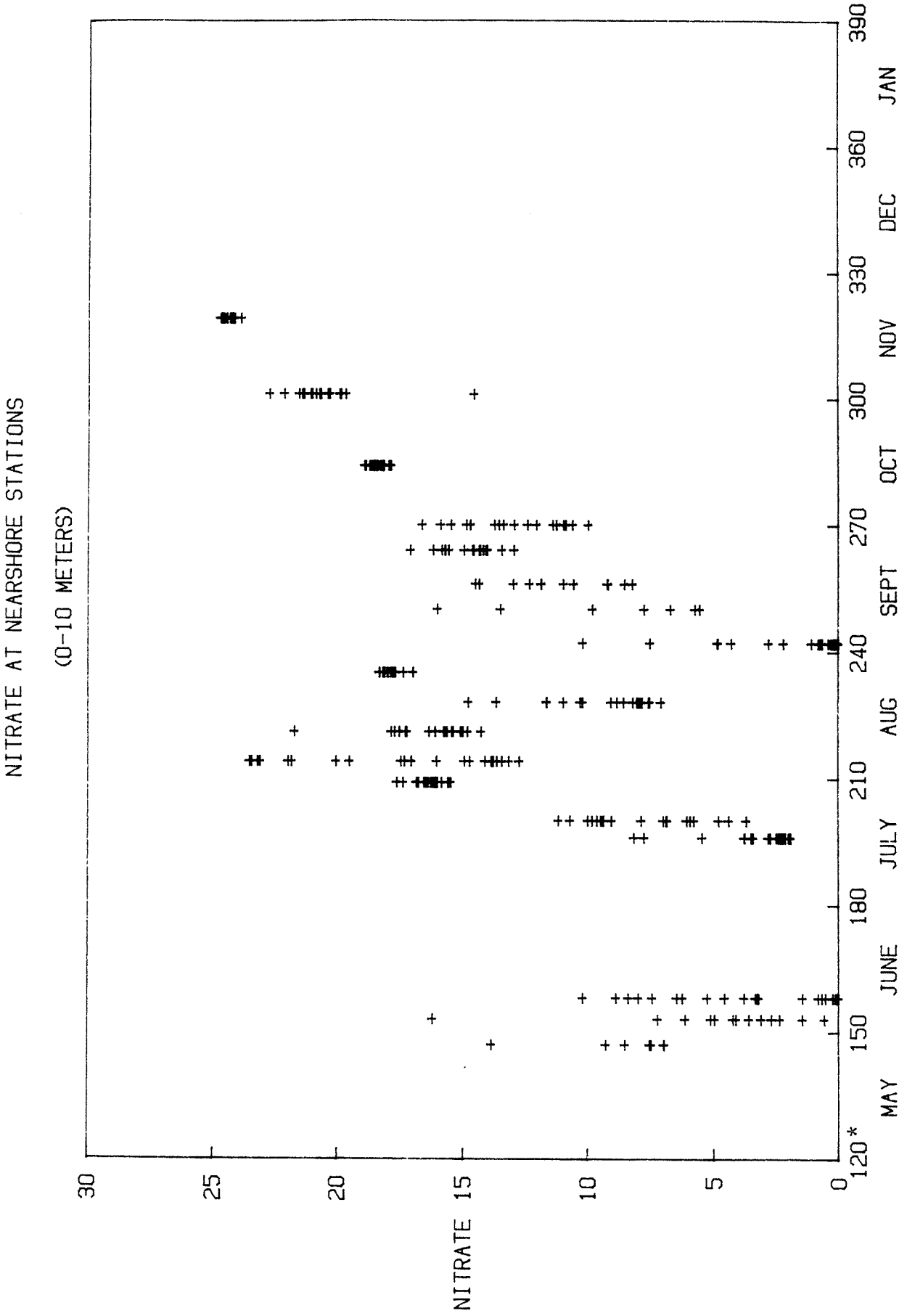



Figure 4.11. Time series of average nitrate for the upper 10 meters at nearshore stations (5-10). Nitrate is in µg-at/l. *Julian calander days.

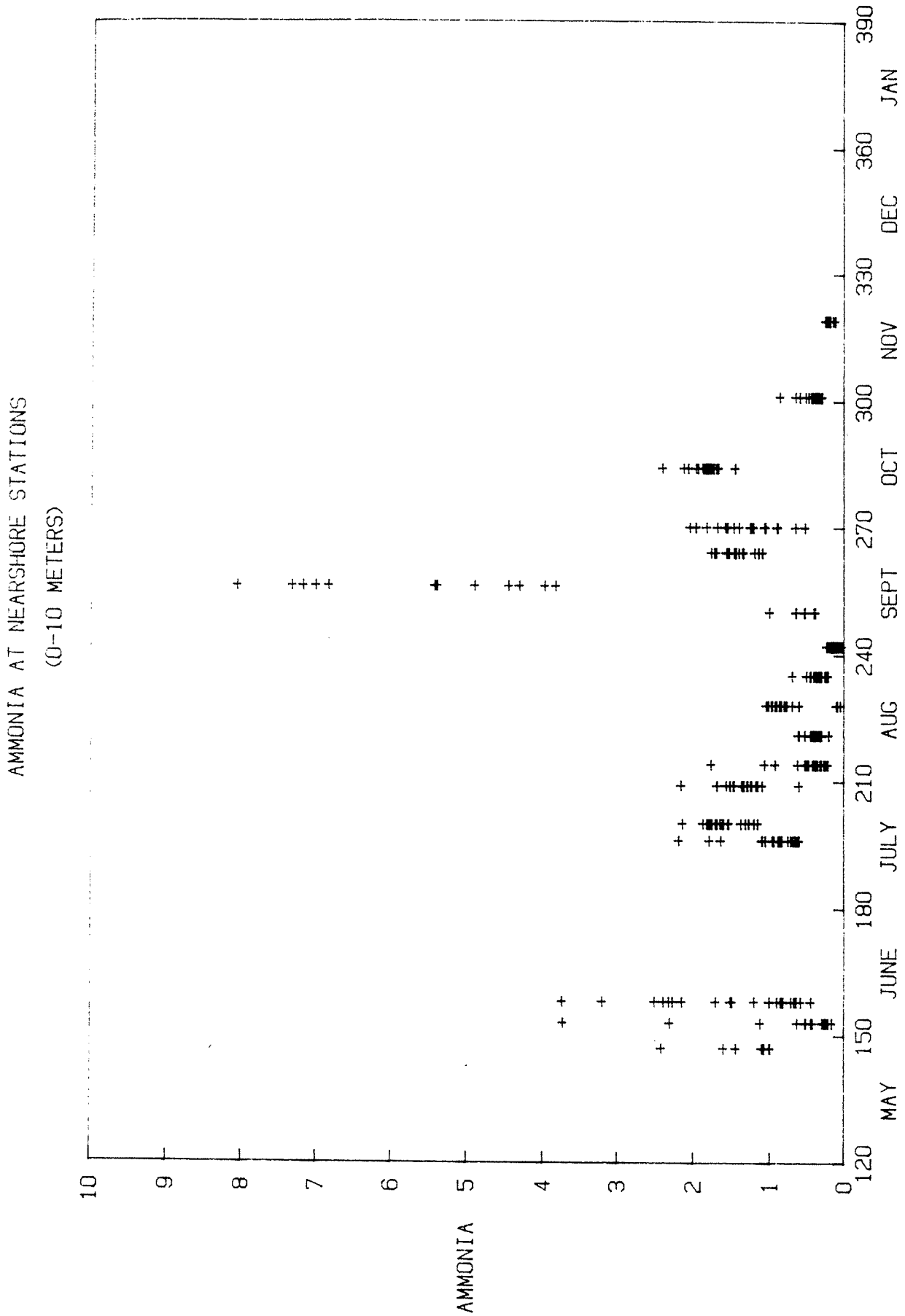



Figure 4.12. Time series of average ammonia for the upper 10 meters at nearshore stations (5-10). Ammonia is in µg-at/l.

nutrients are shown in µg-at/1. Probability distributions have been calculated for nitrate and ammonia and are shown in Figures 4.13 and 4.14.

Time series plots for nitrate and ammonia for the nearshore environment reflect patterns similar to those seen for the wide area stations, with more pronounced rises and falls. Other nutrients (silicate, phosphate and nitrite) follow similar trends with a midsummer low occurring in late August-early September (see Appendix 4B). The chlorophyll maximum in August-September is reflected in the almost undetectable levels of ammonia and low levels of nitrate in the upper 10 m.

Probability distributions of NH3 and NO3 show that nitrate up to 25 µg-at/1 is common. Low ammonia values are favored but levels to 2.5 µg-at/1 and above are not unusual. These findings should be helpful for post-discharge monitoring.

Primary productivity experiments were carried out at nearshore stations 4, 7 and 10 during Phase I. For the purposes of comparison only the fixation of carbon in the upper 10 m has been considered here, as station 10 is only 10 m deep. The data has been plotted by station against time over the summer of 1982 (Figure 4.15). Further data from Phase I is still being analyzed. Primary production is measured in mg C fixed per $m^3$ per day.

Results of primary productivity experiments support the chlorophyll standing stock data showing healthy growing populations of phytoplankton. Temporal variability among sampling days throughout the summer was greater than spatial variability among stations 4, 7, and 10 for any particular day, making it difficult at this time to indicate either the offshore or the nearshore area of East Passage as having the higher potential algal productivity. The results of nutrient limitation testing are presented in Appendix 4C.

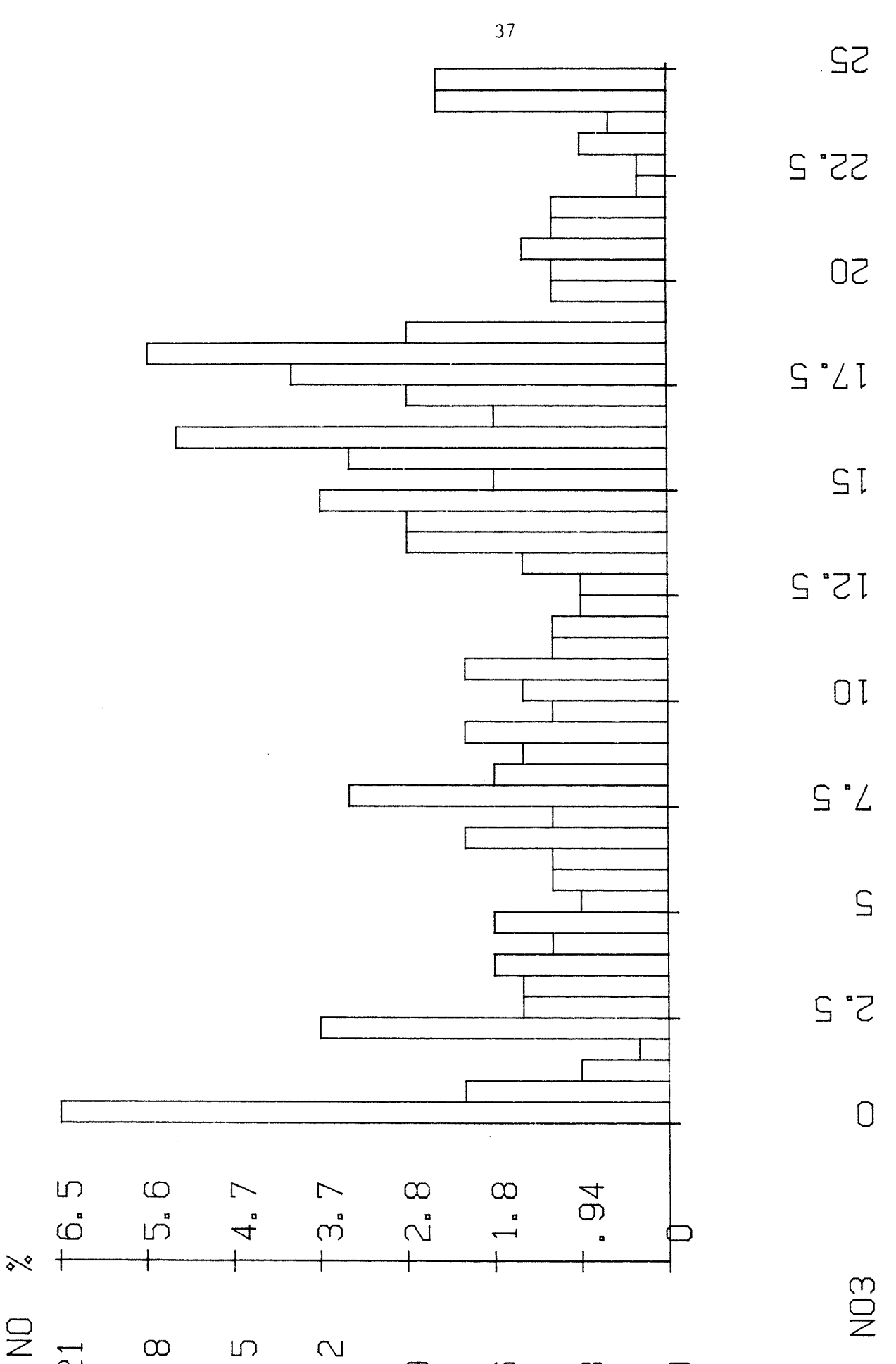



Figure 4.13. Probability distribution of average nitrate in the upper 10 meters at nearshore stations (5-10) for the time period May, 1982 - January, 1983. Nitrate is in µg-at/l.

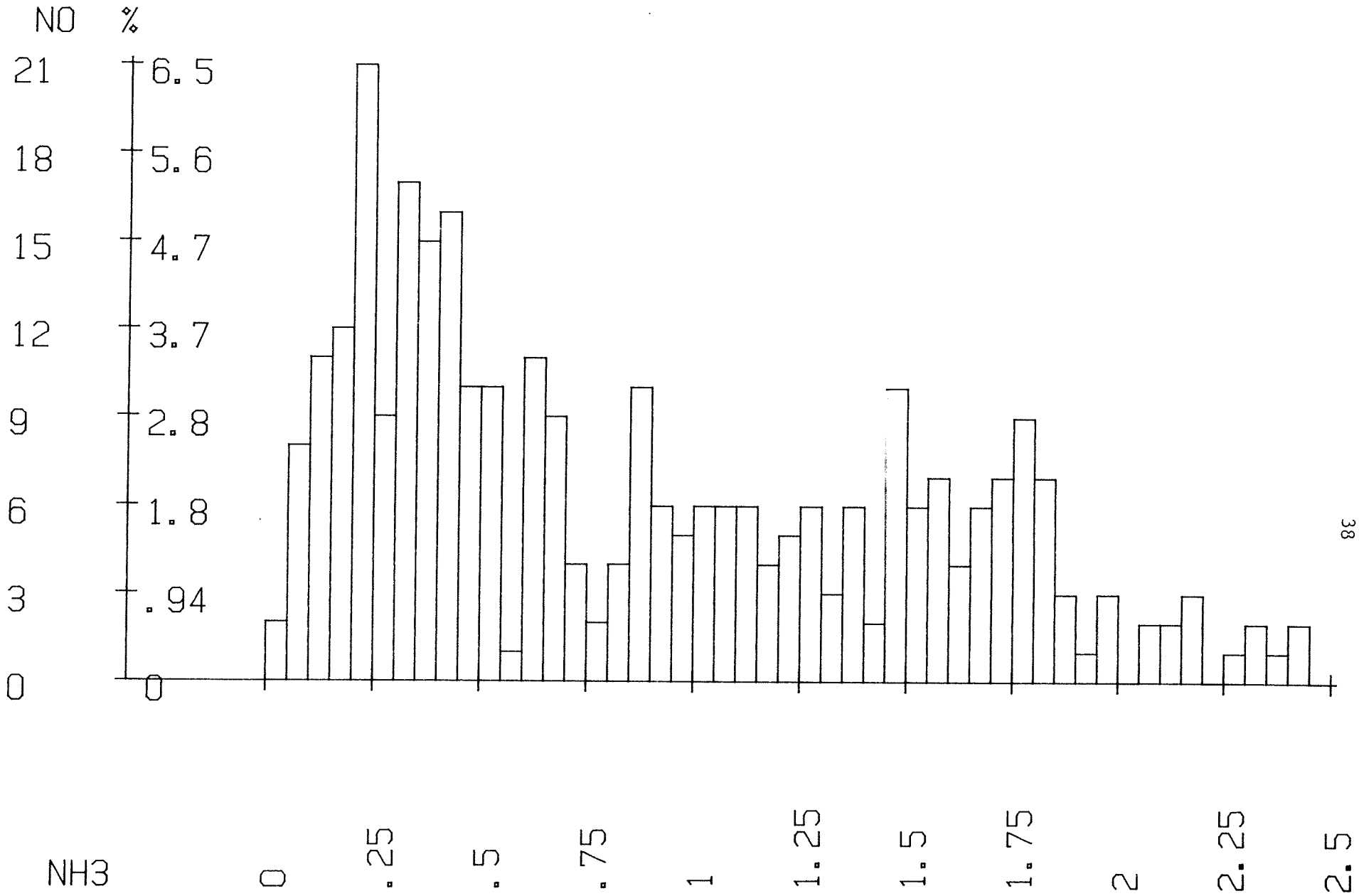



Figure 4.14. Probablity distribution of ammonia in the upper 10 meters at nearshore stations (4-10) for the time period May, 1982 - January, 1983. Ammonia is in µg-at/l.

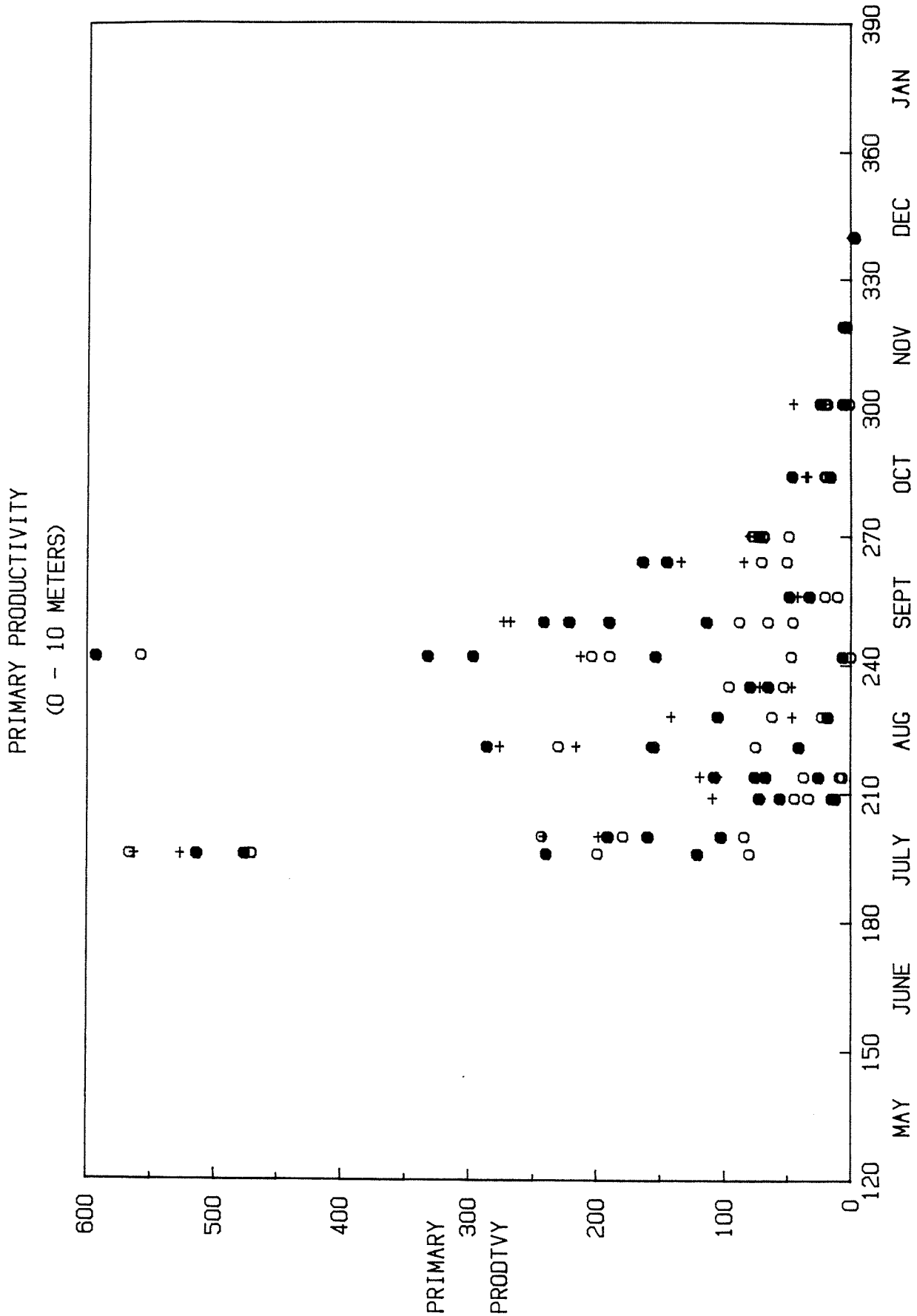



Figure 4.15. Results of net primary production in the upper 10 meters at nearshore stations 4, 7 and 10. Primary production is measured in $mgC/m^3/day$. Time is in Julian days. Station 4 data is represented by open circles (o), station 7 by closed circles (•), and station 10 by crosses (+).

Time series analysis for zooplankton biomass is divided into samples measured for wet volume analysis (May to October 1982) and for dry weight analysis (after August 1982). The plots are presented in Figures 4.16 and 4.17. Wet volume is measured in ml per cubic meter and dry weight in grams per cubic meter.

Statistical examination as well as visual inspection indicate that dry weight analysis is a preferable measure of zooplankton biomass over wet volume analysis. The presence of gelatinous zooplankton as well as thick phytoplankton mats significantly bias the volume while affecting the dry weight analysis very little.

An examination of zooplankton biomass over the summer and fall of 1982 shows a pattern of summer highs and winter lows much like that of chlorophyll. Peak zooplankton biomass appears to lag behind that of phytoplankton due to the necessary development time that most herbivorous zooplankton must pass through before exerting significant grazing pressure.

Peaks of phaeophorbide a (the primary breakdown product of chlorophyll a) in the water column correspond to those of chlorophyll a, indicating that microzooplankton may play a significant role in grazing down the phytoplankton, Figure 4.18.

Probability distributions of zooplankton biomass (wet volume and dry weight) have been constructed to establish a baseline of environmental data for later comparison (Appendix 4D).

4.3.3 Seahurst Inshore Area Chlorophyll, Incident Radiation, Nutrients and Zooplankton

Chlorophyll samples have been collected from the surface at Seahurst Park on a daily basis and have been analyzed as a time series (Figure 4.19) and probability distributions constructed for the occurrence of high or low values

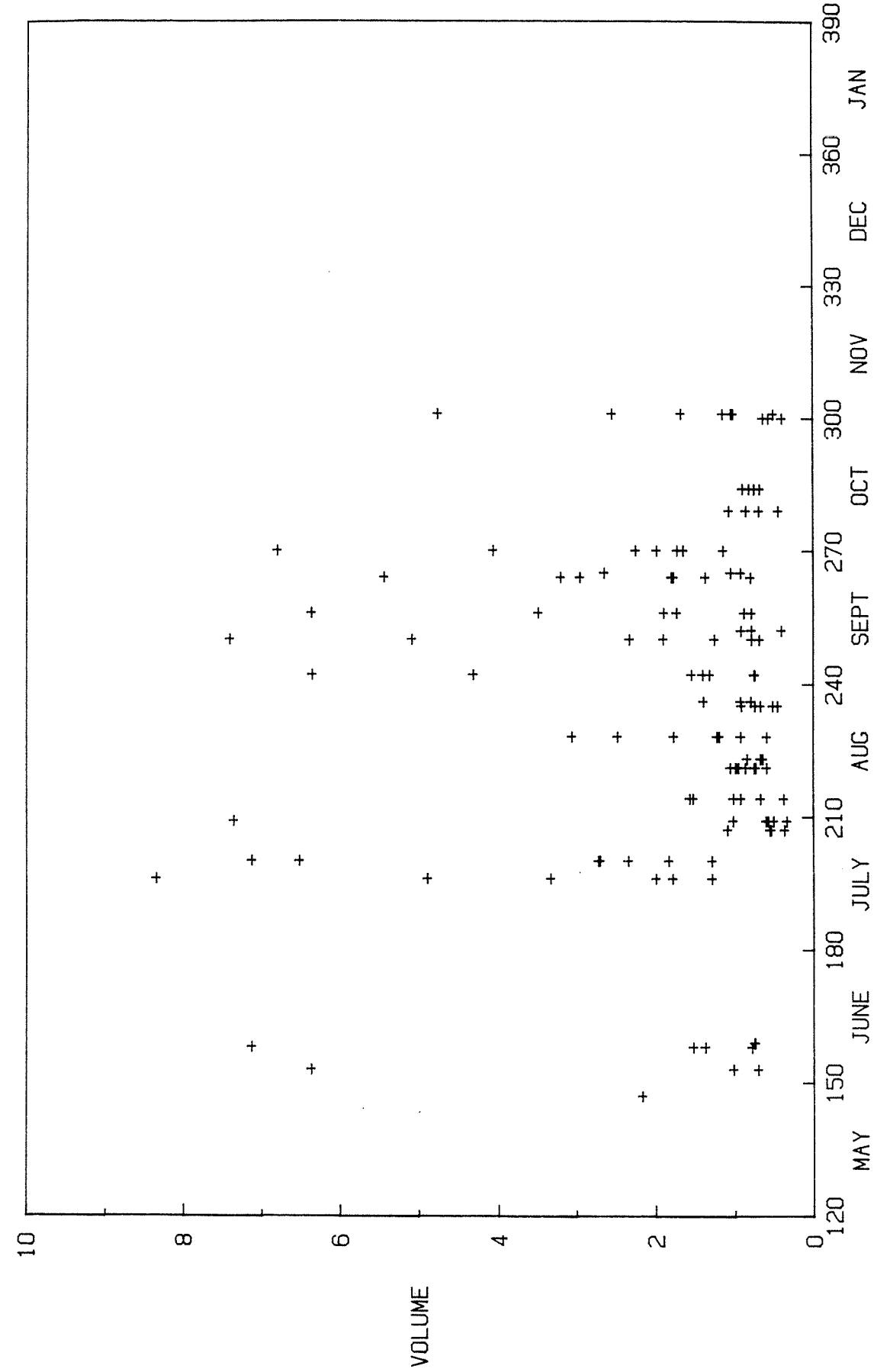



Figure 4.16. Time series of zooplankton biomass (measured as wet volume) at nearshore stations (5-10). Zooplankton volume in $ml/m^3$.

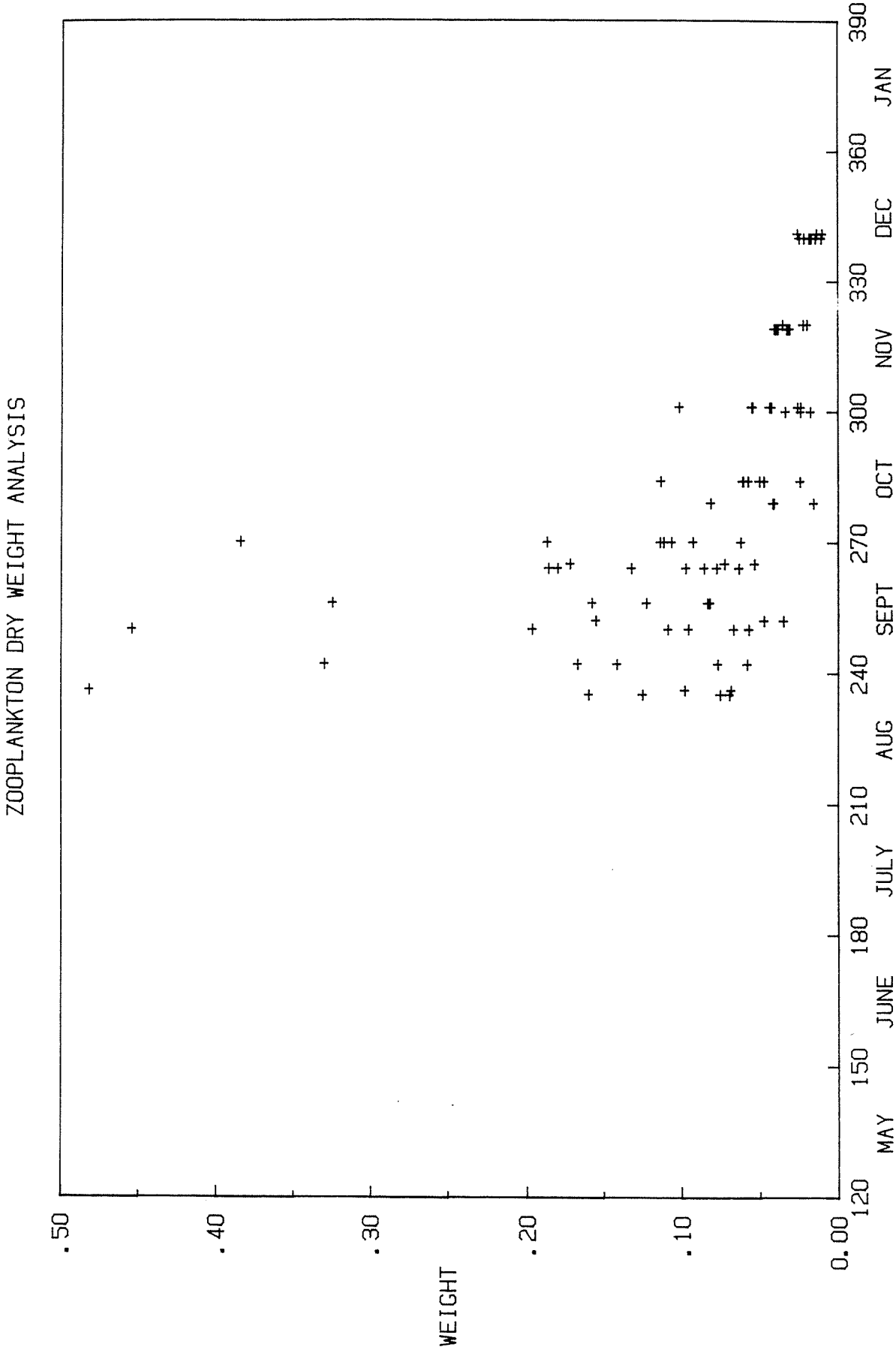



Figure 4.17. Time series of zooplankton biomass (measured as dry weight) at nearshore stations (5-10). Zooplankton dry weight is in $g/m^3$.

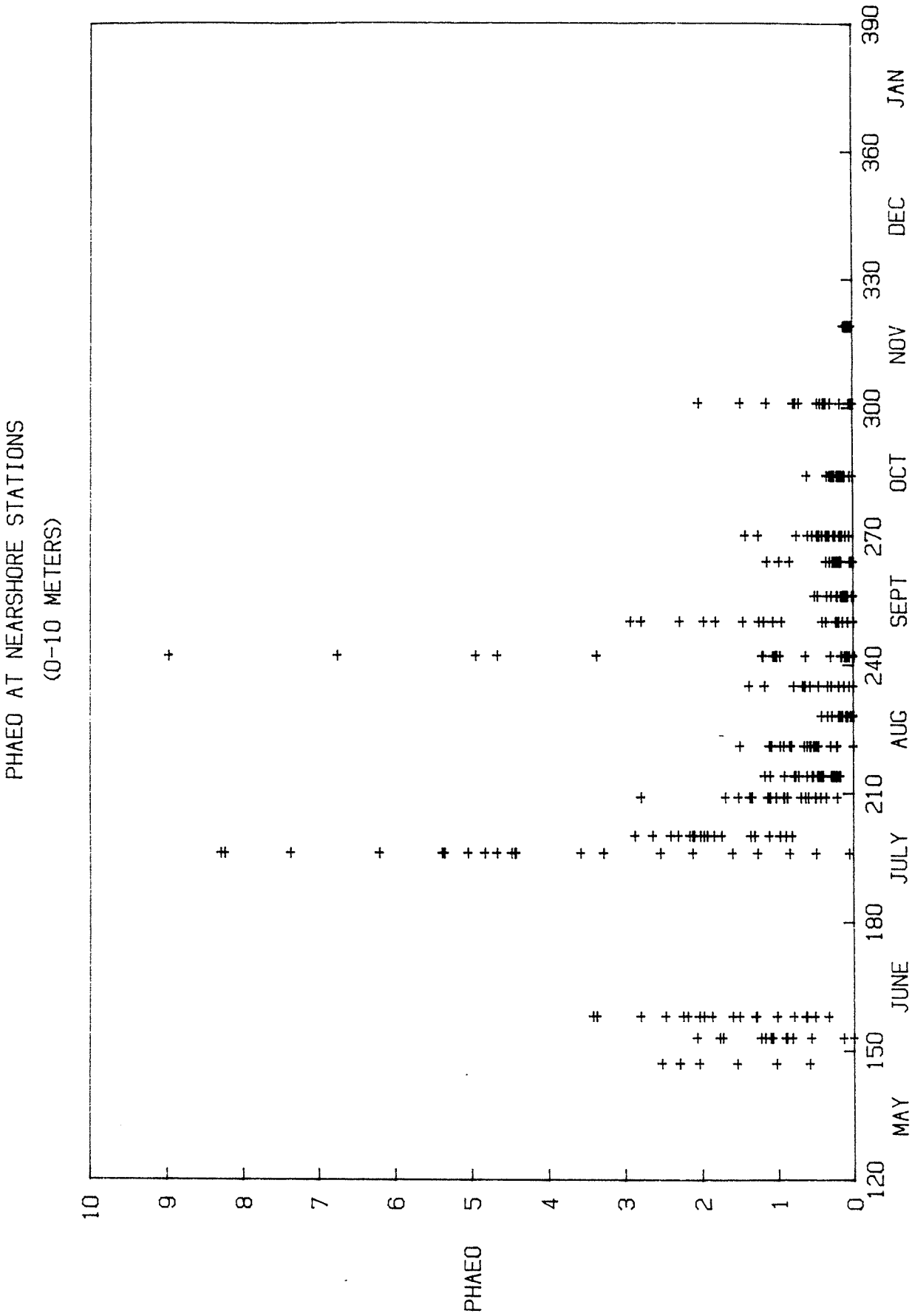



Figure 4.18. Time series of average phaeophorbide for the upper 10 meters at nearshore stations (5-10). Phaeophorbide is in µg/l.

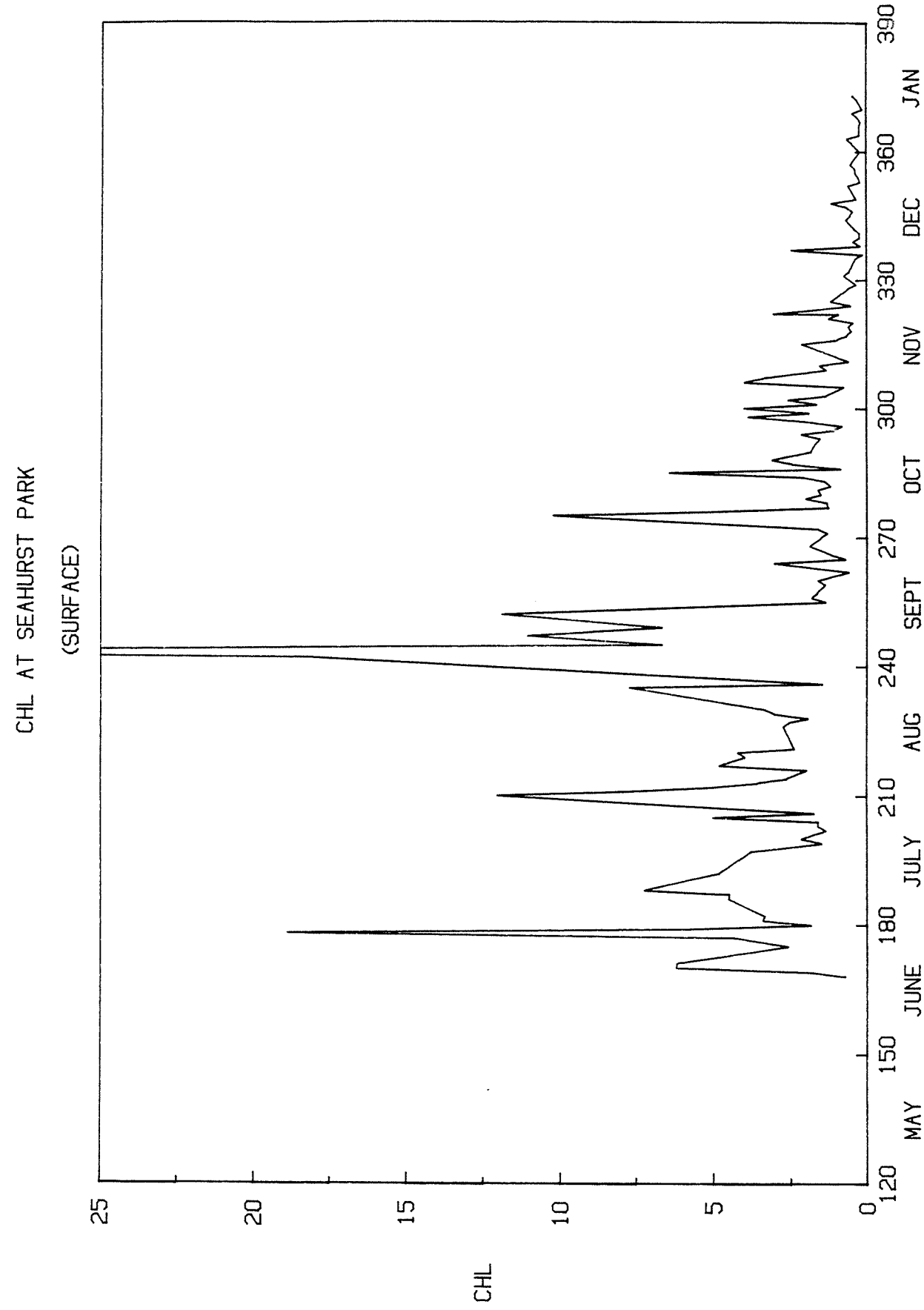



Figure 4.19. Time series of chlorophyll at Seahurst Park (surface). Chlorophyll is in µg/l.

(Figure 4.20). Chlorophyll is measured in ug/1. Daily incident radiation, or sunlight ultimately is the driving force of a pelagic ocean system. Measurement of incident radiation in langleys at Seahurst Park has been carried out throughout Phase 1, and the results are summarized in Figure 4.21.

The chlorophyll, nutrient and incident radiation samples, which are collected daily at Seahurst Park provide a much more detailed picture of the environment than do those collected weekly at the nearshore stations.

A time series plot of chlorophyll shows not only the larger population seen at the nearshore stations, but also many smaller peaks and crashes throughout the summer, and the gradual die off towards winter. The probability distribution of chlorophyll is like that seen for the nearshore stations, but is of a more continuous nature due to the greater number of data points. Generally, chlorophyll levels near the beach are higher than those seen at the closest nearshore station (station 10). It is likely that benthic as well as pelagic algae have been incorporated due to the nature of the sampling. This hypothesis is supported by the fluorescence ratios obtained during analysis.

Daily incident radiation measures show a seasonal trend of high light in summer and a continuous drop to low light in the winter. The variance found about a mean slope of radiation over time for this data, decreases with radiation level.

The same water samples which have been analyzed for chlorophyll content from the Seahurst Park area have also been examined for dissolved nutrient content. Time series for nitrate and ammonia in ug-at/1 are shown in Figures 4.22 and 4.23.

Variability is high for daily nitrate and ammonia levels at Seahurst Park, but a pattern emerges which is similar to that found for the nearshore

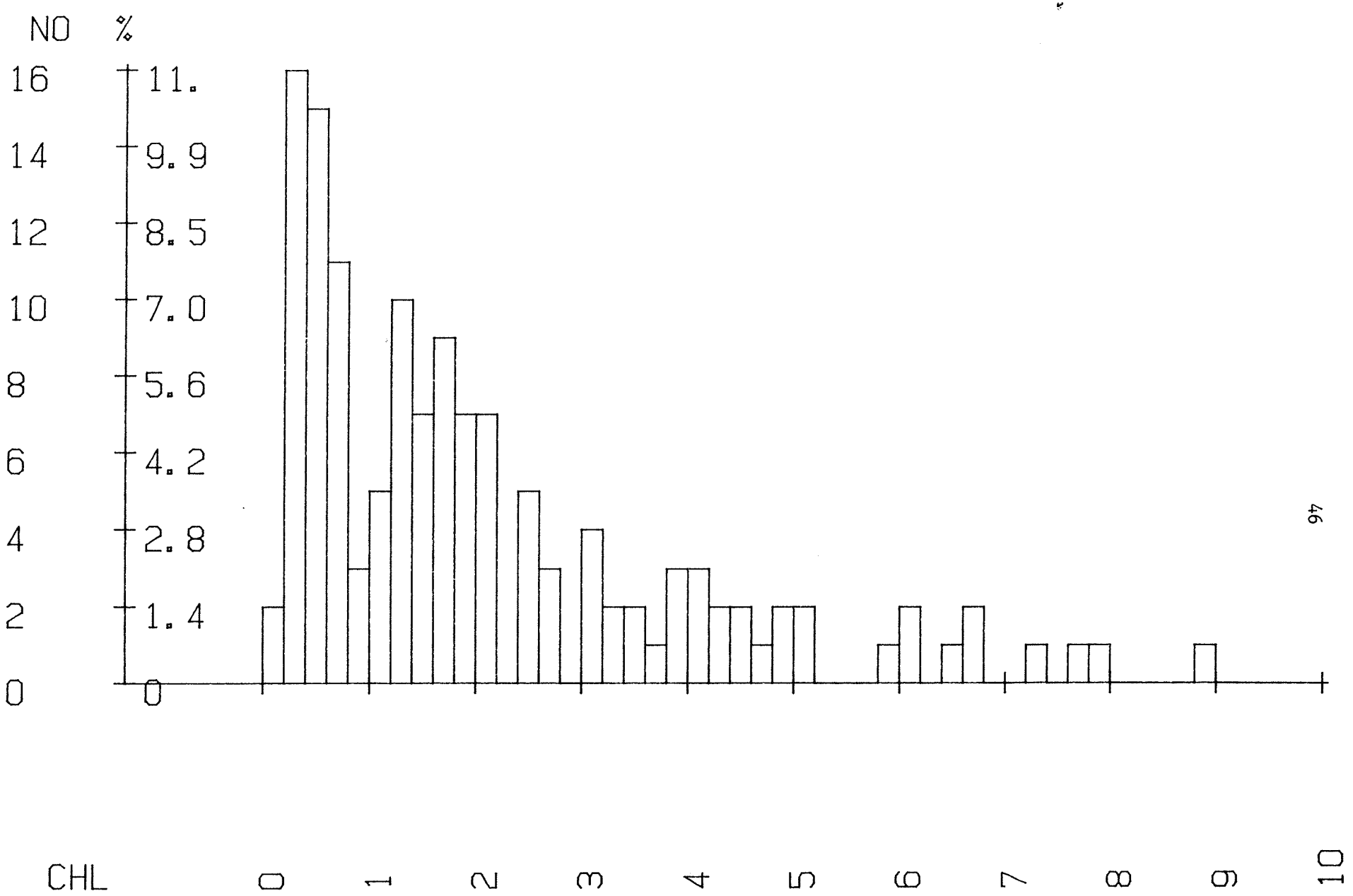



Figure 4.20. Probability distribution of chlorophyll at Seahurst Park (surface) for the time period May, 1982 - January, 1983. Chlorophyll is in µg/l.

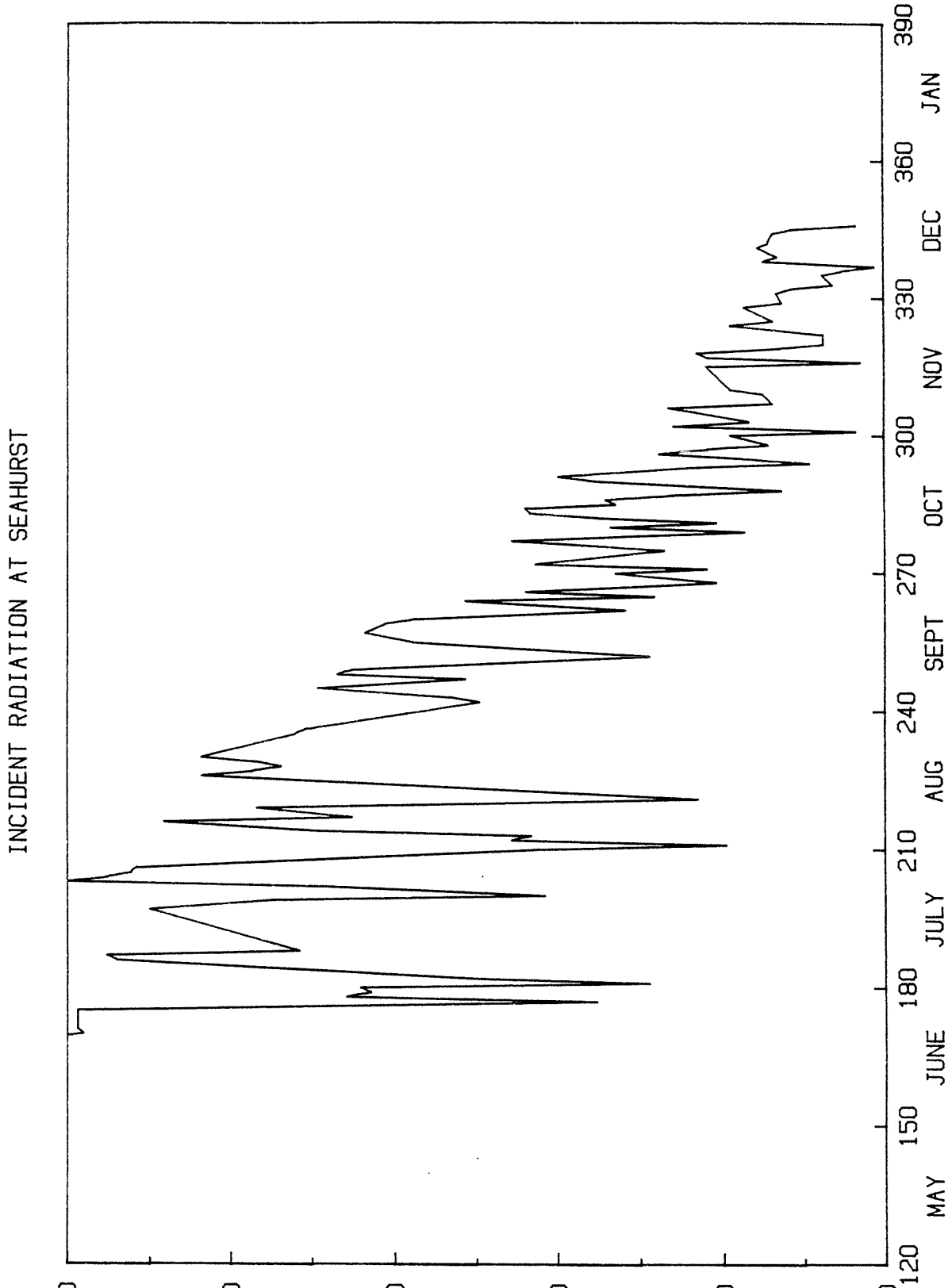



Figure 4.21. Time series of incident radiation at Seahurst Park (surface). Incident radiation is in langleys.

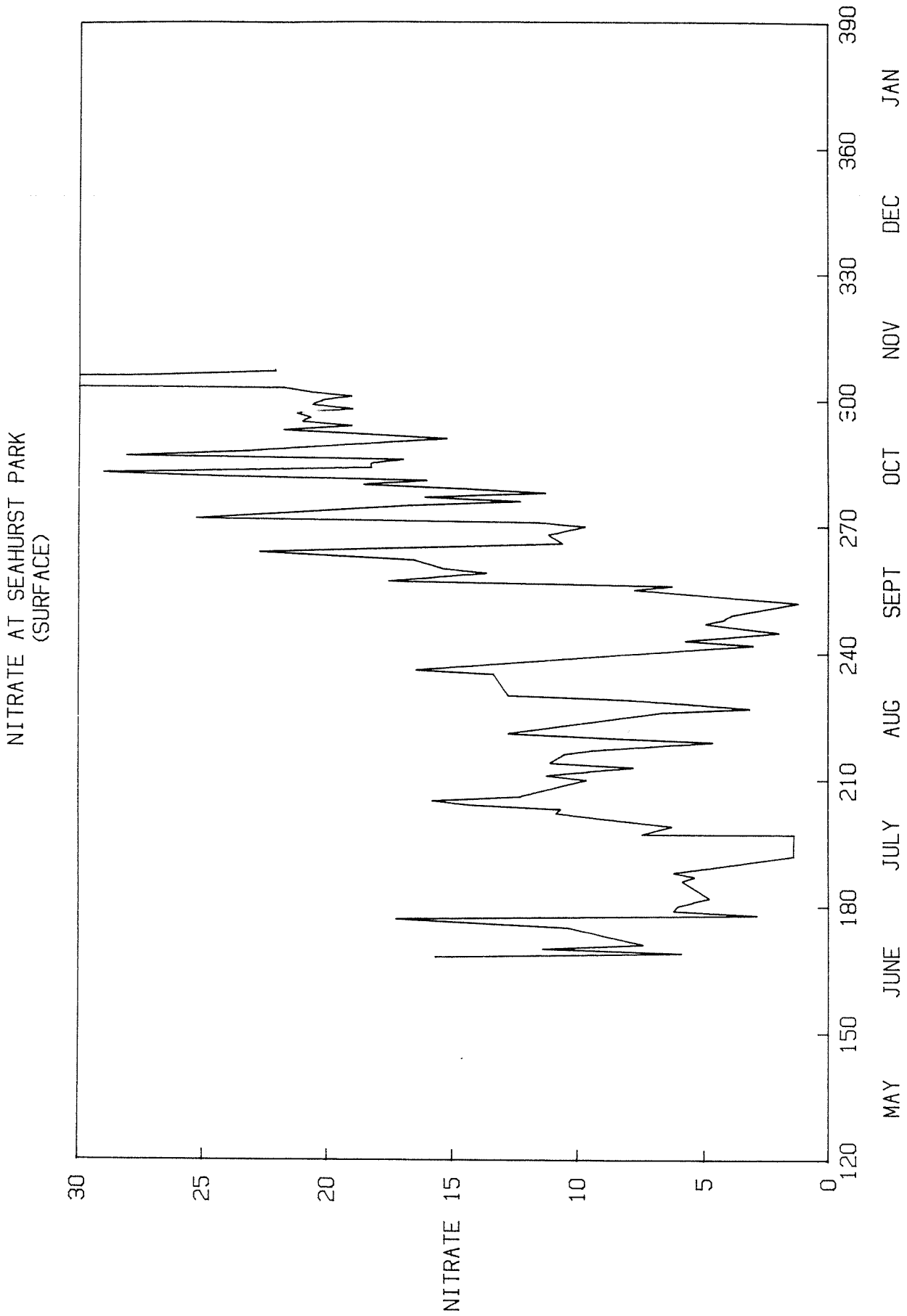



Figure 4.22. Time series of nitrate at Seahurst Park (surface). Nitrate is in µg-at/l.

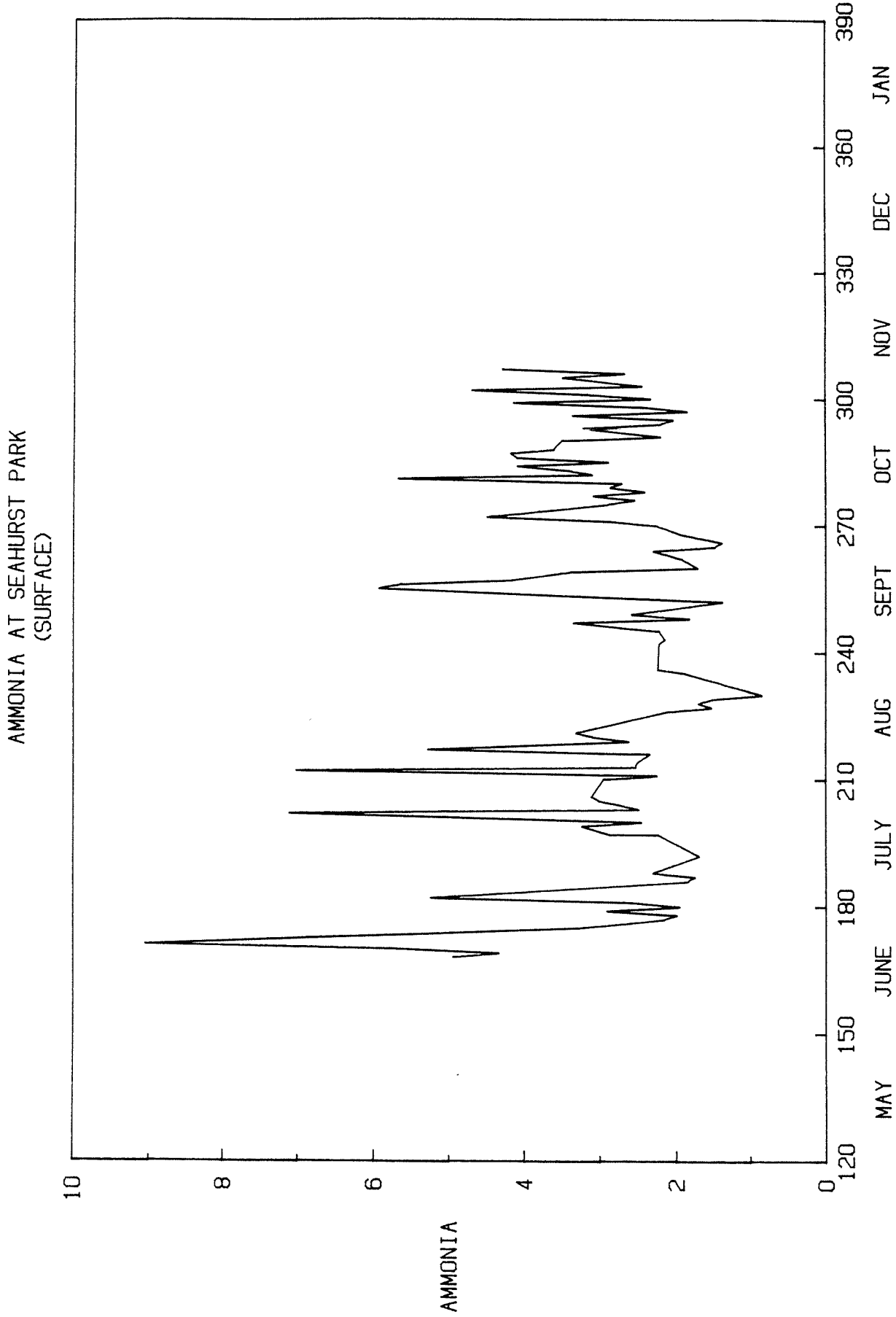



Figure 4.23. Time series of ammonia at Seahurst Park (surface). Ammonia is in µg-at/l.

stations (Appendix 4E). Low ammonia values occur in late August with nitrate lows shortly thereafter. As found in the nearshore area, the peak summer chlorophyll occurs at the same time. Winter levels of nitrate are high, as found elsewhere. However, unlike nearshore and wide area station data, ammonia levels remain high inshore during the winter season, indicating the possibility of a local ammonia source.

Data from the Seahurst inshore generally represents part of the continuum of biological populations from offshore East Passage (station 4) through the nearshore stations (7, 8, 9, and 10) to the shallow beach area.

Results of zooplankton tows taken nearshore at Seahurst Park are being analyzed for species composition. No data is available at this time.

4.3.4 Plankton Species Analysis

4.3.4.1 Phytoplankton

Results of phytoplankton species analyses are tabulated in Appendix 4F. Five dominant species or group of species have been identified for further examination. The dominants are: Skeletonema costatum, Chaetoceros debilis, other Chaetoceros spp., Thalassiosira spp., and Peridinium spp. for the summer of 1982. In addition, the toxic dinoflagellate Gonyaulax catenella has been added to the list of further analysis due to its importance to the shellfish industry. Bar graphs have been constructed for stations 1, 3, 4, 7 and 10 using cell counts for the dominant species over the summer period of 1982. Figure 4.24 A through E present these data.

Dominance in the phytoplankton found in the Seahurst/East Passage area shifts several times throughout the summer. In May and early June there is evidence of a very large bloom of Chaetoceros sp., a chain-forming diatom. Later in June, Skeletonema costatum, another diatom, takes over. At midsummer, cells tend to be small microflagellates, while the diatoms, notably

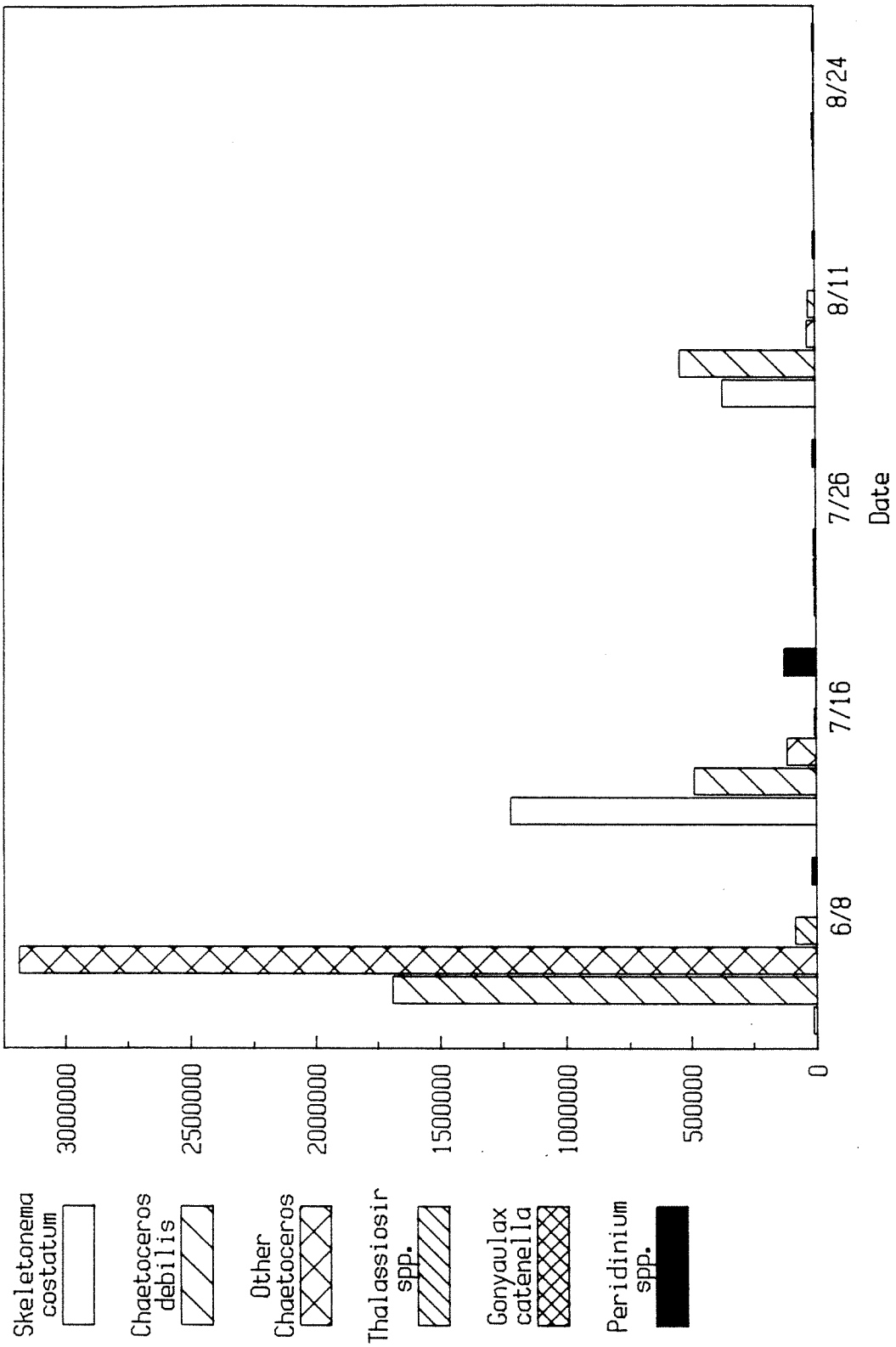



Figure 4.24A. Dominant phytoplankton species at Station 1 (June-August 1982).

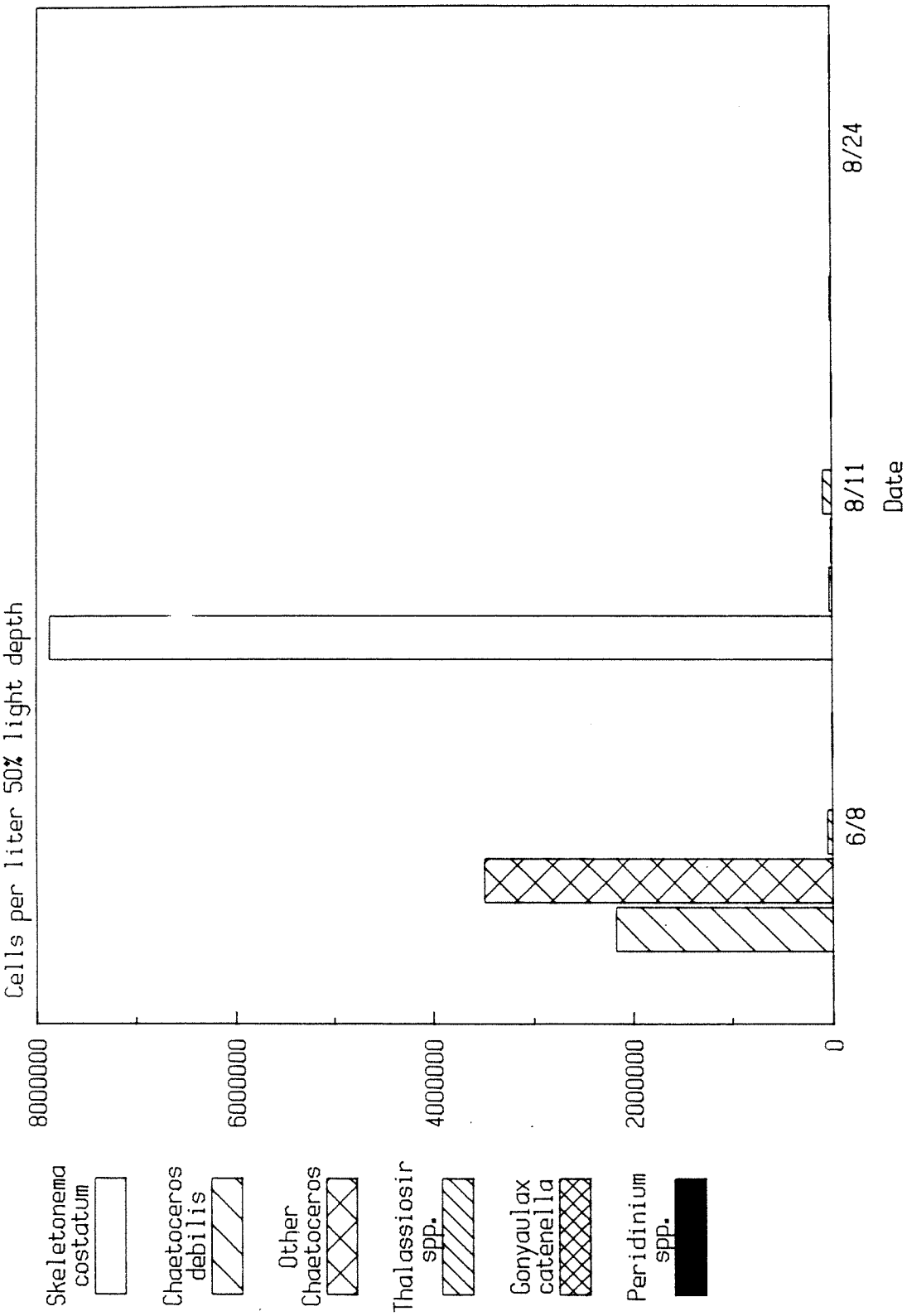



Figure 4.24B. Dominant phytoplankton species at Station 3 (June-August 1982).

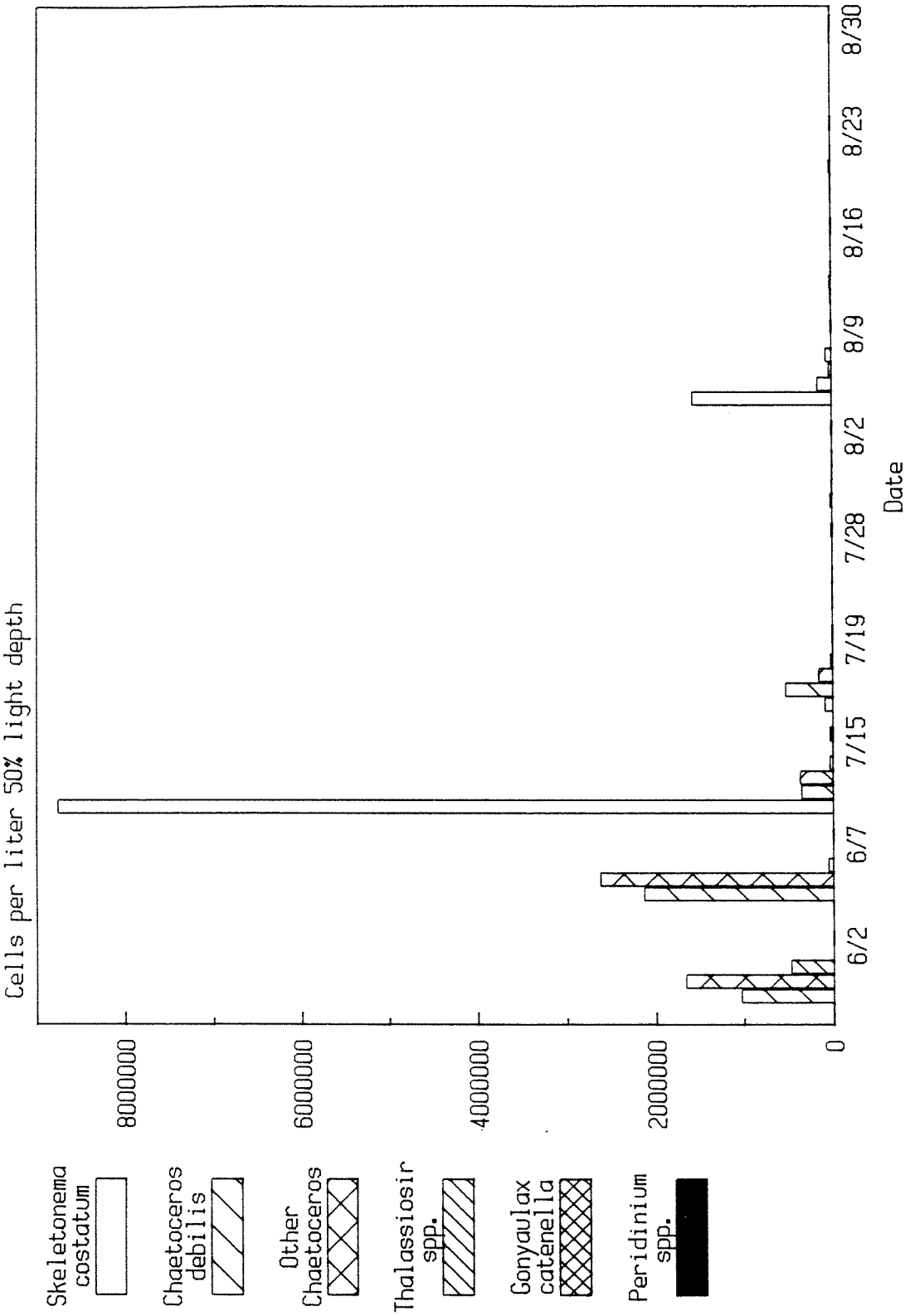



Figure 4.24C. Dominant phytoplankton species at Station 4 (June-August 1982).

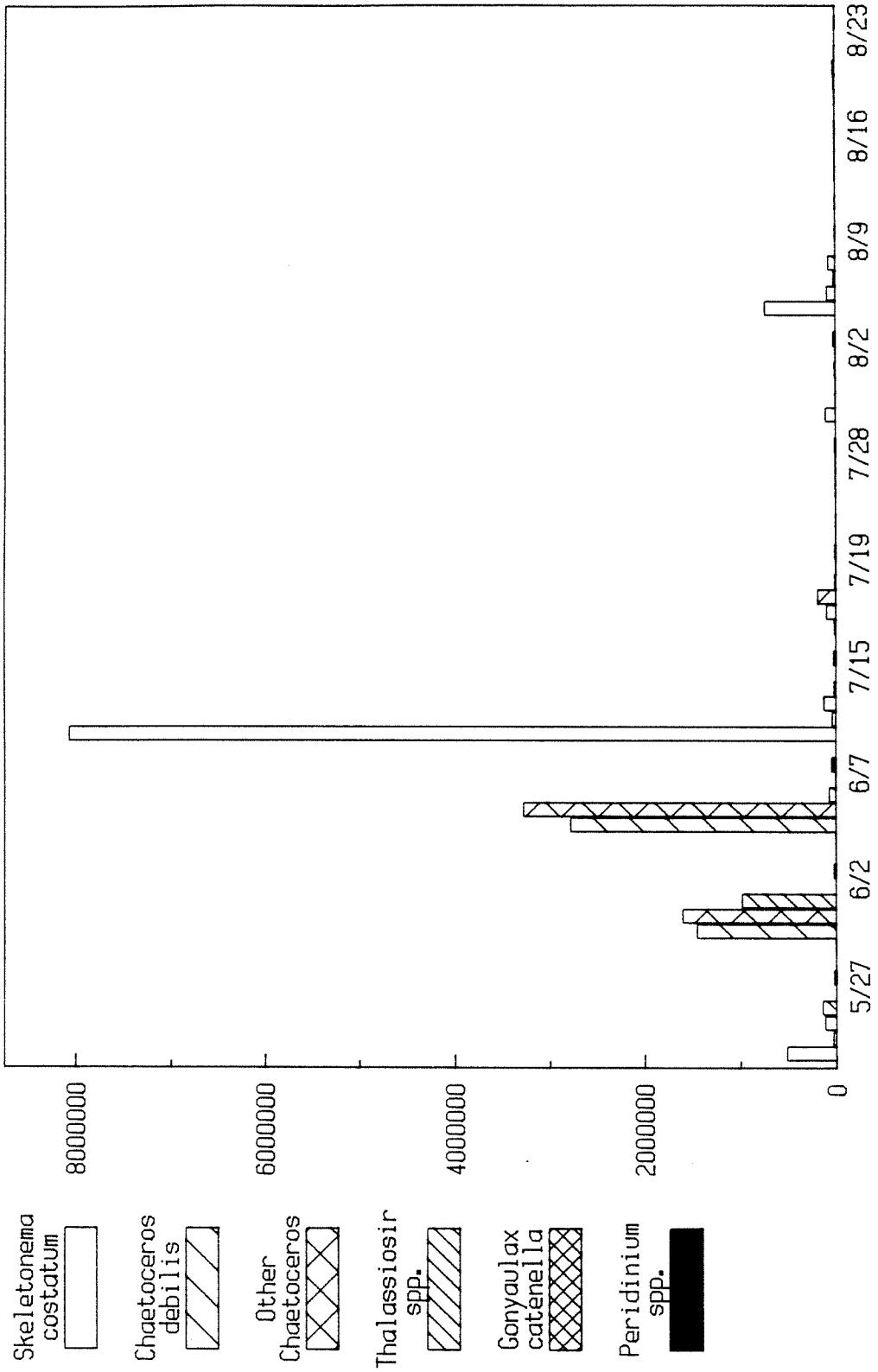



Figure 4.24D. Dominant phytoplankton species at Station 7 (June-August 1982).

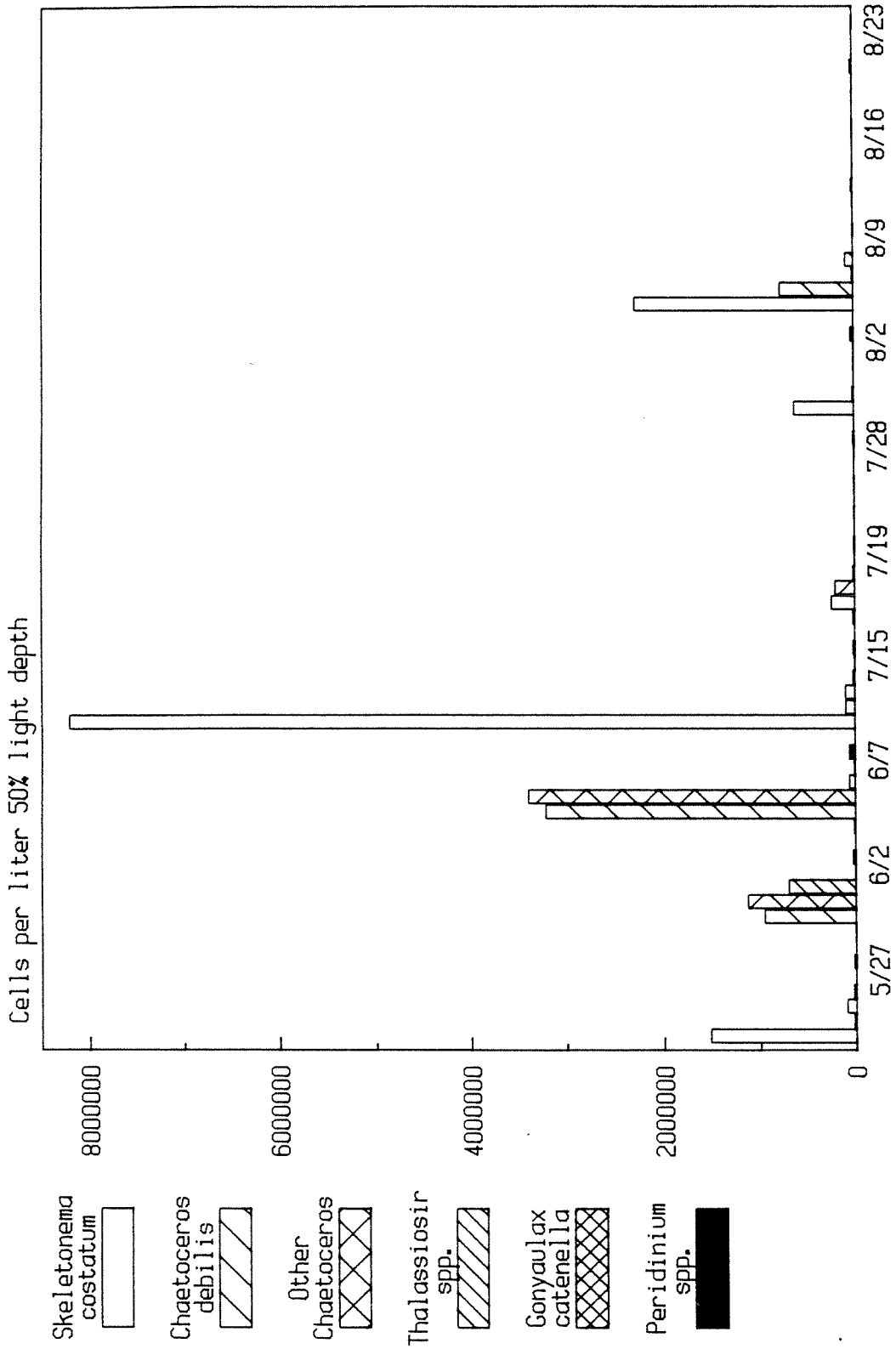



Figure 4.24E. Dominant phytoplankton species at Station 10 (June-August 1982).

Skeletonema costatum, return in large numbers in July-August. A dinoflagellate, Peridinium sp. reaches significant numbers late in August. Gonyaulax catenella, the toxic dinoflagellate, is rarely found, and only at the nearshore stations, never exceeding 0.1% of the dominant species' cells.

The summer phytoplankton pattern in the Seahurst area is one of diatoms during times of ample light and nutrients (early and late summer) and of more opportunistic flagellated forms (dinoflagellates and microflagellates) when nutrients reach lower levels (midsummer).

Wide area stations 1 (West Point) and 3 (Brown's Point) appear to follow similar patterns, although data in these areas are less complete.

4.3.4.2 Zooplankton

Zooplankton species analysis results are tabulated in Appendix 4G. Bar graphs of the dominant species present at the wide area and nearshore stations have been constructed as for the phytoplankton, and are shown in Figure 4.25 A through J.

The dominant species found in the East Passage/Seahurst area are largely copepods: calanoids - Calanus pacificus, Microcalanus sp., and Paracalanus sp.; and cyclopoids - Oithona similis and Corycaeus anglicus. A larvacean Oikopleura dioica is also common. All are herbivores.

At all nearshore stations (4-10) Corycaeus is numerically dominant early in the summer (May-July) and Paracalanus takes over later (August). In late July, Oikopleura shows a large increase.

Certain patterns of zooplankton dominance separate onshore and offshore stations. The further offshore (station 4 and to some extent stations 5, 6, and 7) one goes, the more important Paracalanus becomes in late summer, whereas shallower inshore stations (8, 9 and 10) maintain dominant populations of Corycaeus. An explanation for this may lie in the relative water depth:

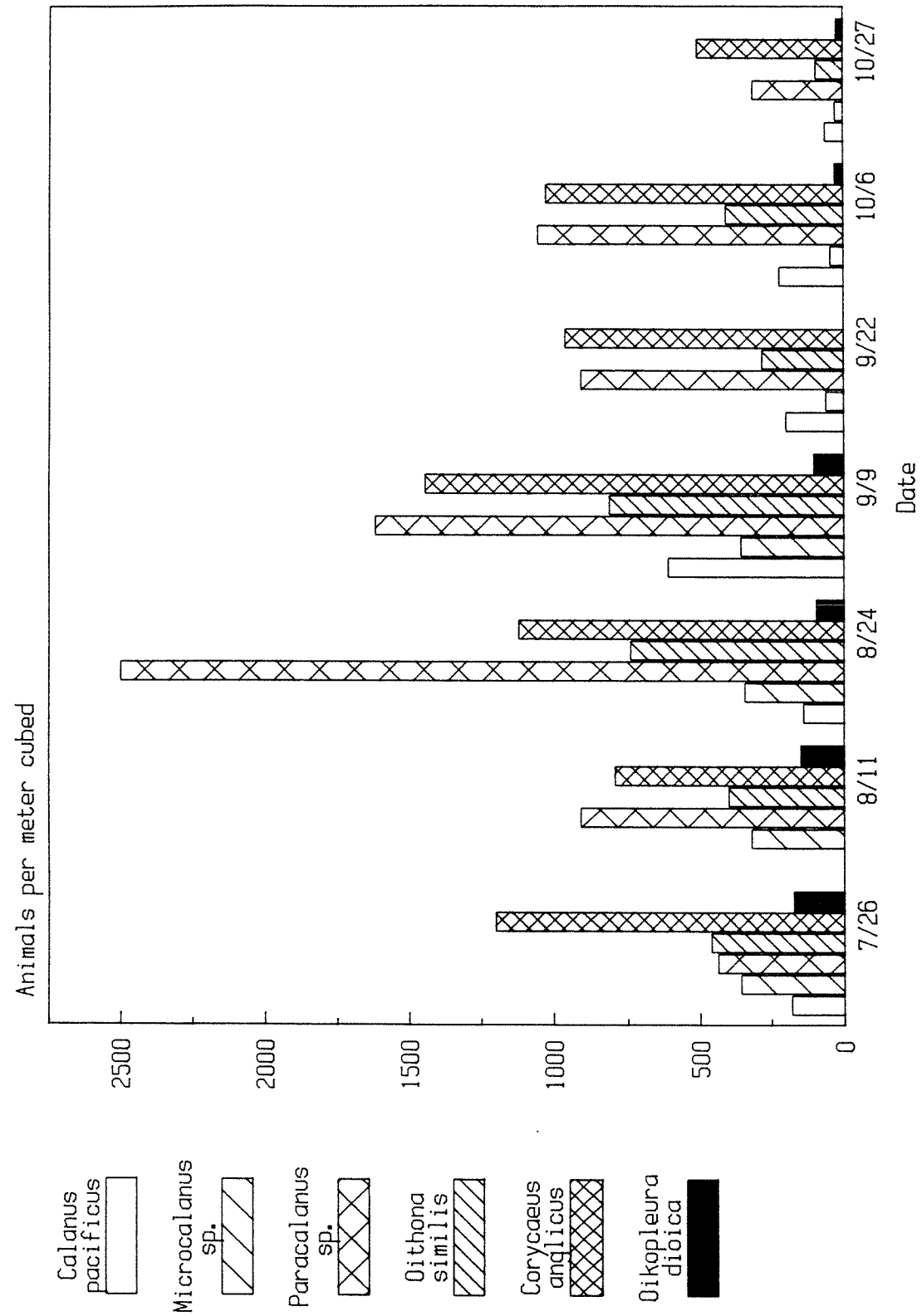



Figure 4.25A. Dominant zooplankton species at Station 1 (July-October 1982).

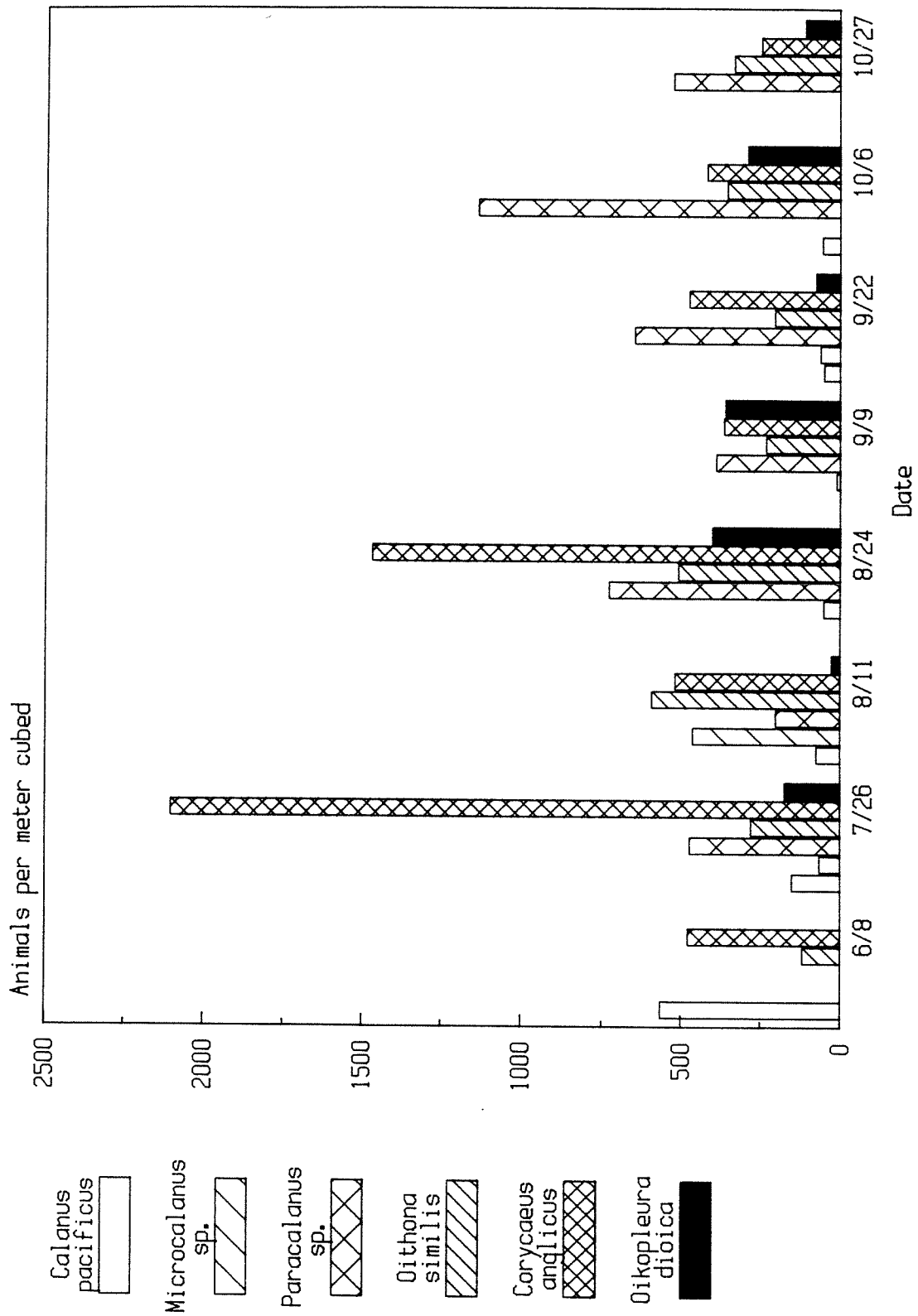



Figure 4.25B. Dominant zooplankton species at Station 2 (June-October 1982).

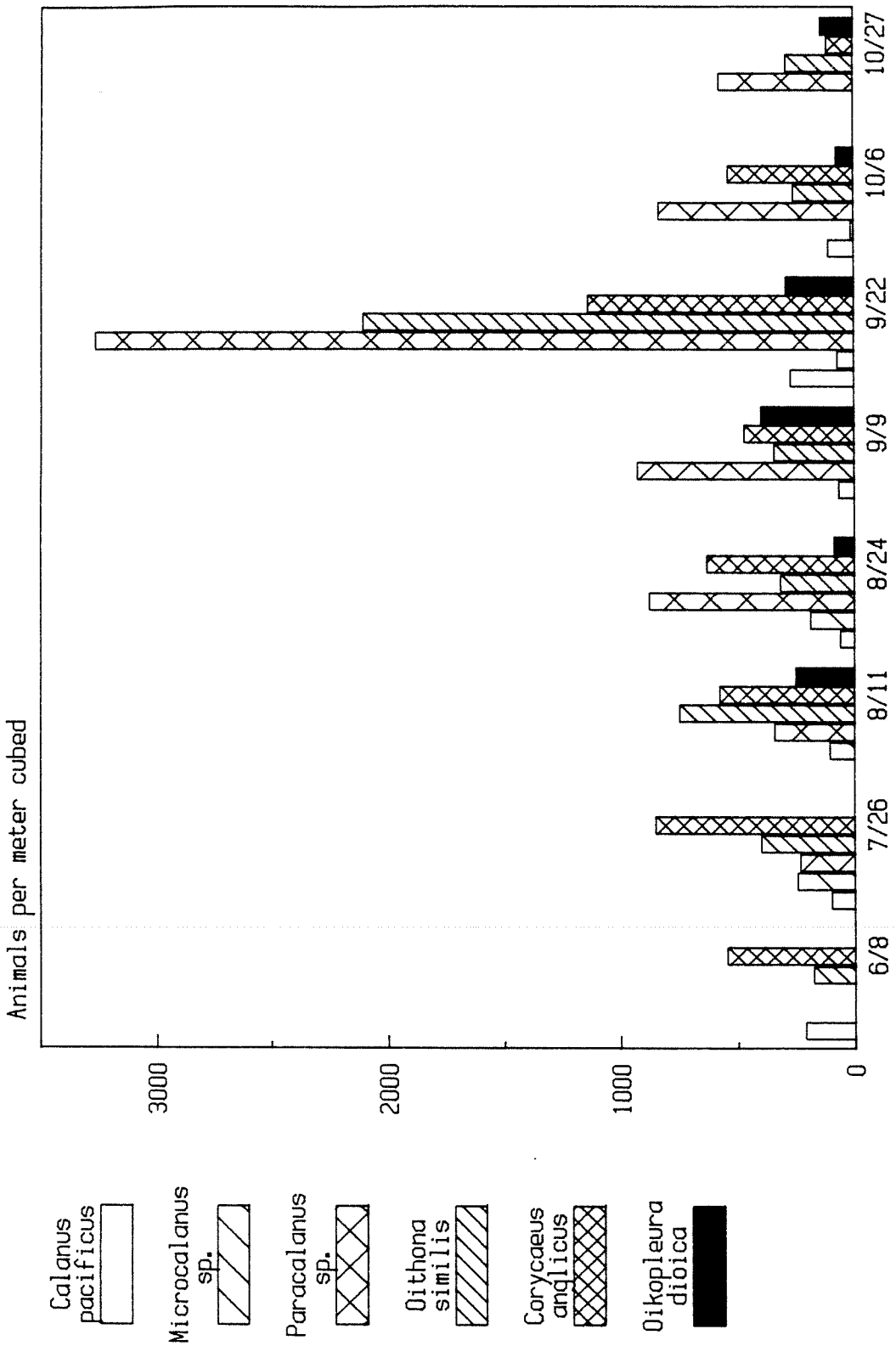
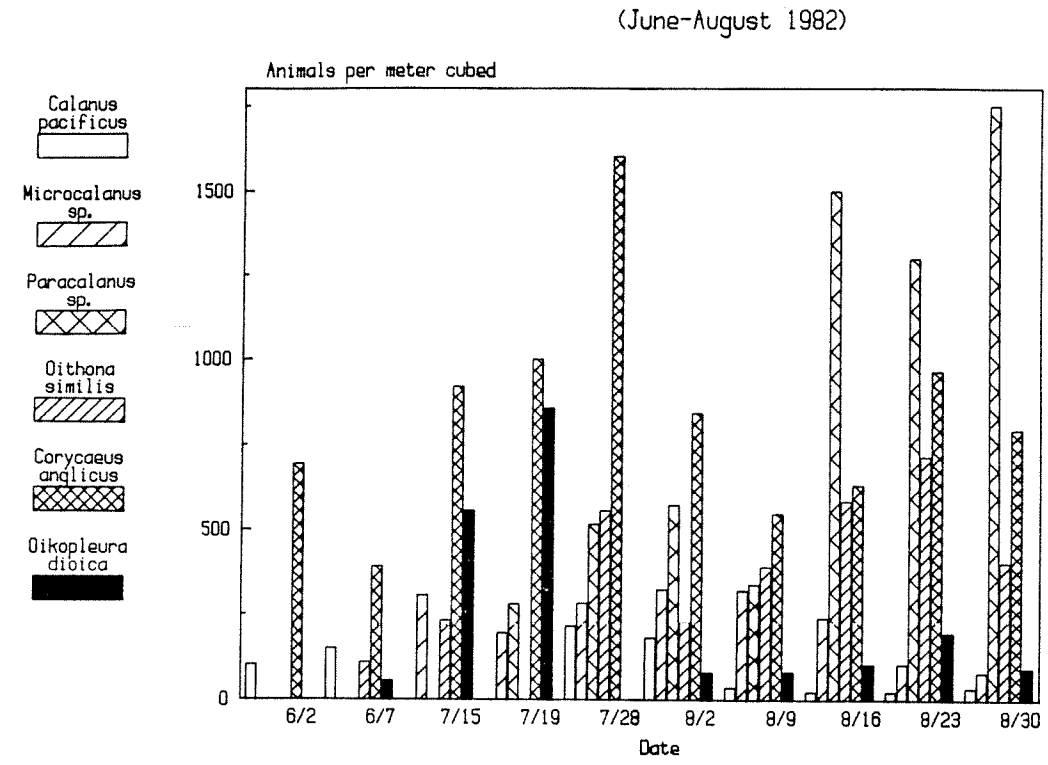



Figure 4.25C. Dominant zooplankton species at Station 3 (June-October 1982).



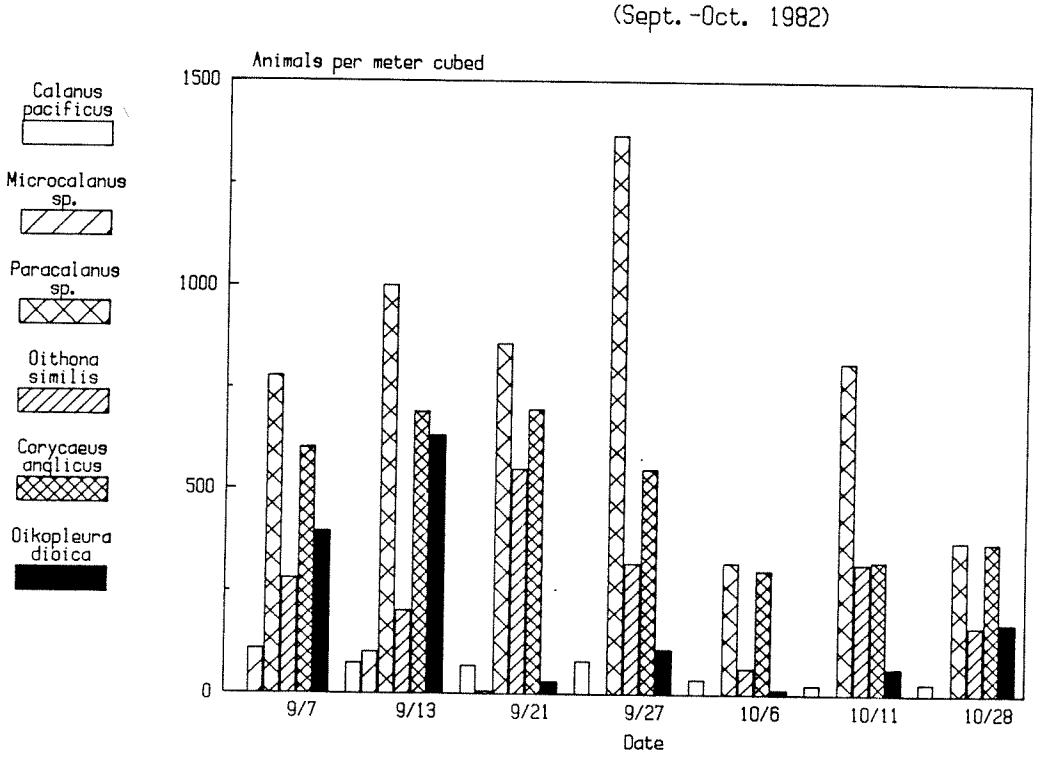
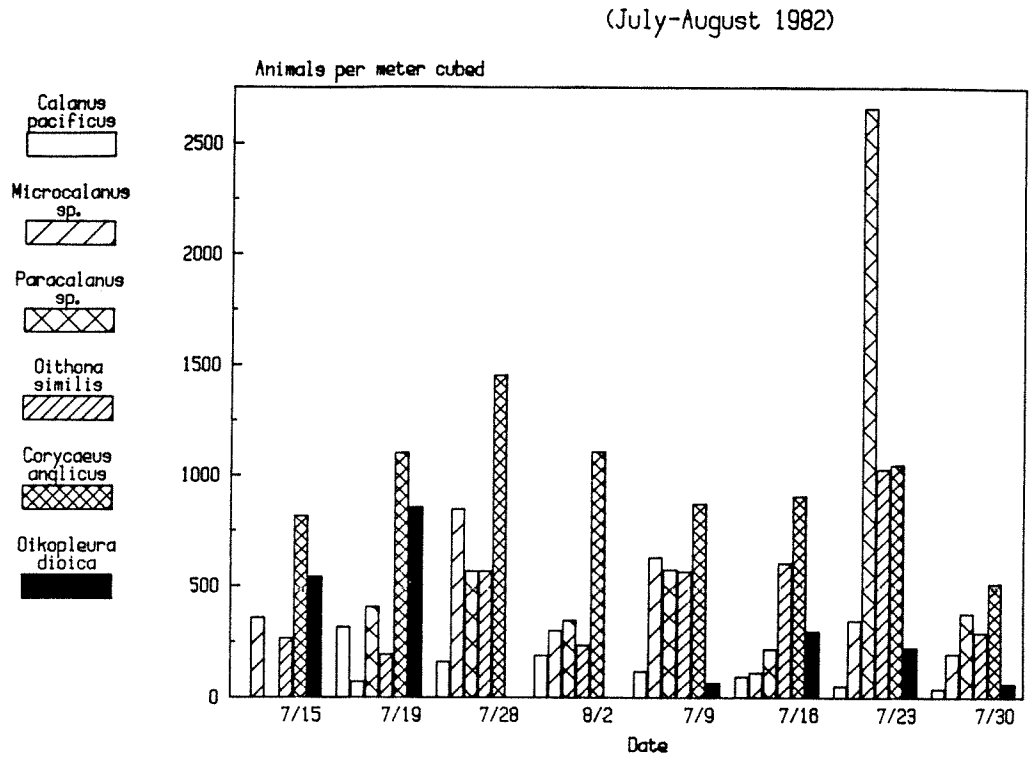




Figure 4.25D. Dominant zooplankton species at Station 4.



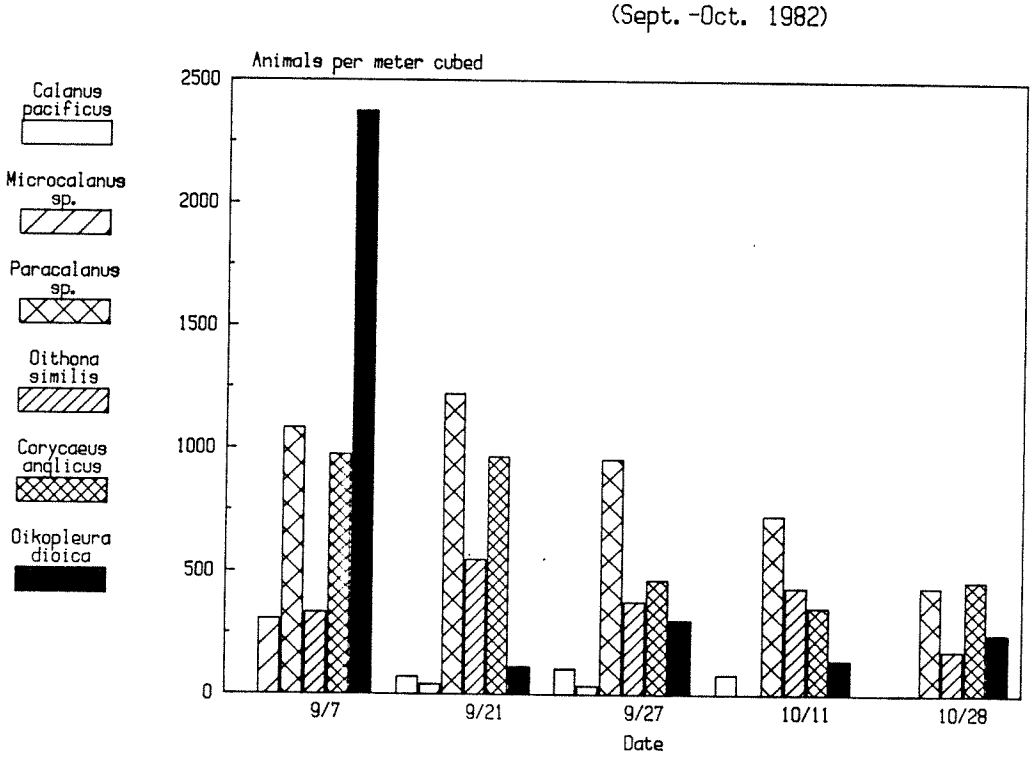




Figure 4.25E. Dominant zooplankton species at Station 5.

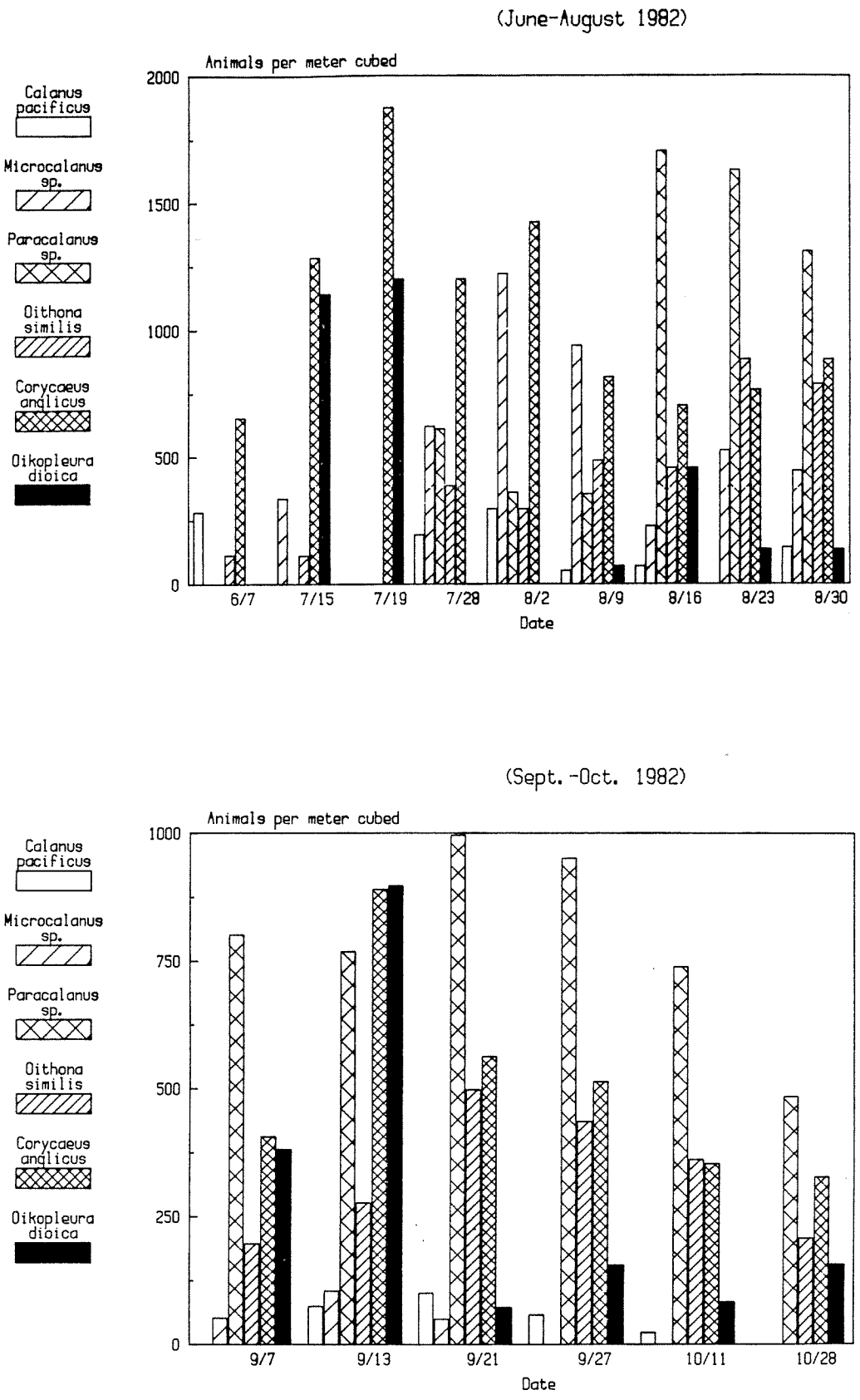
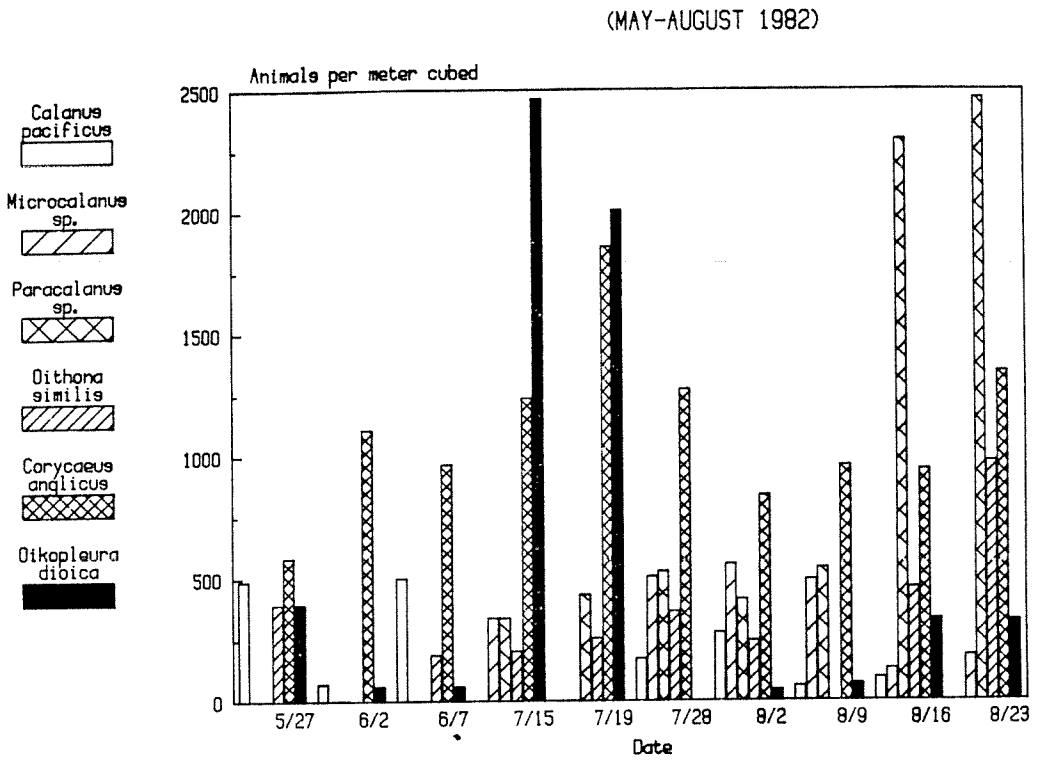



**Figure** 4.25F. Dominant zooplankton species at Station 6.



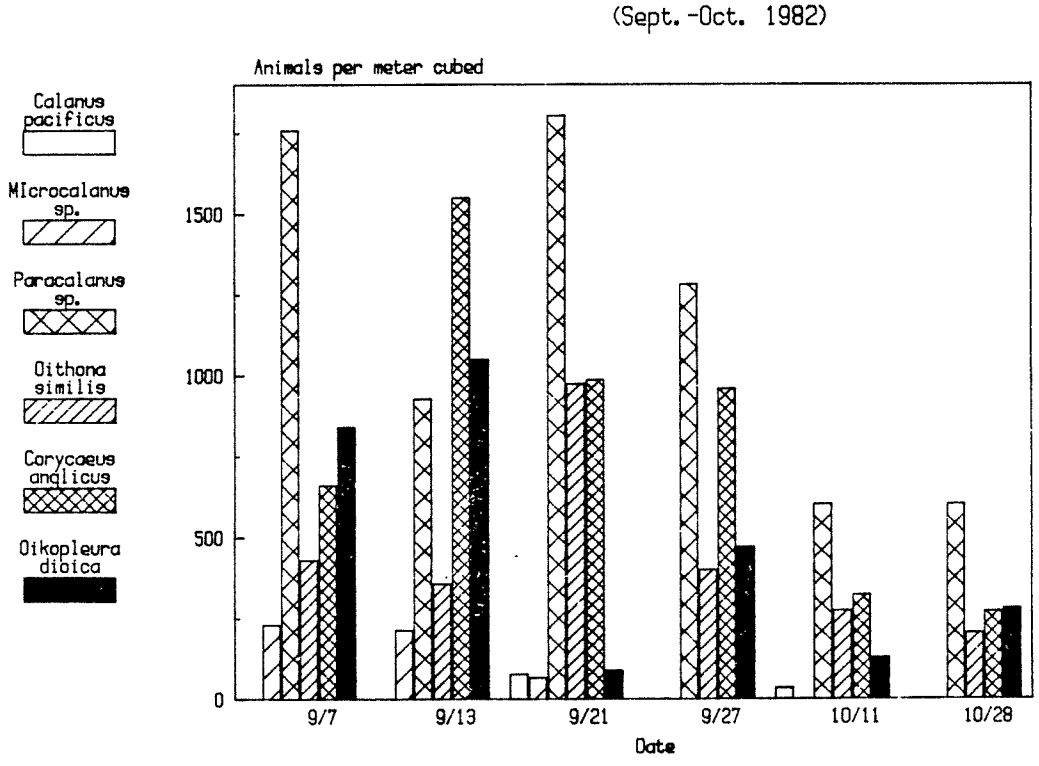




Figure 4.25G. Dominant zooplankton species at Station 7.

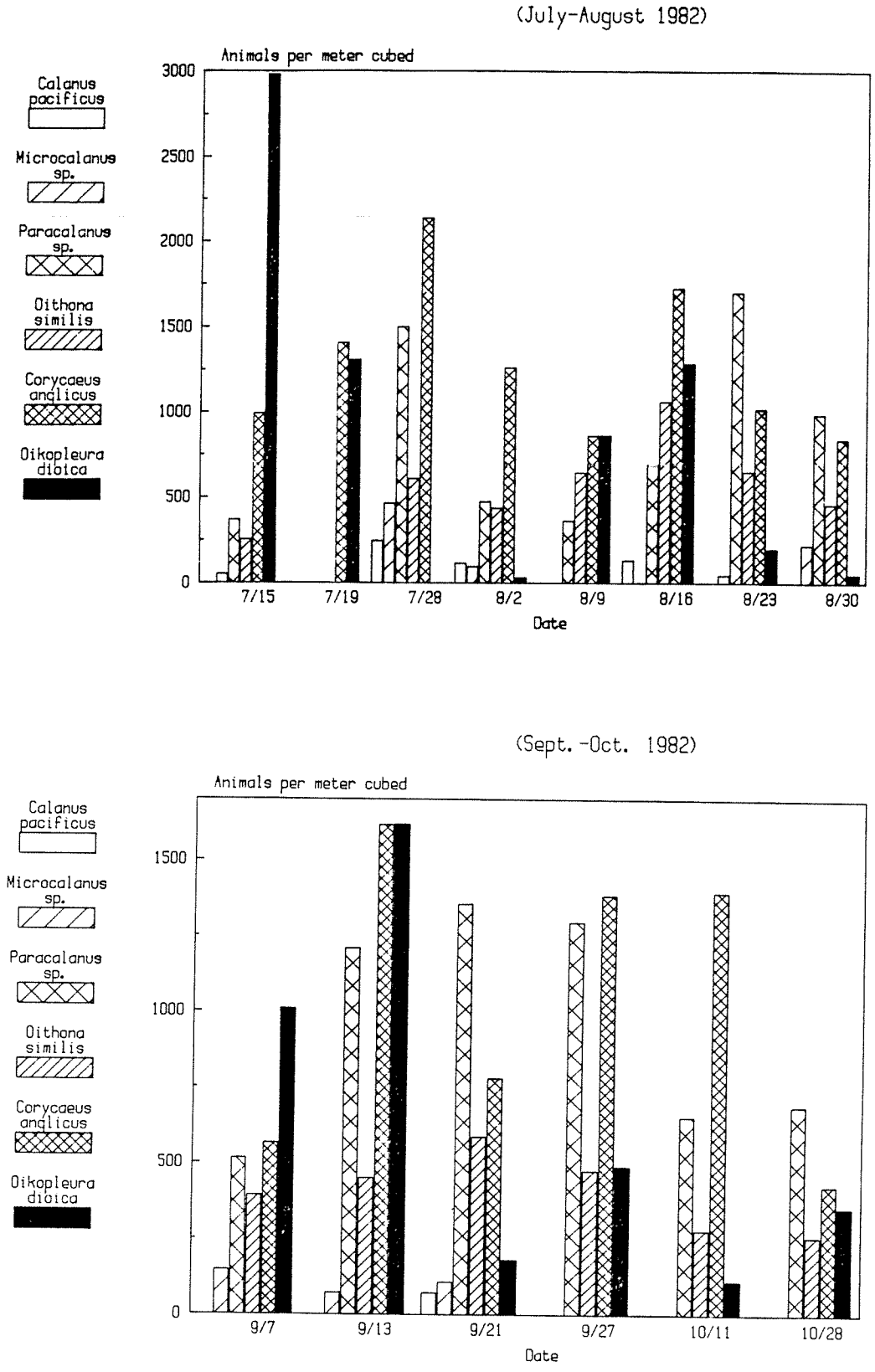
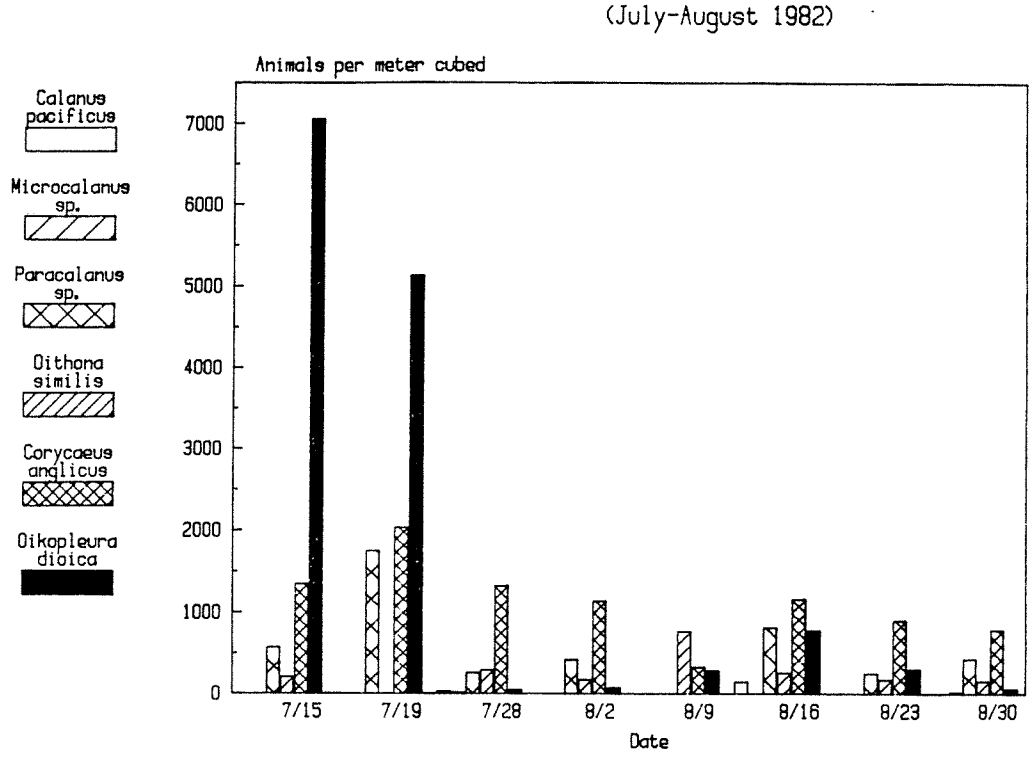



Figure 4.25H. Dominant zooplankton species at Station 8.



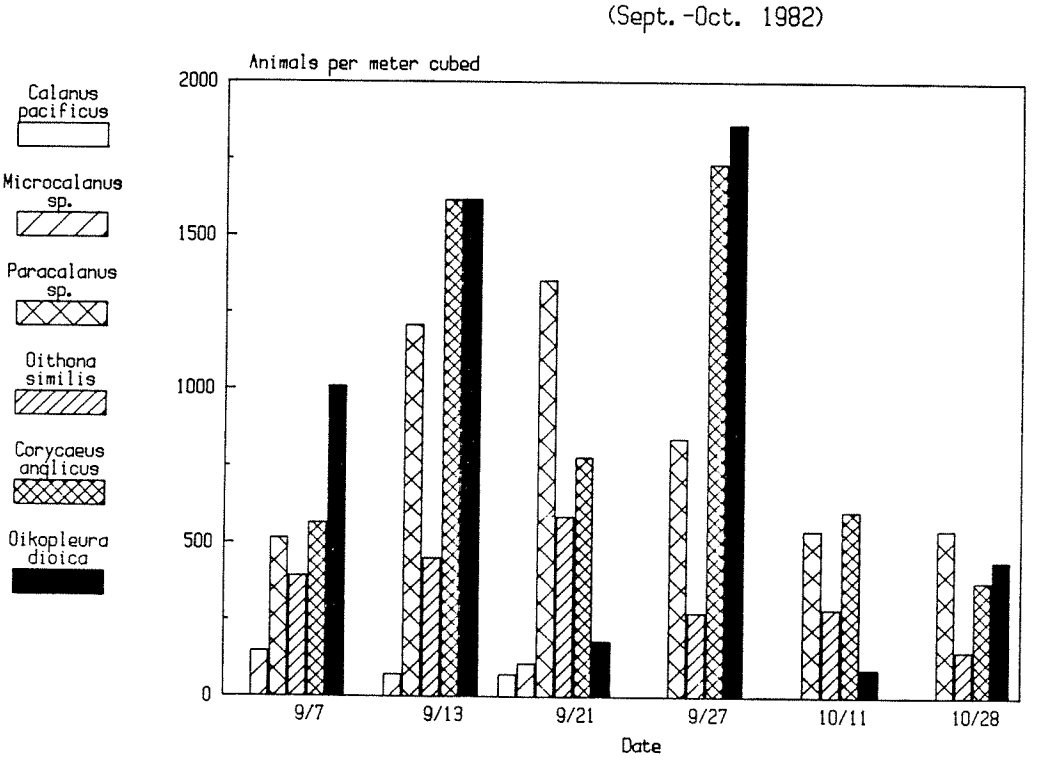




Figure 4.25I. Dominant zooplankton species at Station 9.

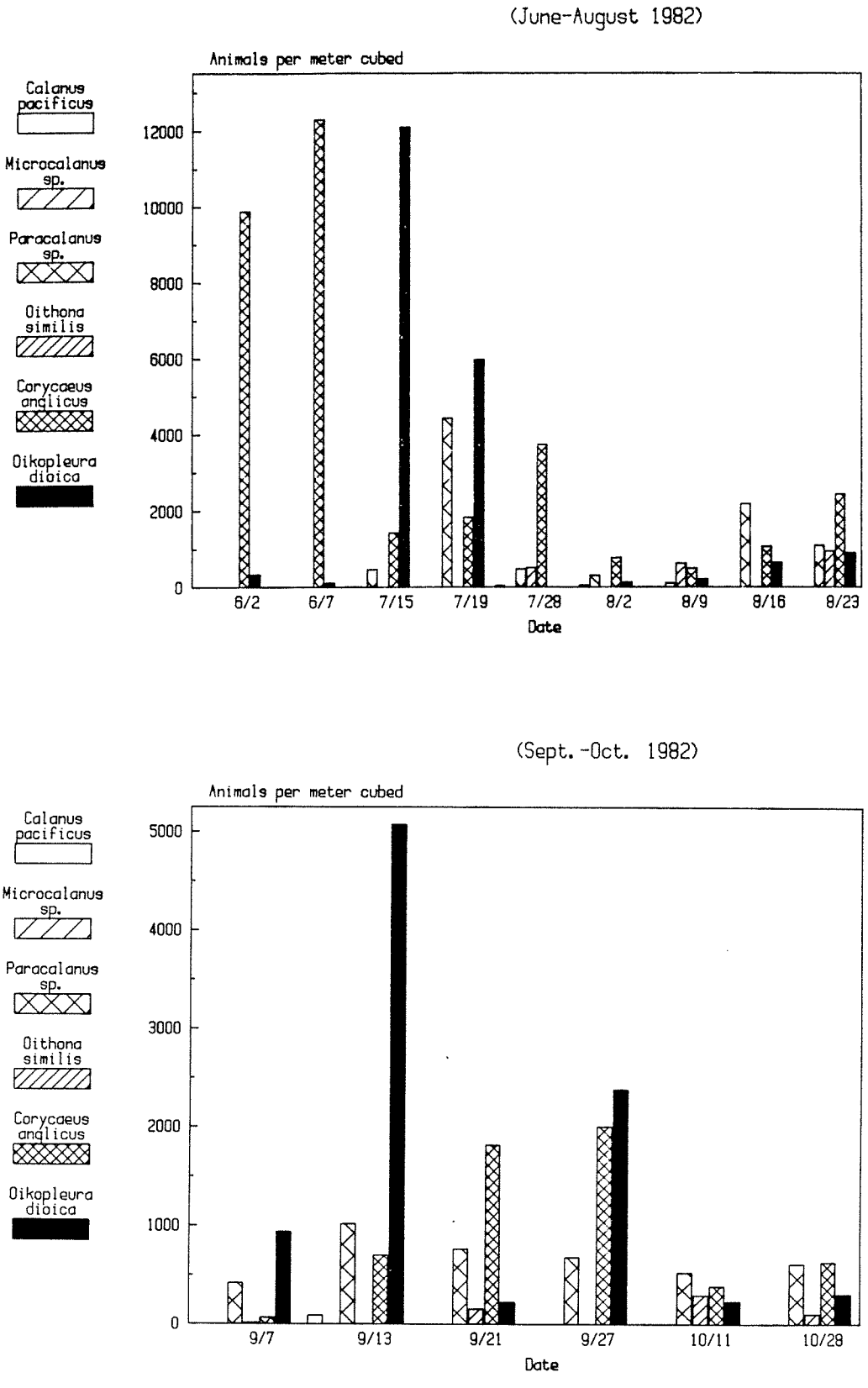



Figure 4.25J. Dominant zooplankton species at Station 10.

Paracalanus is larger than Corycaeus and a vertical migrator, requiring more water than the smaller cyclopoid. Oikopleura, a larvacean dwelling in a gelatinous house, is known to be an opportunistic species (Alldredge, 1975) and may increase to extremely high numbers in quiet nutrient-rich waters. Nearshore stations 7 to 10 have provided these conditions in July with significant levels of Skeletonema costatum and little wind. The larvacean is able to maintain itself throughout the summer at the nearshore stations (especially 8 and 10) and at stations 4, 5, and 6 but never again exhibits the population explosion seen at stations 7, 8, 9 and 10 in July.

## 4.4 Physical Oceanography

### 4.4.1 Mixed Layer Depth

Seasonal variations in the mixed layer depth for the Seahurst Bight/East Passage area have been calculated and are presented graphically in a plot of depth versus time in Figure 4.26. More extensive examination of mixed layer depths can be found in Section 5 of this report on physical oceanography.

Mixed layer depth was calculated from corrected CTD data for stations 7 to 10 and gives an indication of the changes in depth to which phytoplankton can live and grow. Station 7 through 10 have mixed layer depths of 5 to 12 m, which is typical for nearshore Puget Sound areas in the summertime (Winter et al., 1975). A period of warm weather and low winds in later August-early September produces shallower mixed layers and contributes to the large algal bloom present at that time. The mixed layer at most stations deepens in later September as the water column breaks down due to high winds and low radiation levels.

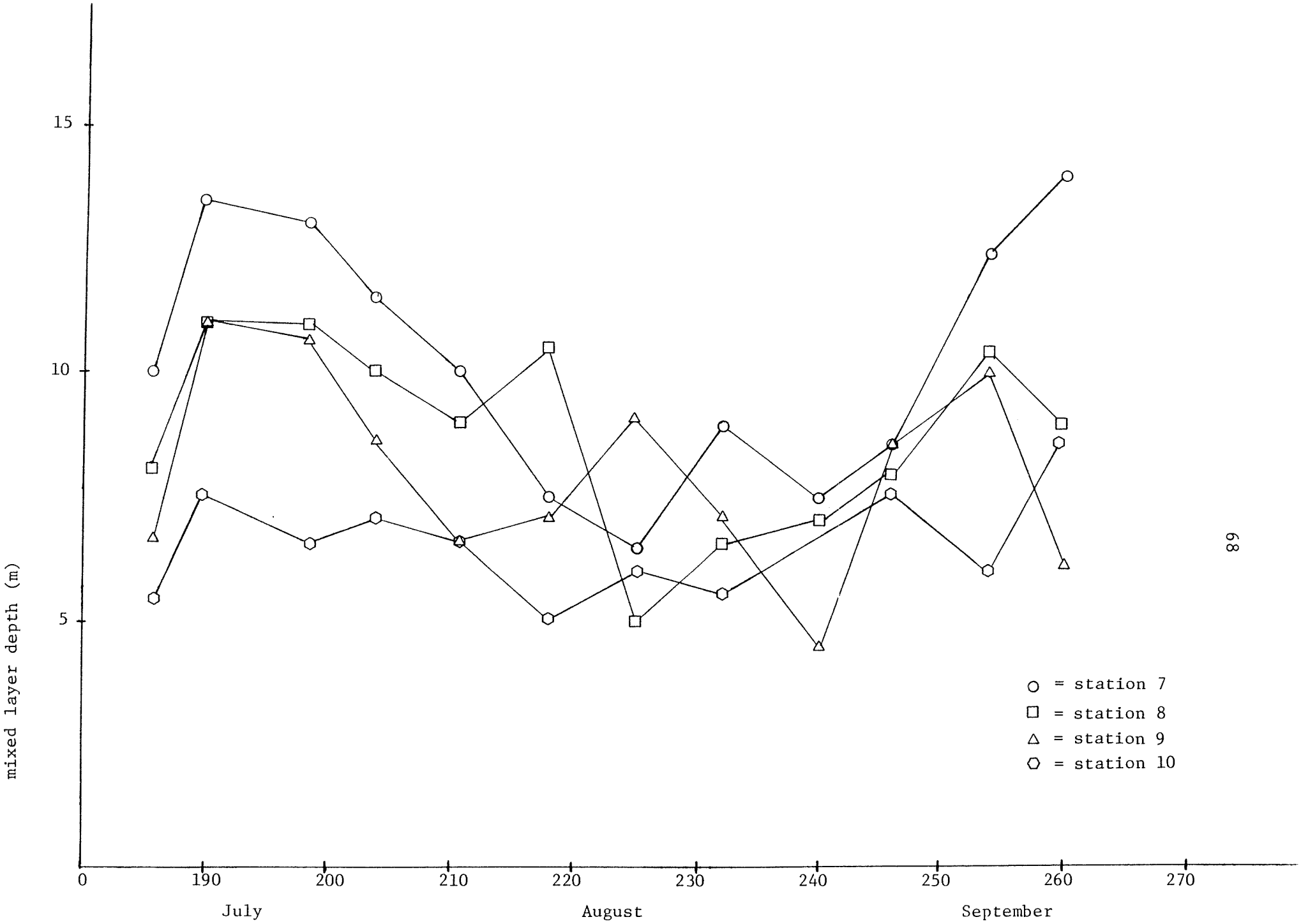



Figure 4.26. Time series of mixed layer depth for nearshore stations 7 to 10 for July-October 1982.

### 4.4.2 Onshore Flow of Bottom Water

An investigation to find a possible onshore bottom flow of water in the Seahurst Park area was carried out throughout the fall and early winter of Phase I. Temperature and salinity readings taken with a Beckman Induction Salinometer were calibrated against the Interocean CTD aboard the R/V Liberty. Figure 4.27 A and B were drawn from results of temperature taken on two separate dates (11/30/82 and 1/28/83) along the same transect (see Figure 4.2). Sampling stations were occupied on each transect with measurements taken every meter from the sea bottom to the surface. Contours have been drawn through the isotherms. Figure 4.27A, from November 1982, shows remnants of a vertically stratified water column, due to residual thermal heating from the summer months. By January 1983 (Figure 4.27B), all semblance of vertical structure has disappeared, leaving a uniformly mixed water column. There is no evidence in these figures or in other data that has been collected to indicate a shoreward lean of isotherms suggesting a movement of bottom water.

If a net movement of water towards the shore were present, it is to be expected that the coefficient of variation (s/x) for the near surface and bottom water would differ. Statistical analysis of the data for five sampling dates (Table 4.5) shows that the two coefficients of variation are not significantly different at the 8% level. CTD profiles from discrete sampling stations likewise show no indication of onshore bottom water flow.

All the evidence gathered here leads to the conclusion that there is no onshore movement of bottom water. Weekly CTD traces will continue to be examined for evidence to the contrary. On that basis, the investigation using the Induction Salinometer will be discontinued.

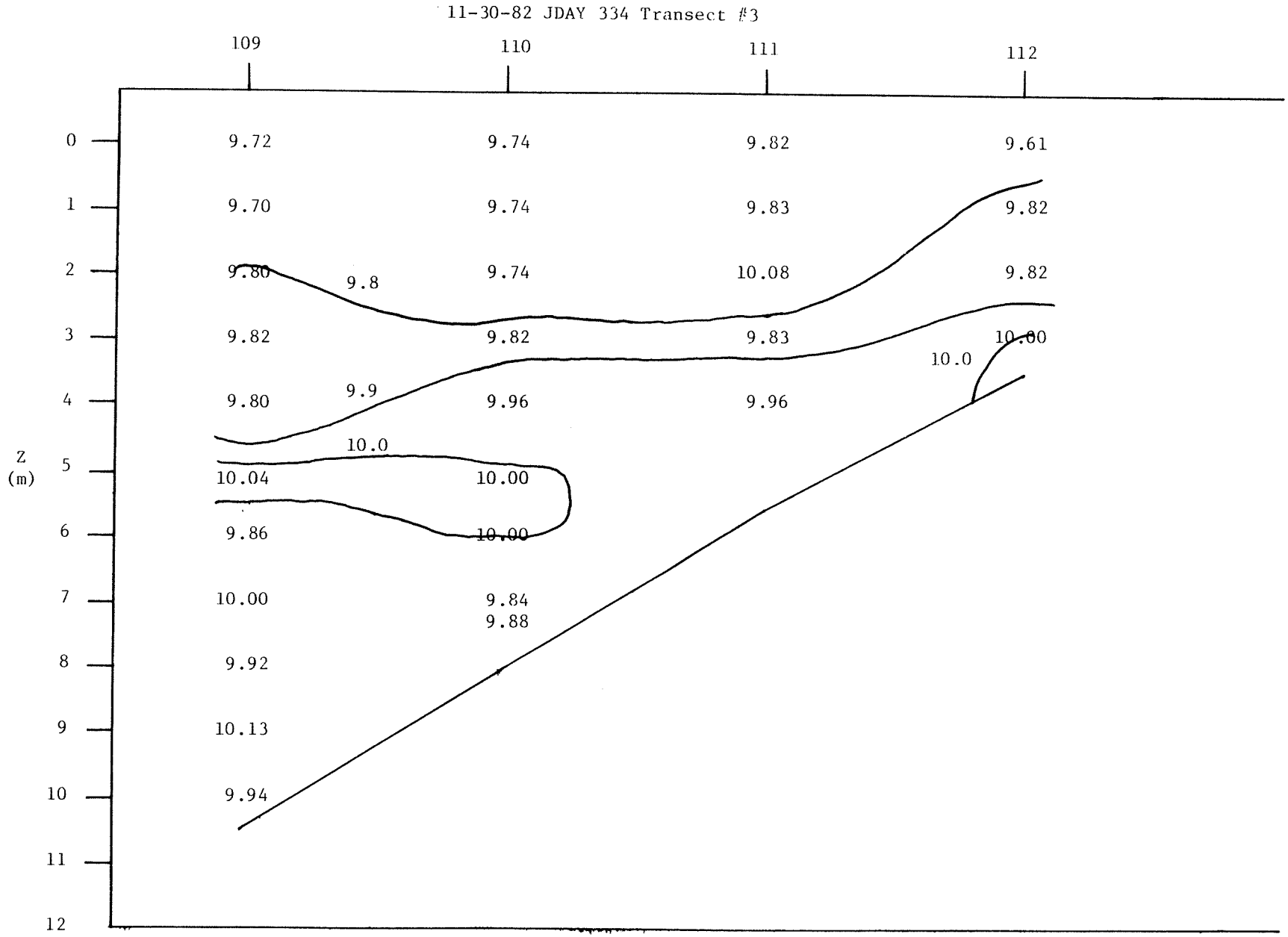



Figure 4.27A. Cross section of temperature data with isotherms taken with an induction salinometer at transect 3 of the Seahurst Inshore Studies, on November 30, 1982. Temperature is in degrees centigrade.

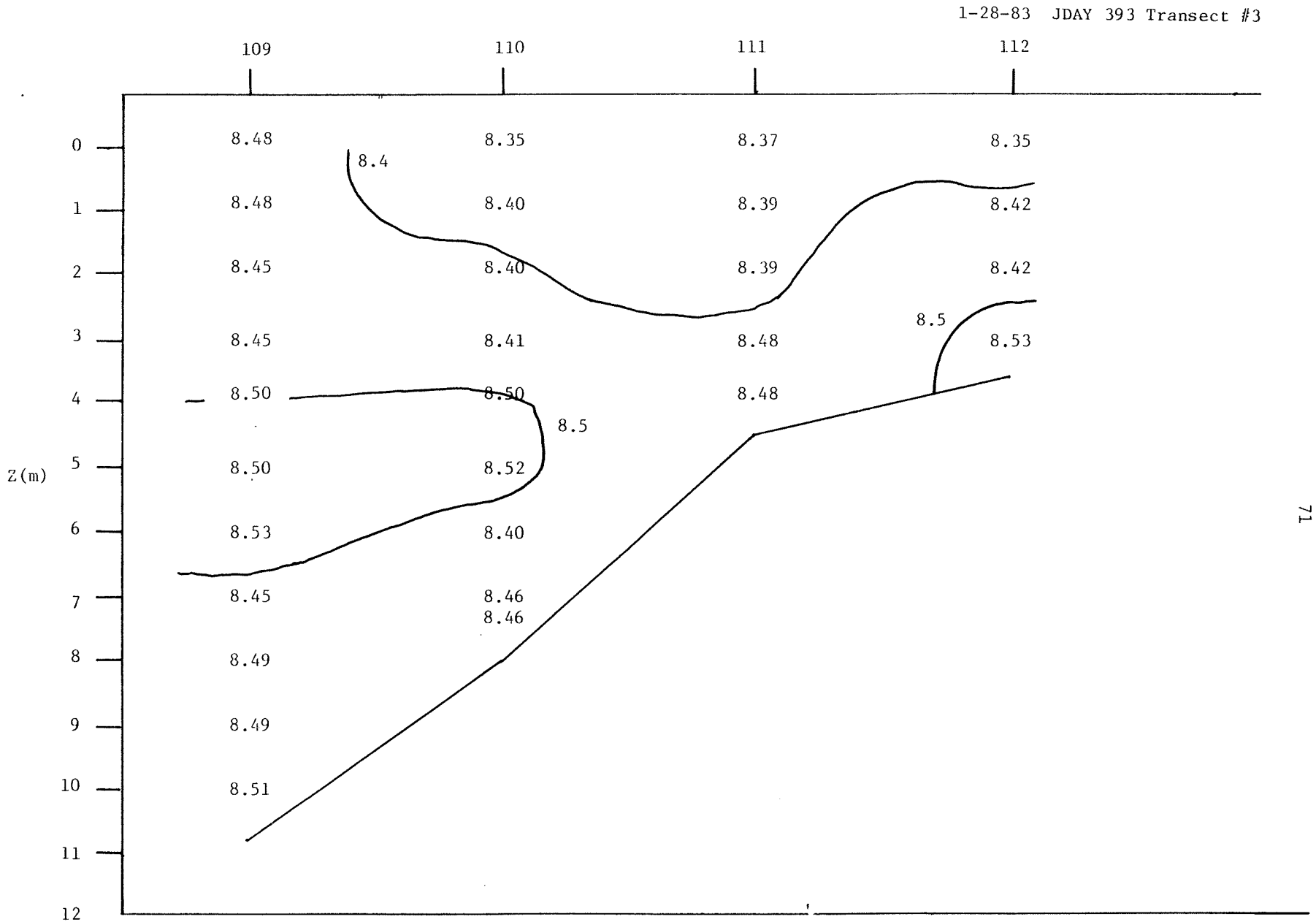



Figure 4.27B. Cross section of temperature data with isotherms taken with an induction salinometer at transect 3 of the Seahurst Inshore Studies, on January 28, 1983.

Table 4.5. Statistical analysis of Seahurst Inshore studies temperature data. Temperature in degrees centigrade.

| | | 2 Meter Water | | | Bottom Water | | |
|---|---|---|---|---|---|---|---|
| Date | Transect | Mean | Variance | Coef. Var. | Mean | Variance | Coef. Var. |
| 10/19/82 | 1 | 11.39 | .109 | .0096 | 11.40 | .040 | .0035 |
| | 2 | 11.45 | .049 | .0043 | 11.40 | .025 | .0022 |
| | 3 | 11.39 | .030 | .0026 | 11.41 | .060 | .0053 |
| | 4 | 11.44 | .039 | .0034 | 11.40 | .050 | .0044 |
| 11/30/82 | 1 | 9.80 | .048 | .0049 | 9.98 | .047 | .0047 |
| | 2 | 9.73 | .068 | .0070 | 9.94 | .013 | .0013 |
| | 3 | 9.86 | .130 | .0132 | 9.95 | .043 | .0043 |
| | 4 | 9.83 | .094 | .0096 | 10.03 | .161 | .0161 |
| 1/11/83 | 1 | 8.82 | .032 | .0036 | 8.87 | .034 | .0038 |
| | 2 | 8.76 | .040 | .0046 | 8.84 | .026 | .0029 |
| | 3 | 8.82 | .044 | .0050 | 8.84 | .034 | .0038 |
| | 4 | 8.71 | .128 | .0147 | 8.82 | .068 | .0077 |
| 1/20/83 | 1 | 8.40 | .057 | .0068 | 8.47 | .043 | .0051 |
| | 2 | 8.33 | .167 | .0200 | 8.48 | .050 | .0059 |
| | 3 | 8.34 | .025 | .0030 | 8.49 | .059 | .0069 |
| | 4 | 8.34 | .072 | .0086 | 8.50 | .043 | .0051 |
| 1/28/83 | 1 | 8.54 | .030 | .0035 | 8.50 | .048 | .0056 |
| | 2 | 8.48 | .037 | .0044 | 8.53 | .043 | .0050 |
| | 3 | 8.42 | .023 | .0027 | 8.50 | .027 | .0032 |
| | 4 | 8.46 | .030 | .0035 | 8.53 | .022 | .0026 |

### 4.4.3 Underway Surface Mapping

#### 4.4.3.1 Inshore Transects

A predetermined pattern of navigation course changes was followed weekly from Brace Point to Point Pulley. This inshore transect was run at speeds from 4 to 10 knots and continuous underway data for temperature, conductivity, nephelometry, chlorophyll and ammonia were recorded. For ease of analysis, the transect has been divided into 8 legs, labeled A through H (see Figure 4.1 for locations). Representative sections of this data plotted against time (which equates to distance), are seen in Figure 4.28, A-1 through E-3. Legs E and F, G and H are plotted together whenever possible as legs F and G are very short. On 8/16/82 there was a delay at the turn between legs E and F, so that for this date, the legs have been plotted separately. Not all instruments are plotted on all days. Additionally, Figure 4.29 is a time series of the entire inshore transect on 9/22/82, showing ammonia, conductivity and nephelometry, the significant properties for that date. It should be noted in examining these figures that legs B and C converge at Point Pulley, legs C and D meet very close to the beach, as do legs A and B, and F and G; legs D and E meet away from the beach, and legs G and H are directed away from the beach towards Brace Point.

By careful examination of the data from transects on 8/16/82, 8/23/82, 9/22/82 and 9/27/82 it is possible to identify some general patterns regarding surface water properties in the Seahurst Park nearshore area:

1. Chlorophyll levels increase towards the beach. This trend is most evident when chlorophyll levels are high. Note particularly 9/27/82, the approach to shore on legs E and F, and the retreat on legs G and H.
2. Particle content (nephelometry) increases towards the beach,

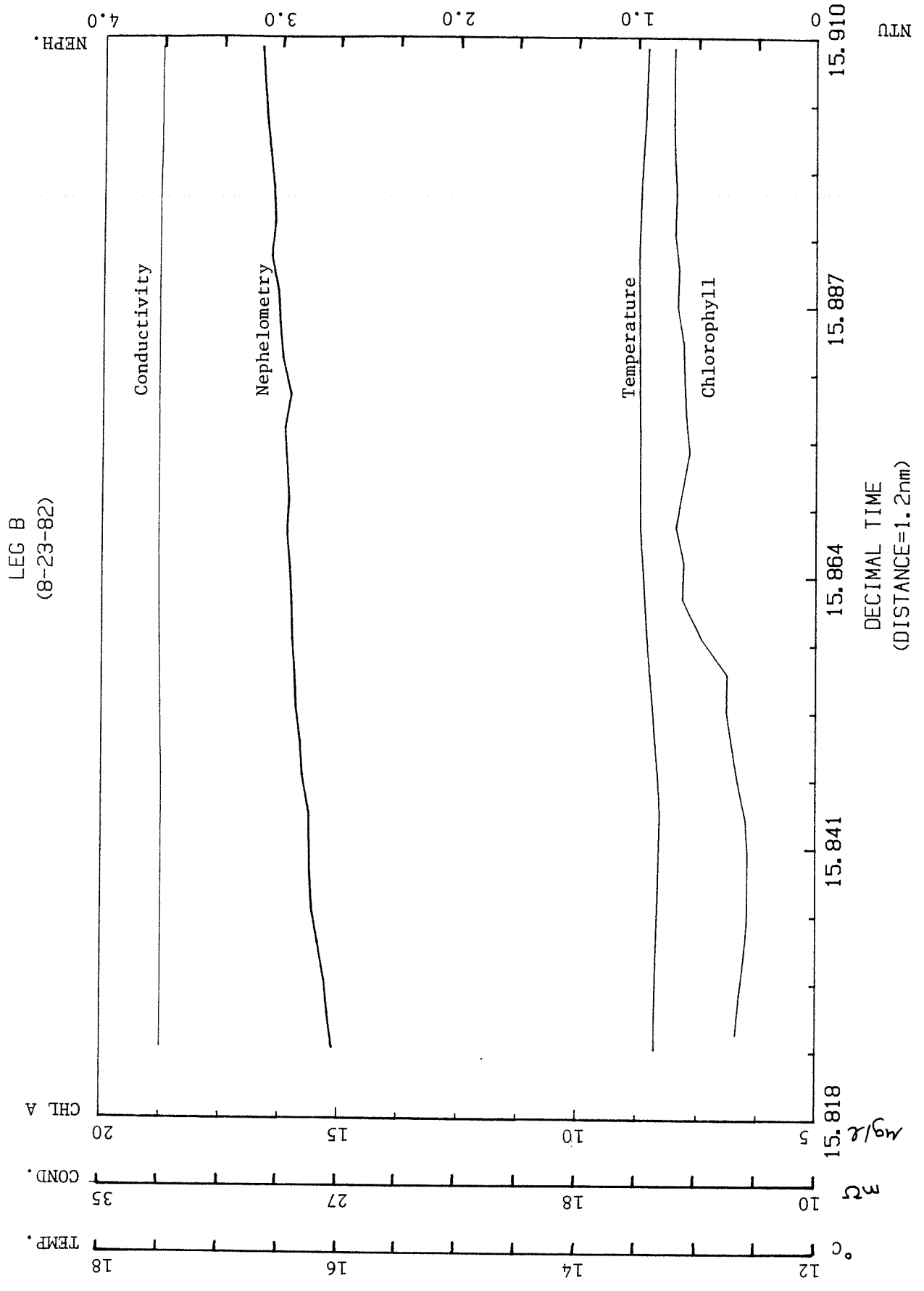



Figure 4.28A-1. Leg B, underway surface data from the Seahurst Park area, August 23 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

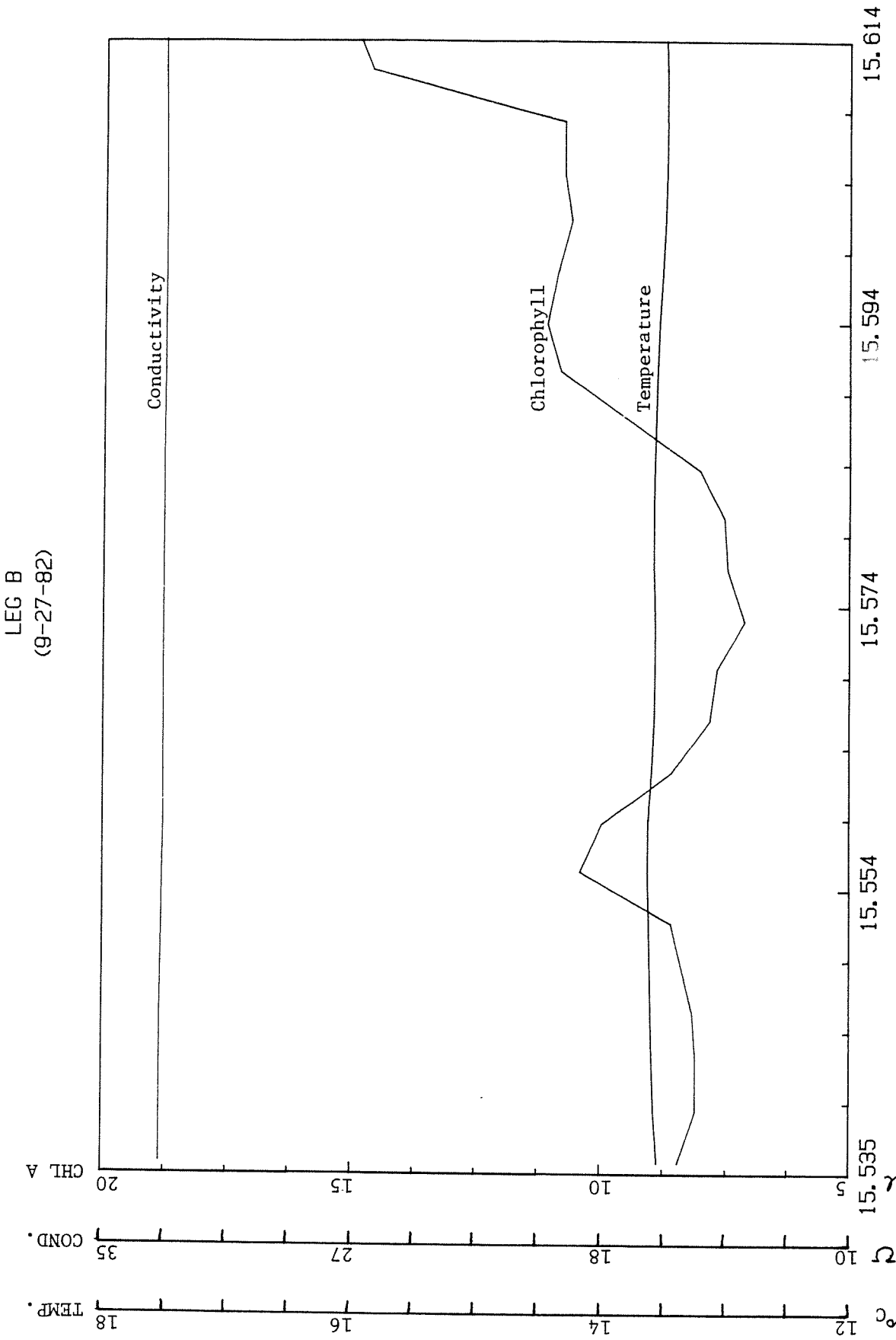



Figure 4.28A-2. Leg B, underway surface data from the Seahurst Park area, September 27 1982, showing temperature, conductivity and chlorophyll a over decimal time.

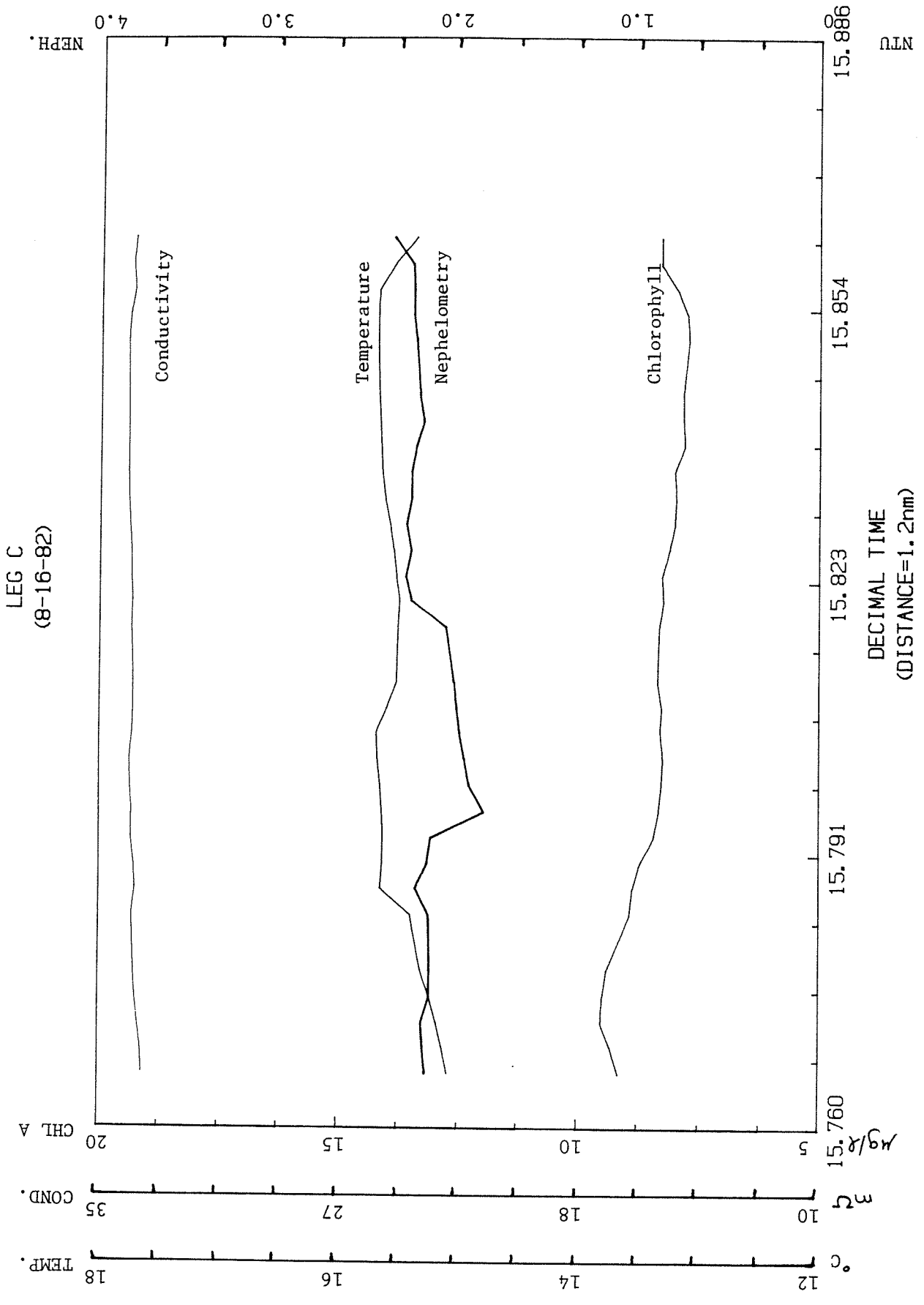



Figure 4.28B-1. Leg C, underway surface data from the Seahurst Park area, August 16 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

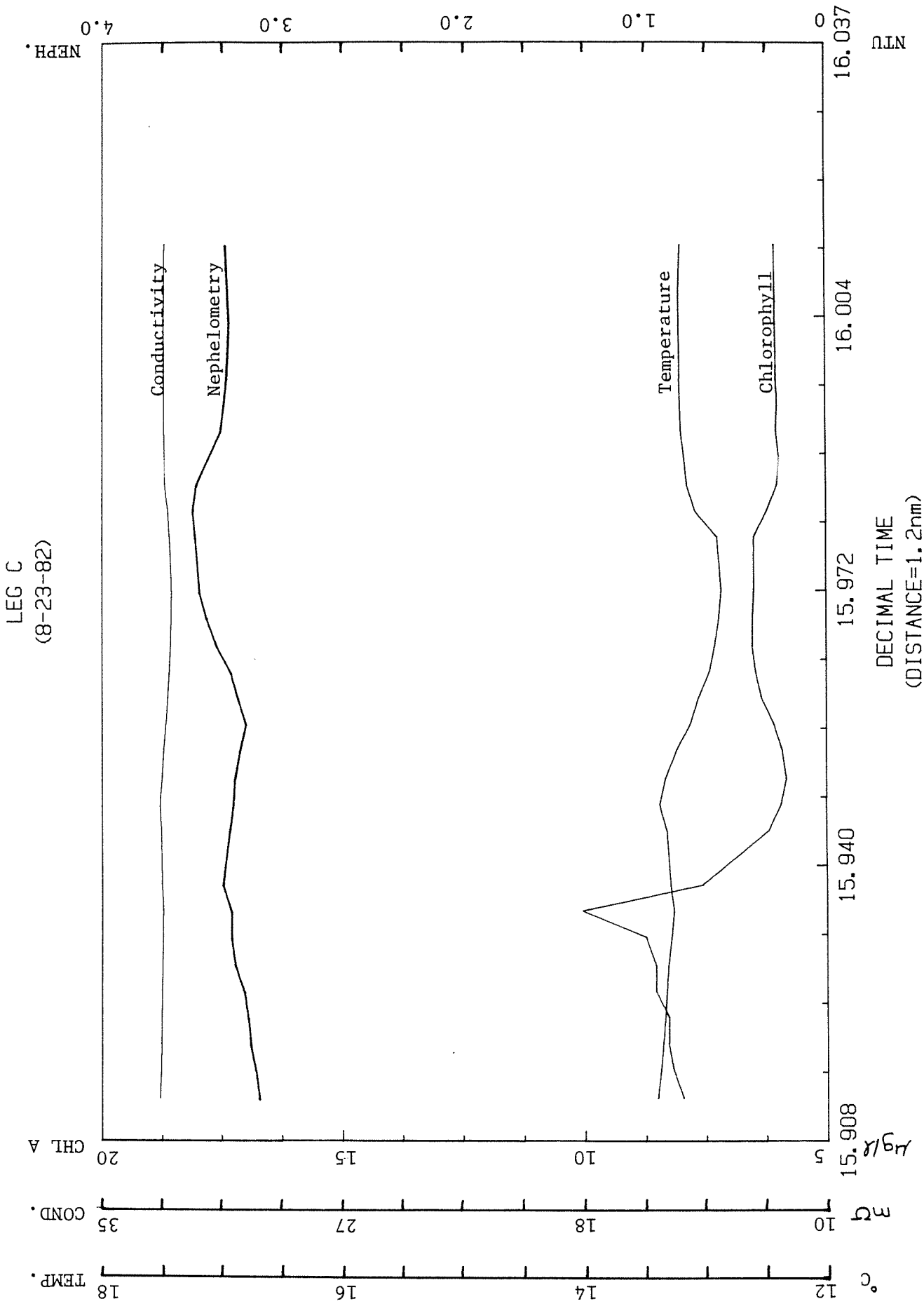



Figure 4.28B-2. Leg C, underway surface data from the Seahurst Park area, August 23 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

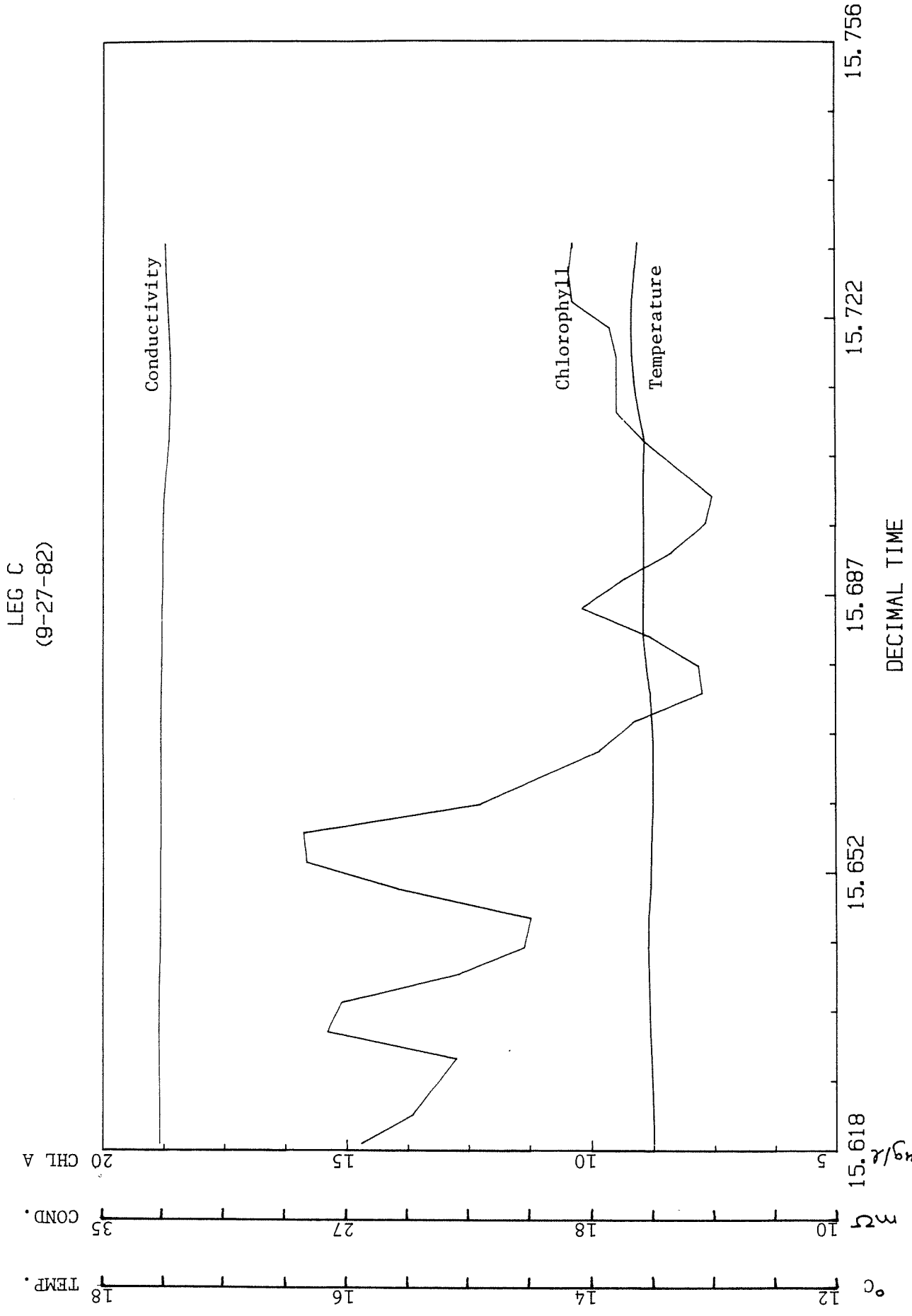



Figure 4.28B-3. Leg C, underway surface data from the Seahurst Park area, September 27 1982, showing temperature, conductivity and chlorophyll a over decimal time.

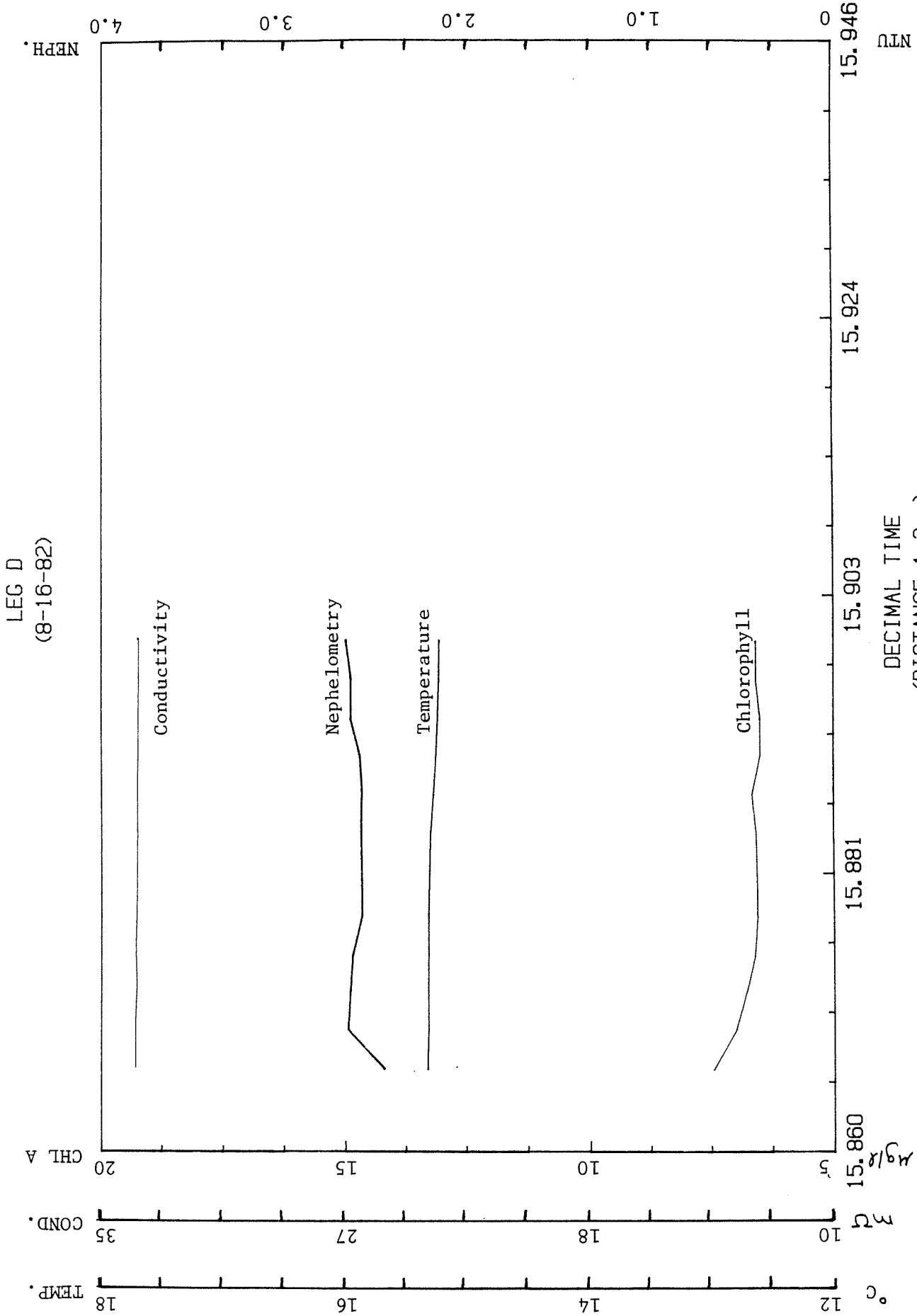



Figure 4.28C-1. Leg D, underway surface data from the Seahurst Park area, August 16 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

Figure 4.28C-2. Leg D, underway surface data from the Seahurst Park area, August 23 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

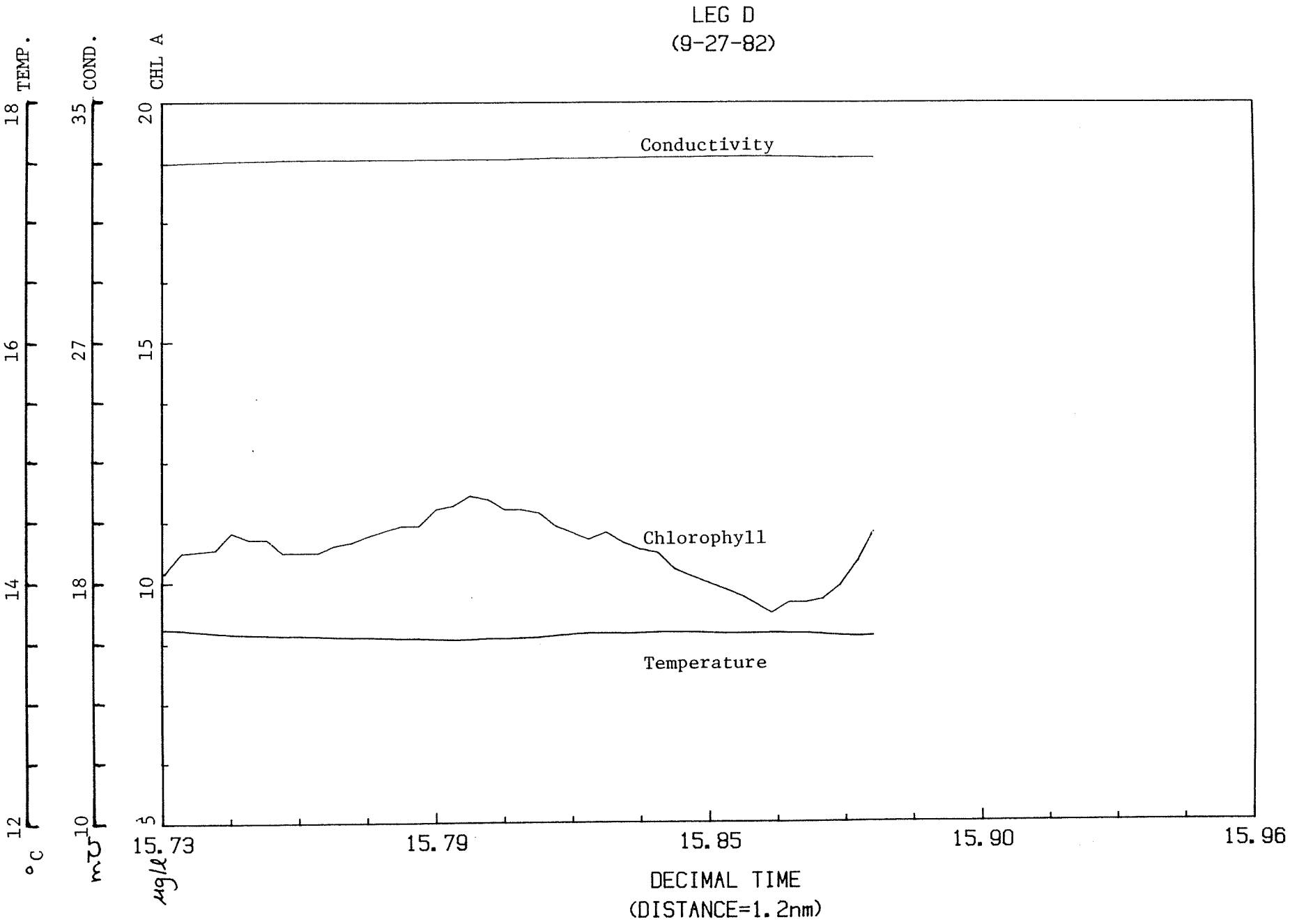



Figure 4.28C-3. Leg D, underway surface data from the Seahurst Park area, September 27 1982, showing temperature, conductivity and chlorophyll a over decimal time.

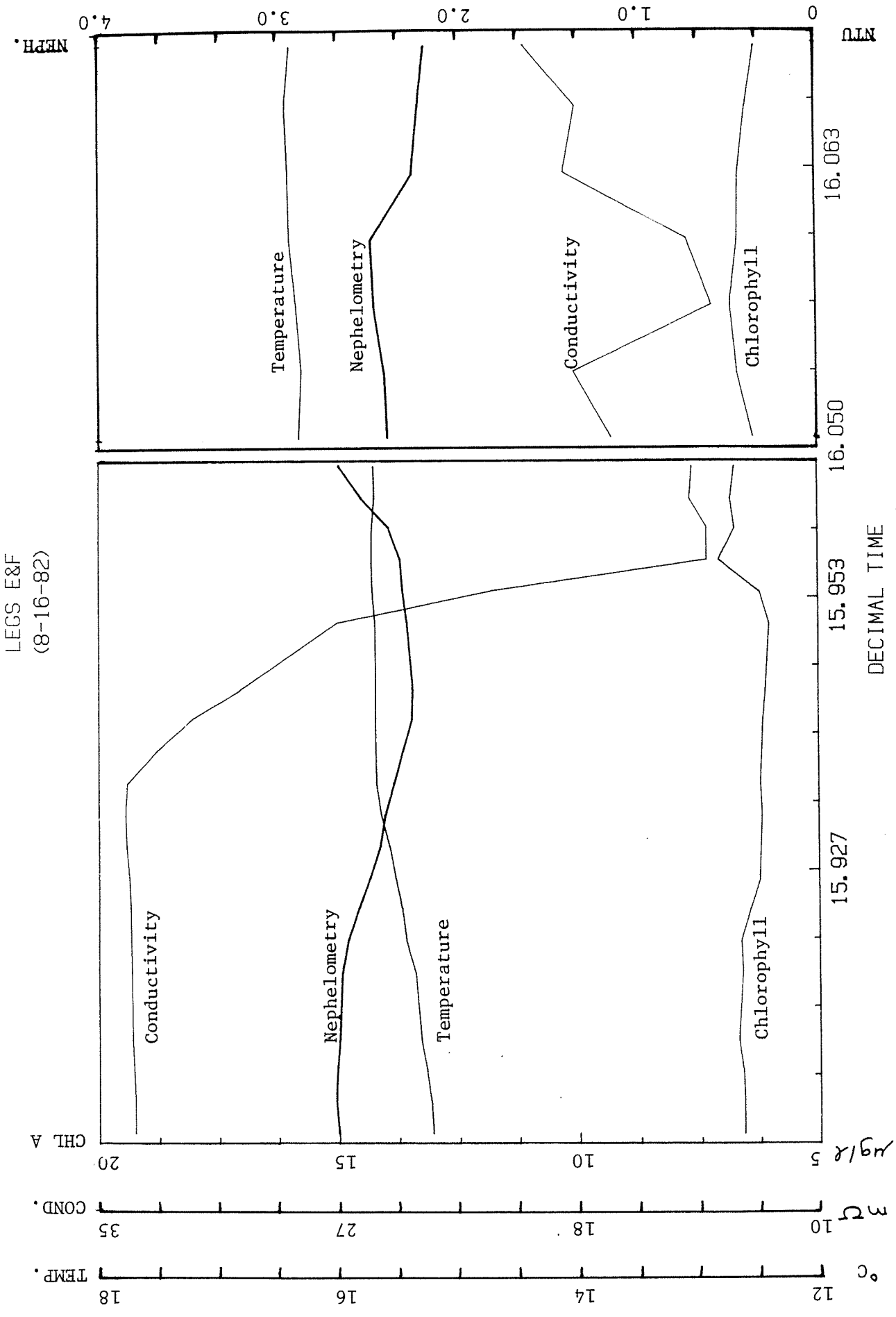



Figure 4.28D-1. Legs E and F, underway surface data from the Seahurse Park area, August 16 1982, showing temperature, conductivity, chlorophyll a and nephelomctry over decimal time.

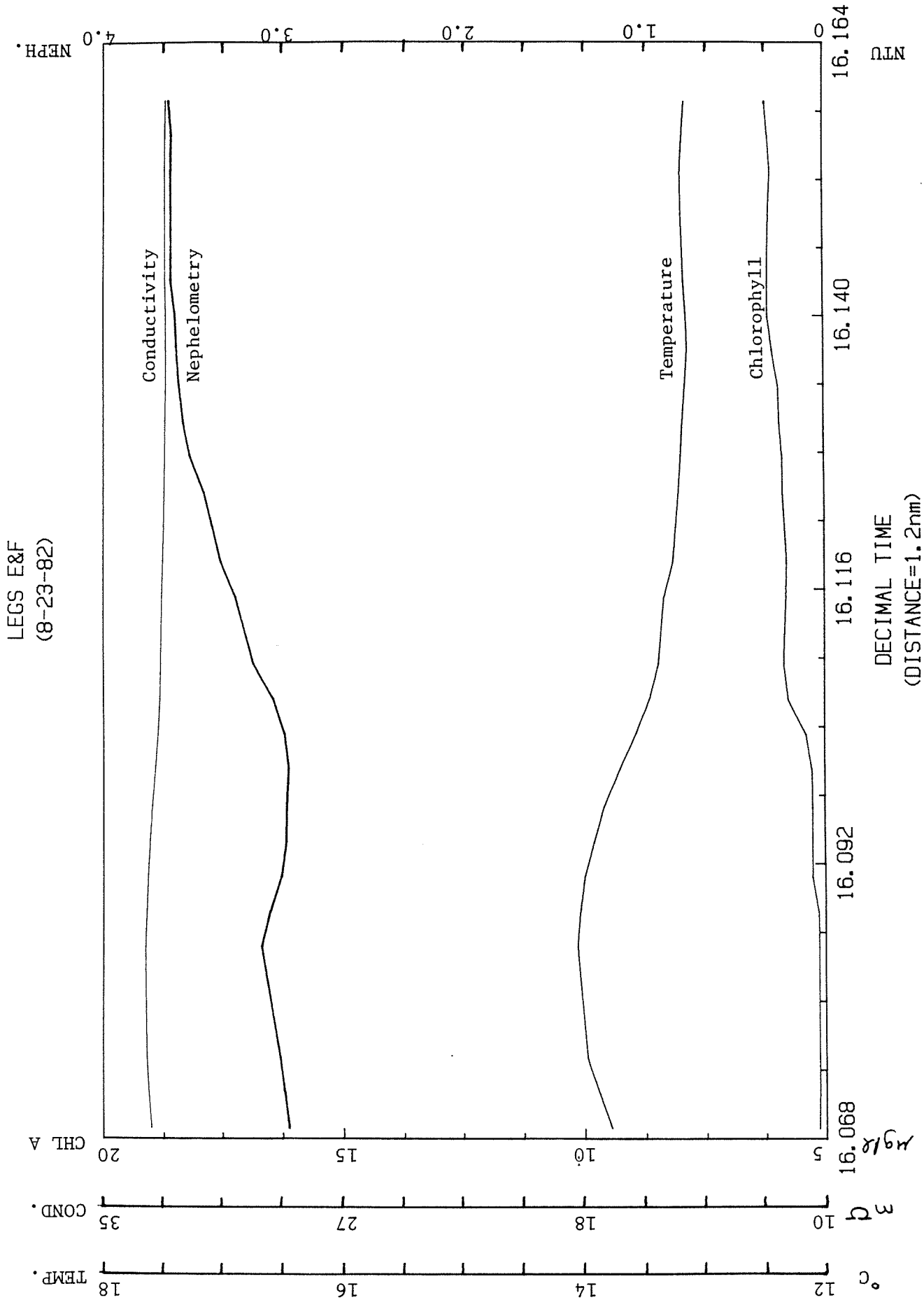



Figure 4.28D-2. Legs E and F, underway surface data from the Seahurst Park area, August 23 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

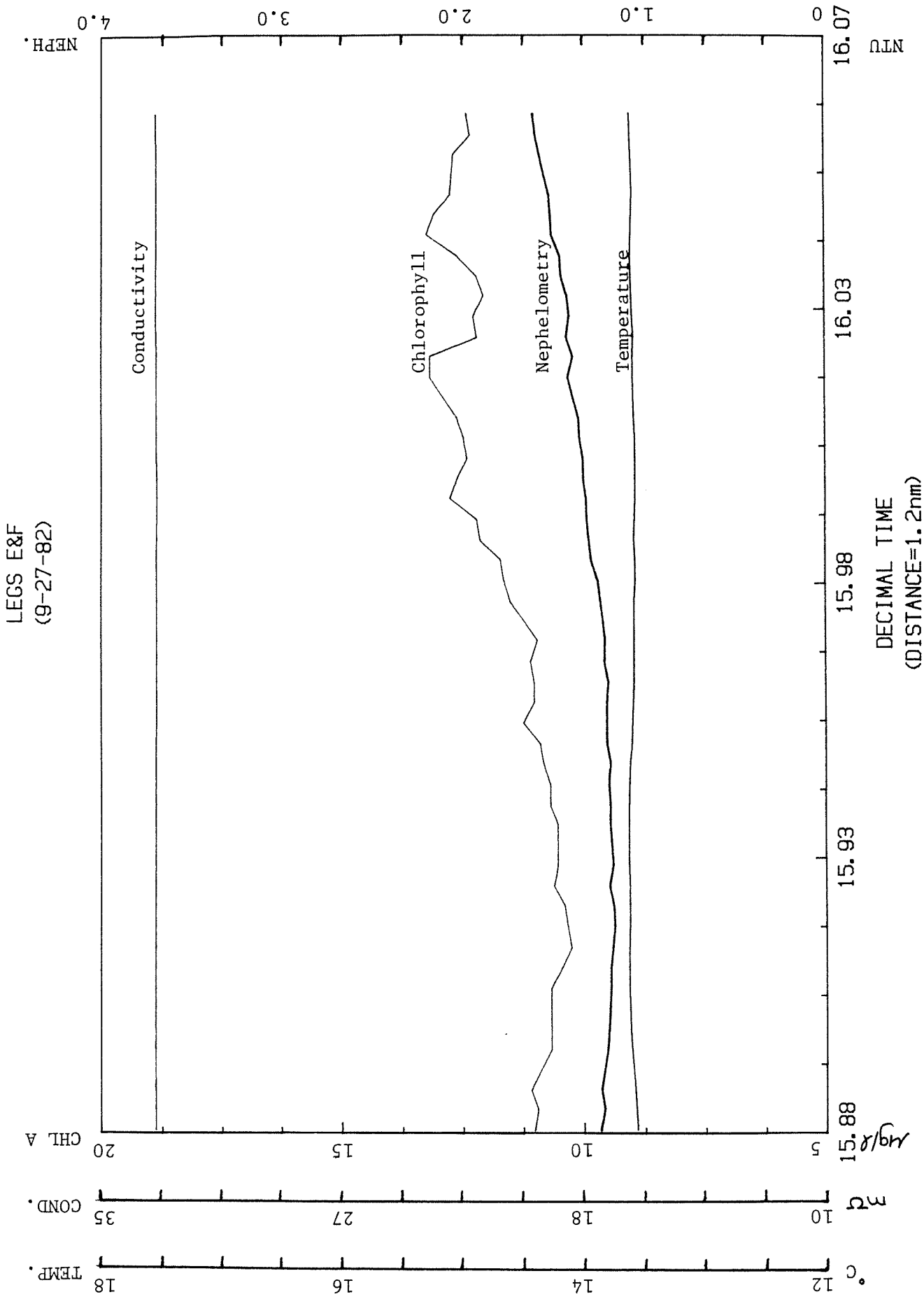



Figure 4.28D-3. Legs E and F, underway surface data from the Seahurst Park area, September 27 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

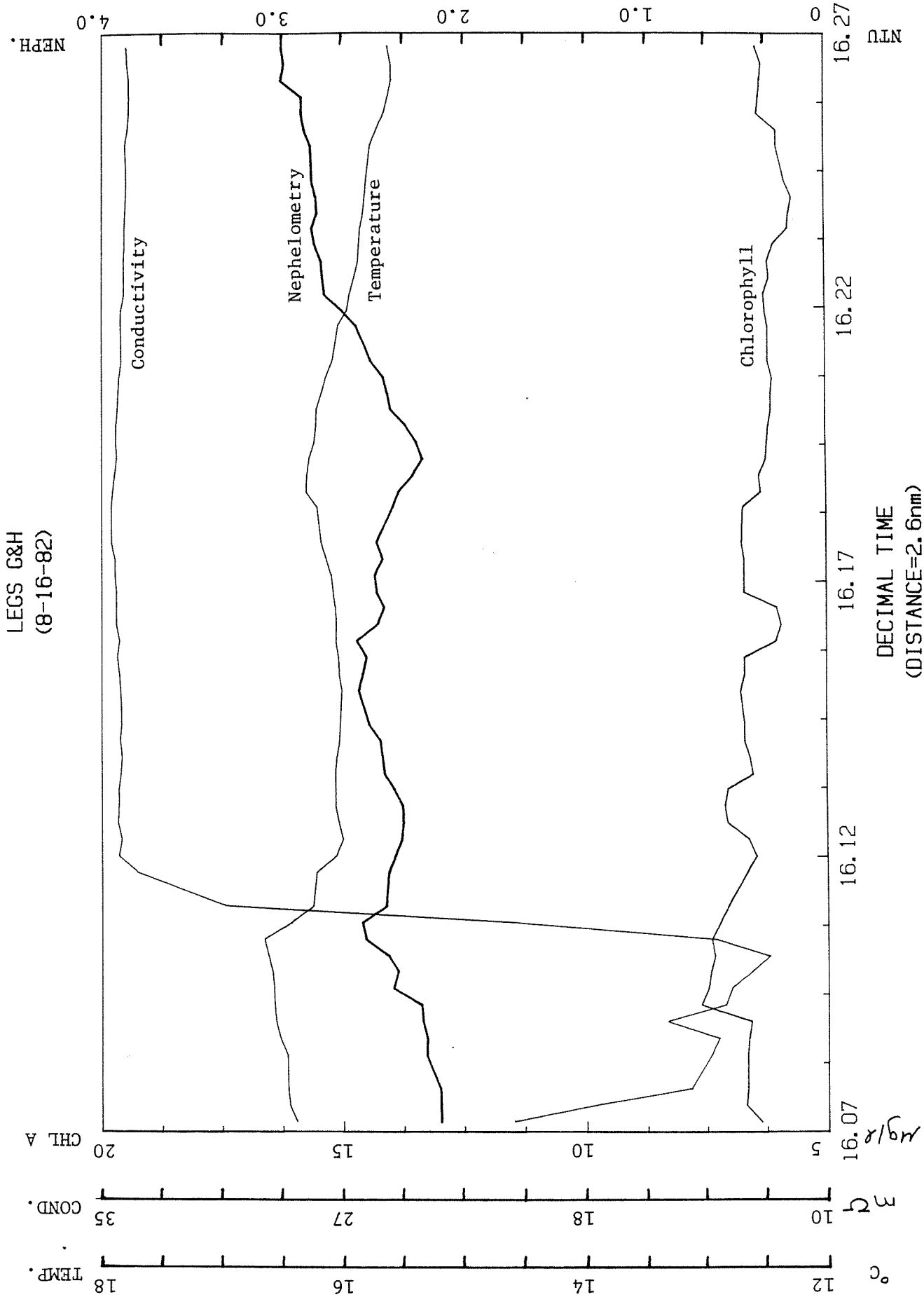



Figure 4.28E-1. Legs G and H, underway surface data from the Seahurst Park area, August 16 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

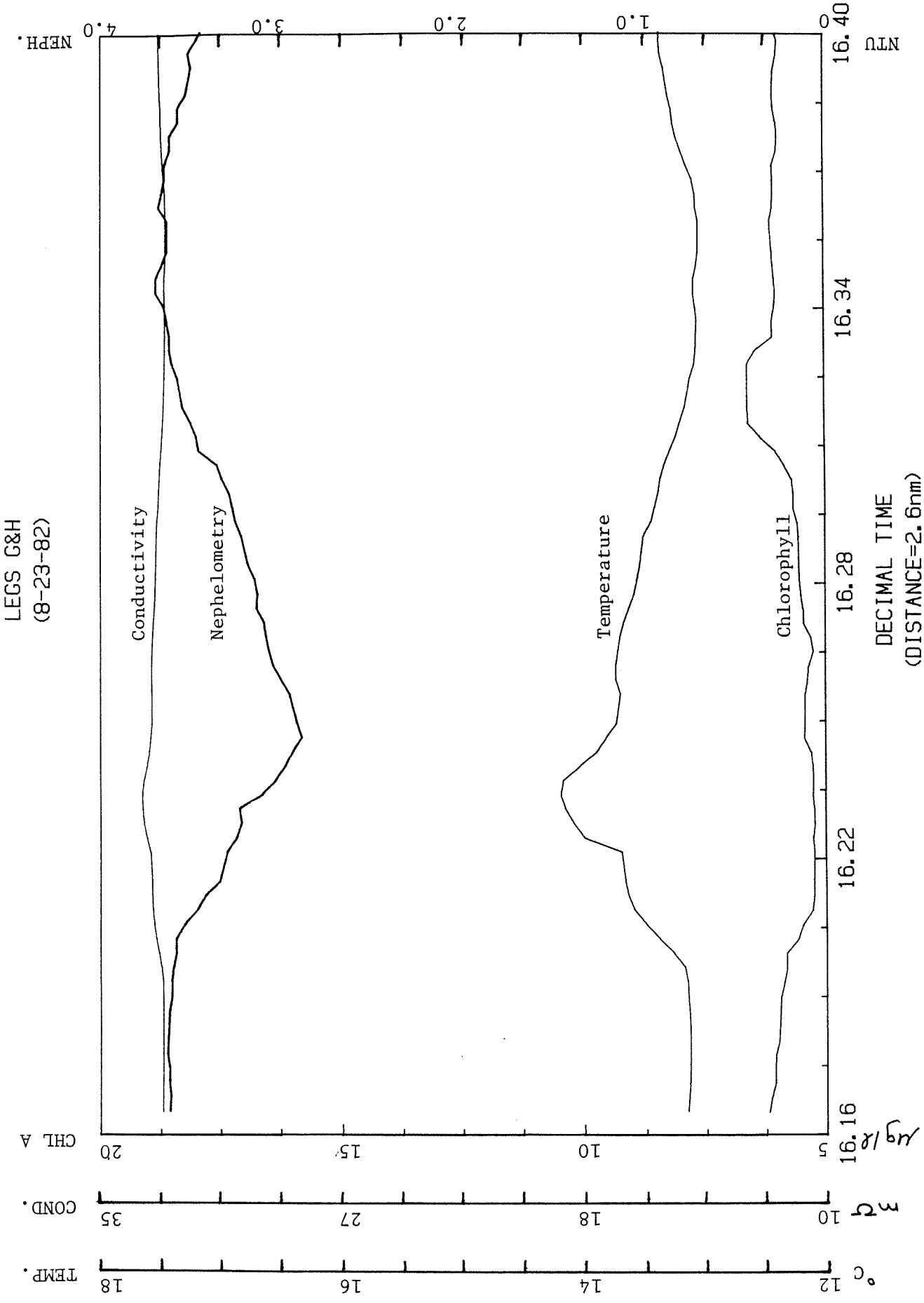



Figure 4.28E-2. Legs G and H, underway surface data from the Seahurst Park area, August 23 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

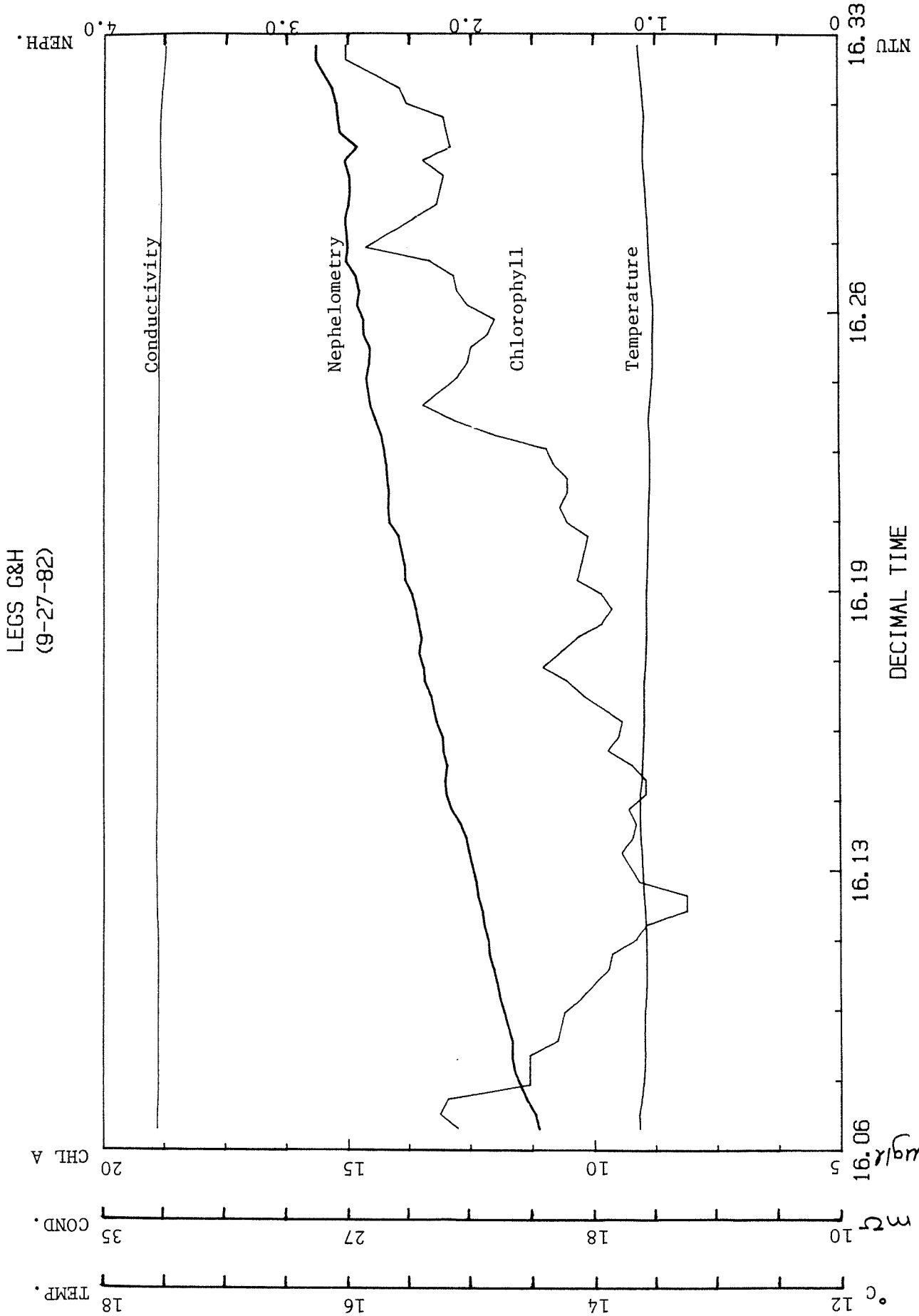



Figure 4.28E-3. Legs G and H, underway surface data from the Seahurst Park area, September 27 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

associated with phytoplankton biomass (chlorophyll).

3. There is a local freshwater source close to the Seahurst Marine Laboratory. This is apparent in the conductivity and ammonia signals of 9/22/82 and in the conductivity signal from legs E, F and G on 8/16/82. This source has been identified as the trout stream in the picnic area south of the OSC facility.

4. Ammonia increases with proximity to the beach. For example, the ammonia source identified from the stream, and that present inshore south of Point Pulley (see leg A, 9/22/82).

5. Point Pulley is the focus of chlorophyll maxima, with associated increases in nephelometry. These features are dependent on the state of the tide and represent parcels of water which have broken off from the flood tide eddy (south of Point Pulley) or the ebb tide eddy (north of Point Pulley), as documented by Evans-Hamilton (Tunnel Annual Report, 1982). See legs B and C (9/27/82) for strong evidence of this phenomenon.

Some additional results of underway mapping are available in Appendix 4H.

Surface water properties can be accurately pinpointed by the underway mapping system due to the rapid data acquisition rate and the sensitivity of the instruments employed. Data from vertical station profiles as well as measurements of surface water properties must be analyzed in order to predict eventual enhancement and/or toxicity to living populations by the addition of effluent to the system. In particular, ammonia can be of importance in stimulating phytoplankton growth, while warm fresh water is generally detrimental to the cells. Locating sources of ammonia and freshwater runoff are the first step to understanding the interactive effects of growth mechanisms in different parts of the Seahurst Park Bight.

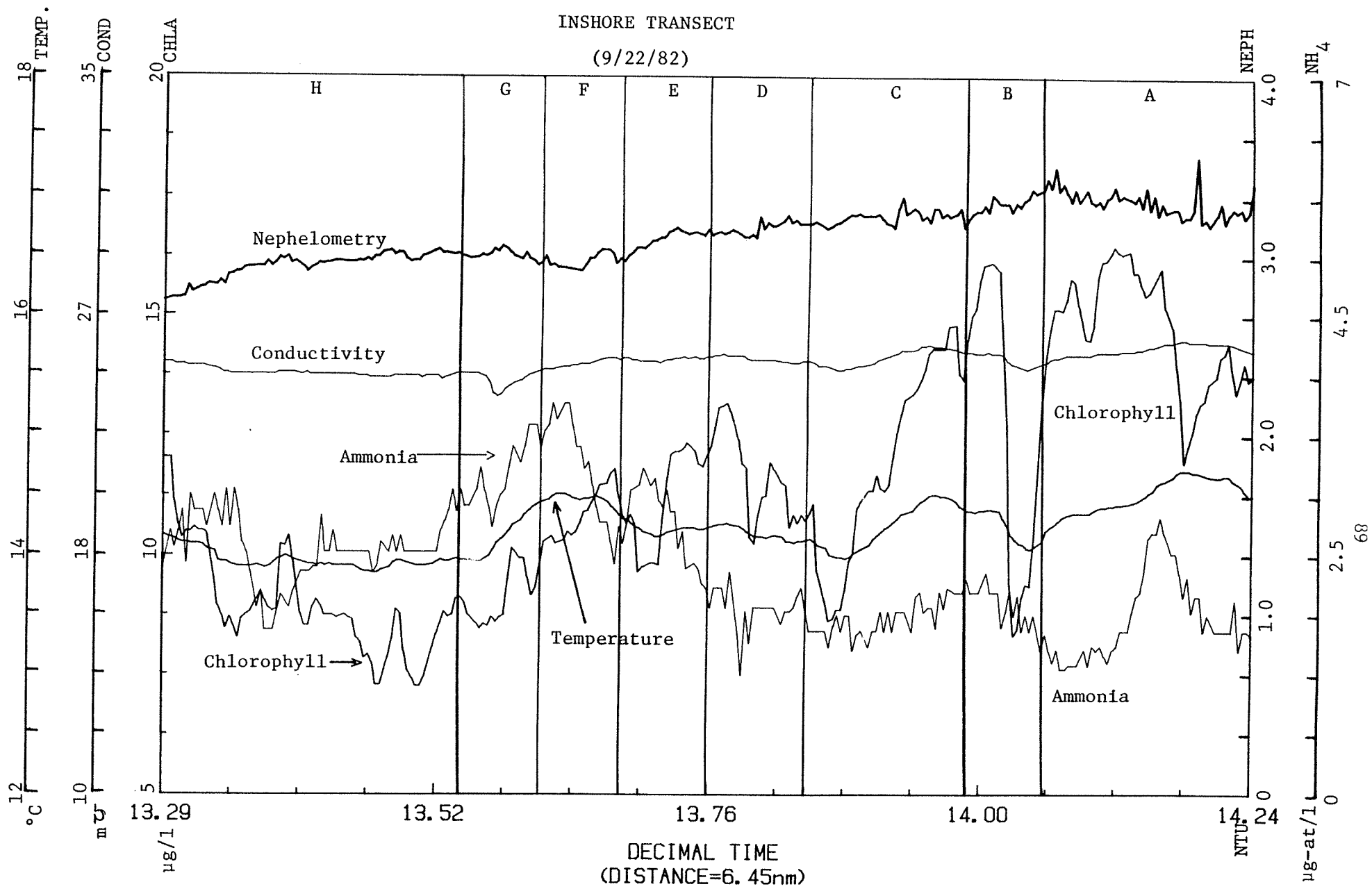



Figure 4.29. Underway surface mapping in the Seahurst Park area, September 22, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

Further documentation of the general patterns found in the data presented here continues as later transects are analyzed. Seasonal changes as well as spatial changes will be examined during the remaining field season and throughout Phase 2.

4.4.3.2 Surface Water Properties Around Vashon Island

The underway mapping system was operated in midchannel from station 1 (off West Point), south through East Passage (Station 4) to the Commencement Bay area (station 3) north through Colvos Passage, stopping at station 2, and finally north to Shilshole Bay Marina. Selected sections of the data obtained on two sampling dates, 7/16/82 and 12/07/82, representative of summer and winter cruise tracts, are shown in Figures 4.30 A-C and 4.31 A-D. Data are presented in pieces running from one wide area station to another. In examining these transects, it must be noted that the time/distance scales are much larger than were those for the inshore transects, and thus consist of many more data points (the acquisition rate of the system is one measurement every 30 seconds), accounting for the jagged appearance of the sections.

Few generalizations can be made for this series of underway data due to the large area being sampled and the wide range of marine environments which it represents.

Examining first a summer transect in some detail, it is apparent that different areas of Puget Sound can be identified by their surface water characteristics.

Leaving West Point for East Passage (Figure 4.30A) temperature and conductivity rises slightly while chlorophyll and nephelometry fall, indicating a movement to the saltier, clearer water away from the influence of ship canal and West Point outfall sediment loading. Temperature and conductivity remain relatively constant on the journey to East Passage (14.2

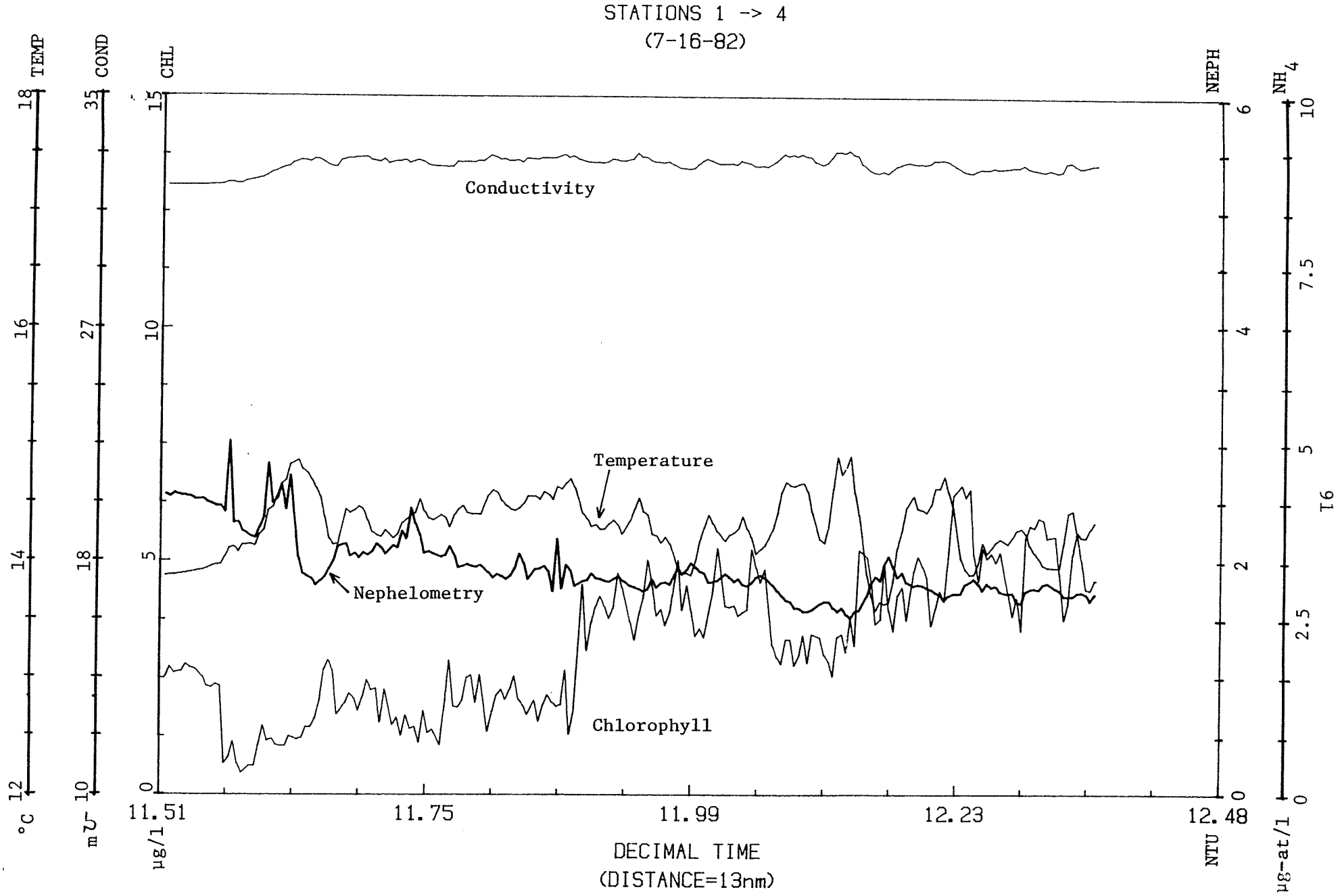



Figure 4.30A. Underway surface mapping around Vashon Island, July 16, 1982, showing temperature, conductivity, chlorophyll a and nephelometry over decimal time.

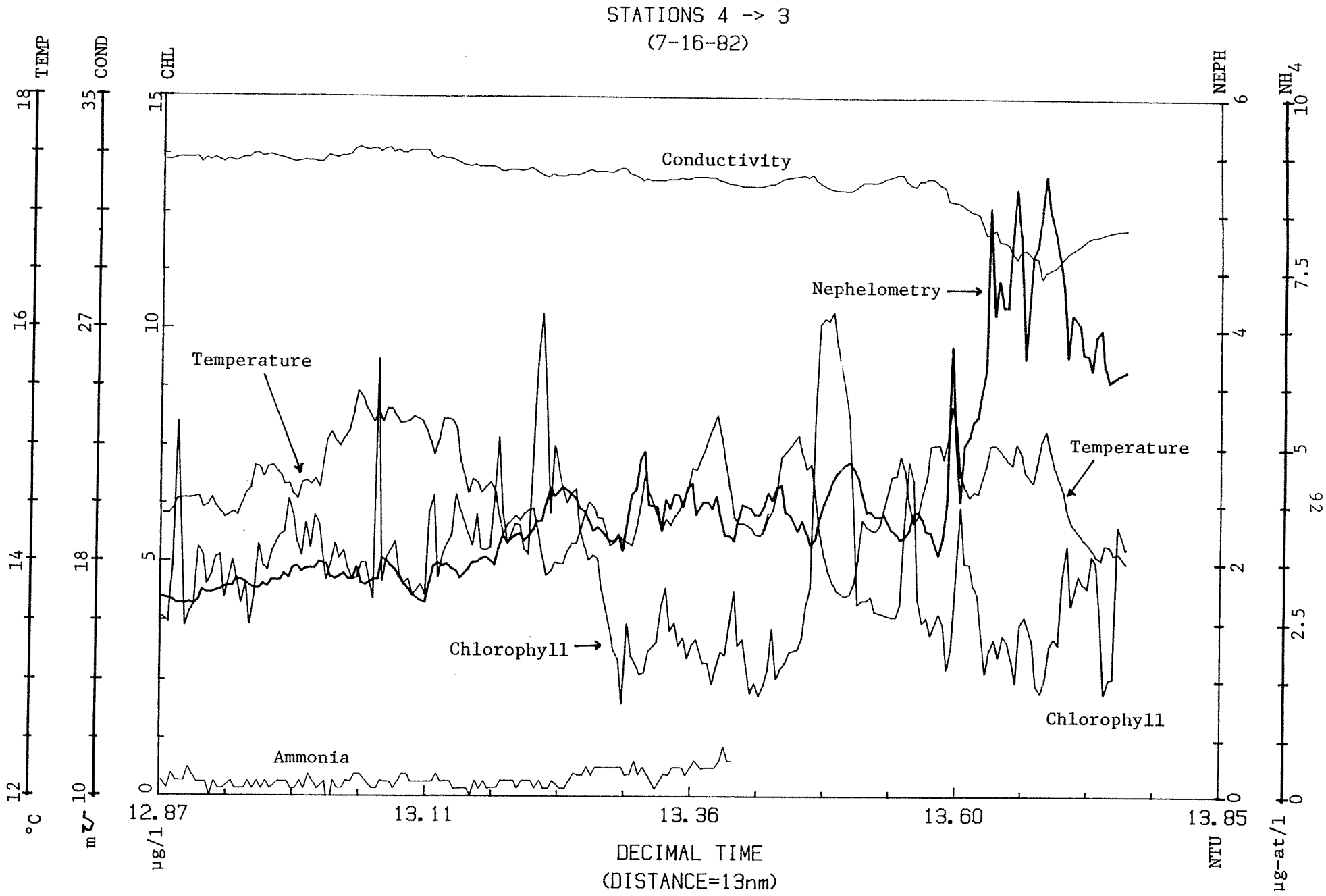



Figure 4.30B. Underway surface mapping around Vashon Island, July 16, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

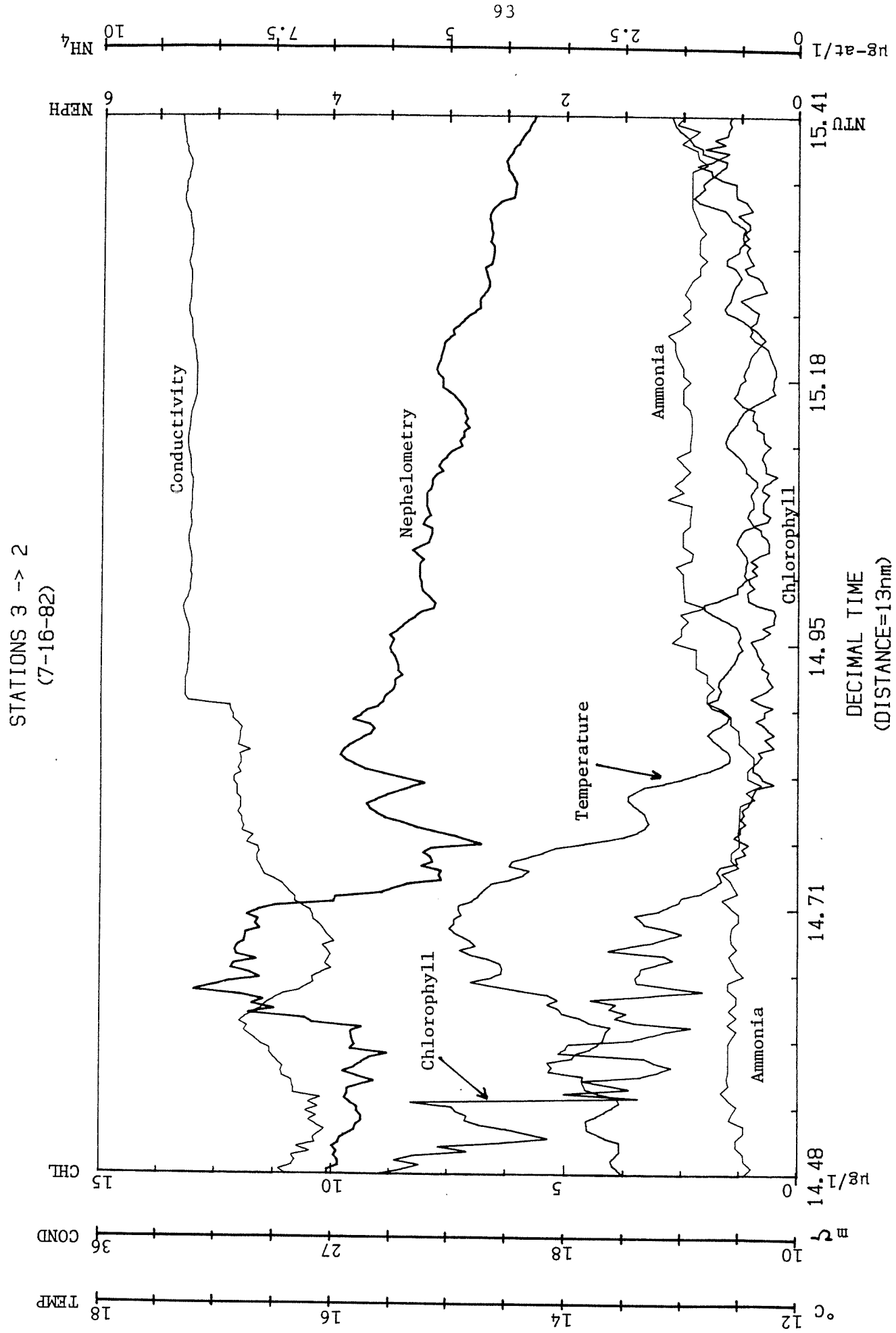



Figure 4.30C. Underway surface mapping around Vashon Island, July 16, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

C, and 17.5 mU, respectively), while chlorophyll rise steadily. Particle concentrations continue to decrease (from approximately 2.2 to 1.5 NTU) in the clear open Sound water.

Surface water properties from East Passage to Commencement Bay show a transition zone in conductivity and particle content in the area south of Poverty Bay (Figure 4.30B). Fresh, sediment-laden water is seen in this area. The particles are not associated with phytoplankon (no rise in chlorophyll levels), indicating a terrigenous origin, possibly from Commencement Bay. Chlorophyll levels are high (5-10 ug/1) throughout East Passage, with localized minima off Poverty Bay and at the southern tip of Vashon Island, indicating a possible inhibitory effect, such as a freshwater lens from Commencement Bay. Ammonia levels are low (>.5 ug-at/1) and variable.

Following a time lag (for discrete station work) the cruise track continued up Colvos Passage. Sharp rises in nephelometry and temperature and a fall in conductivity (at 14.7 hours) mark the same water mass that was observed previously at station 3 (Figure 4.30C). Data collected between 14.48 and 14.7 hours is indicative of another water mass which has replaced the previous one. This new water parcel is characterized by high chlorophyll levels (7.5 ug/1) and lower temperature and particulate levels. After passing the warm fresh Commencement Bay water parcel, surface water properties return to previous levels: conductivity = 17 mU, nephelometry = 2.5 NTU, temperature and chlorophyll low (indicating a well-mixed system - a situation corroborated by vertial station profiles). Ammonia was low on this leg until chlorophyll fell below 1 ug/1. A lower phytoplankton biomass (caused by physical mixing of cells out of the photic zone) has lower nitrogen uptake requirements and would allow ammonia to accumulate in the water column, to levels of 1.5 ug-at/1.

The winter transect chosen took place on 12/07/82 and follows the same cruise track as that of 7/16/82 (Figure 4.31).

Beginning at the channel marker (Sierra Gulf ) off West Point (Figure 4.31A) the fresh cool water from the ship canal/outfall is quickly replaced by saltier warmer water (time = 9.25 hours). Proceeding south, Elliott Bay was traversed and appears as drop in temperature, conductivity and chlorophyll, and a marked rise in ammonia to 2+ ug-at/1 (time = 9.45 to 9.65 hours). Ambient levels of temperature and conductivity area maintained on the route south to Commencement Bay with a local minima south of Point Pulley. Particle concentrations, chlorophyll and ammonia remain low and somewhat variable to the Commencement Bay station.

Parcels of cool fresh water are seen on the approach to station 3 in Commencement Bay. An increase in nephelometry and ammonia (up to 5 ug-at/1) and a small rise in chlorophyll are associated with this water.

Leaving station 3, temperature, conductivity, nephelometry and ammonia return to average Puget Sound levels. Chlorophyll peaks briefly in southern Colvos Passage, then decreases to very low levels (<.5 ug/1). With the end of the phytoplankton peak (time = 13.22 hours), ammonia shows a local maximum (up to 4.5 µg-at/1), then returns to ambient levels (<1 ug-at/1). The well-mixed nature of the winter water column in Colvos Passage is clearly demonstrated in the flat curves for temperature, conductivity, nephelometry and chlorophyll.

From station 2 (Figure 4.31D) in Colvos Passage returning to Shilshole Bay, cooler fresher surface water is present with local minima at Elliott Bay (time = 13.25 hours) and off West Point (time =13.52 hours). The ammonia peak off Elliott Bay is less pronounced than it was earlier in the day, but high (3-4 µg-at/1) concentrations of ammonia are seen off West Point. Particle content of the water is low, as is chlorophyll except for a small maximum from

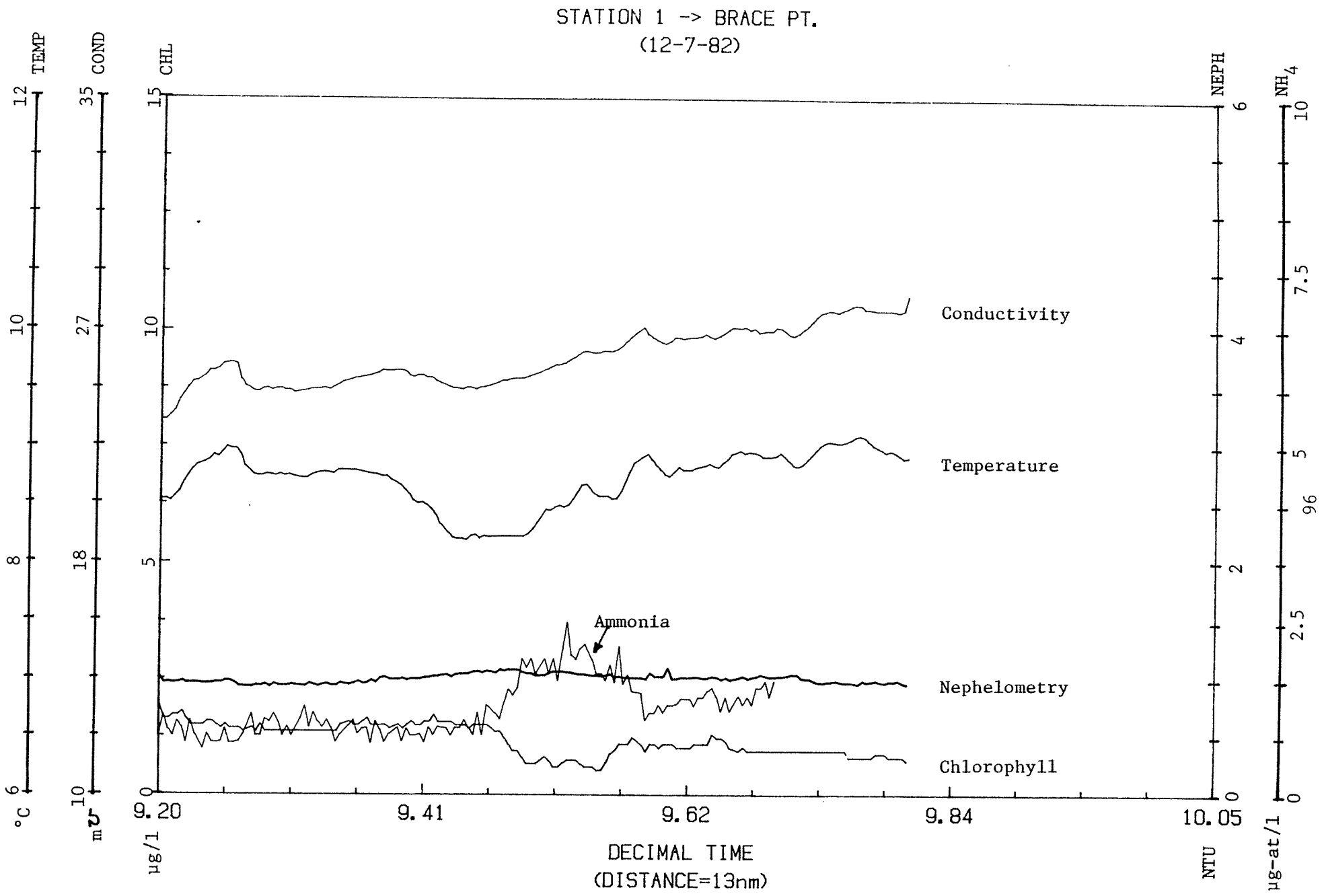



Figure 4.31A. Underway surface mapping around Vashon Island, December 7, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

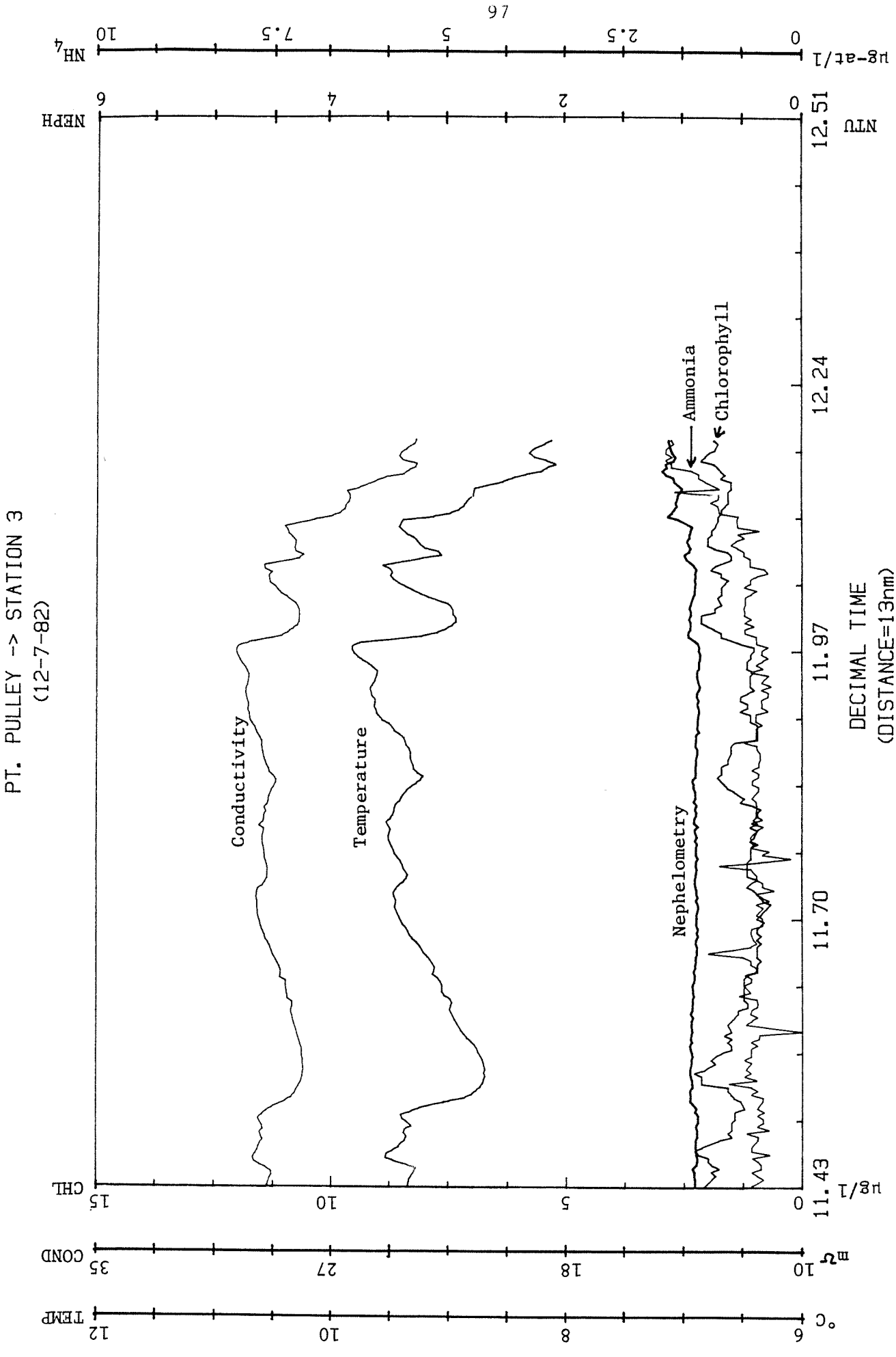



Figure 4.31B. Underway surface mapping around Vashon Island, December 7, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

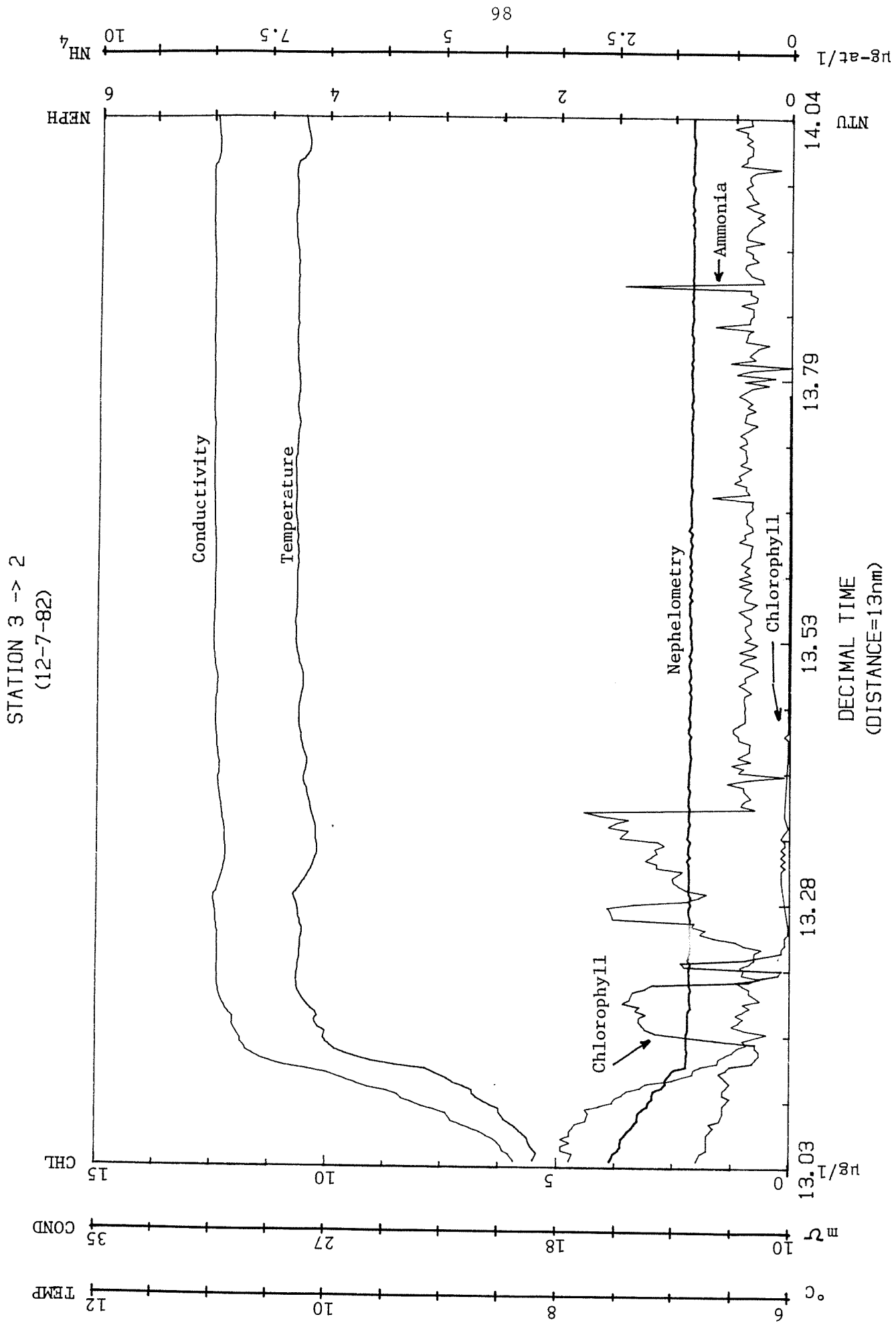



Figure 4.31C. Underway surface mapping around Vashon Island, December 7, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

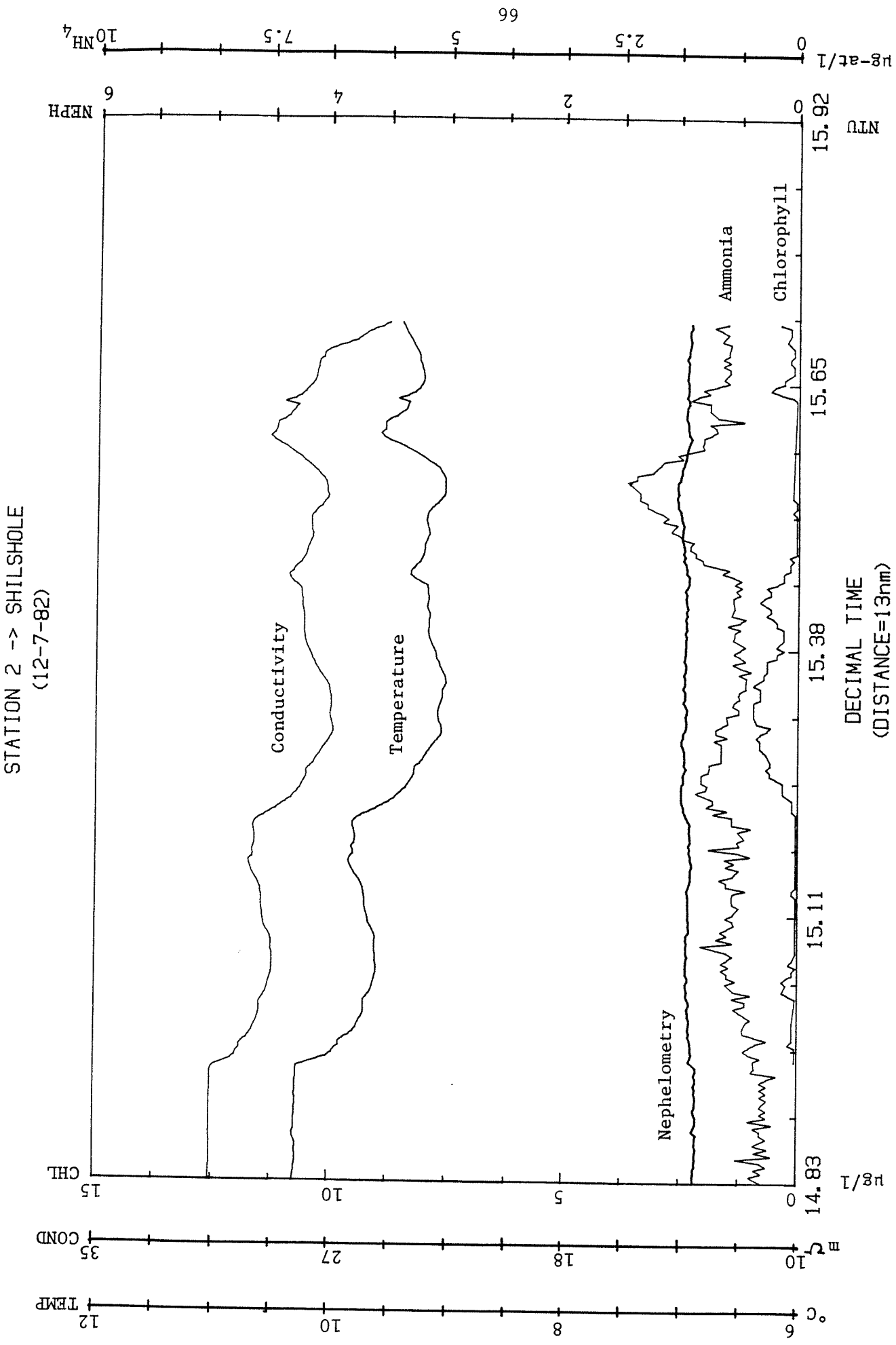



Figure 4.31D. Underway surface mapping around Vashon Island, December 7, 1982, showing temperature, conductivity, chlorophyll a, nephelometry and ammonia over decimal time.

Alki to Magnolia Bluff.

The low concentrations of chlorophyll and generally low particle content of the water observed on this day are to be expected as light is severely limiting to phytoplankton growth at this time and much of the particle content of the open waters of Puget Sound is related to living cells and detritus produced by recently living cells.

Despite the varied nature of the data from summer to winter sampling, a few generalizations may be reached:

1. Commencement Bay appears to be the origin of cool fresh water parcels which frequently are carried north into Colvos Passage, and occasionally into East Passage.
2. Ammonia associated with Commencement Bay parcels is utilized in situ by phytoplankton in summer and accumulates in the water column in winter.
3. Other freshwater sources can be pinpointed in Puget Sound, including the ship canal and/or the West Point outfall, Elliott Bay and Shilshole Bay Marina. Ammonia peaks may be associated with this freshwater.
4. Mixing of phytoplankton cells below the critical depth in Colvos Passage causes ammonia accumulation in the water column.

4.4.3.3 Special Underway Survey - Commencement and Elliott Bay Surface Water

A special underway survey was conducted on November 17, 1982 to study the surface water properties in Commencement and Elliott Bays. The purpose of the survey was to identify possible sources of water containing high levels of ammonia and particulates which might enter East Passage from the north (originating in Elliott Bay) or from the south (Commencement Bay). The cruise track passed the entrance to Quartermaster Harbor on Vashon Island and made

stops in Des Moines and Shilshole Marinas (Figures 4.32 and 4.33).

The cruise track down the main channel exhibited low concentrations of ammonia (1 ug-at/1) and of particulate material and average levels of chlorophyll. High concentrations of ammonia were observed in Commencement Bay (32 ug-at/1), at the entrance of Quartermaster Harbor (32 ug-at/1) and at the mouth of the Duwamish River (15 ug-at/1). Small increases in ammonia were evident in the two marinas (Des Moines Marina and Shilshole Bay Marina) (2 to 5 ug-at/1) as seen in Figure 4.34. High concentrations of particulate material was associated with river water from the Duwamish River which empties into Elliott Bay and the Puyallup River which empties into Commencement Bay (Figures 4.35). A peak of chlorophyll was observed in the freshwater plume originating from the Ballard Locks (position 4, Figure 4.36). Figure 4.37 further pinpoints freshwater locations by temperature.

The sources of ammonia in the surface waters are important because ammonia is known to be both a stimulant for phytoplankton growth and a toxicant for higher organisms. The ammonia in Elliott Bay is associated with the Duwamish River water, while an analysis of the distributions of ammonia and conductivity in Commencement Bay indicate that there are several non river-borne sources of ammonia in the Bay as indicated by high ammonia levels not associated with low conductivity. The presence of ammonia in Commencement Bay was not unexpected but the levels reached were surprising. High ammonia levels at the entrance to Quartermaster Harbor were not expected and there is a possibility that the large peak recorded (Figure 4.34) is due to instrument error. Additional investigations during Phase 2 should resolve this issue.

At this time, it is not possible to evaluate the effect high ammonia levels may have on phytoplankton growth or on the health of zooplankton and fish in Puget Sound. These questions are under investigation. The

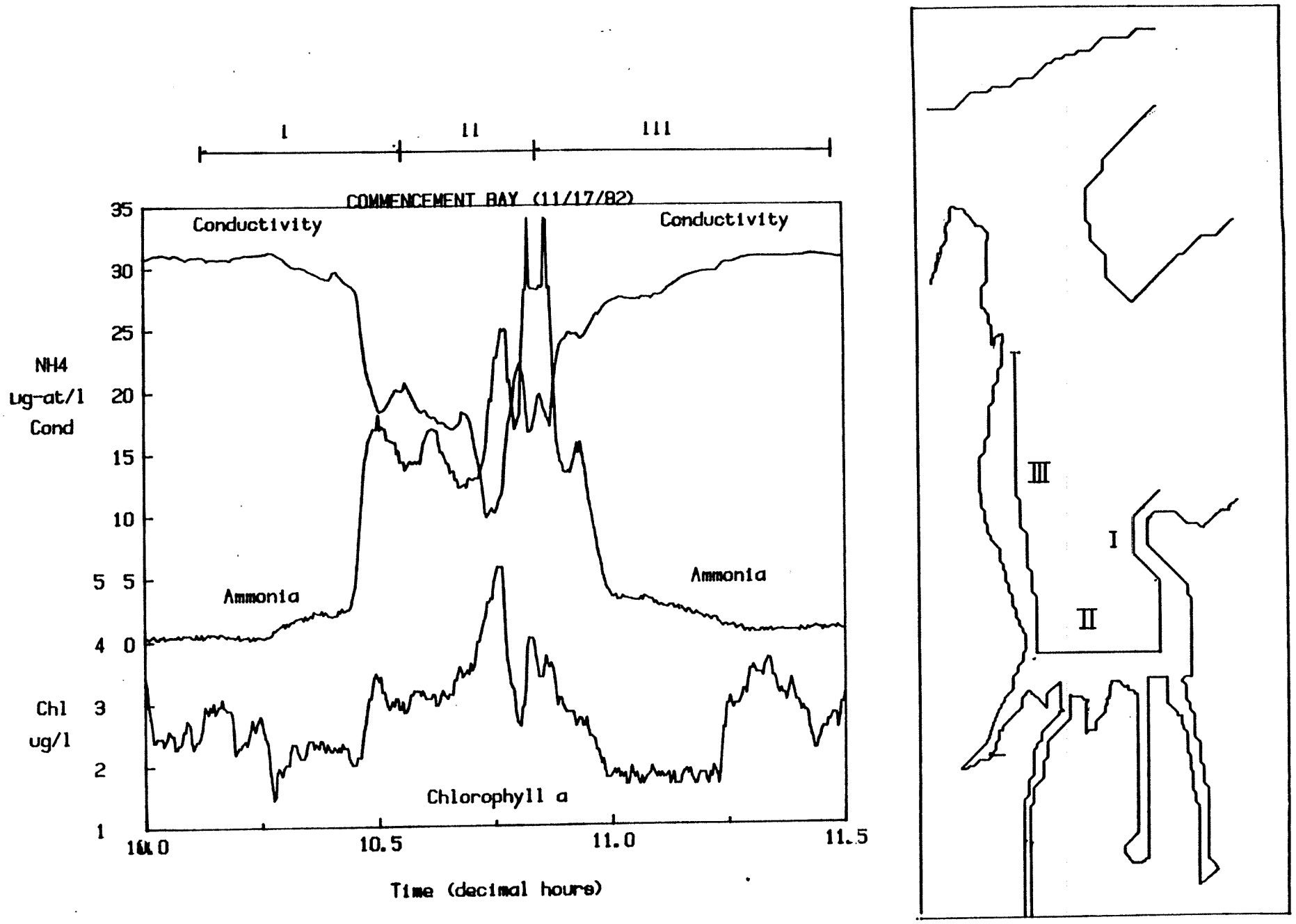



Figure 4.32. Section of a cruise track through Commencement Bay on November 17, 1982, showing conductivity, ammonia and chlorophyll a.

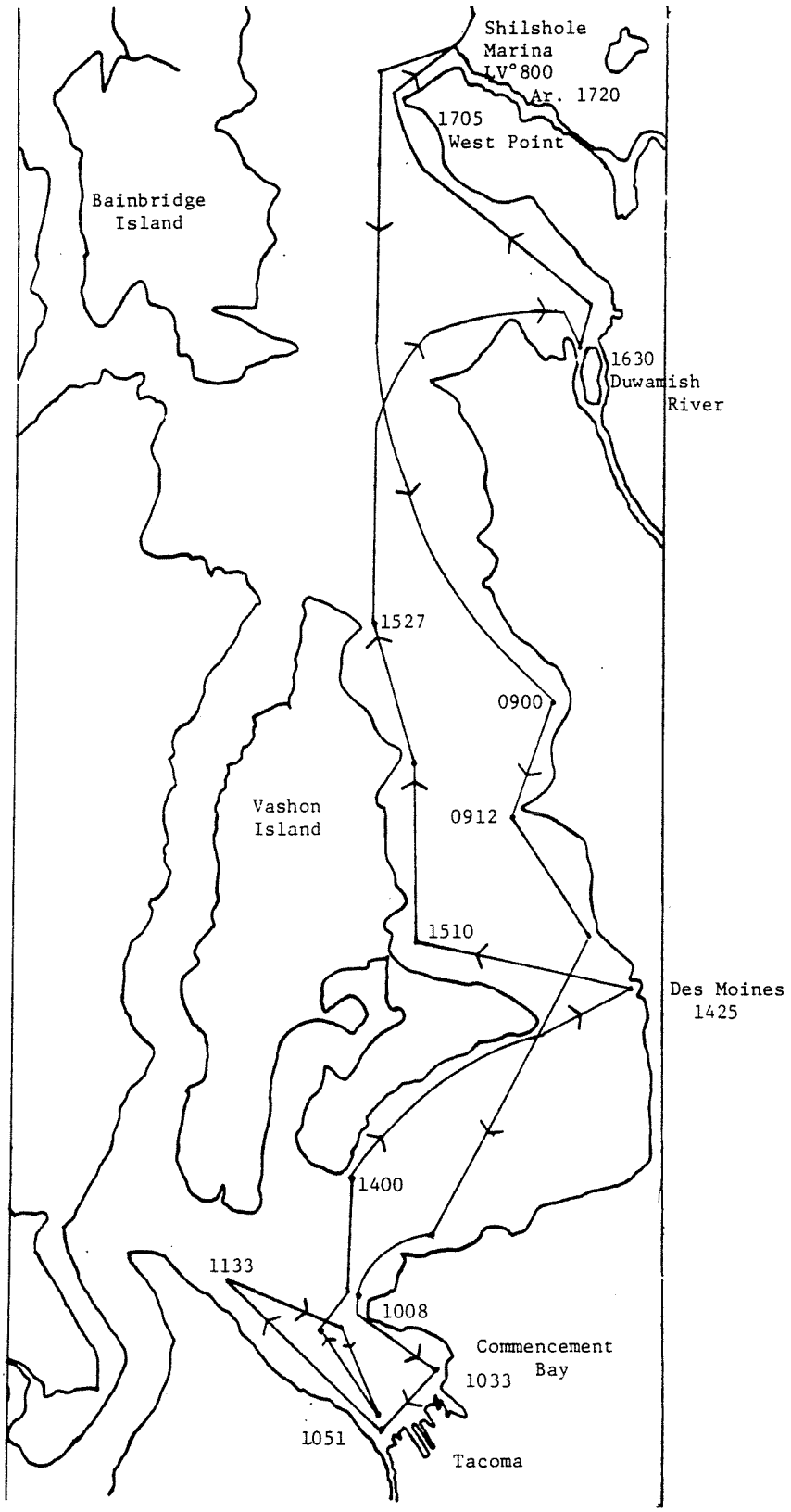



Figure 4.33. Cruise track of special underway sampling (Nov. 17, 1982) between Commencement Bay and Shilshole Marina. Special locations: (1) outside Quartermaster Harbor, (2) inside Des Moines Marina, (3) at mouth of Duwamish River, (4) crossing Ballard locks fresh water plume and (5) inside Shilshole Marina.

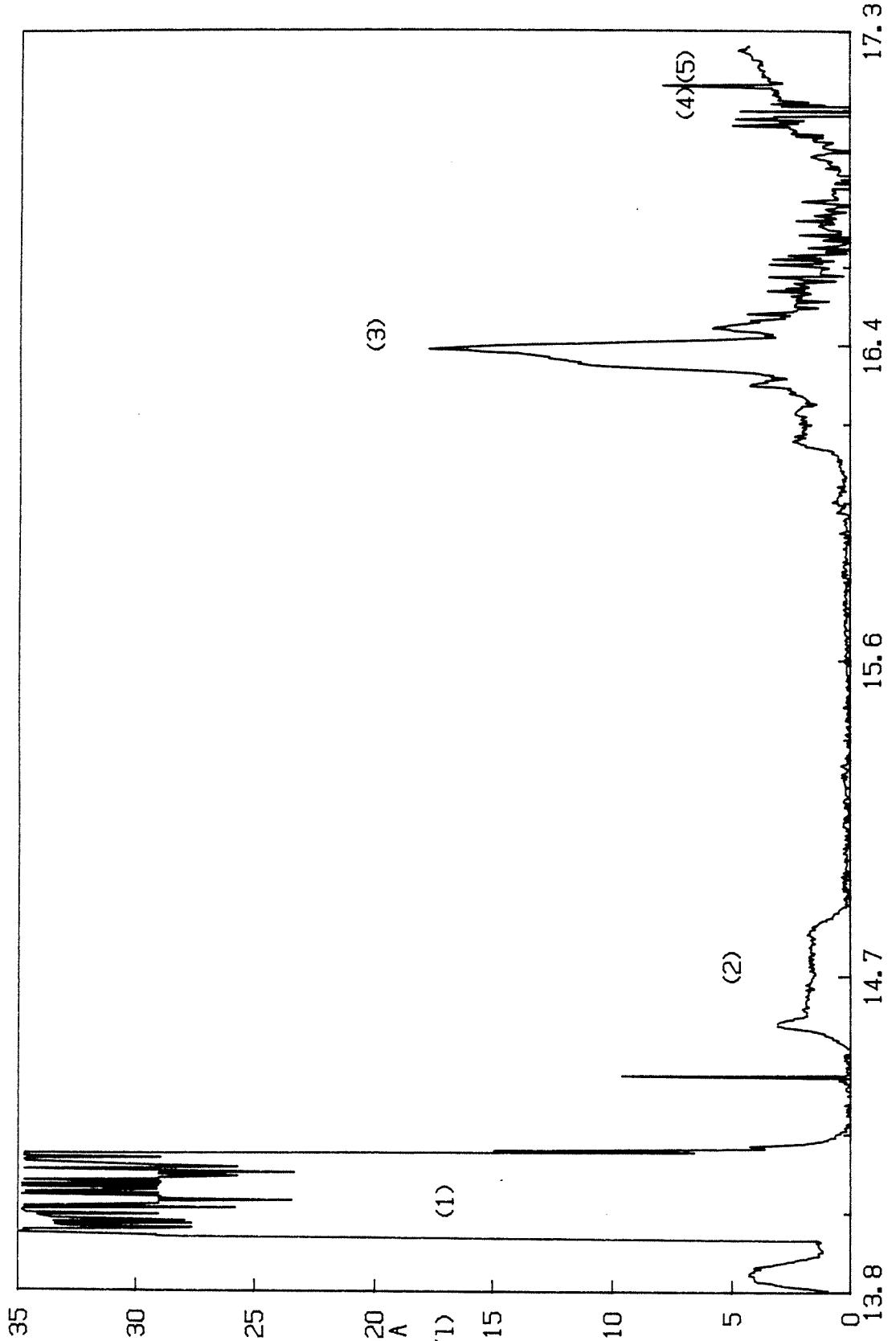



Figure 4.34. Ammonia in µg-at/l vs. time in decimal hours along cruise track of Figure 4.33 where locations are identified.

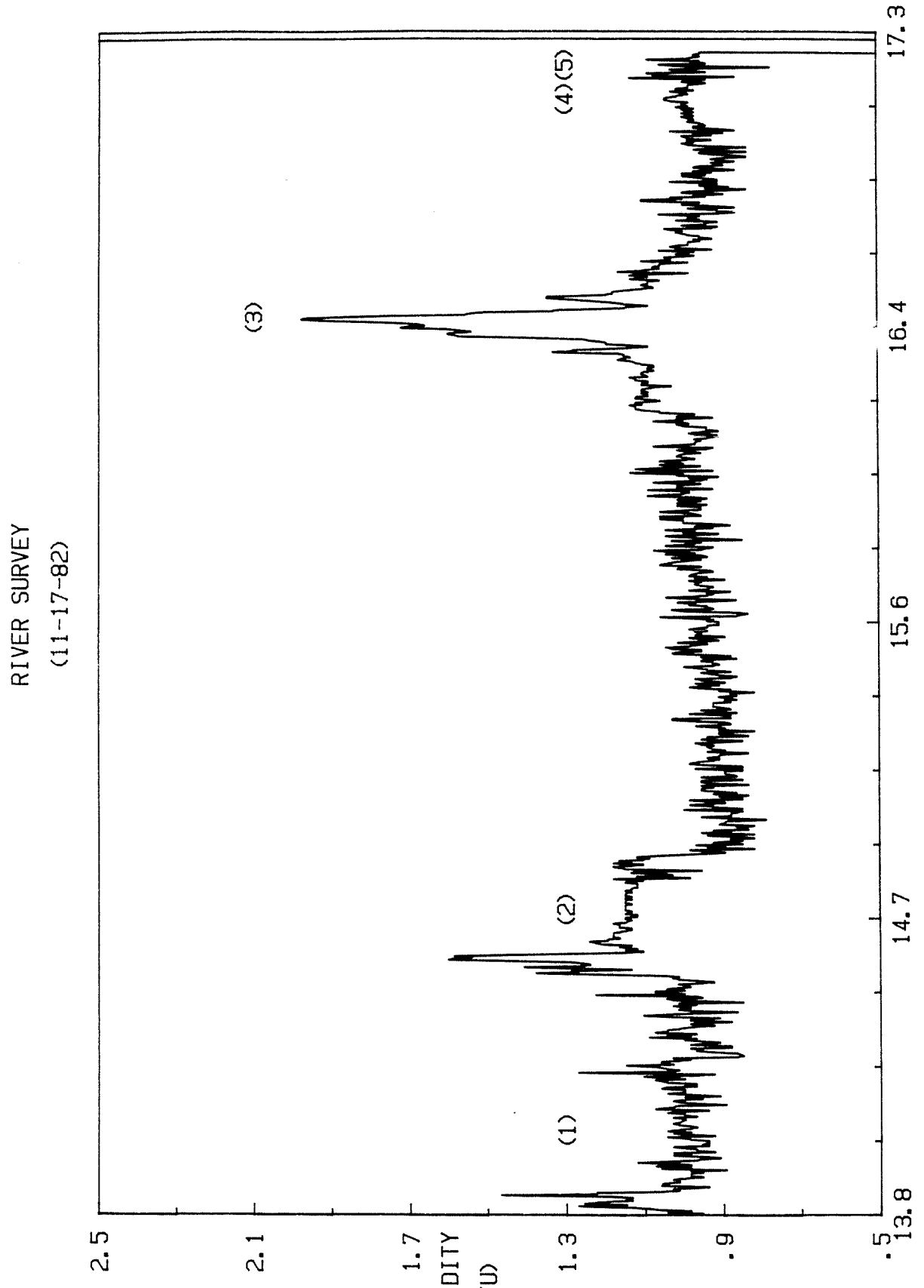



Figure 4.35. Nephelometer distributions vs. decimal hours along cruise track between Commencement Bay and Shilshole. Geographic locations identified in Figure 4.33.

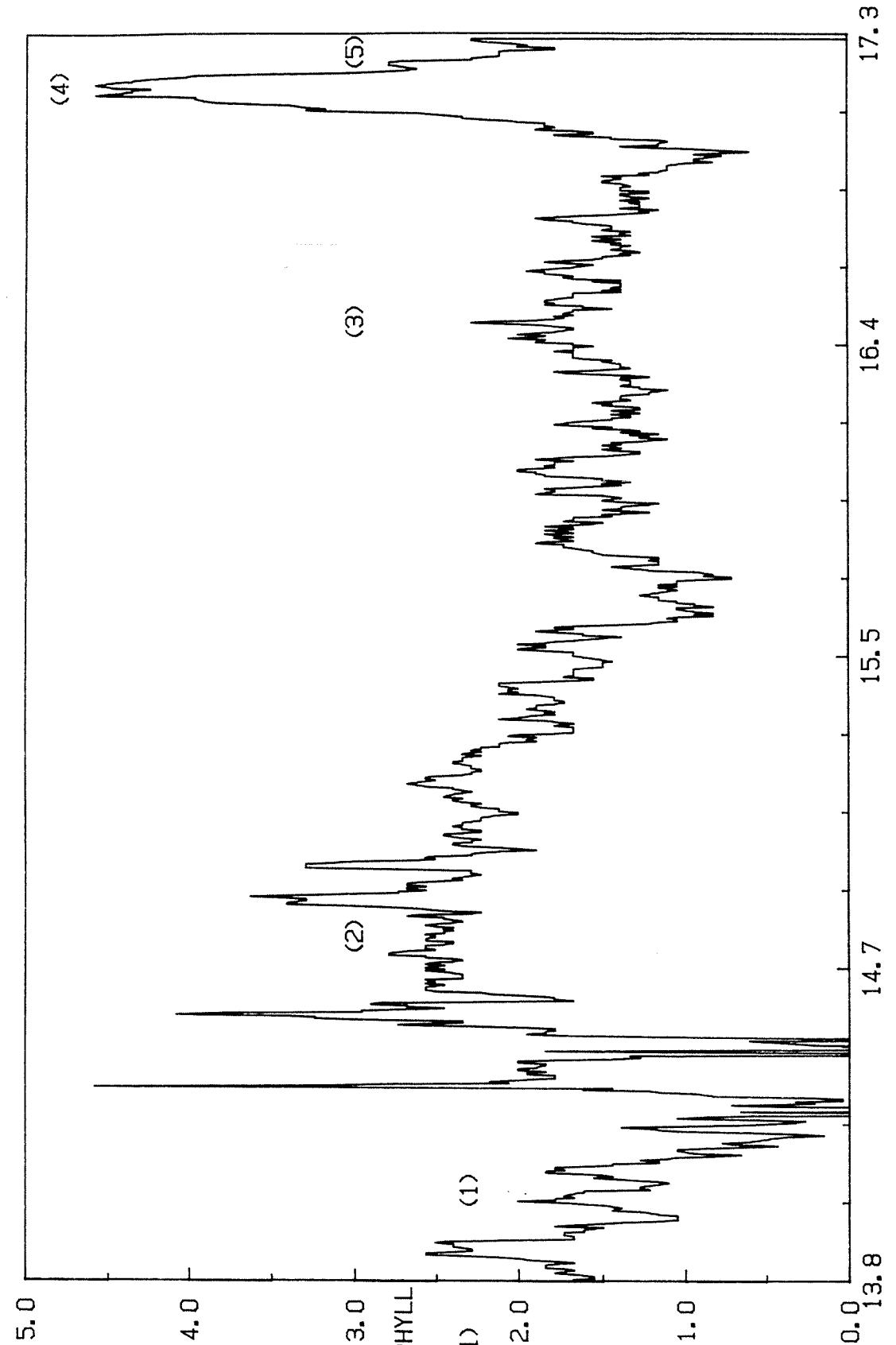



Figure 4.36. Chlorophyll distributions (µg/l) vs decimal hours along cruise track between Commencement Bay and Shilshole.

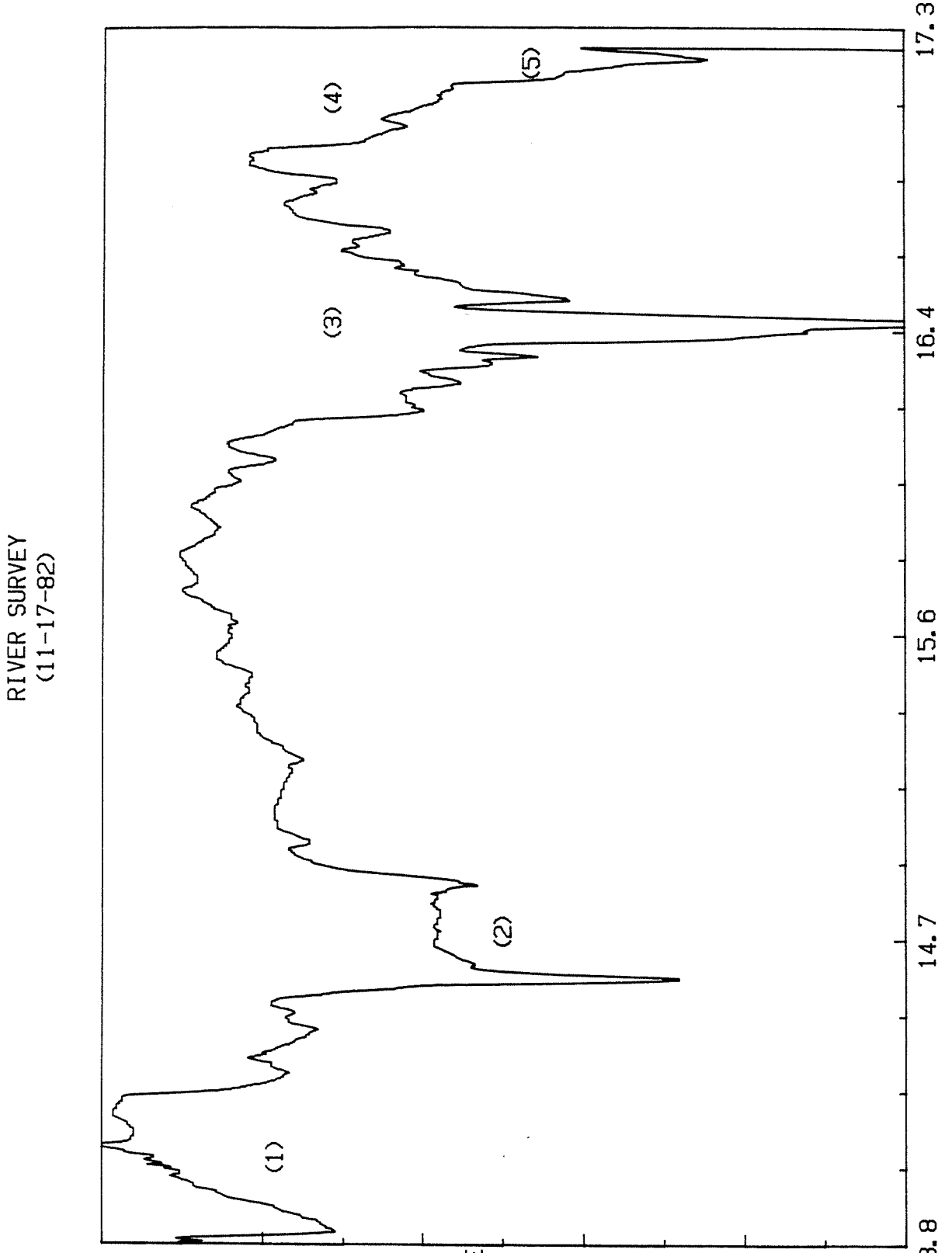



Figure 4.37. Temperature distribution (°C) versus decimal hours along cruise track from Commencement Bay to Shilshole.

chlorophyll peak associated with fresh water from the ship canal is a well documented fact (METRO Interim Report, 1974) and is probably the result of a brackish water environment which encourages growth of both marine phytoplankton and freshwater species carried from Lake Washington. The cruise track passed directly over the METRO West Point outfall. There was no indication of a surface effluent plume on any of the sensors.

4.4.4 Sediment Trap Studies

Two successful sediment trap deployments and recoveries have been completed during Phase I. The results of the second have not yet been analyzed. The results of the first deployment, which took place from November 24, 1982 until recovery on January 17, 1982, are summarized in Table 4.6.

Analysis of material captured by a pair of sediment traps showed no significant difference between traps for flux of phaeophorbide, total carbon, total nitrogen or dry weight. Certain differences between the traps can be seen by gross analysis, however: Trap A contained largely dark-colored sand. Additionally, trap A showed a lower amount of total material (as measured by dry weight analysis), but was richer in organics (0.30% Nitrogen, 3.08% Carbon) than was trap B (0.24% N, 2.17% C). Phaeophorbide, the major breakdown product of chlorophyll contributed to the traps as herbivore fecal pellets, was lower in trap A. Structurally, traps A and B differed in the presence of a plastic grate at the mouth of trap B, to encourage laminar flow at the mouth of the trap and to prevent washout (Gardner, 1978). Disturbance in the flow pattern around trap A may account for the absence of sand in that trap.

The deployment period of this array encompassed a time of high winds and stormy seas, which may have led to both intermittent washout of the traps and intervals of extremely high sedimentation from terrigenous sources, not

Table 4.6 Results of sediment trap sample analysis.

| Analysis | Trap A (w/o grate) | Trap B (w/ grate) |
|---|---|---|
| Phaeophorbide ($\mu g/cm^2/d$) | .0019 | .0027 |
| Total Nitrogen ($\mu m/cm^2/d$) | .333 | .319 |
| Total Carbon ($\mu m/cm^2/d$) | 3.415 | 2.860 |
| Dry Weight ($\mu g/cm^2/d$) | 111.05 | 131.80 |
| C/N | 10.37 | 10.15 |
| Gross Analysis | dark silt | light-colored sand |

necessarily typical of the East Passage area in the wintertime.

## 4.5 Conclusions

1. The wide area stations are distinct from one another biologically, chemically and physically.
2. Weekly variation in chlorophyll, dissolved nutrients and zooplankton biomass during the summer and fall are as great as the overall variation for this period. Temporal variation of these properties exceeds spatial variation among stations.
3. The nearshore and offshore areas cannot be distinguished in terms of phytoplankton productivity.
4. Concentrations of chlorophyll and nutrients in the surface water increase towards shore.
5. The species of dominant phytoplankton and zooplankton change over the summer season, and show differences between wide area and nearshore stations. Diatoms and herbivorous copepods are the common dominants.
6. Commencement Bay may be an important biological source of ammonia and may contribute surface water to the East Passage area. Also, Elliott Bay and the ship canal are responsible for significant incursions of fresh water into Puget Sound.
7. There is no evidence of bottom water intrusion into the nearshore region at Seahurst.

# 5.0 PHYSICAL/CHEMICAL OCEANOGRAPHY

C. C. Ebbesmeyer, C. A. Coomes, J. M. Cox

Evans-Hamilton, Inc.

## 5.1 Introduction

The data collected with METRO's conductivity-temperature-depth (CTD) system during 15 July through 31 October 1982 are described. Specifically, the data include temperature, salinity, density, and dissolved oxygen which are recorded simultaneously by the CTD system.

This report describes the locations of the CTD stations, the methods by which the profiles were calibrated, and the ancillary measurements of wind and runoff. Analyses of the data include comparisons with historical norms, and descriptions of the water structure and flow patterns.

## 5.2 Methods

The data consists of three types of observations: profiles of temperature, salinity, density, and dissolved oxygen; wind speed and direction; and discharge of selected rivers. The following sections describe the pertinent aspects of the observations.

### 5.2.1 CTD Profiles

METRO's CTD system was used to measure conductivity, temperature and depth (hence the name CTD), in addition to dissolved oxygen. The CTD system was manufactured by InterOcean Systems, Inc., and installed aboard METRO's research vessel Liberty.

The profiles were obtained at ten stations located in the southern portion of the Main Basin of Puget Sound (Figure 5.1). From north to south the stations were located as follows: station 1, off West Point; station 2, in northern Colvos Passage; station 4, mid channel off Seahurst Park in East Passage; stations 5, 6, 7, 8, 9, and 10 in Seahurst Bay, and station 3, off Brown's Point.

The stations were occupied at different frequencies. Table 5.1 shows the dates on which profiles were obtained. Stations 1, 2, and 3 were mostly sampled at two week intervals whereas stations 4 - 10 were sampled weekly.

The data were processed in a series of steps beginning with collection of raw data in the field, and ending with calibrated observations. The following steps of data reduction have been developed during this project:

1. The CTD was lowered from the R/V Liberty at a controlled rate close to 0.25 m/s between the water surface and approximately 5 m above the bottom. This distance (5 m) was maintained in order to assure safety of the CTD probe. The descent rate enabled the temperature, conductivity, depth, and dissolved oxygen to be recorded at a rate of eight to ten values per meter. These values were recorded aboard the R/V Liberty on a floppy disk using a micro-computer (Super brain).

   On each CTD cast, check samples were obtained using bottles and reversing thermometers. After the CTD probe completed its descent it was held at nearly constant depth and the reversing thermometers were allowed to equilibrate with surrounding waters for a period of five minutes. Afterward the thermometers were reversed and the bottle was closed; on the ascent a second bottle was closed near 20 m depth. The result was that check values of temperature, salinity

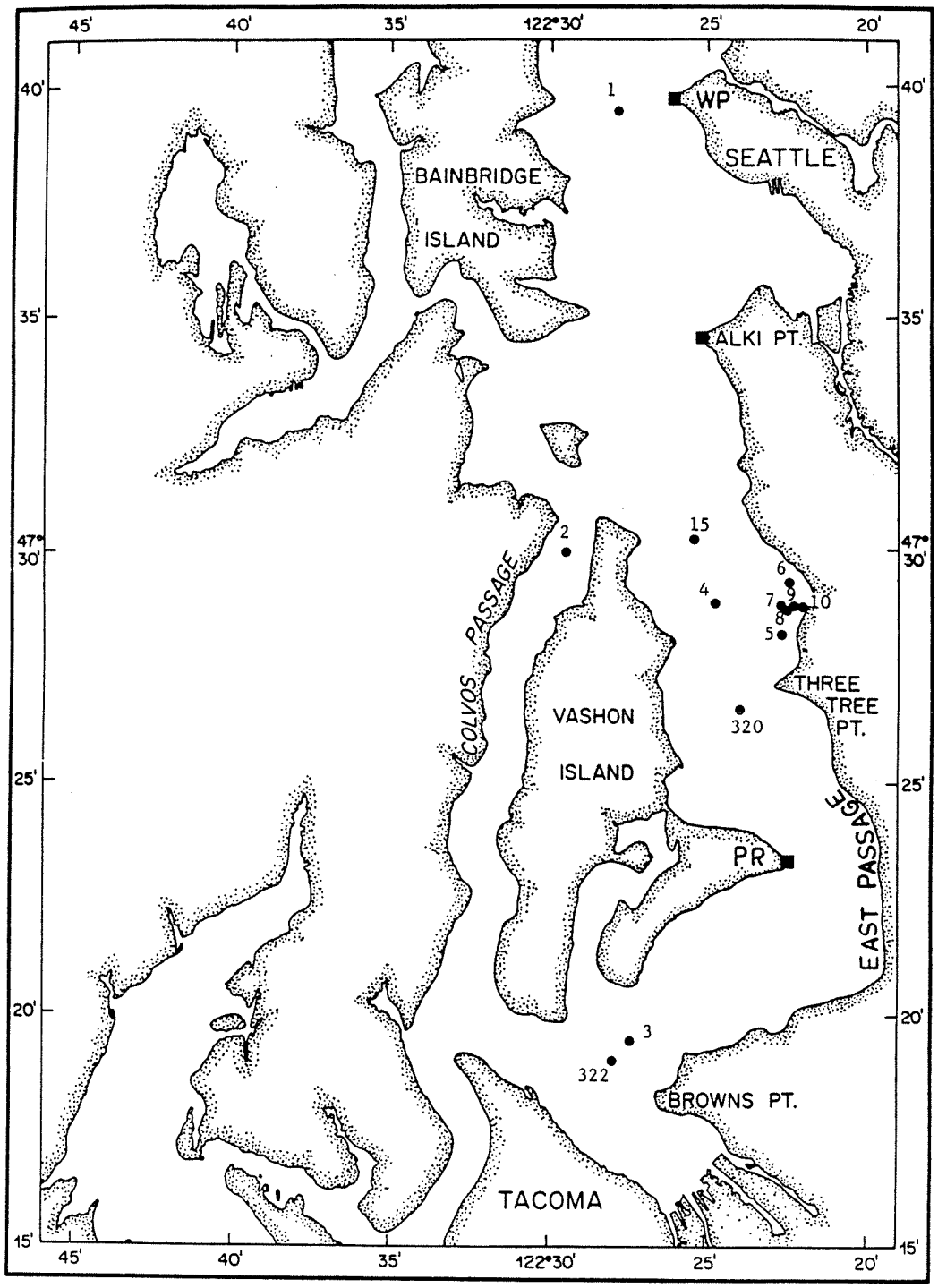



Figure 5.1. Locations of the 10 Baseline Monitoring stations, ETS station 15, historical sites 320 and 322, and wind stations (■) at West Point (WP), Alki Point, and Point Robinson (PR).

Table 5.1 Dates on which CTD profiles were obtained.

| Sampling interval | Date | Stations sampled | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 7/15/82 | | | | X | X | X | X | X | X | X |
| | 7/16/82 | X | X | X | X | | | | | | |
| | 7/19/82 | | | | X | X | X | X | X | X | X |
| 2 | 7/26/82 | X | X | X | X | | | | | | |
| | 7/28/82 | | | | X | X | X | X | X | X | X |
| 3 | 8/2/82 | | | | X | X | X | X | X | X | X |
| 4 | 8/9/82 | | | | X | X | X | X | X | X | X |
| | 8/11/82 | | X | X | | | | | | | |
| 5 | 8/16/82 | | | | X | X | X | X | X | X | X |
| 6 | 8/23/82 | | | | X | X | X | X | X | X | X |
| | 8/24/82 | X | X | X | | | | | | | |
| 7 | 8/30/82 | | | | X | X | X | X | X | X | X |
| 8 | 9/7/82 | | | | X | X | X | X | X | X | |
| | 9/9/82 | X | X | X | | | | | | | |
| 9 | 9/13/82 | | | | X | X | X | X | X | X | X |
| 10 | 9/21/82 | | | | X | X | X | X | X | X | X |
| | 9/22/82 | X | X | X | | | | | | | |
| 11 | 9/27/82 | | | | X | X | X | X | X | X | X |
| 12 | 10/6/82 | X | X | X | X | | | | | | |
| 13 | 10/11/82 | | | | X | X | X | X | X | X | X |
| 14 | 10/27/82 | X | X | X | | | | | | | |
| | 10/28/82 | | | | X | X | X | | X | X | X |

and dissolved oxygen were obtained near the bottom of each cast and near 20 m depth.

Finally, position and water depth were recorded at the beginning and end of each cast using Loran C and the radar coordinates of selected points of land.

2. The data on the floppy disks was then plotted. As the data came off the floppy disk the conductivity and temperature were converted to salinity and density values. The plots were reviewed and spurious points occurring mostly as spikes were deleted. The remaining data were averaged within the depth intervals of 0.5 m.

3. The averages obtained from the CTD profiles were compared with the check values. The check values of temperature, salinity, and dissolved oxygen were obtained from analysis performed at the University of Washington (UW). The comparisons yielded differences of CTD–check value at selected depths for salinity, temperature, and dissolved oxygen. Figure 5.2 shows a typical set of differences. The means and standard deviations of the temperature and salinity differences were computed for all values obtained within each sampling interval (Table 5.2). The mean differences were used to offset the CTD profiles.

In contrast with the salinity and temperature differences, the oxygen differences exhibited a dependence on depth (e.g., Figure 5.2). To account for this dependence the following equation was fit to the differences within each sampling interval using a least-square procedure:

$$\Delta DO = ae^{bz} - c, \qquad (1)$$

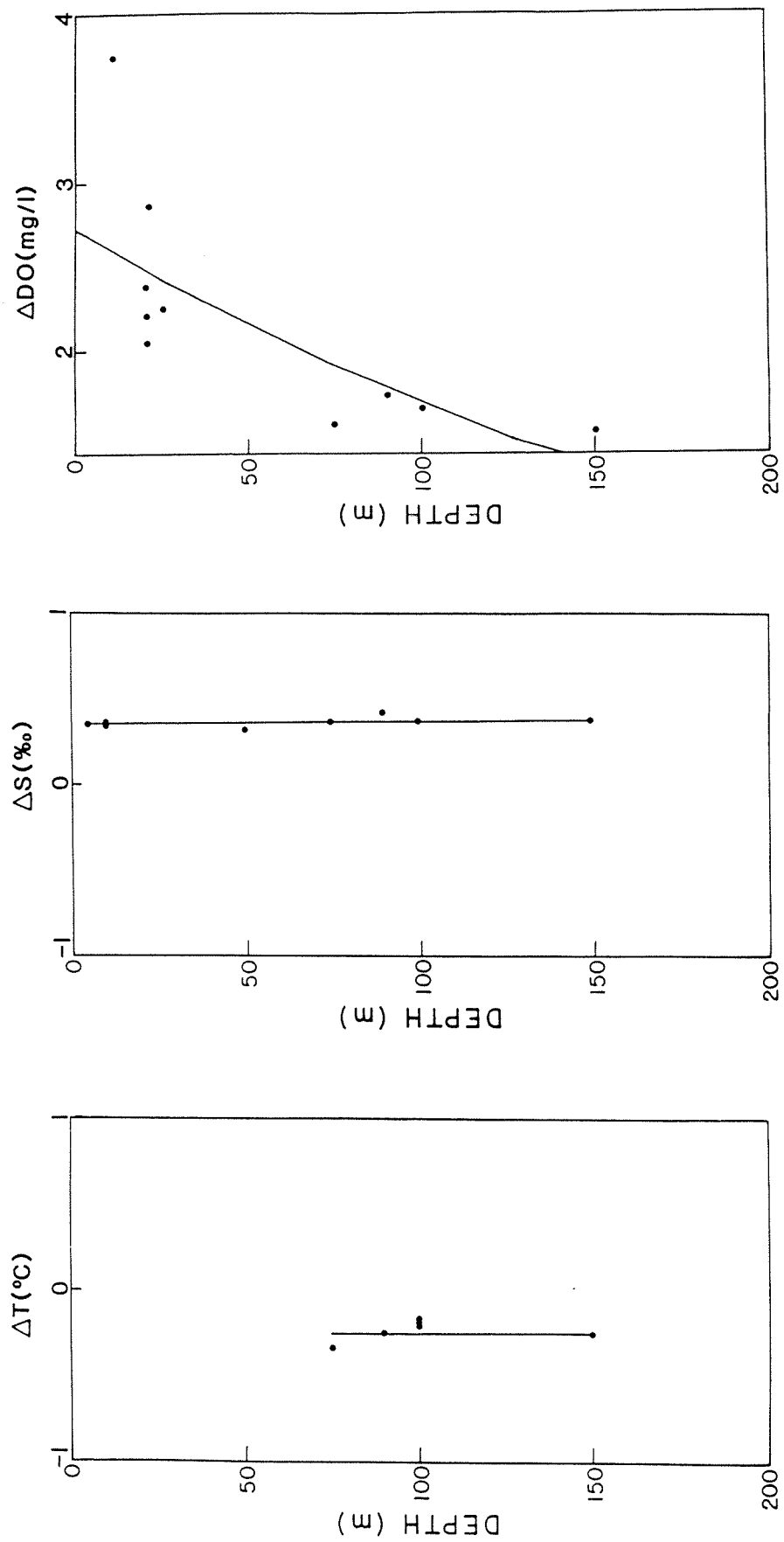



Figure 5.2. Differences of CTD-check values for temperature (a), salinity (b), and dissolved oxygen (c) during sample interval 9. Lines represent corrections applied to the data.

Table 5.2. Mean differences, sample sizes (n), and coefficients used to calibrate the CTD profiles. Also shown are the standard deviations of the differences between bottle and profile data after the calibrations have been applied.

| | ΔTemperature | | | ΔSalinity | | | | ΔDissolved Oxygen | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling interval | Mean | Standard deviation | N | Mean | Standard deviation | N | $r^2$ | a | b | c | Standard deviation | N |
| 1 | -0.207 | 0.0348 | 14 | 0.322 | 0.0406 | 19 | 0.351 | 4.480 | -0.00221 | 5 | 0.616 | 19 |
| 2 | -0.205 | 0.0439 | 6 | 0.330 | 0.0260 | 10 | 0.482 | 3.946 | -0.00103 | 5 | 0.188 | 17 |
| 3 | -0.249 | 0.00845 | 6 | 0.322 | 0.0178 | 9 | 0.612 | 4.133 | -0.00152 | 5 | 0.211 | 10 |
| 4 | -0.164 | 0.0348 | 8 | 0.335 | 0.0261 | 13 | 0.606 | 4.453 | -0.00392 | 0 | 0.377 | 17 |
| 5 | -0.301 | 0.0340 | 8 | 0.308 | 0.0423 | 11 | 0.766 | 4.423 | -0.00324 | 0 | 0.295 | 11 |
| 6 | -0.198 | 0.0456 | 10 | 0.322 | 0.0310 | 17 | 0.536 | 5.652 | -0.00227 | 0 | 0.636 | 22 |
| 7 | -0.202 | 0.0220 | 6 | 0.355 | 0.0247 | 18 | 0.895 | 4.388 | -0.01015 | 0 | 0.637 | 12 |
| 8 | -0.165 | 0.0225 | 10 | 0.332 | 0.0234 | 18 | 0.463 | 7.227 | -0.00205 | 5 | 0.915 | 23 |
| 9 | -0.254 | 0.0702 | 6 | 0.360 | 0.0295 | 9 | 0.629 | 2.721 | -0.00473 | 0 | 0.460 | 10 |
| 10 | -0.196 | 0.0386 | 6 | 0.323 | 0.0220 | 16 | 0.838 | 6.132 | -0.00175 | 5 | 0.230 | 12 |
| 11 | -0.158 | 0.0473 | 8 | 0.350 | 0.0169 | 11 | 0.765 | 6.550 | -0.00239 | 5 | 0.347 | 11 |
| 12 | -0.170 | 0.00957 | 4 | 0.417 | 0.0198 | 8 | 0.729 | 4.759 | -0.00122 | 0 | 0.248 | 8 |
| 13 | -0.159 | 0.0115 | 3 | 0.372 | 0.00649 | 9 | 0.218 | 5.265 | -0.000537 | 5 | 0.282 | 8 |
| 14 | -0.105 | 0.0622 | 8 | 0.383 | 0.0288 | 15 | 0.491 | 5.415 | -0.00169 | 5 | 0.393 | 14 |
| Mean | -0.195 | 0.0347 | | 0.345 | 0.0254 | | | | | | | |

where Table 5.2 lists the coefficients (a, b, c) for each sampling interval. The resulting equation for each sampling interval was used to offset the oxygen profiles as a function of depth. The final result was calibrated CTD profiles of temperature, salinity, density, and dissolved oxygen.

The calibration for dissolved oxygen show considerably more scatter than those for temperature and salinity. Oxygen probes are notorious for their erratic behavior. The calibration data presented here are all that could be obtained given the resources available to the Baseline project. It is realized that the data are erratic but an attempt has been made to calibrate them so that some usable information may be obtained. To our knowledge this is the first routine use of an oxygen probe in Puget Sound.

The present analysis is based on 113 profiles obtained during 15 July - 28 October 1982. Phase I of the Baseline program extended from 1 April 1982 through 31 March 1983, a period which is longer than the present data base. The difference in the time intervals may be explained as follows. First, METRO obtained its CTD system in March, 1982. Subsequently, the time during March, April, and May was devoted to modifying the CTD system so as to perform satisfactorily aboard the R/V Liberty. During June, the system was fully utilized by the oceanographic studies made in conjunction with the Effluent Transfer System (ETS). As a result, sampling for the Baseline study was delayed until mid-July. During the remainder of July and through August, September, and October sampling proceeded according to the intended schedule. During November the CTD system was again fully utilized by the ETS oceanographic studies. After the November ETS study, two months were required to calibrate the CTD data taken during December. However, in order to prepare

the yearly report, analysis had to begin in early January in order to produce a report by April, 1983. As a result this report focuses on the CTD data obtained between the two ETS studies. It should be noted that the ETS November data was yet uncalibrated as of 1 February 1983, and thus was not included in the present report.

The later analyses utilize averages computed at selected depths. Appendix 5A lists the calibrated data used in the computations.

5.2.2 Wind Observations

Figure 5.1 shows the locations of meteorological stations at West Point, Alki Point, and Point Robinson. Wind speed and direction recorded every third hour at these stations were obtained from the National Weather Service. Daily net wind speed and direction were computed.

5.2.3 River Discharge

Figure 5.3 shows the major rivers discharging into Puget Sound. Daily calibrated values were obtained from the U.S. Geological Survey (USGS) for eight gages on seven rivers: the gage at Union on the South Fork Skokomish River; Puyallup gage on Puyallup River; Auburn, Green River; Gold Bar, Skykomish River; Carnation, Snoqualmie River; Arlington, Stillaguamish River; Newhalem, Skagit River; and Concrete, Skagit River. The gaged values were used to compute the total runoff into Puget Sound using the technique described by Coomes et al. (1982).

5.2.4 Historical Data

Historical observations made off Three Tree Point (station 320, as indexed by Collias, (1970) and Browns Point (station 322) will later be compared with the recent CTD profiles (see Figure 5.1). A complete data list for these stations has been given by Ebbesmeyer et al., (1982).

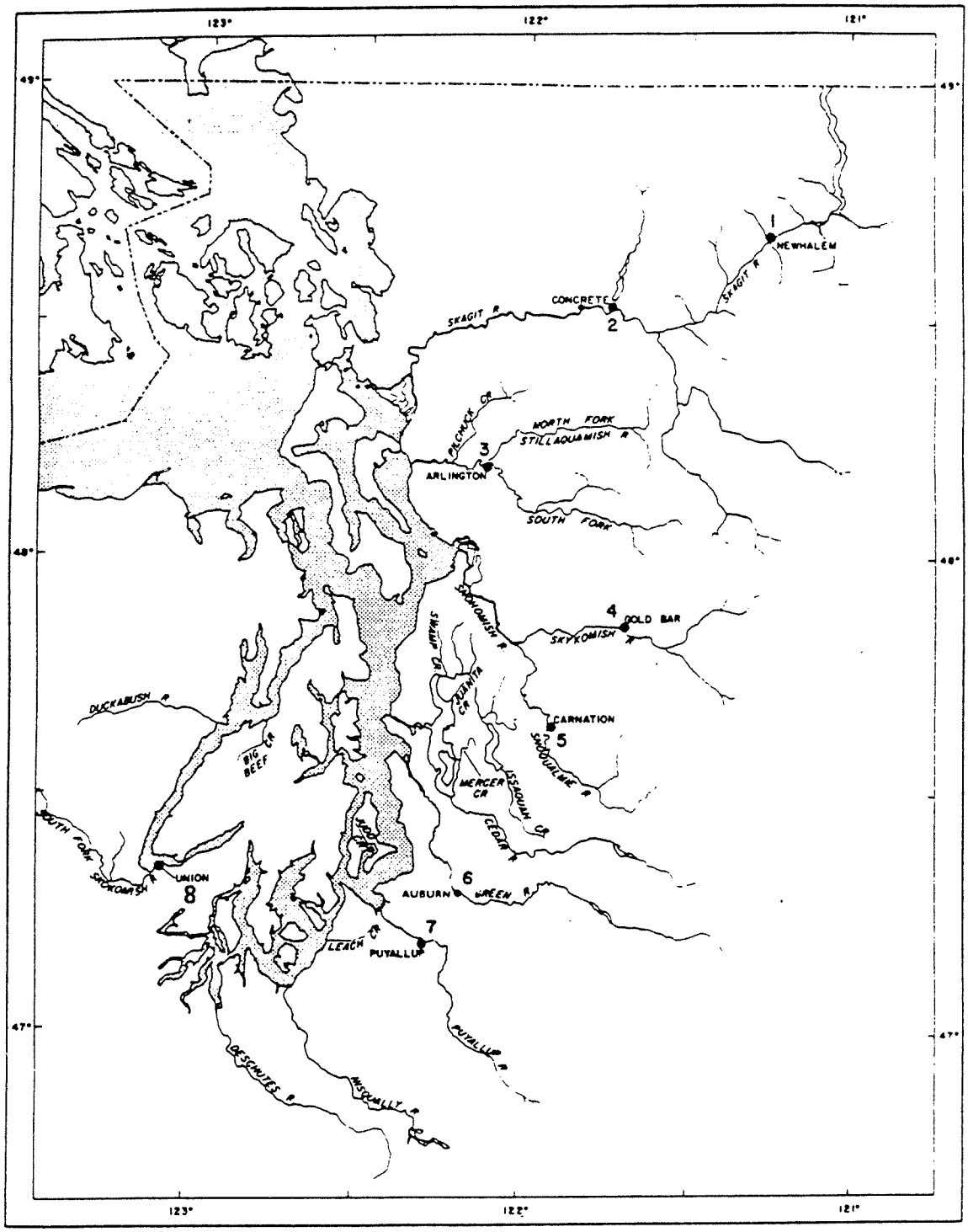



Figure 5.3. Locations of the major rivers discharging into Puget Sound. Numbers refer to the eight gage locations calibrated data was obtained from USGS.

## 5.3 Analysis and Results

This section consists of three elements: comparisons with historical norms; water mass structure; and flow patterns.

### 5.3.1 Comparison with Historical Norms

During many years historical observations of temperature, salinity, density, and dissolved oxygen have been made at mid-channel off Three Tree Point (station 320, Figure 5.1). The data obtained at this site were compared with the CTD data obtained at station 4 which is located approximately 5 km north of station 320 and ETS station 15 which is located 2.5 km north of station 4 (see Figure 5.1.). This historical site was used as opposed to others located between Brace Point and Point Robinson because it was visited most consistently over the years.

Figures 5.4 and 5.5 show the temporal progression of water properties versus depth for the historical and CTD stations, respectively. The historical data were contoured using monthly averages for July (8 observations), August (5), September (6), and October (8). The average date these values occurred near mid-month and were therefore plotted on the 15th of each month. The CTD data were contoured using observations obtained during the Baseline project of July-October and the ETS study in June.

#### 5.3.1.1 Temperature Comparison

Figure 5.6 shows vertical profiles of historical and CTD data averaged during August and September. The averages were computed by combining the mean monthly values obtained from individual observations for August and September. At depths shallower than 40 m the CTD values are cooler than the norm, whereas at greater depths the CTD values are warmer. The largest differences occur near the surface (0.2 $^{o}$C between 0 and 10 m), and below 100 m depth (0.05 $^{o}$C).

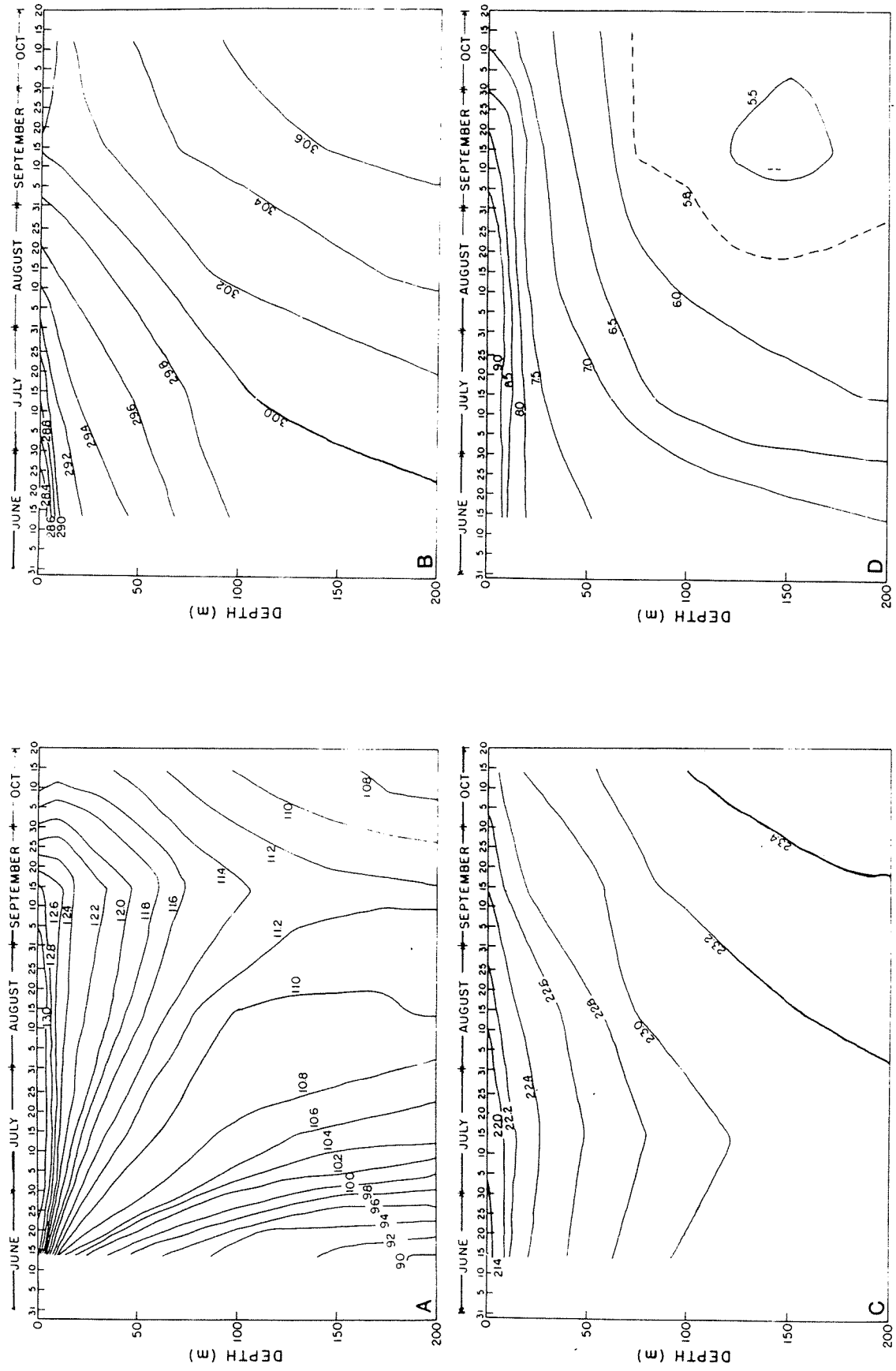



Figure 5.4. Temporal progression of temperature ($^{o}C$; A), salinity ($^{o}/oo$; B), density ($\sigma_t$ units; C), and dissolved oxygen (mg/l; D) for historical site 320.

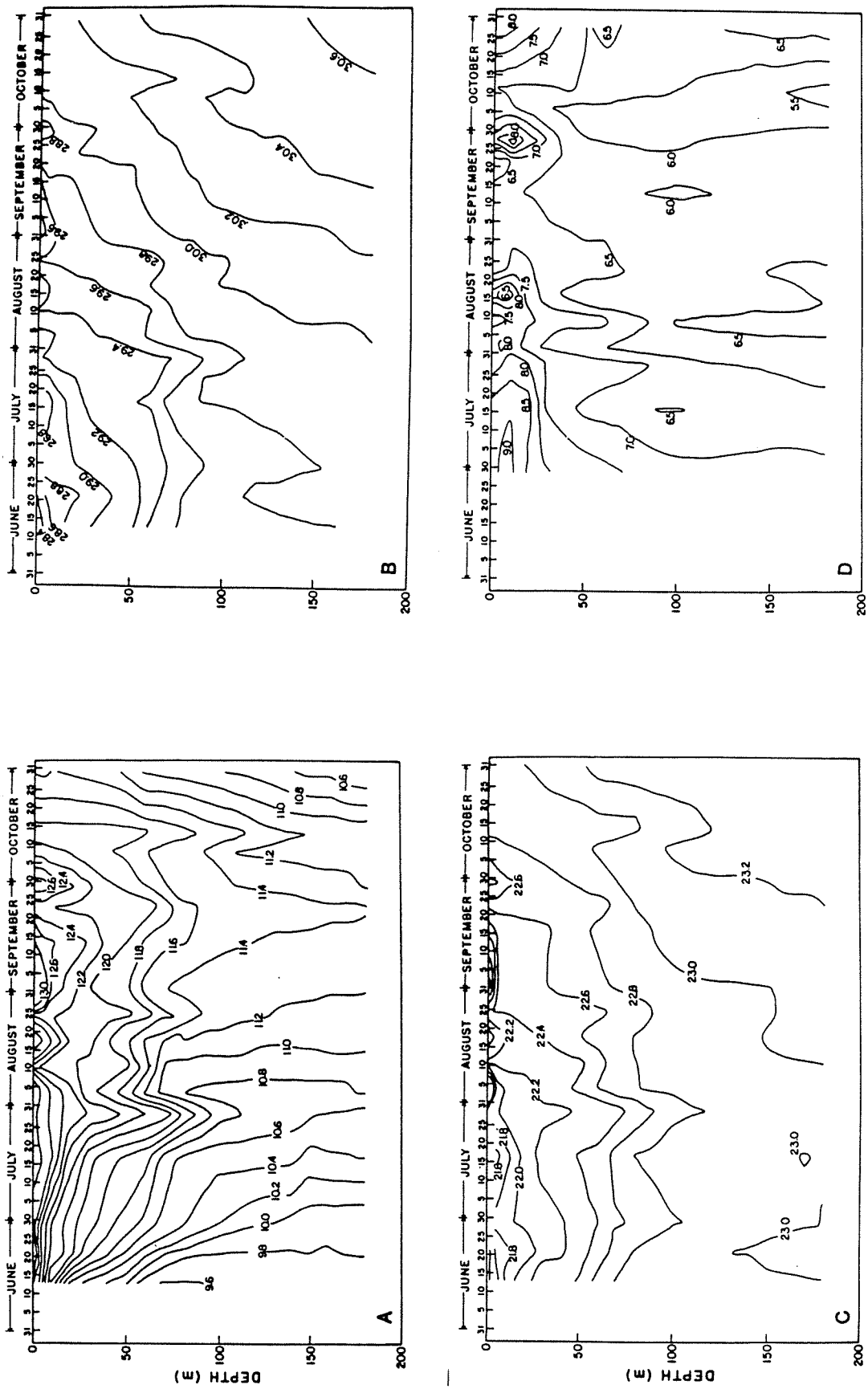



Figure 5.5. Temporal progression of temperature (°C; A), salinity (°/oo; B), density ($\sigma_t$ units; C), and dissolved oxygen (mg/l; d) for CTD stations 4 and 15 during 1982.

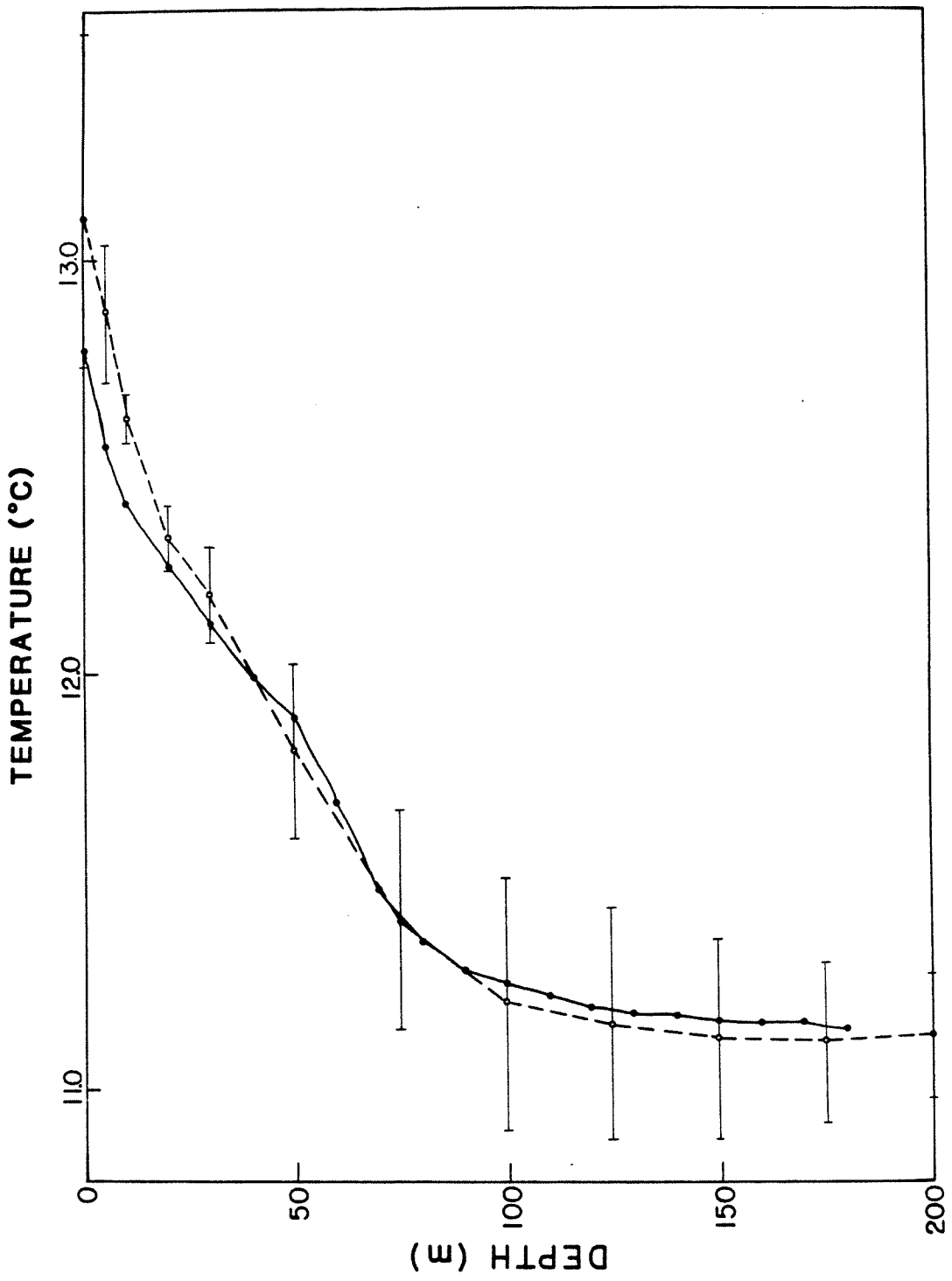



Figure 5.6. Vertical profiles of temperature (°C) for historical station 320 (dashed) and CTD station 4 (solid) during August-September. Bracketed line indicates 1 standard deviation from the historical norm.

Figure 5.7 shows the superimposition of selected isotherms in the time-depth plane. In general, the temperature patterns follow one another. To compare the temporal fluctuations more closely, Figure 5.8 shows the seasonal progression of the historical norm and CTD temperature at the surface and 100 m depth. Figure 5.9 shows an expanded view of the comparison. The CTD data show that the surface waters fluctuate about the norm, and the water near 100 m depth was slightly warmer than the norm most of the time.

5.3.1.2 Salinity

Figure 5.10 shows vertical profiles of historical and CTD salinity means for the months of August and September. Throughout the water column the salinities were lower than the norm by approximately 0.3 °/oo. Previously, Barnes and Ebbesmeyer (1978) and Ebbesmeyer and Barnes (1980) examined the longitudinal gradients along the Main Basin and found that they were slight. Ebbesmeyer and Barnes (1980) compared the deviations from the norm in salinity at 100 m depth at Point Jefferson, with deviations from the norm of runoff into Puget Sound. They found that increased runoff was correlated with decreased salinities. Because the longitudinal gradients are small in the Main Basin, it seems reasonable that a correlation can be made between Puget Sound runoff and CTD salinities observed at Three Tree Point at 100 m depth.

The persistently lower salinities off Three Tree Point suggest that total runoff was above normal. Unfortunately, the total river runoff could not be computed during January, March, July, and August because data were unavailable for the South Fork Skokomish River gage.

Figure 5.11 shows selected salinity contours in the time-depth plane for historical norms and CTD data. The CTD salinity pattern appears shifted toward later times than the historical norm on the order of a fraction of a month in the upper-layer, to a month at depth.

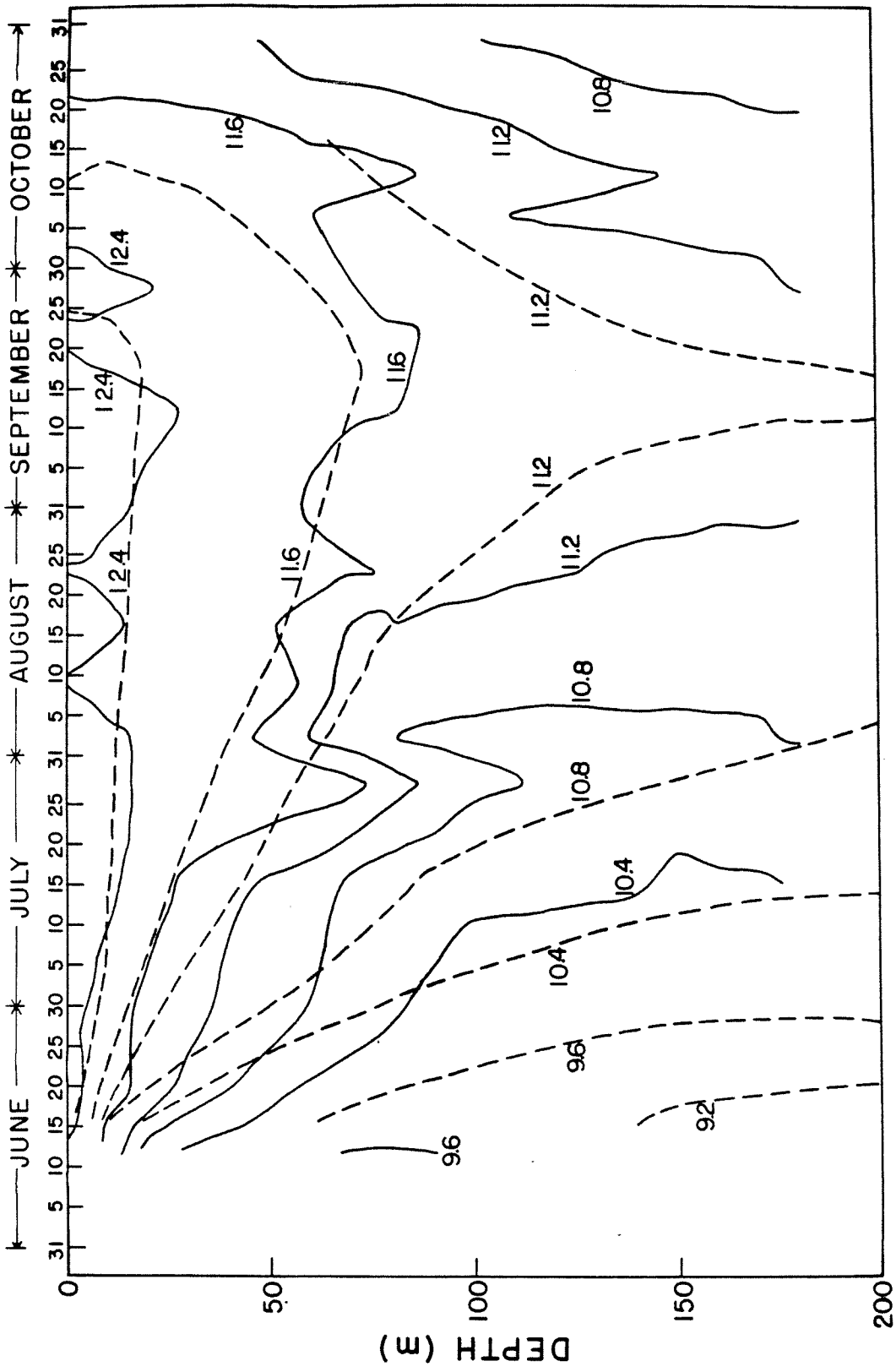



Figure 5.7. Temporal progression of selected isotherms (°C) for historical site 320 (dashed line) and CTD stations 4 and 15 (solid).

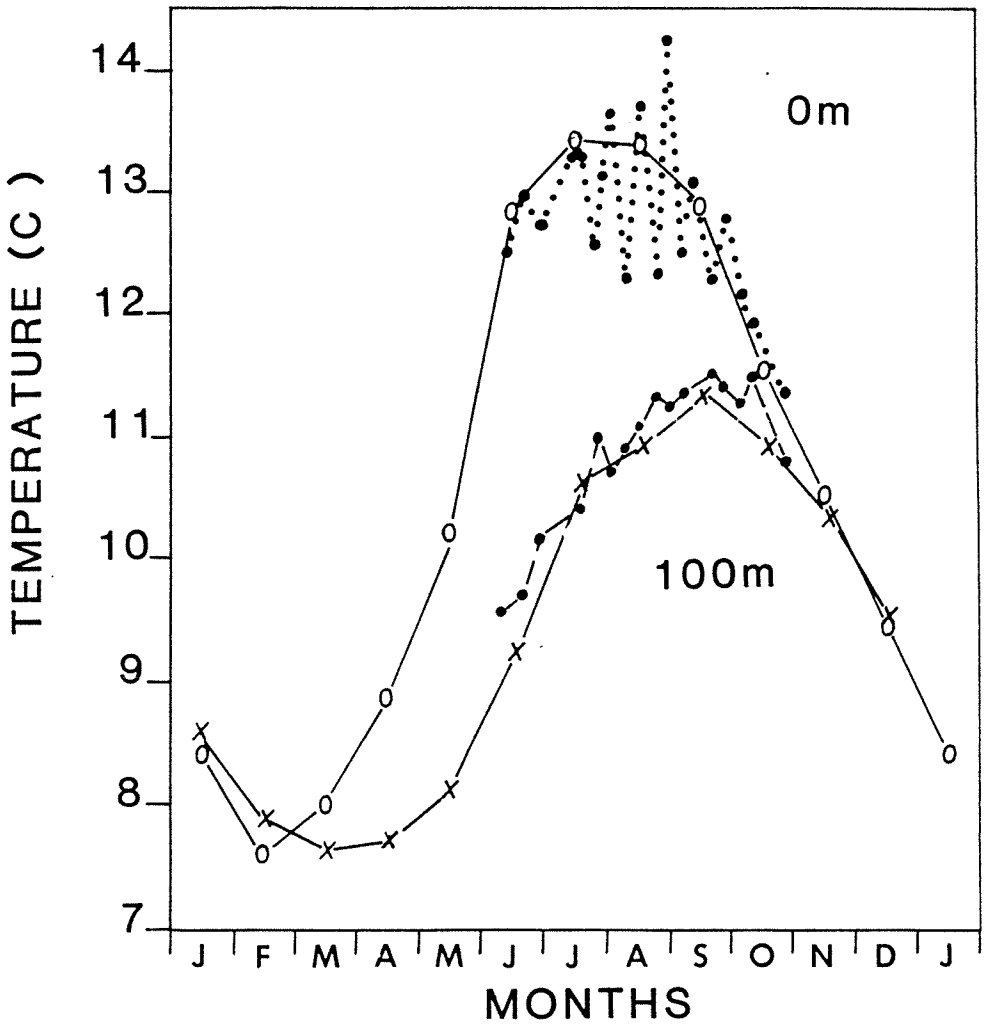



Figure 5.8. Seasonal progression of temperature at 0 m and 100 m depth for site 320 (solid) and CTD stations 4 and 15 (dotted, 0 m; and dashed, 100 m).

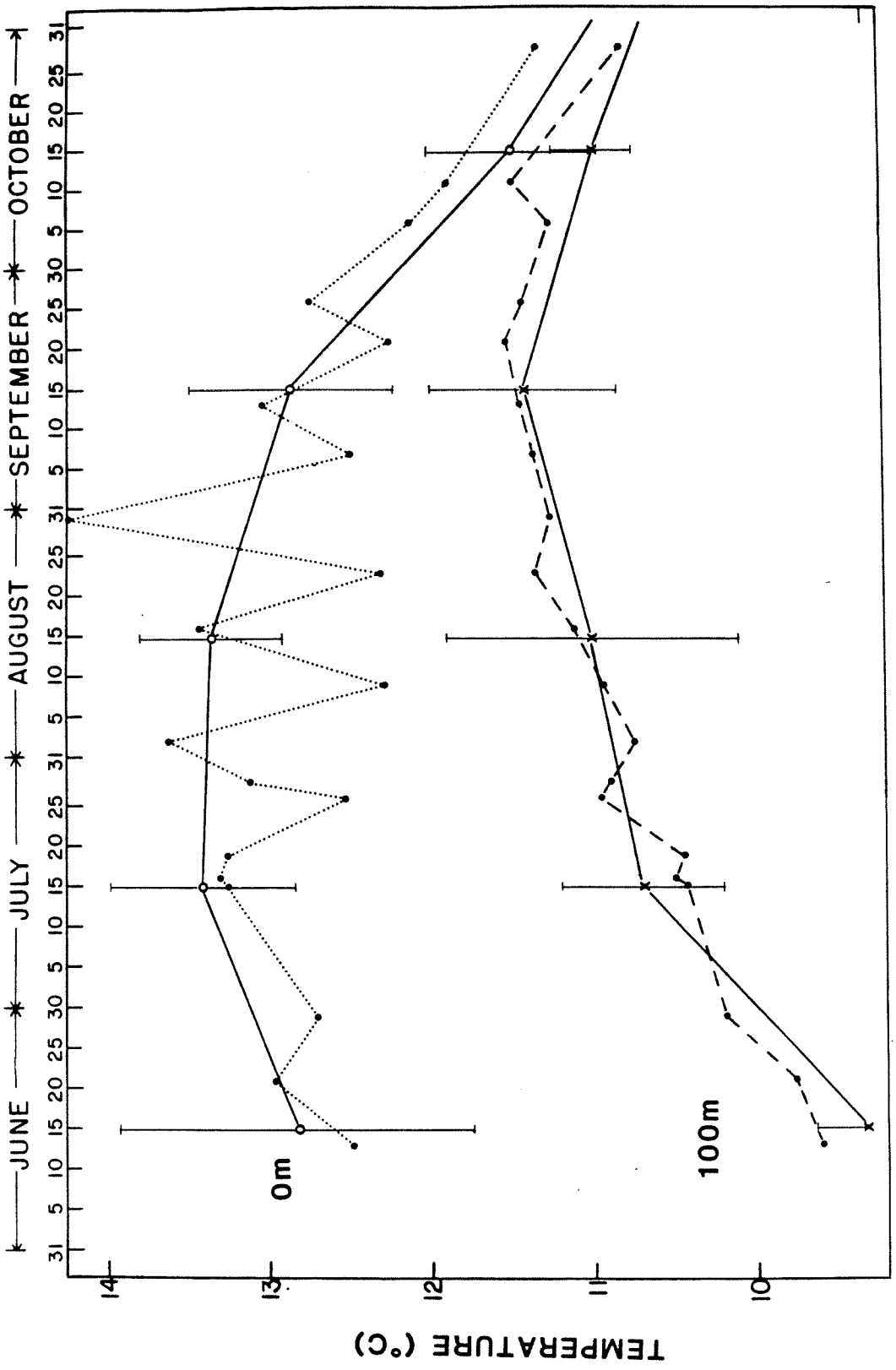



Figure 5.9. Expanded view of the seasonal progression of temperature shown in Figure 5.8. Notation: solid lines, historical norm for site 320; dotted line, CTD stations 4 and 15 at 0 m; dashed line, CTD data for stations 4 and 15 at 100 m; bracketed lines, 1 standard deviation about norms.

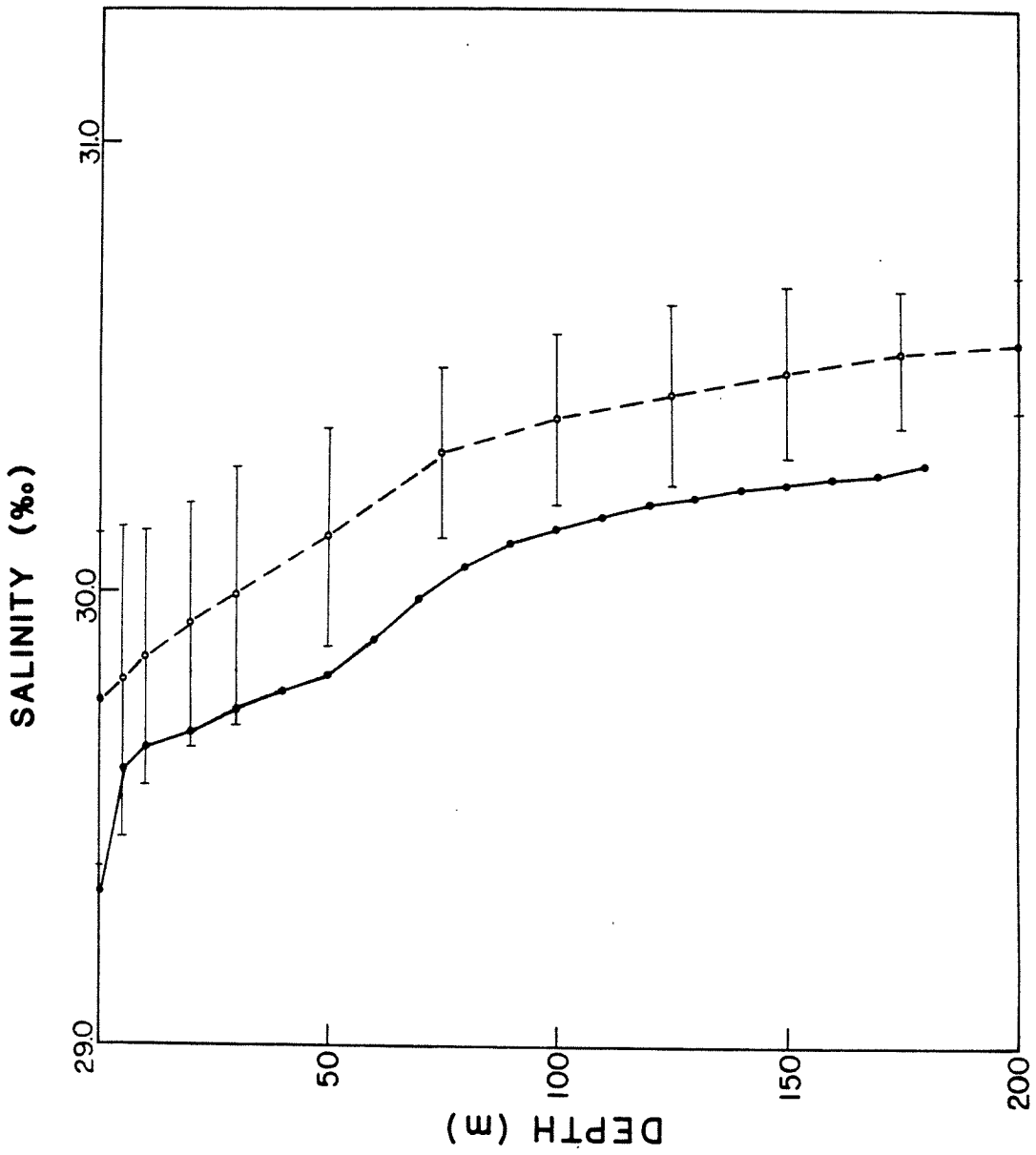



Figure 5.10. Vertical profiles of salinity for historical station 320 (dashed) and CTD station 4 (solid) during August-September. Bracketed line indicates 1σ about the historical norm.

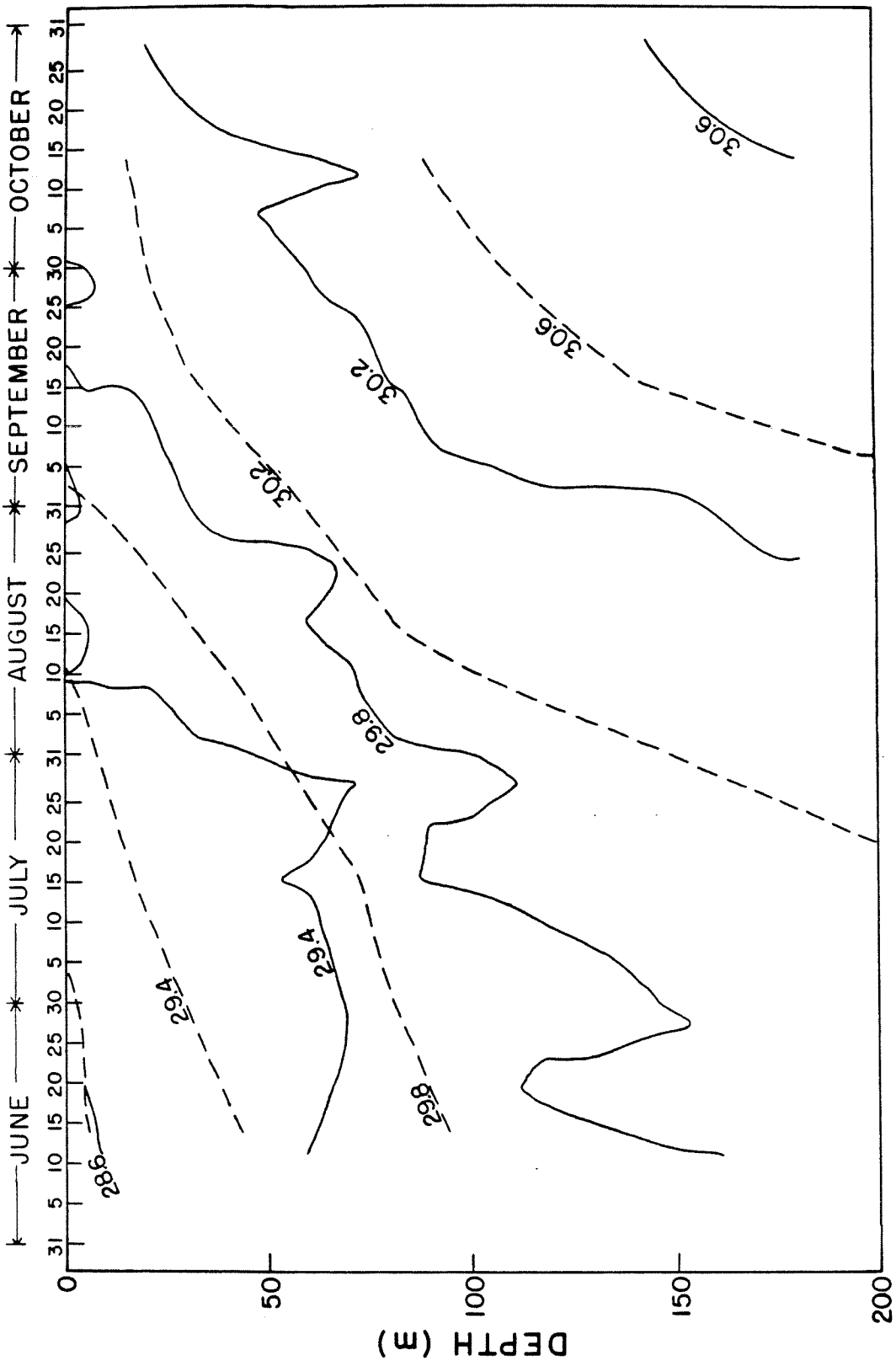



Figure 5.11. Superposition of selected isohalines ($^{o}/_{oc}$) for historical site 320 (dashed) and CTD stations 4 and 15 (solid).

Figure 5.12 shows the seasonal progression of the historical norm and CTD data for salinity at the surface and 100 m depth. Figure 5.13 shows an expanded view of the comparison. It can be seen that the salinities observed during June-October at 100 m depth always lay below the norm, whereas, at the surface some of the observations during June-October lay above the norm.

5.3.1.3 Density

Figure 5.14 shows vertical profiles of historical and CTD means for the months of August and September. The density throughout the water column is lower than the historical norm. However, the vertical density gradients differ between the CTD and the norm. Table 5.3 shows the density gradient computed in four depth ranges: 0-10 m; 10-50 m; 50-80 m; and 80-180 m. In the range of 0-10 m the CTD gradient is 1.5-fold larger than the stratification of the norm. In the range of 10-50 m the CTD gradient is about half that for the norm. Near 50 m depth there is a break in the CTD density profile which does not exist in the historical norm. The density gradient is comparable for both data sets in the two deeper depth ranges.

Figure 5.15 shows selected density contours in the time-depth plane for the norm and CTD data. The comparison of these two data sets is similar to that seen for salinity. The CTD density pattern is shifted to later times than the historical norm on the order of a month at 22.8 sigma-t units, to about 1.5 months at 23.2 sigma-t units.

Figure 5.16 shows the seasonal progression of the norm for density at surface and 100 m depth superimposed with the CTD data. Figure 5.17 shows an expanded view of the comparison during June through October. At the surface the CTD values oscillate about the norm, however, at 100 m depth it is always below the norm.

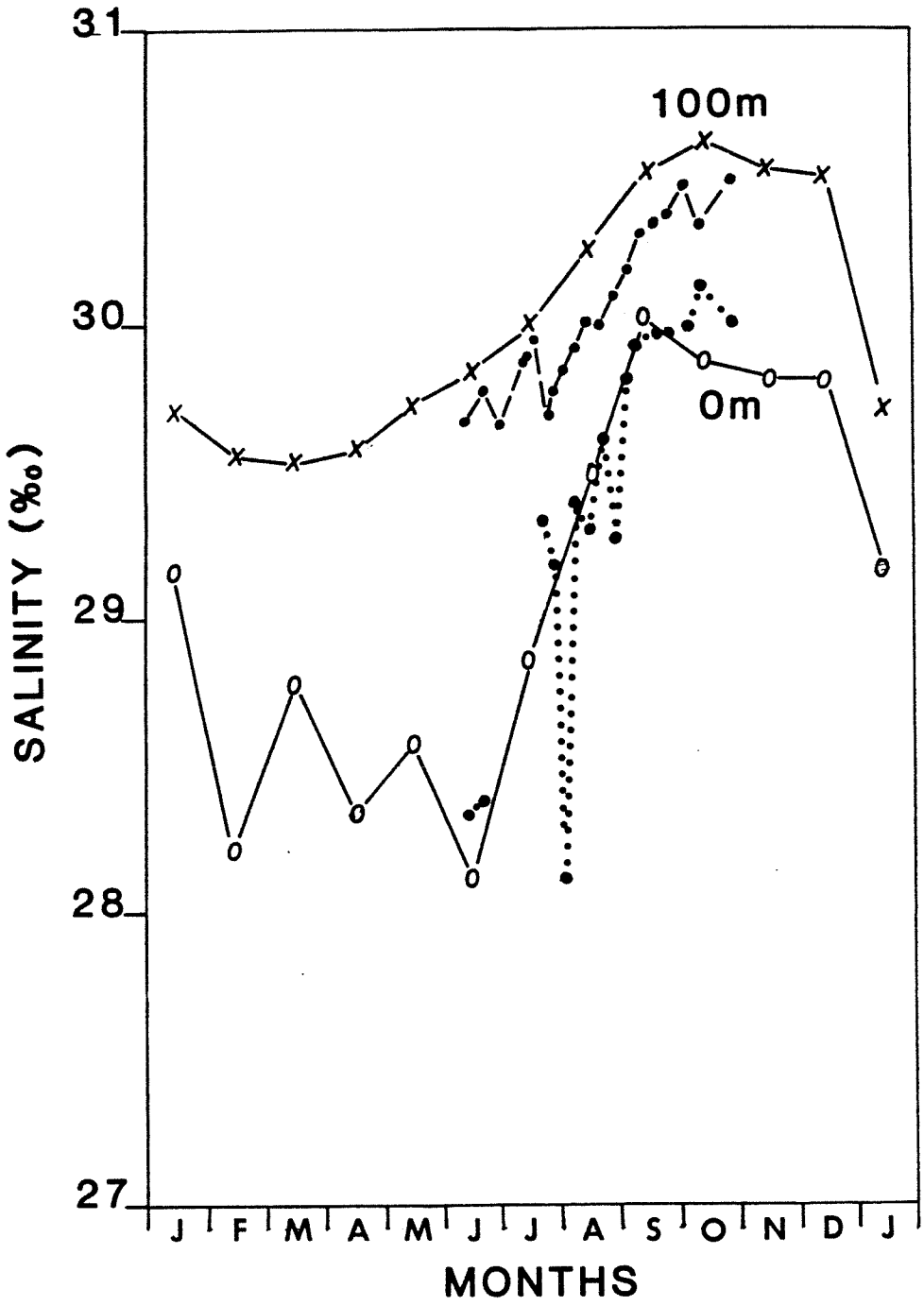



Figure 5.12. Seasonal progression of salinity at 0 m and 100 m depth for site 320 (solid) and CTD stations 4 and 15 (dotted, 0 m; and dashed, 100 m).

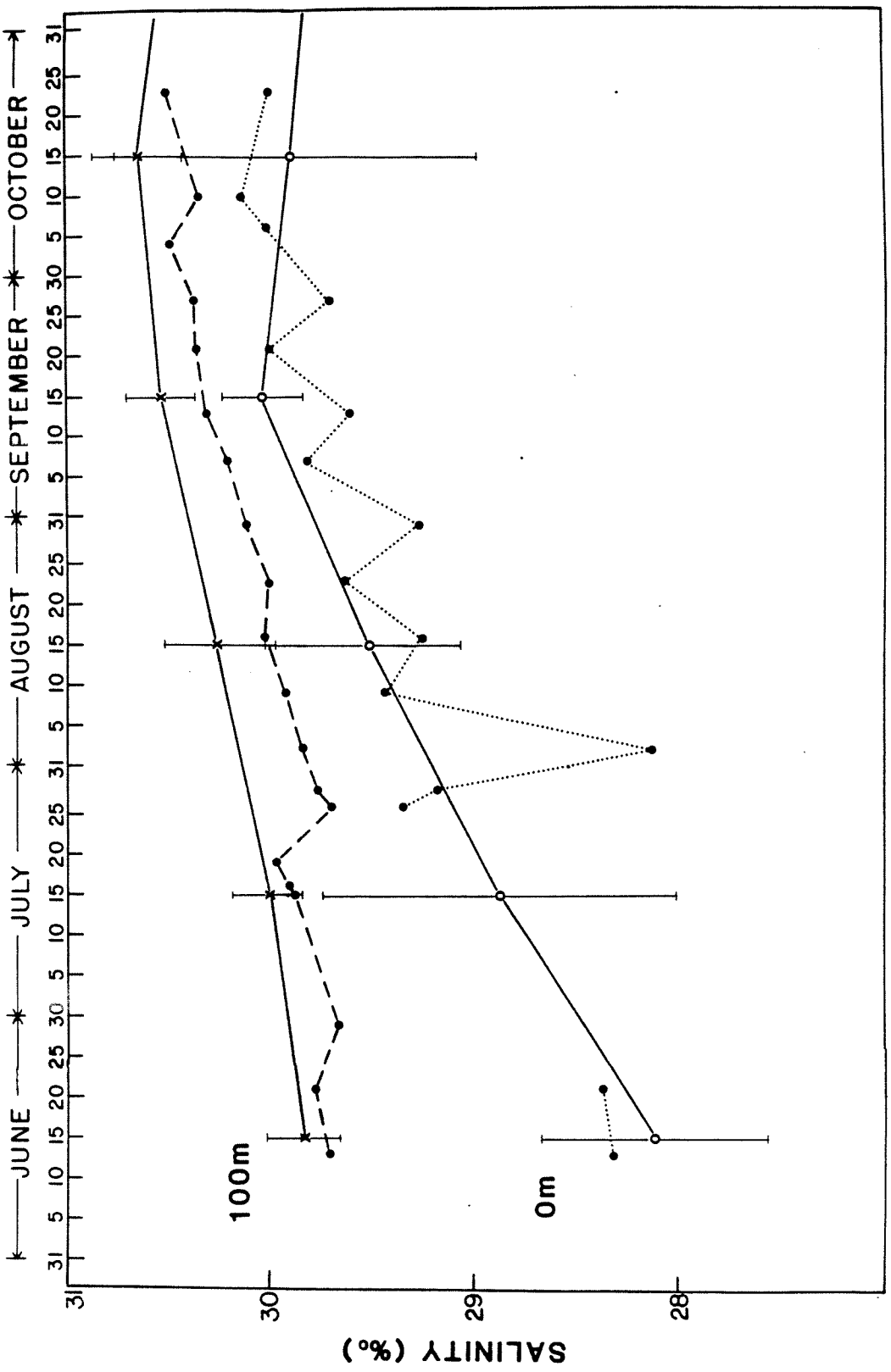



Figure 5.13. Expanded view of the seasonal progression of salinity shown in Figure 5.12. Notation: solid lines, historical norm for site 320; dotted line, CTD stations 4 and 15 at 0 m; dashed line, CTD station 4 and 15 at 100 m; bracketed lines, 1 σ about the norms.

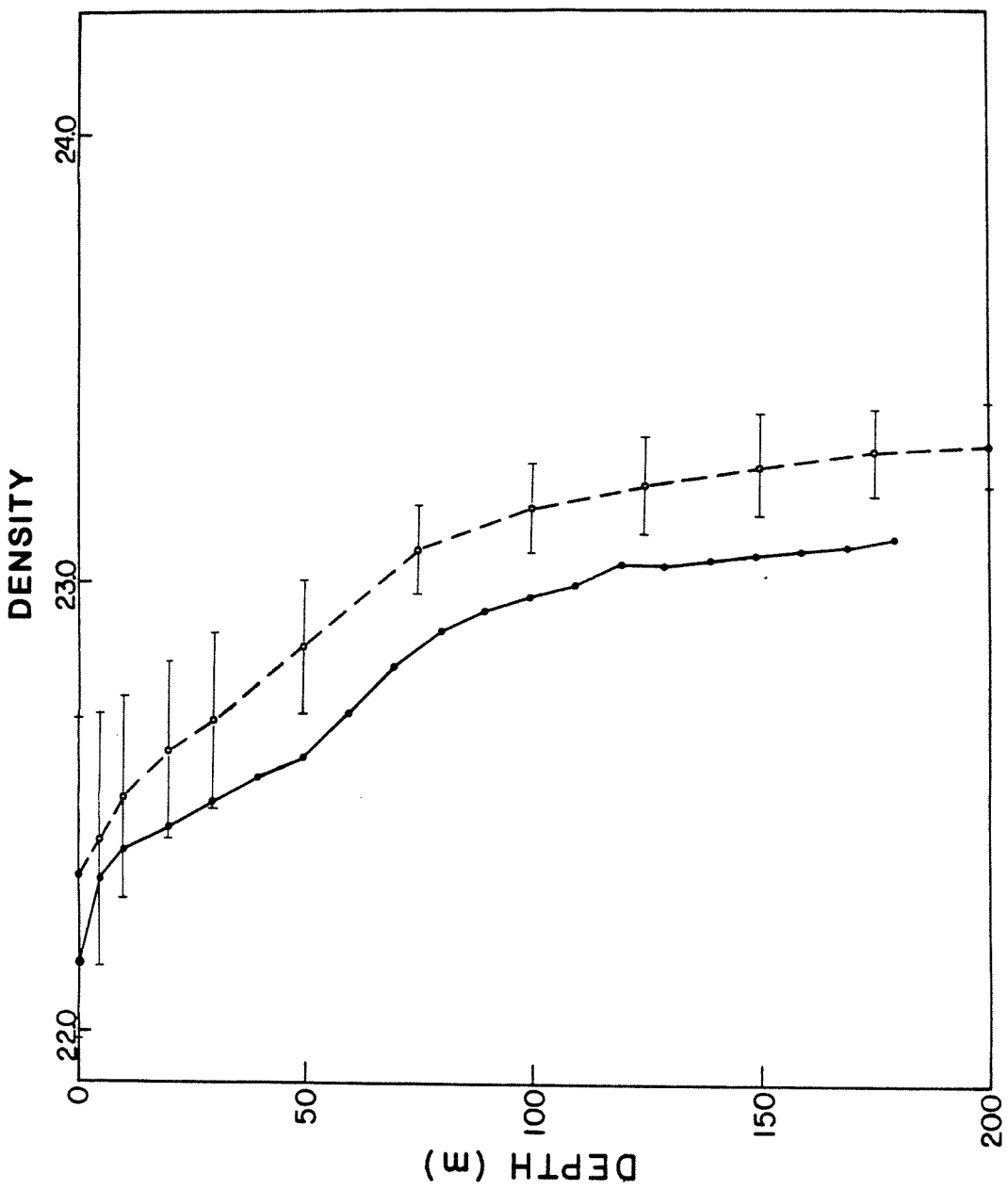



Figure 5.14. Vertical profiles of density for historical site 320 (dashed) and CTD station 4 (sølid) during August-September. Bracketed line indicates 1 σ about the historical norm.

Table 5.3. Mean density gradients computed during August and September over four depth ranges for historical site 320 and CTD station 4.

| Depth (m) | Historical | CTD |
|---|---|---|
| 0-10 | 0.018 | 0.026 |
| 10-50 | 0.008 | 0.005 |
| 50-80 | 0.008 | 0.009 |
| 80-180 | 0.002 | 0.002 |

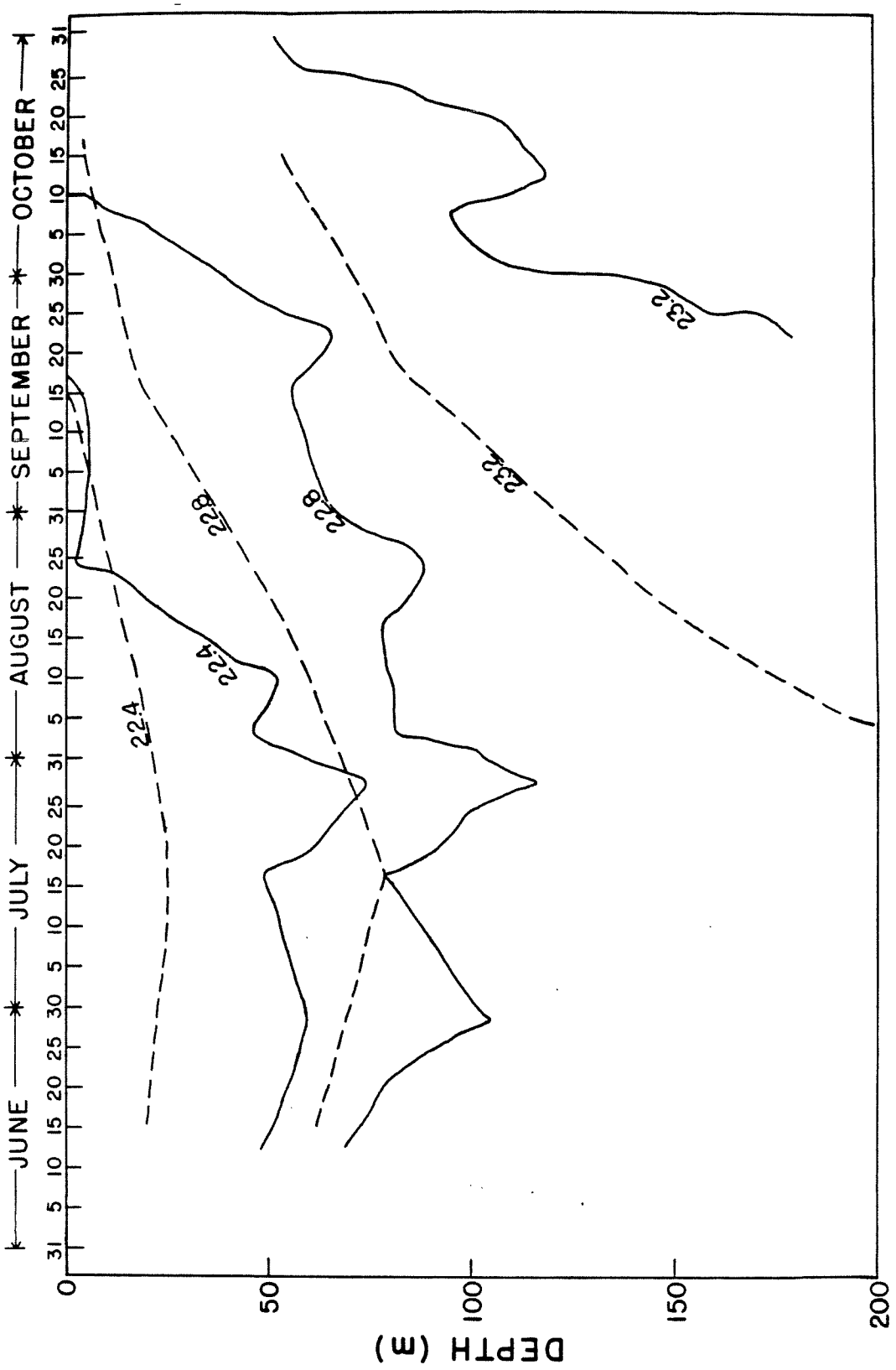



Figure 5.15. Superposition of selected density contours for historical site 320 (dashed) and CTD stations 4 and 15 (solid).

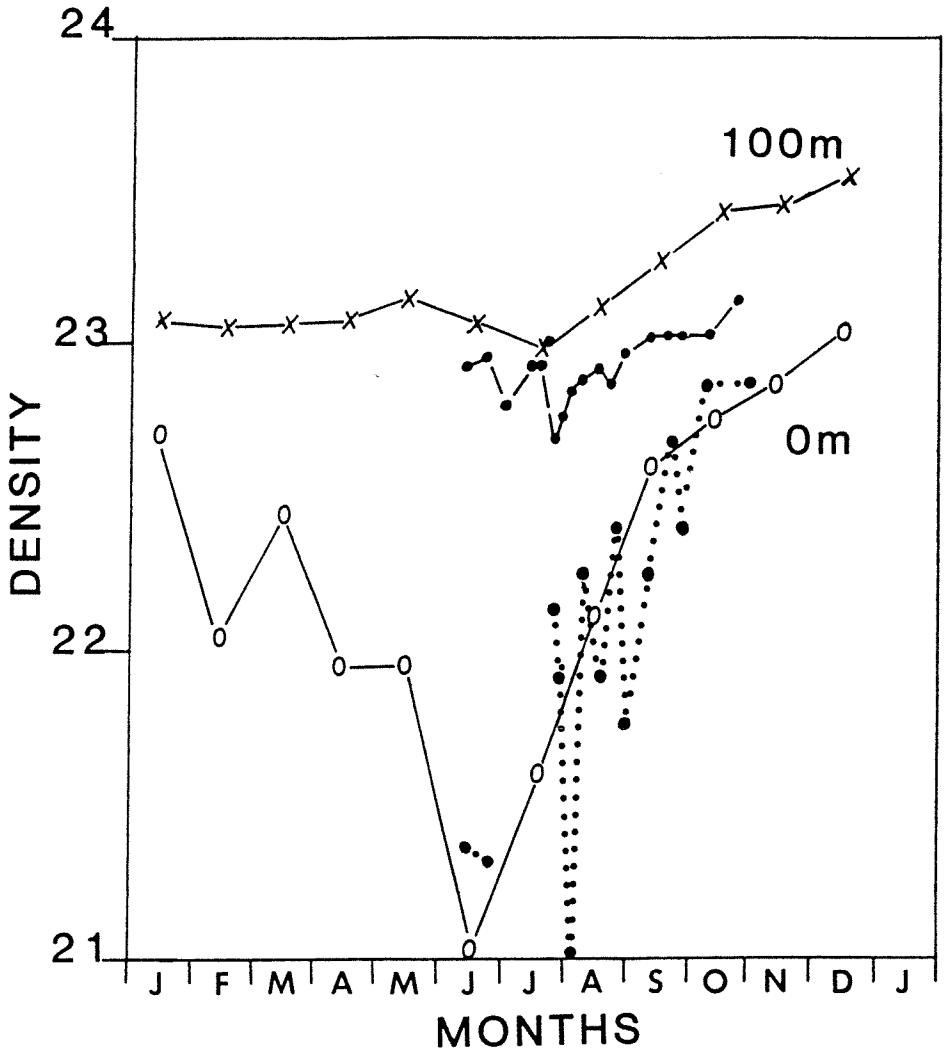



Figure 5.16. Seasonal progression of density at 0 m and 100 m depth for site 320 (solid) and CTD stations 4 and 15 (dotted, 0 m; and dashed, 100 m).

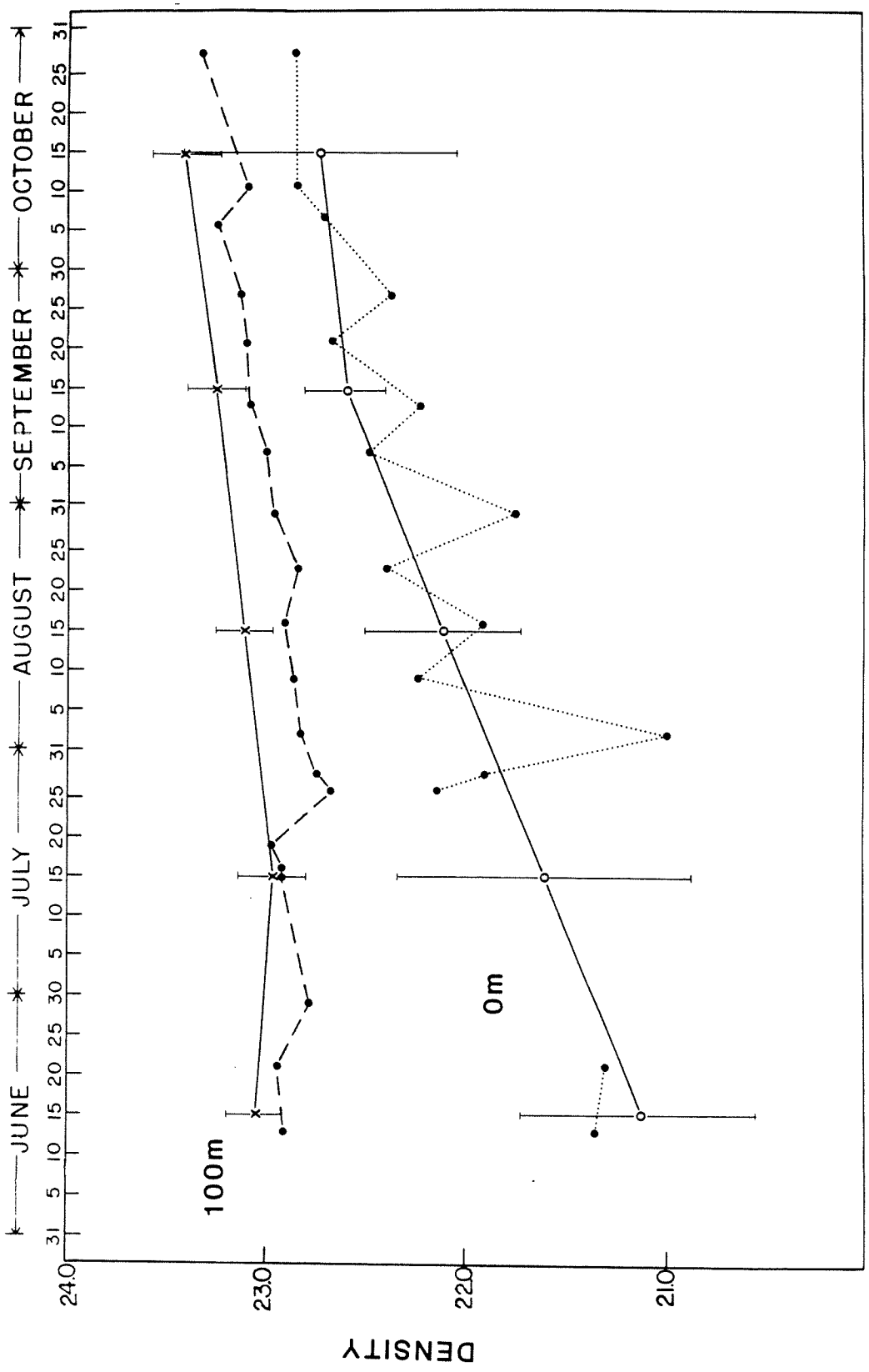



Figure 5.17. Expanded view of the seasonal progression of density shown in Figure 5.16. Notation: solid lines, historical norm for site 320; dotted line, CTD stations 4 and 15 at 0 m; dashed line, CTD stations 4 and 15 at 100 m; bracketed lines, 1 σ about the norms.

5.3.1.4 Oxygen

Figure 5.18 shows the vertical profiles of historical and CTD means for the months of August and September. Shallower than approximately 50 m the CTD data show lower oxygen compared to the historical data. Above 20 m the difference increases dramatically, where, at the water surface the difference is largest at nearly 2 mg/l. At 10 m depth the CTD oxygen concentration reaches approximately 7.5 mg/l. At depths greater than 50 m the CTD oxygen concentration is greater than the historical norm; the difference reaches a maximum of 0.7 mg/l at 180 m depth.

Both the historical and CTD profiles show a minimum in the oxygen concentrations below 50 m depth, but the CTD minimum occurs at 90 m depth whereas the historical minimum occurs near 150 m depth.

Figure 5.19 shows selected oxygen contours in the time-depth plane for historical and CTD data. The differences are most pronounced in the deeper water. Below approximately 70 m depth the 7.0 mg/l CTD isopleth occurs later than normal. Below approximately 60 m depth the 6.0 mg/l CTD isopleth also occurs later by as much as 2-3 months. The oxygen minimum below approximately 5.5 mg/l occurs approximately one month later than normal.

Figure 5.20 shows the seasonal progression of the norm for oxygen at surface and 100 m depth superimposed with the CTD data. Figure 5.21 shows an expanded view of the comparison during June through October. The CTD oxygen concentration at the surface is persistently lower than the norm except during late October. At 100 m depth the oxygen concentrations are all higher than the norm except observations made during mid-September when the CTD oxygen concentrations were slightly below normal.

5.3.2 Water Structure

The water structure was examined both in vertical sections and plan

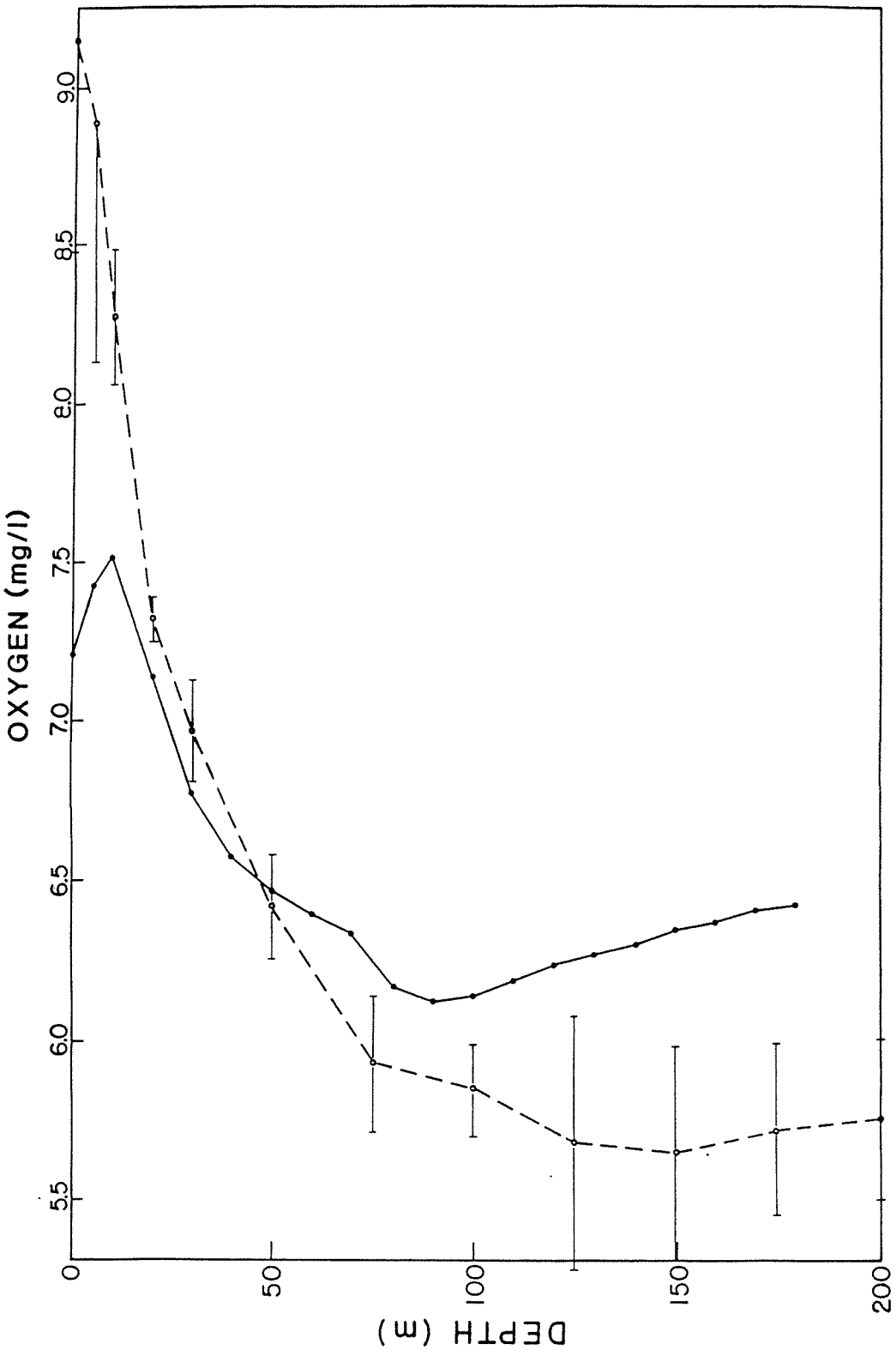



Figure 5.18. Vertical profiles of oxygen for historical site 320 (dashed) and CTD station 4 (solid) during August-September. Bracketed line indicates 1 σ about the historical norm.

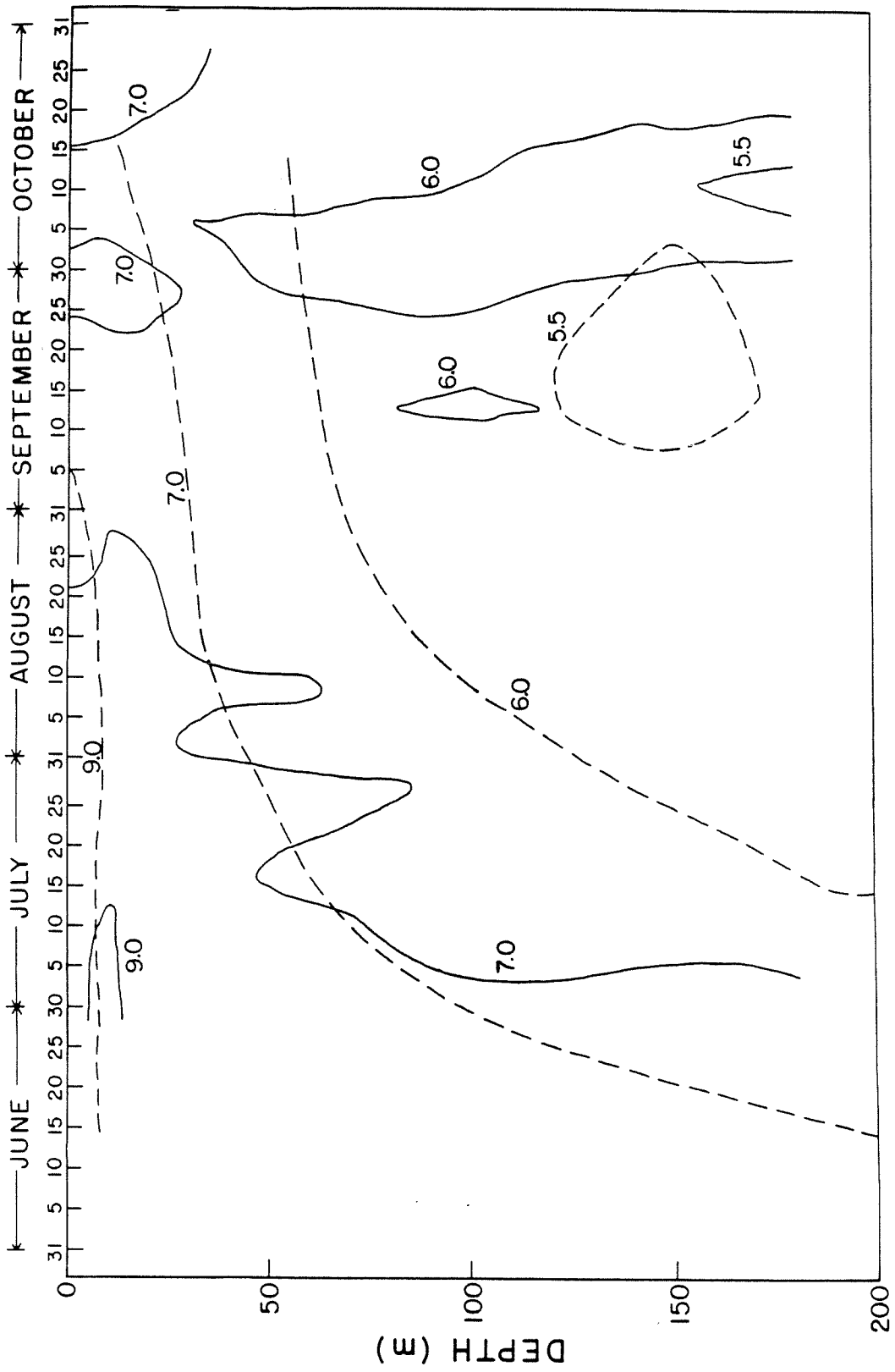



Figure 5.19. Superposition of selected oxygen contours for historical site 320 (dashed) and CTD stations 4 and 15 (solid).

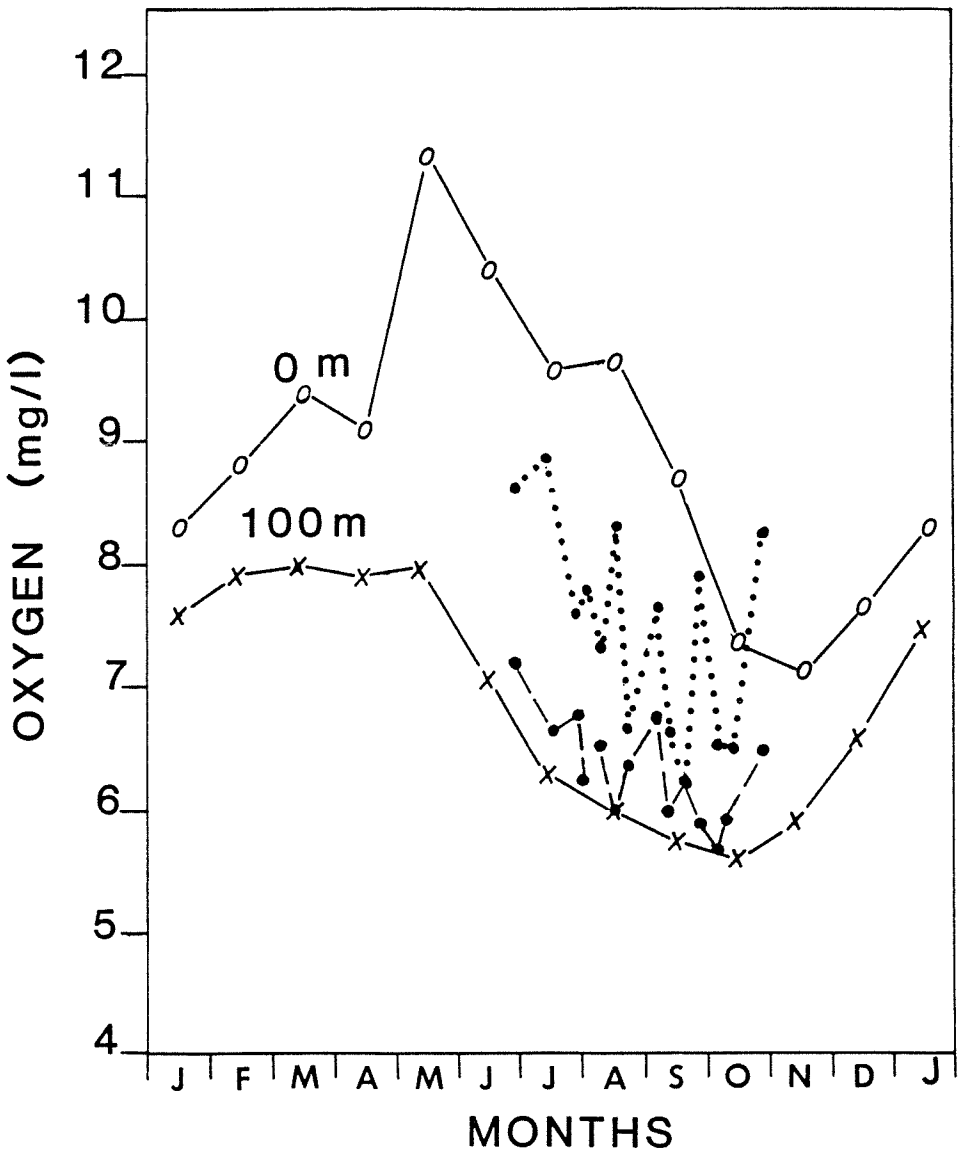



Figure 5.20. Seasonal progression of oxygen at 0 m and 100 m depth for site 320 (solid) and CTD stations 4 and 15 (dotted, 0 m; and dashed, 100 m).

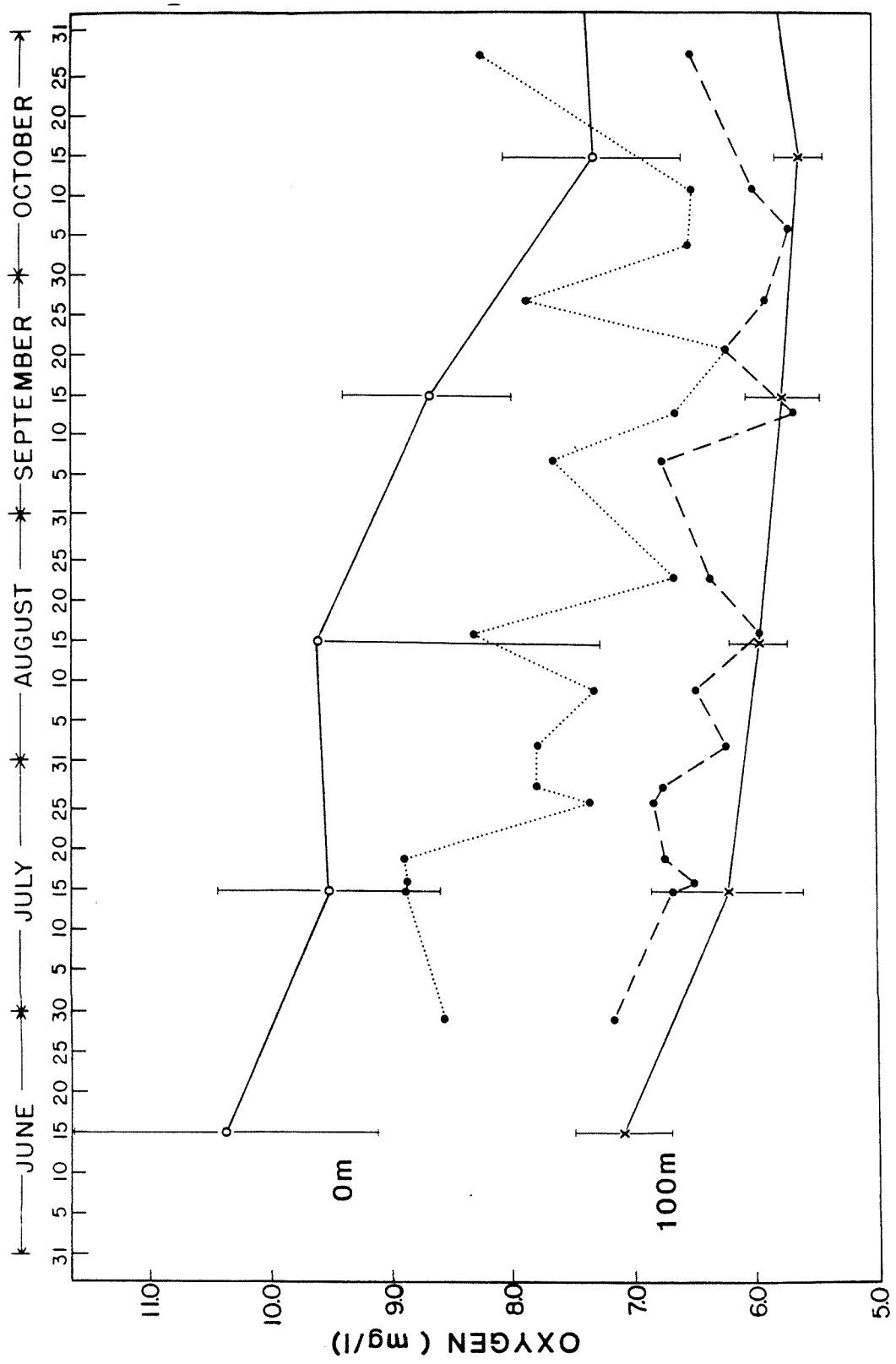



Figure 5.21. Expanded view of the seasonal progression of oxygen shown in Figure 5.20. Notation: solid lines, historical norm for site 320; dotted line, CTD stations 4 and 15 at 0 m; dashed line, CTD stations 4 and 15 at 100 m; bracketed lines; 1 σ about the norms.

views. The vertical sections will be discussed first in order to determine which depths are most suitable for the construction of plan views.

5.3.2.1 Vertical Structure

The vertical structure along three transects was examined (Figure 5.22): along mid-channel in the Main Basin connecting stations 1, 4, and 3 (mid-channel section); a transect from mid-channel to immediately offshore of Seahurst Park connecting stations 4, 7, 8, 9, and 10 (Seahurst section); and a transect running parallel to shore in Seahurst Bay connecting stations 6, 7, and 5 (the Bay section).

Two types of presentations are shown for each transect. First, Appendix 5B shows contours constructed for each sampling date. Second, in order to gain some generalized pictures of the pattern, transects were constructed using averaged data. Table 5.4 shows the dates of observations that were used to compute the means for each transect. For the Seahurst and Bay transects seven sampling dates spanning 8/2-9/27 were combined, and seven sampling dates spanning 7/16-10/28 were combined for the mid-channel transect.

Figure 5.23 shows the mean contours and Figure 5.24 shows the mean vertical profiles along the mid-channel transect for temperature, salinity, density, and dissolved oxygen.

At station 3 off Browns Point a layer approximately 10 m deep is found wherein the stratification is comparatively large at 0.083 sigma-t units per meter. The high stratification is due to low salinities associated with freshwater discharged from the Puyallup River. The vertical profiles show that the salinities off Seahurst Park at station 4 and off Browns Point at station 3 are quite similar below a depth of approximately 10 m. At shallower depths the two curves diverge markedly; for example, at 5 m depth the mean salinity off Seahurst is approximately 29.6 $^{o}/_{oo}$ in contrast with the salinity

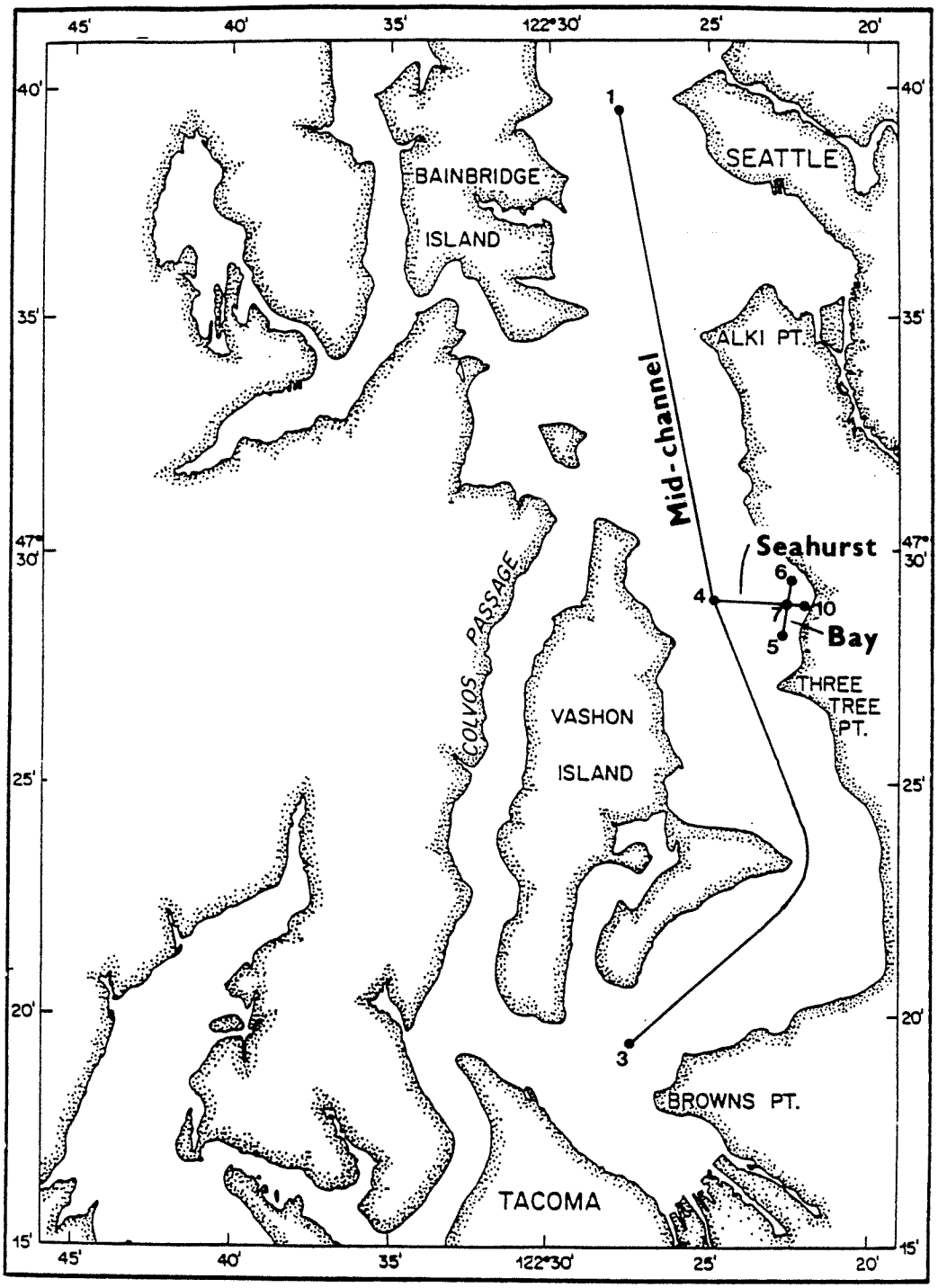



Figure 5.22. The three transects (Mid-channel, along stations 1, 4, 3; Seahurst, stations 4, 7, 8, 9, 10; and the Bay, stations 5, 6, 7) used to construct vertical profiles of water properties.

Table 5.4 Dates of observations used to compute means for station transects.

| Stations 1 - 4 - 3 Midchannel transect | | |
|---|---|---|
| 7/16 | 7/16 | 7/16 |
| 7/26 | 7/26 | 7/26 |
| 8/24 | 8/23 | 8/24 |
| 9/9 | 9/7 | 9/9 |
| 9/22 | 9/21 | 9/22 |
| 10/6 | 10/6 | 10/6 |
| 10/27 | 10/28 | 10/27 |

| Stations 4 - 7 - 8 - 9 - 10 Seahurst transect<br>Stations 5 - 7 - 6 Bay transect |
|---|
| 8/2 |
| 8/9 |
| 8/16 |
| 8/23 |
| 9/13 |
| 9/21 |
| 9/27 |

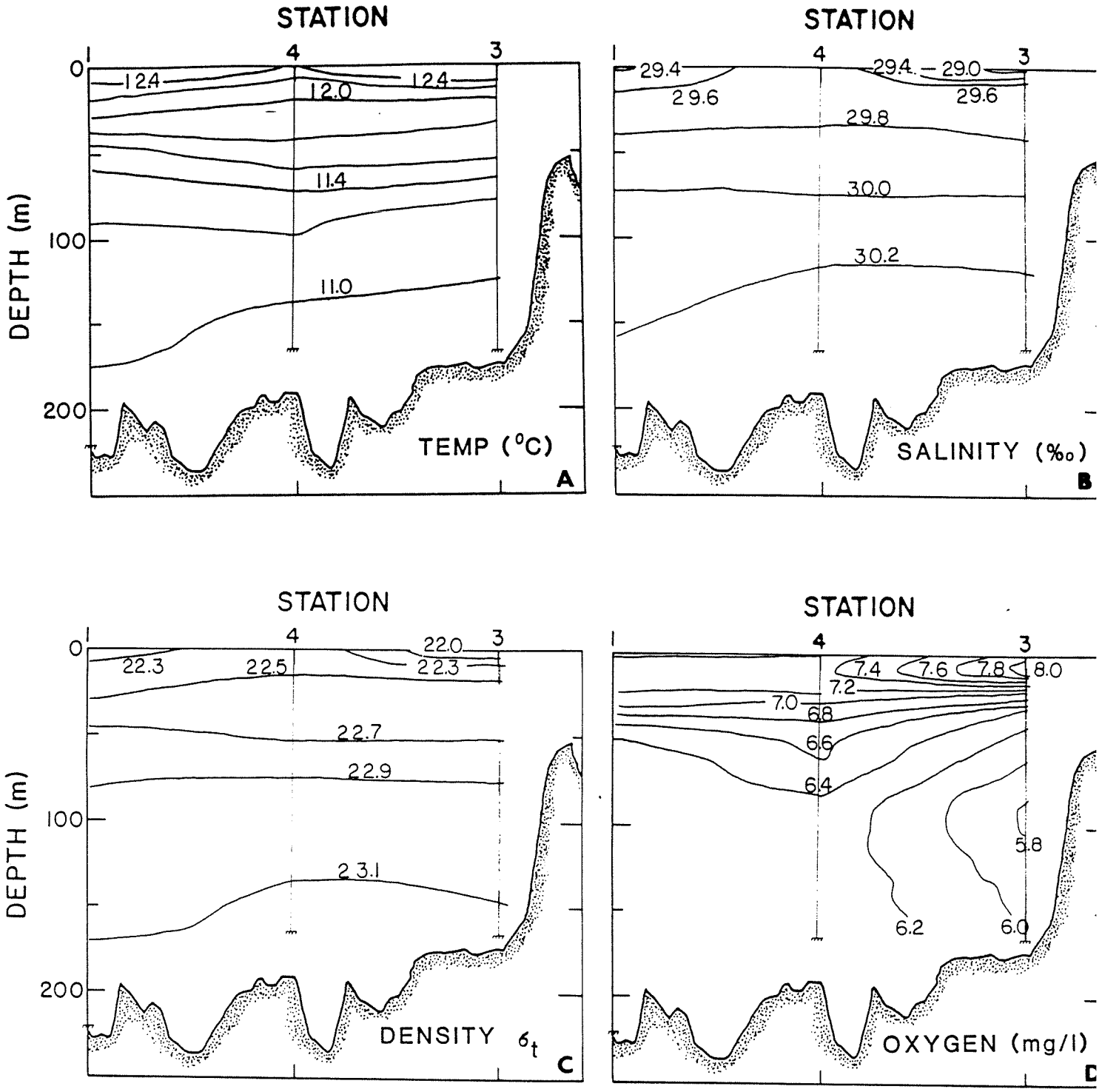



Figure 5.23. Mean vertical contours of temperature (a), salinity (b), density (c), and dissolved oxygen (d) along the mid-channel transect for 7/16 - 10/28/82.

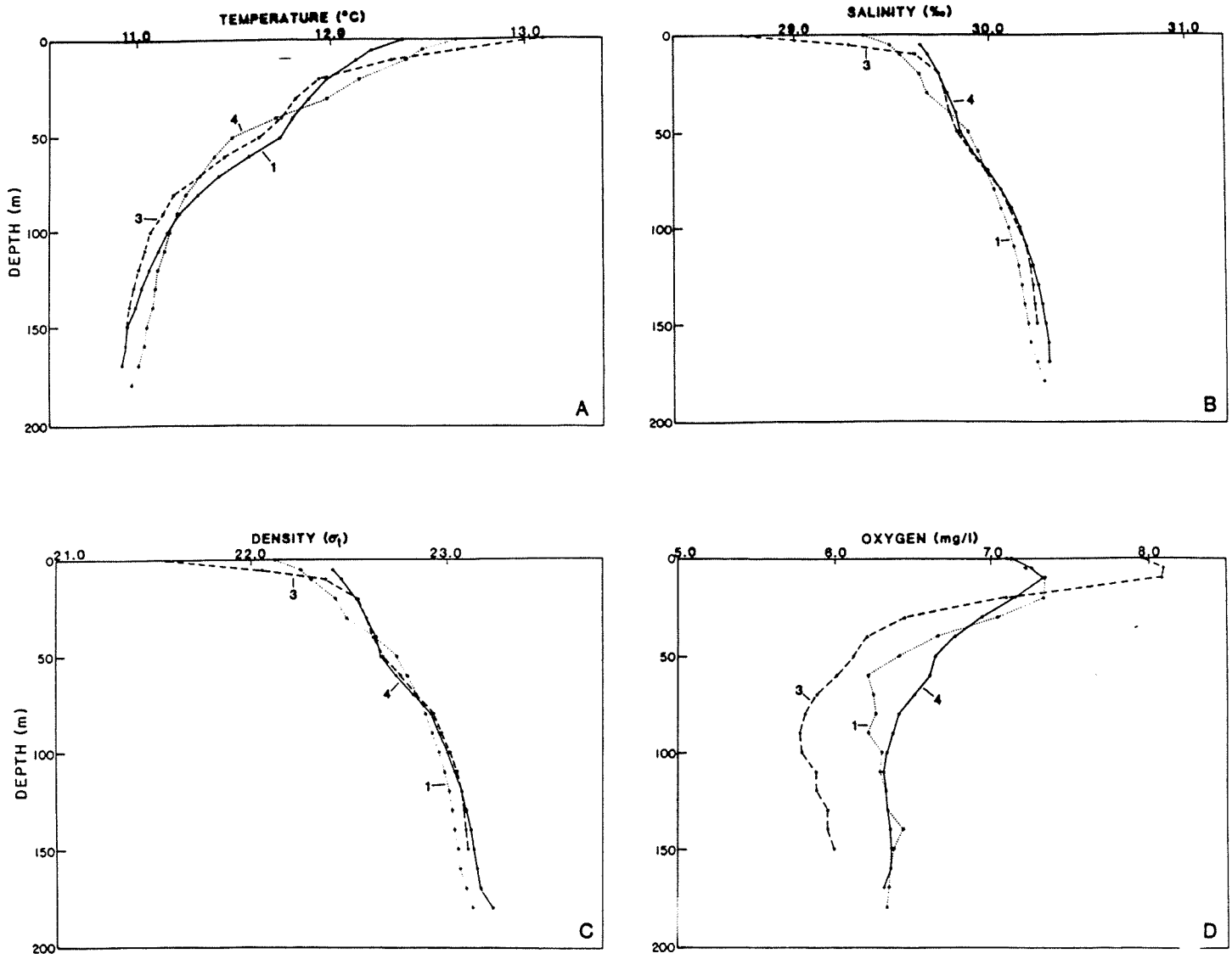



Figure 5.24. Mean vertical profiles of temperature (a) salinity, (b) density, (c) and dissolved oxygen, (d) for stations along mid-channel transect. Dates of the data used to obtain the means are listed in Table 5.4.

off Browns Point of 29.3 °/oo, which is approximately 0.3 °/oo lower. The surface values of salinity and density at station 4 have not been shown because the surface values were not recorded during July (7/16 and 7/26) due to instrument malfunctions. If the Seahurst profile were extrapolated to the surface using the same gradient between the 5 and 10 m depths, the surface salinity off Browns Point would be approximately 1 °/oo lower than off Seahurst Park.

The high stratification off Browns Point apparently leads to elevated temperatures and oxygen concentrations. The surface temperature off Browns Point is 0.7 °C warmer than at mid-channel off Seahurst Park, and nearly 0.5 °C warmer than the water off West Point. At the surface the oxygen content off Browns Point is approximately 0.8 mg/l higher than off both West Point and Seahurst.

Figure 5.25 shows the mean vertical contours and Figure 5.26 shows the mean vertical profiles along the Seahurst transect for temperature, salinity, density, and dissolved oxygen. These transects show that the water in the Bay differs from that at mid-channel in several respects.

At the surface the water is warmer by approximately 0.3 °C between stations 4 and 10. The transect also shows that there is a lens of warmer water within the Bay. In the upper 20 m the water in the Bay is less saline than station 4 at mid-channel; as a consequence this water is less dense down to a depth of approximately 10 m. The vertical profile for oxygen appears quite different from those of temperature, salinity, and density. It is striking that at 5 m depth there is a tongue of more highly oxygenated water extending from the Bay toward mid-channel. More specifically, at 5 m depth the oxygen concentration closest to shore is nearly 8 mg/l, whereas the concentration at mid-channel (station 4) is nearly 7.5 mg/l, i.e., there is a

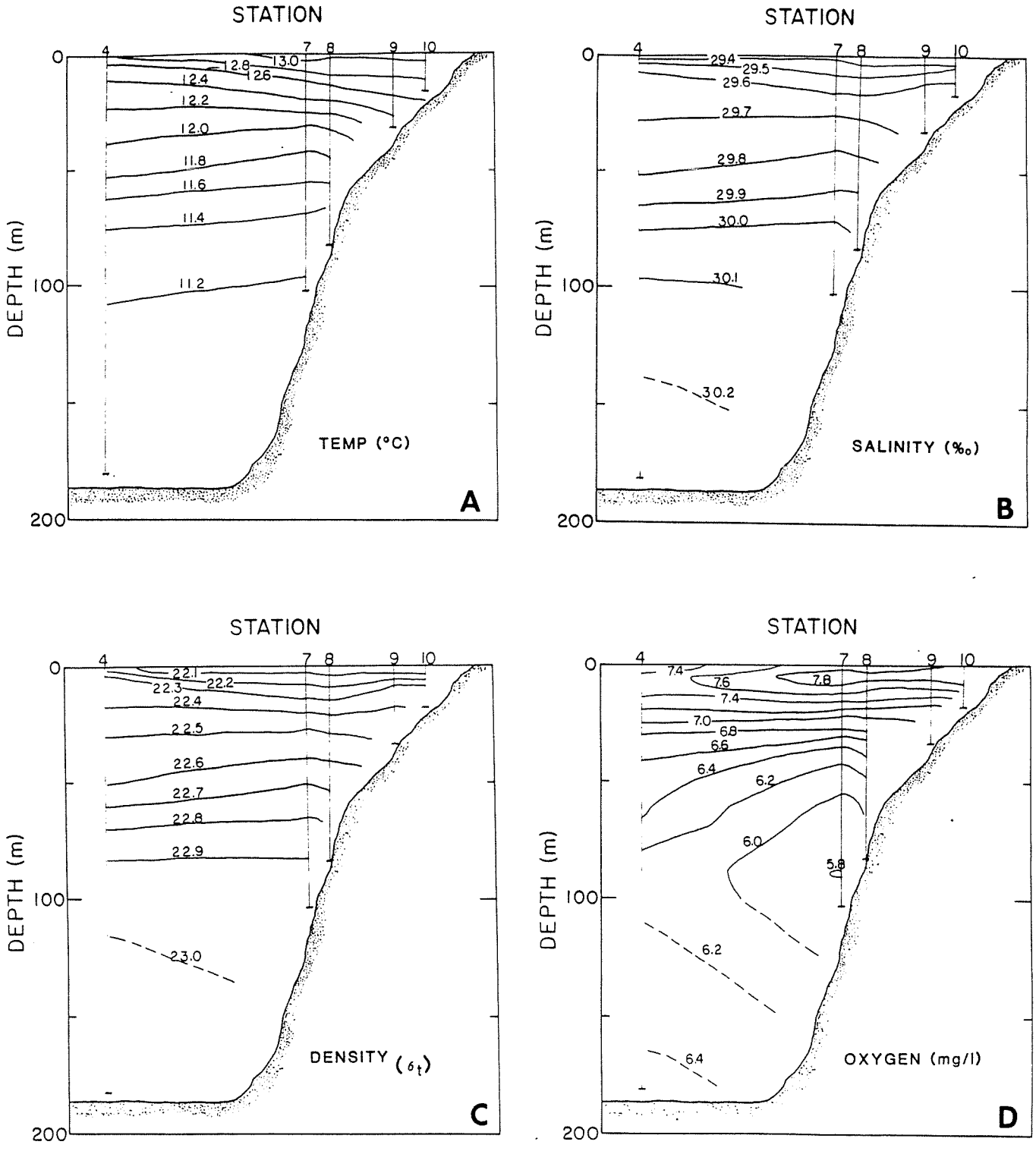



Figure 5.25. Mean vertical contours of temperature (a), salinity (b), density (c), and dissolved oxygen (d) along the Seahurst transect for 8/2 - 9/27/82.

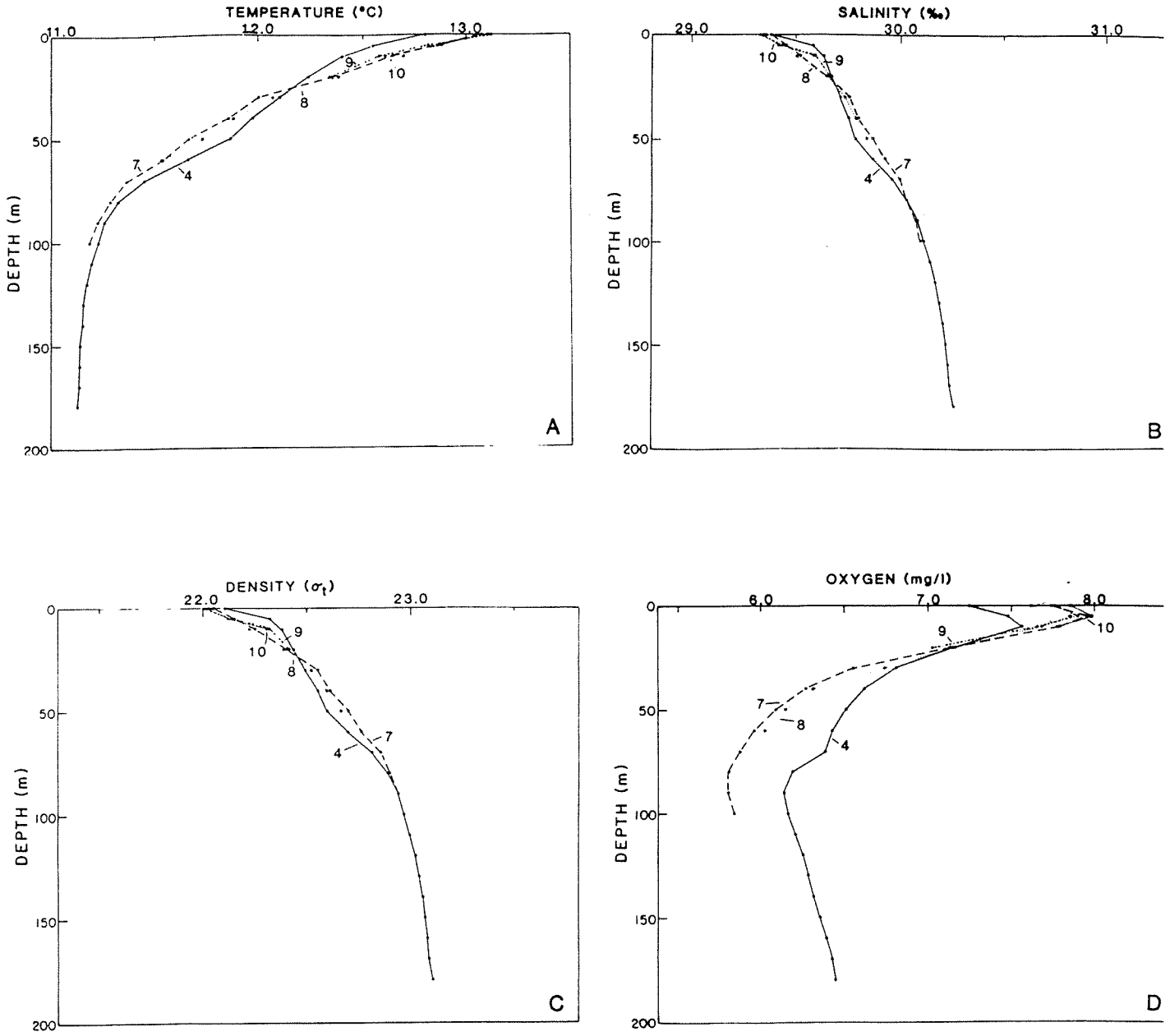



Figure 5.26. Mean vertical profiles of temperature (a), salinity (b), density (c), and dissolved oxygen (d) for stations along the Seahurst transect.

0.5 mg/l difference in concentration between the Bay and mid-channel. Below 30 m depth the Bay is less oxygenated than at mid-channel by a difference which is maximum near 70 m depth of approximately 0.5 mg/l.

In the transects, these features are evident as a shallow layer in the Bay which is warmer, more oxygenated, and less saline than water at mid-channel. The lower oxygen concentration appears as a tongue with lowest values occurring near 90 m depth along the steep slopes in the Bay.

Figure 5.27 shows the mean vertical contours and Figure 5.28 shows the mean vertical profiles along the Bay transect for temperature, salinity, density, and dissolved oxygen. Above 30 m the mean temperatures are approximately equal. Below that depth the coldest temperatures are found at station 7, intermediate temperatures at station 5, and warmest temperatures at station 6, with a maximum difference occurring near 50 m. Vertical profiles of salinity along the transect are nearly identical and, in consequence, so are the densities. Above approximately 40 m depth slightly higher oxygen concentrations are found at station 7. Below that depth the lowest oxygen concentrations are found at stations 6 and 7. Thus, as one proceeds northward in the Bay between stations 5 and 6 the oxygen content decreases by approximately 0.1 mg/l at 90 m depth.

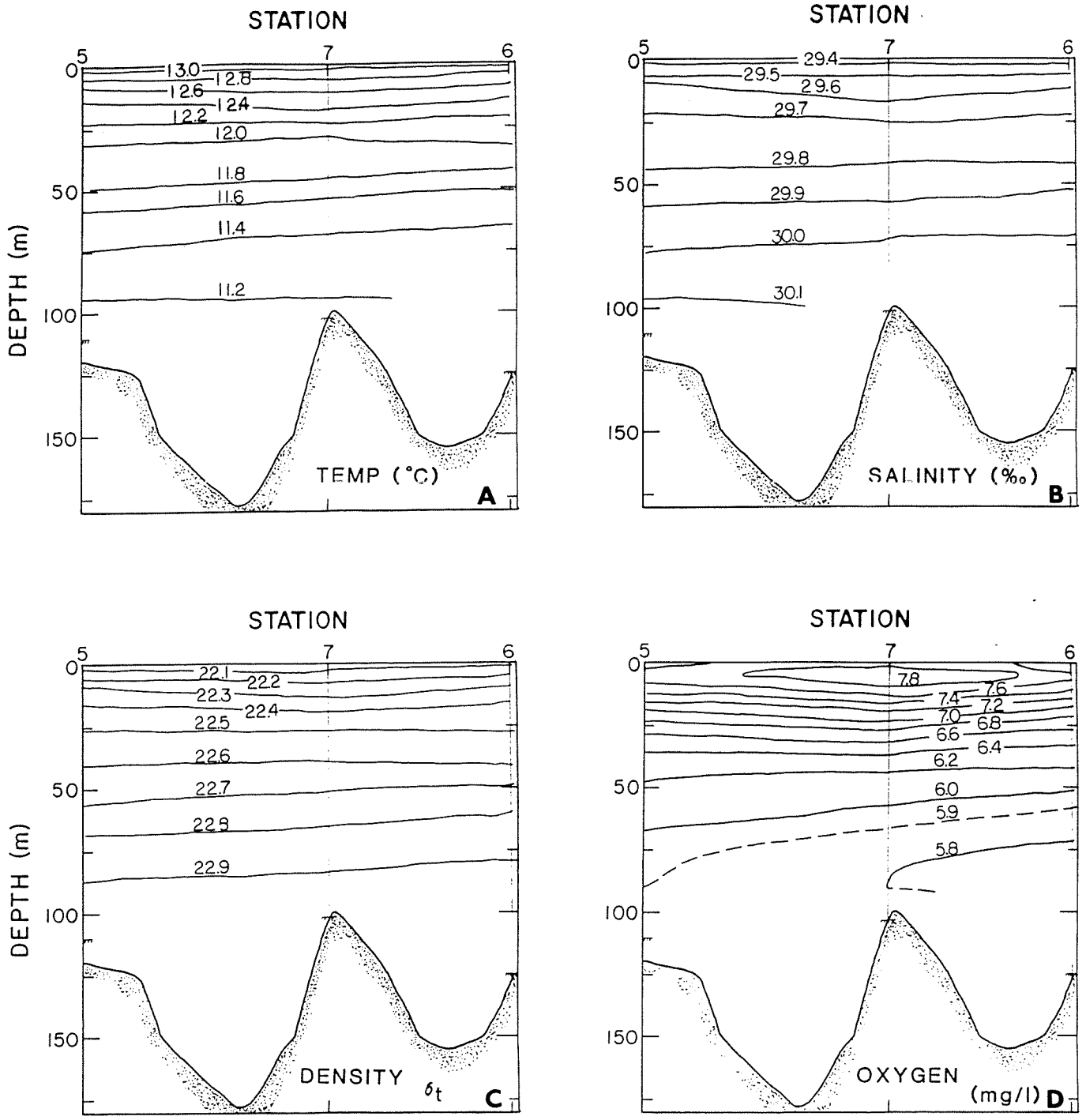



Figure 5.27. Mean vertical contours of temperature (a), salinity (b), density (c), and dissolved oxygen (d) along the Bay transect for 8/2 - 9/27/82.

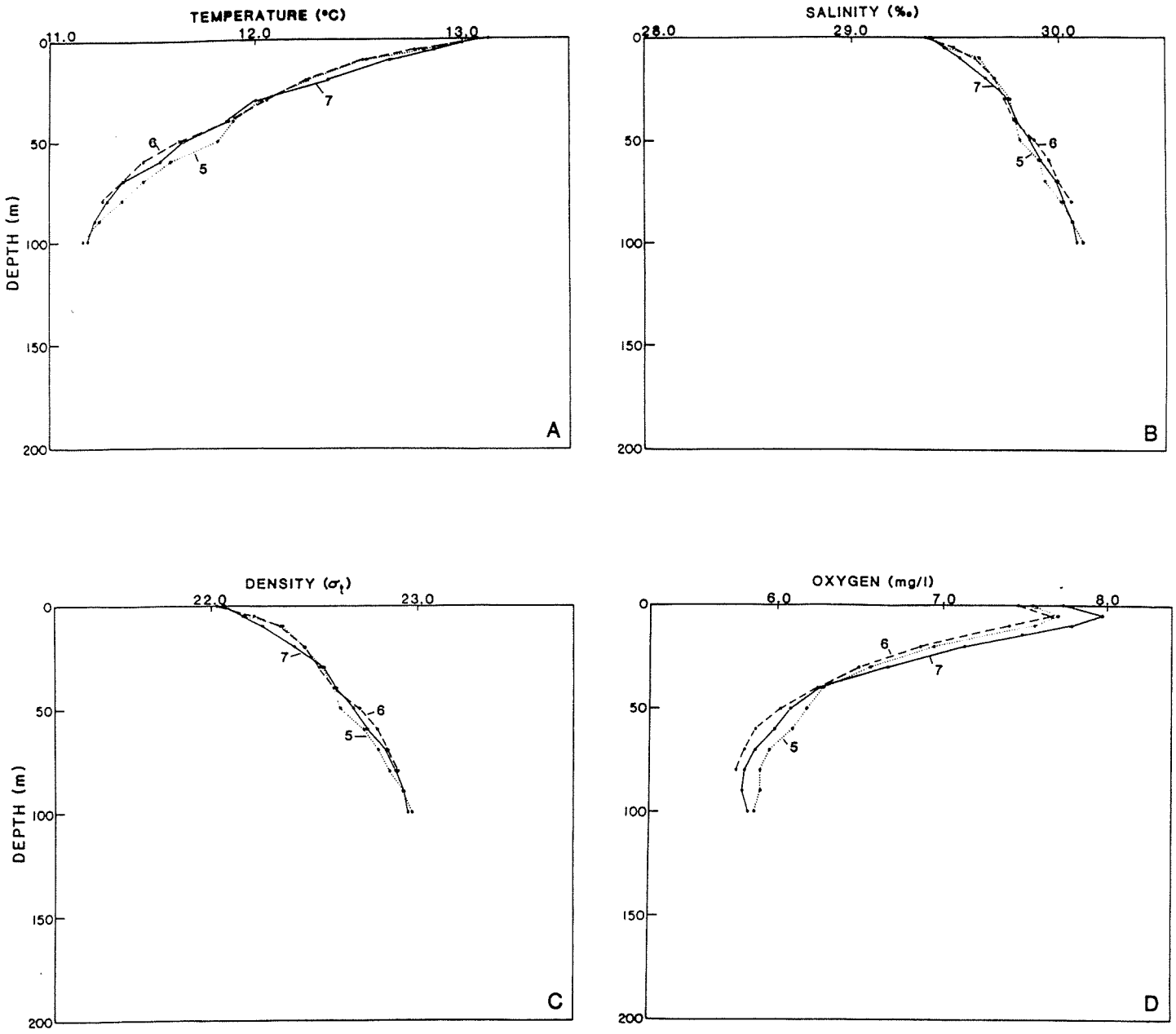



Figure 5.28. Mean vertical profiles of temperature (a), salinity (b), density (c), and dissolved oxygen (d) for stations along the Bay transect.

5.3.2.2 Horizontal Structure

The stations located in and near Seahurst Bay, although sparse, can be used to gain some idea of the general pattern in the horizontal plane. Specifically, there is a triangular shaped area embraced by stations 4, 5, 10, and 6 within which contours can be constructed. Two depths were selected for contouring: 5 m, to gain an idea of the extent of the shallow lens near the surface; and 80 m, to map the extent of the low oxygen core. These contours were constructed from the mean values used earlier in the vertical profiles.

Figure 5.29 shows the plan view of temperature, salinity, density, and oxygen at 5 m depth. The temperature within the Bay increases steadily from mid-channel to nearshore, whereas the salinity and density both decrease. In contrast, the dissolved oxygen increases from 7.5 mg/l at mid-channel, to nearly 8.0 mg/l closest to shore at stations 7 through 10. Viewed together, the contours suggest a warmer, less saline, and more oxygenated region toward the shore. However, there are insufficient data to diagnose the extent of the region over more than a fraction of the Bay between Brace and Three Tree points.

Figure 5.30 shows the plan view of temperature, salinity, density, and dissolved oxygen at 80 m depth. The temperature contours show a northward increase of nearly 0.1 $^{o}$C between stations 5 and 6, whereas the salinity and density decrease northward between these two stations by 0.08 $^{o}$/oo and 0.08 sigma-t units, respectively. In contrast, the oxygen decreases both eastward and northward. The eastward decrease between stations 4 and 7 is approximately 0.4 mg/l; and the northward decrease is 0.04 mg/l between stations 5 and 7, and 0.1 mg/l between stations 5 and 6.

5.3.2.2.1 Surface Salinities

Surface water off Browns Point in the vicinity of Commencement Bay is

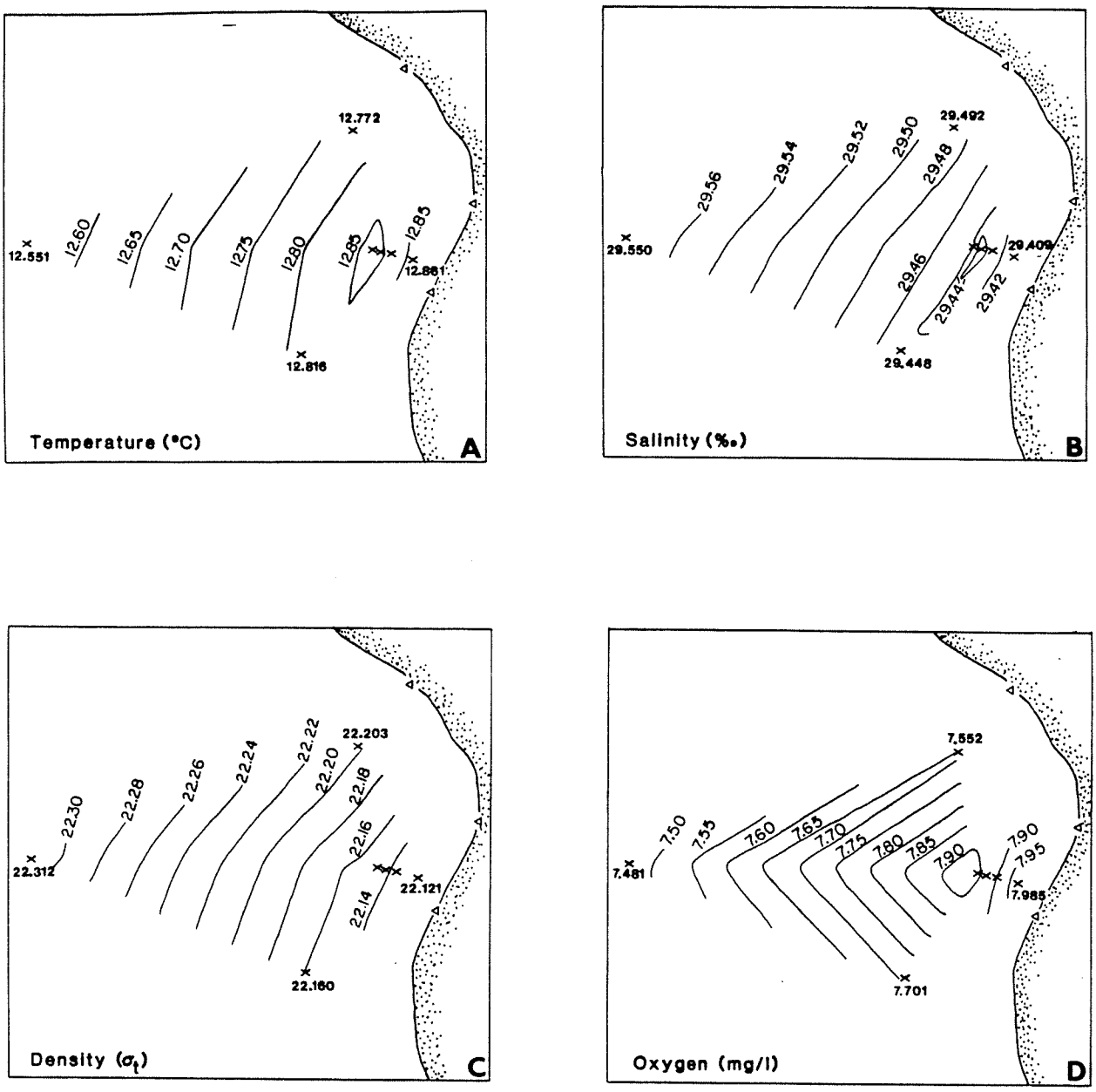



Figure 5.29. Plan view of mean temperature (A), salinity (B), density (C), and dissolved oxygen (D) at 5 m depth in Seahurst Bay for seven sample periods during 8/2-9/27/82. Notation: x, locations for stations 4-10; numbers near x, mean CTD values at outlying stations 4, 6, 10, and 5.

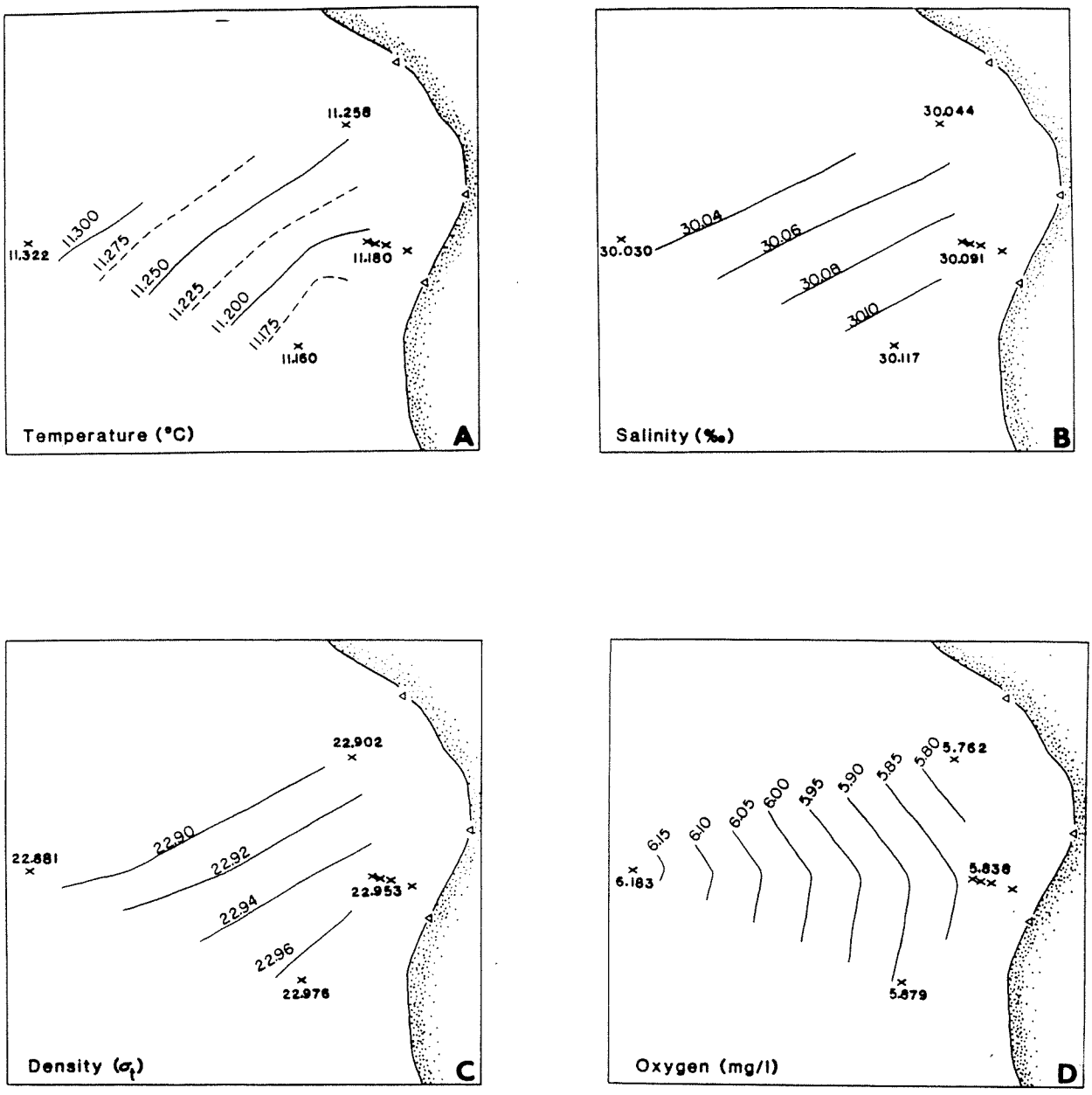



Figure 5.30. Plan view of mean temperature (A), salinity (B), density (C), and dissolved oxygen (D) at 80 m depth in Seahurst Bay for seven sample periods during 8/2-9/27/82. Notation: x, locations for stations 4-10; numbers near x, mean CTD values at outlying stations 4, 5, 6, and 7.

characterized by markedly lower salinities than off Seahurst (cf., station 3 off Browns Point, and station 4 at mid-channel off Seahurst; Figure 5.1). Thus, it may be expected that if patches of Commencement Bay water migrate northward to Seahurst, they may appear as anomalous low salinity values. To investigate this hypothesis, histograms of surface salinity were prepared for stations in the Bay and for station 3 near Commencement Bay. In addition, historical site 322 off Browns Point was also used in the comparison. The histogram was constructed from varying sample sizes. At CTD station 3 only seven samples of surface salinity were available, whereas there was a fourfold greater sample size (28) available from the historical data during July-October. In the Bay for this period there were a total of 67 values available for stations 5-10.

Figure 5.31 shows the three histograms of Commencement Bay CTD data, Commencement Bay historical data, and Seahurst Bay CTD data. At stations 322 (historical) and 3 (CTD) off Browns Point the salinities are skewed toward low values, most likely due to the proximity of the Puyallup River discharging into Commencement Bay. Salinities observed at station 3 were between 27-30 °/oo, whereas the historical data shows salinities as low as 23 °/oo. In contrast, salinities in the Seahurst Bay were observed as low as 28 °/oo. The sample size at site 3 appears too small to be representative of the historical distribution. The distribution in the Seahurst Bay does not show low salinities that might be associated with water from Commencement Bay. A much larger data set obtained over a longer period of time will be required to fully explore this hypothesis.

To further investigate the surface salinity, the salinities observed at station 4 were correlated with winds observed at Point Robinson. Winds as measured at West Point, Alki Point, and Point Robinson were compared and found

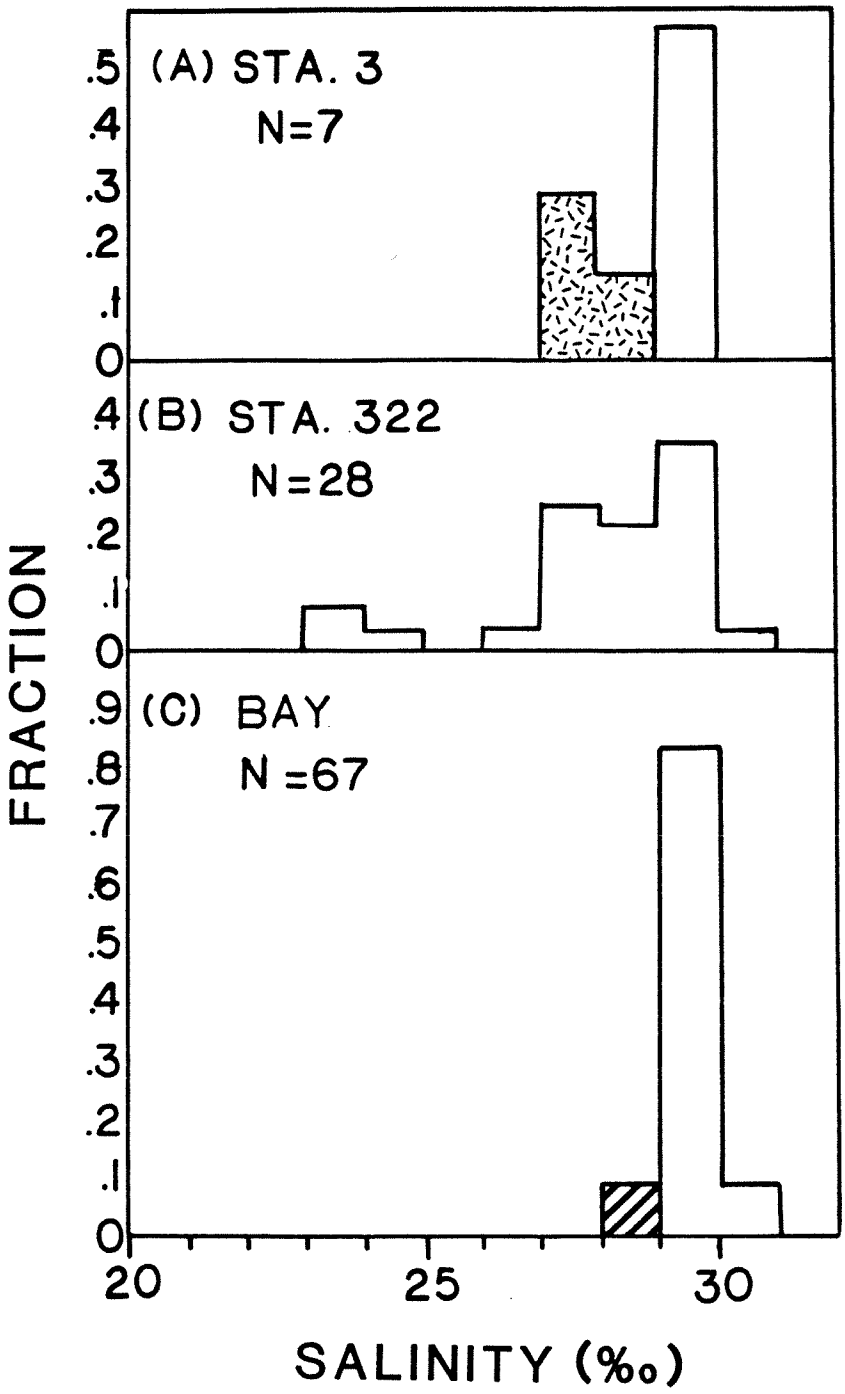



Figure 5.31. Histograms of surface salinities at CTD station 3 (a), historical station 322 (b), and CTD stations 5-10 (c). Notation: N, sample size; hatched area; surface salinities recorded 2 August 1982; stippled area, skewed low values probably due to the proximity of the Puyallup River.

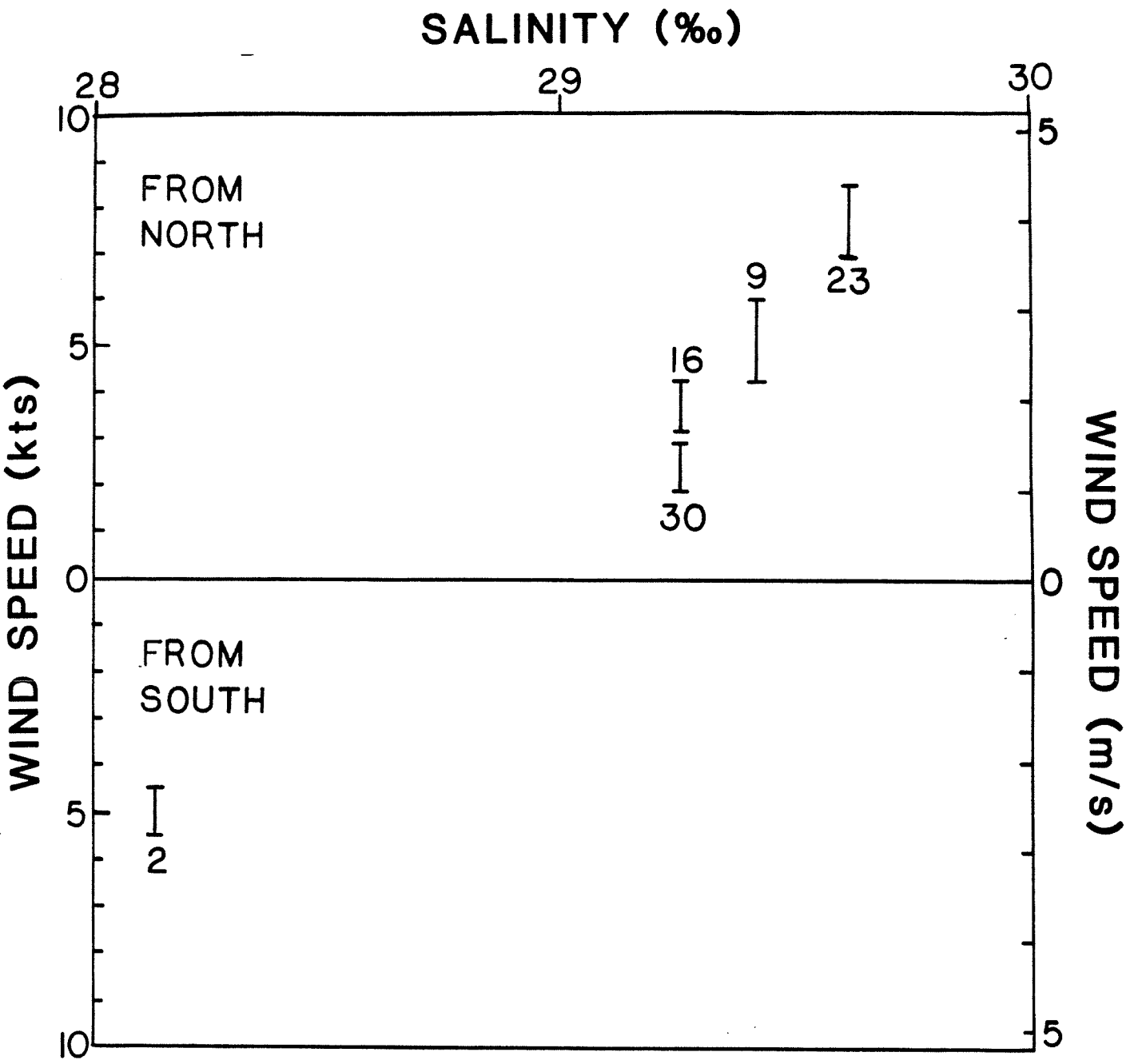



Figure 5.32. Surface salinity observed at station 4 versus net wind speed. Notation: bracketed lines, difference between 24 and 48 hour net wind interval prior to salinity observation; number, date in August of salinity observation.

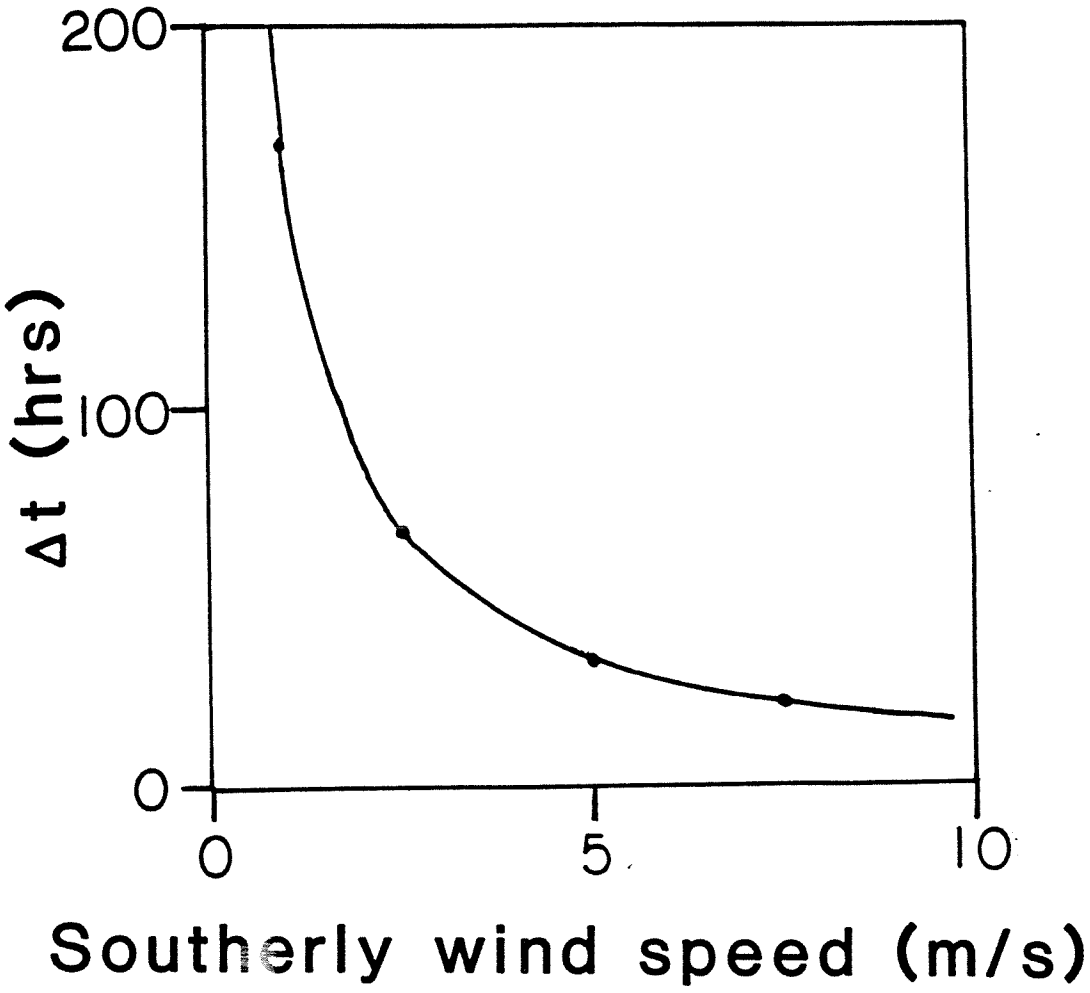



Figure 5.33. Southerly wind speed versus time in hours for a hypothetical water parcel to travel from Commencement Bay to Seahurst Bay.

to be similar in speed and direction. Point Robinson was chosen for comparison with salinity values because of its location between Commencement Bay and Seahurst. In order to eliminate the effects of seasonal progression, a one month interval during August was chosen for the comparison for which five surface salinities were available.

Figure 5.32 shows the surface salinity observed at station 4 versus the net wind speed computed during a time interval prior to the salinity observation. Two intervals were chosen: 24 and 48 hours. Despite the choice of the interval there appears to be a dependence of the salinity on the wind, where winds from the south tend to lower the salinity and winds from the north increase it. In particular, on 2 August a mean speed of 4-6 knots occurred immediately preceding the salinity observation. The salinities observed in the Bay at stations 5-10 make up the entire class interval of 28-29 $^{o}/oo$ shown in Figure 5.31c. Thus, it seems likely that the low salinity water observed at this time originated from the south.

Some preliminary calculations of wind effect seem appropriate. Consider a wind that causes the surface water to move at 3% of the wind speed. Then compute the time required for the wind to move Commencement Bay water to Seahurst as the distance between the two locations divided by 3% of the southerly wind speed. Figure 5.33 shows that a wind speed of approximately 14 knots would be sufficient to transport surface water from Commencement Bay to Seahurst Park during a 24-hour period. During August through April the wind is typically from the south at approximately 5-9 m/s (Ebbesmeyer et al., 1982). On the average these winds are sufficient to move Commencement Bay water to the vicinity of Seahurst. Unfortunately, salinity observations sufficient to document this wind effect were not calibrated in time for inclusion in this annual report.

#### 5.3.2.3 River Discharge

Experiments conducted in the UW hydraulic model showed that Puyallup River water will often be carried to site 3 by tidal currents. The influence of Puyallup River water was evident in the mean vertical salinity profile (Figure 5.24) and the histogram (Figure 5.31) of surface salinities lower than 29 °/oo. In the histogram at stations 3 and 322, the dominant mode is considered to be background water; salinities comprising the skewed tails are considered to be diluted Puyallup River water.

## 5.4 Discussion

In the following discussion three aspects are addressed: layers in the water column; bottom creep of water towards shore; and northward intrusion of Commencement Bay water into the area off Seahurst Park.

### 5.4.1 Layers in the Water Column

In the analysis, layers were evident between various depths in the water column. Layers of approximately 10 m depth were found off Browns Point and in the Bay. The shallow layer off Browns Point consisted of water lower in salinity and density, and higher in temperature and oxygen than found at mid-channel off Seahurst. This layer is attributed to discharge from the Puyallup River.

A shallow layer appears within the Bay. This water is also lower in salinity and density and higher in temperature and dissolved oxygen than found at mid-channel off the Bay. Elsewhere in this report, the water column studies have shown that the concentrations of chlorophyll and nutrients in the surface water increase towards shore. Although there is local drainage into Seahurst Bay, it does not appear sufficient to generate the signatures

observed. Lateral connections of the lens with other sources should be sought, such as larger rivers or creeks. However, the present data base is not sufficient to trace the horizontal extent of the lens, and thus connect it to other possible sources.

Below the surface layers there are differences both along mid-channel in the Main Basin, and between mid-channel and inshore waters off Seahurst Park. Along mid-channel there is a discontinuity near 50 m depth in the two stations within East Passage (stations 3 and 4), but not for the station off West Point (station 1). The discontinuity occurs near the sill depth (53 m) between Blake and Vashon islands across which much of the flow from Colvos Passage exits both northward past West Point and southward into East Passage. A reasonable speculation is that the discontinuity is associated with the sill depth; however, the associated dynamics remain unknown.

This discontinuity is not evident in the Bay. Moreover, above approximately 80 m depth there are density gradients between mid-channel and the Bay. This leads to speculation that the flow dynamics in the Bay differ from those at mid-channel.

Some evidence of the dynamics at depth may be seen in the vertical sections of dissolved oxygen. A striking feature is the tongue of low oxygen centered near 90 m depth below the shelf break. This feature occurs at the southern end of an eddy-like circulation (Figure 5.34; URS Engineers 1983). This pattern has been inferred from a number of moored current meter records. It is speculated that the slow circulation leads to low oxygen concentrations because of natural oxygen utilization in the water column.

### 5.4.2 Bottom Creep Along Shore

In the analysis, contours were constructed along a transect from mid-channel to shore. The contours did not reveal signatures of upwelling along

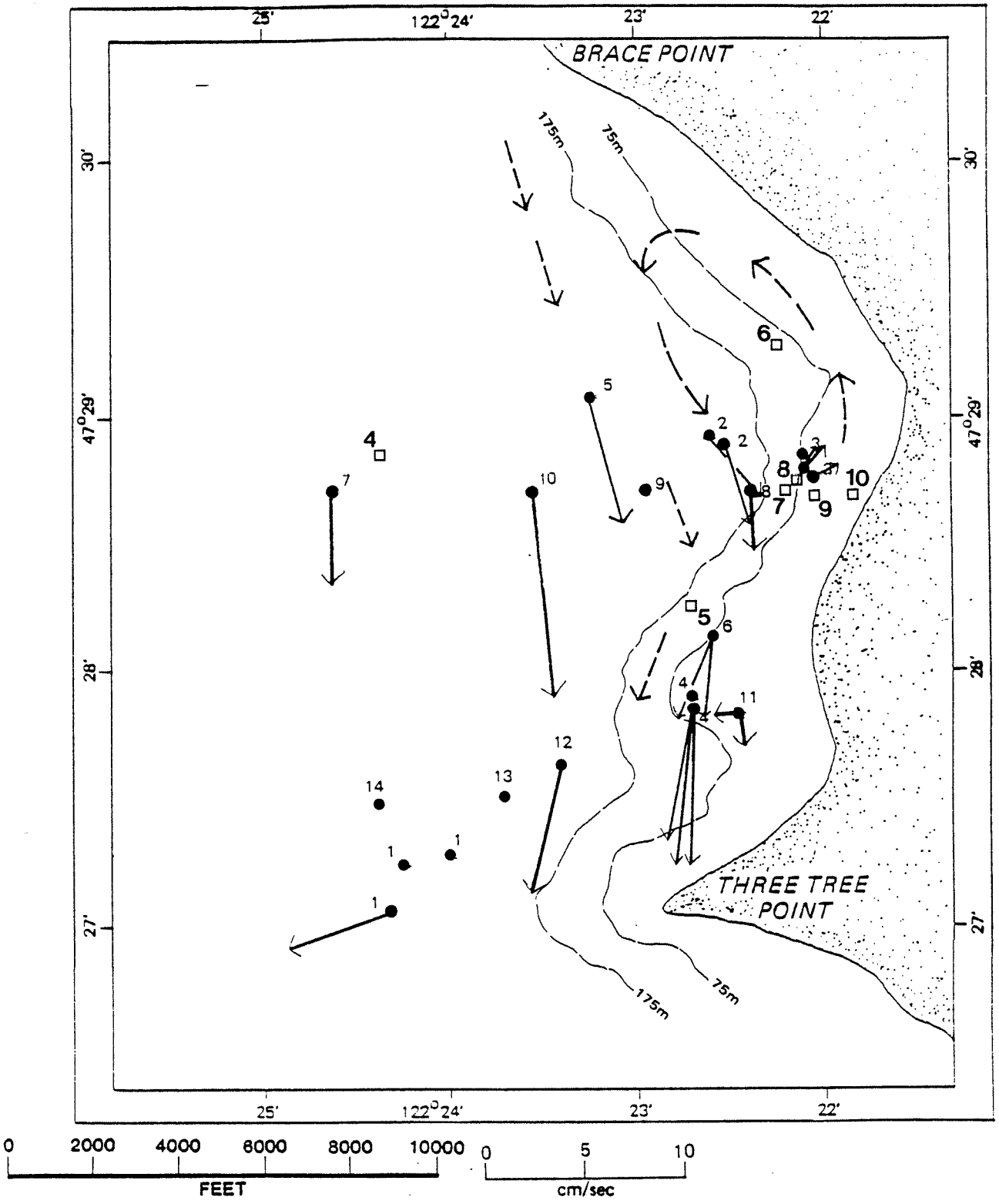



Figure 5.34. Net velocities in Seahurst Bay in the depth range of 30-60 m (URS Engineers, 1983). Dashed arrows represent inferred circulation. Notation: moored current meter sites (●); Baseline CTD stations (□).

the bottom. The water column studies have also not found evidence of bottom water intrusion.

### 5.4.3 Intrusion of Commencement Bay Water

The present analysis is based on data collected during July through October. Historically, this is a time of low runoff and mostly northerly winds. Moreover, Commencement Bay may be a statistically significant source of ammonia and may contribute surface water northward in East Passage. Computations suggest that during the winter, a period of higher runoff and persistent southerly winds, Commencement Bay surface water can be transported to the vicinity of Seahurst Park. The observations reported herein are suggestive but do not prove this transport.

# 6.0 INTERTIDAL AND SHALLOW SUBTIDAL BENTHIC STUDIES

R. Thom, R. Albright, C. Simenstad, J. Cordell,
J. Hampel, W. Evans, B. Calder, J. Hoyle, K. Chew

## 6.1 Introduction

The importance of studying nearshore benthic assemblages became evident early in the first year of the baseline studies. Indications from the water column and circulation tasks were that there existed a high probability that floatable and dissolved constituents of the effluent may reach the beach. Circulation studies showed that water moves in two basic patterns in the Seahurst Bight. First, the majority of drift cards released off Seahurst Park moved directly eastward to the shoreline. Second, a certain proportion of deeper southerly flowing water offshore is entrained in a slow moving, northward flowing back eddy. This water may transfer effluent to the nearshore environment without subjecting it to biological activity and mixing in the more open water environment.

Because people come in direct contact with the nearshore environment, and consume benthic organisms in the Seahurst Bight, the study of the nearshore benthic biota is of great interest. Effects associated with movement of effluent to the nearshore environment may include increased chances of noxious algal blooms, increased toxic loads in benthic organisms, increased bacteria and pathogen concentrations in benthic organisms, increased chances of toxic dinoflagellate blooms, and modifications of food web structure.

During the course of the first year, benthic studies were extended to shallow subtidal sand and eelgrass habitats. These habitats are extensive in the Seahurst Bight and elsewhere in the East Passage. Further, benthic populations are abundant and very productive in these habitats. Shallow

subtidal areas are utilized extensively by fish populations, and have the added advantage of being removed from direct disturbance (eg. trampling, clamming) by man.

The first year of studies consisted of a prestudy, a habitat distribution and characterization investigation, and the initiation of seasonal sampling. The present report contains the results of the prestudy, habitat distribution and characterization and seasonal studies through the first three quarters (9 months) of Phase I.

6.1.1 Purpose

The purpose of the intertidal and shallow subtidal benthic studies is to document the spatial and temporal aspects of the various assemblages existing in the nearshore environment of the East Passage. The work is concentrated in habitats which meet the following criteria: 1) they must be extensive in the East Passage region; 2) they must contain a relatively abundant and/or productive benthic assemblage; 3) they must allow sampling in a quantitative and repeatable manner; and 4) they must contain a benthic assemblage that is sensitive to the effects of effluent. The first two criteria are related to the ecological importance of the habitat in the region. The second two criteria are required for efficient baseline and future monitoring efforts. In addition, the quantitative parameters of the assemblages (eg. species abundance, productivity rates) were chosen based on their relatively high sensitivity to documenting the effects of environmental disturbances.

6.1.2 Objectives

The objectives of the first nine months of study were to: 1)identify major nearshore benthic habitats in the study region; 2) document the benthic populations inhabiting these habitats in the study region; 3) conduct a pre-study to determine sample sizes required to adequately estimate values for the

selected biological parameters; 4) choose long-term study sites; and, 5) conduct the first three quarters of sampling at these sites.

## 6.2 Description of Study Region

Study sites were located in the East Passage and Colvos Passage (the West side of Vashon Island), ranging southward from Lincoln Park to Dash Point (Figure 6.1). The region is roughly bounded, both physically and chemically, by Commencement Bay, the Puyallup River, and the Tacoma Narrows to the south, and the Duwamish River to the north. The Seahurst Bight is centrally located in the study region. Early evidence (Ebbesmeyer, et al. 1982) suggested that the general flow pattern was southerly in East Passage. We therefore placed the majority of study sites to the south of the Seahurst area.

The shoreline in the region consists of steeply to gently sloping beaches. Several streams enter Puget Sound in the East Passage, and form rather extensive alluvial fans in the intertidal zone. Substrata is highly variable and is comprised of mud, fine and coarse sands, and cobble-boulder fields. Eelgrass (Zostera marina) forms dense stands at low intertidal and shallow subtidal depths throughout much of the region. Drift logs accumulate in the upper fringes of the intertidal zone in many areas. Well over 90% of the tidelands in the region are privately owned. Convenient access to public beaches is provided at Lincoln Park, Seahurst Park, Point Pully, Redondo, Dash Point, Aquarium, Ellisport, Point Robinson, and Dockton. The majority of the area immediately above the intertidal zone on the eastern shore is occupied by single family residences, while forests predominate on the western shore of East Passage. Ground water discharged across the beach, terrestrial plant litter, and leakage from septic tank systems may affect the shoreline biota.

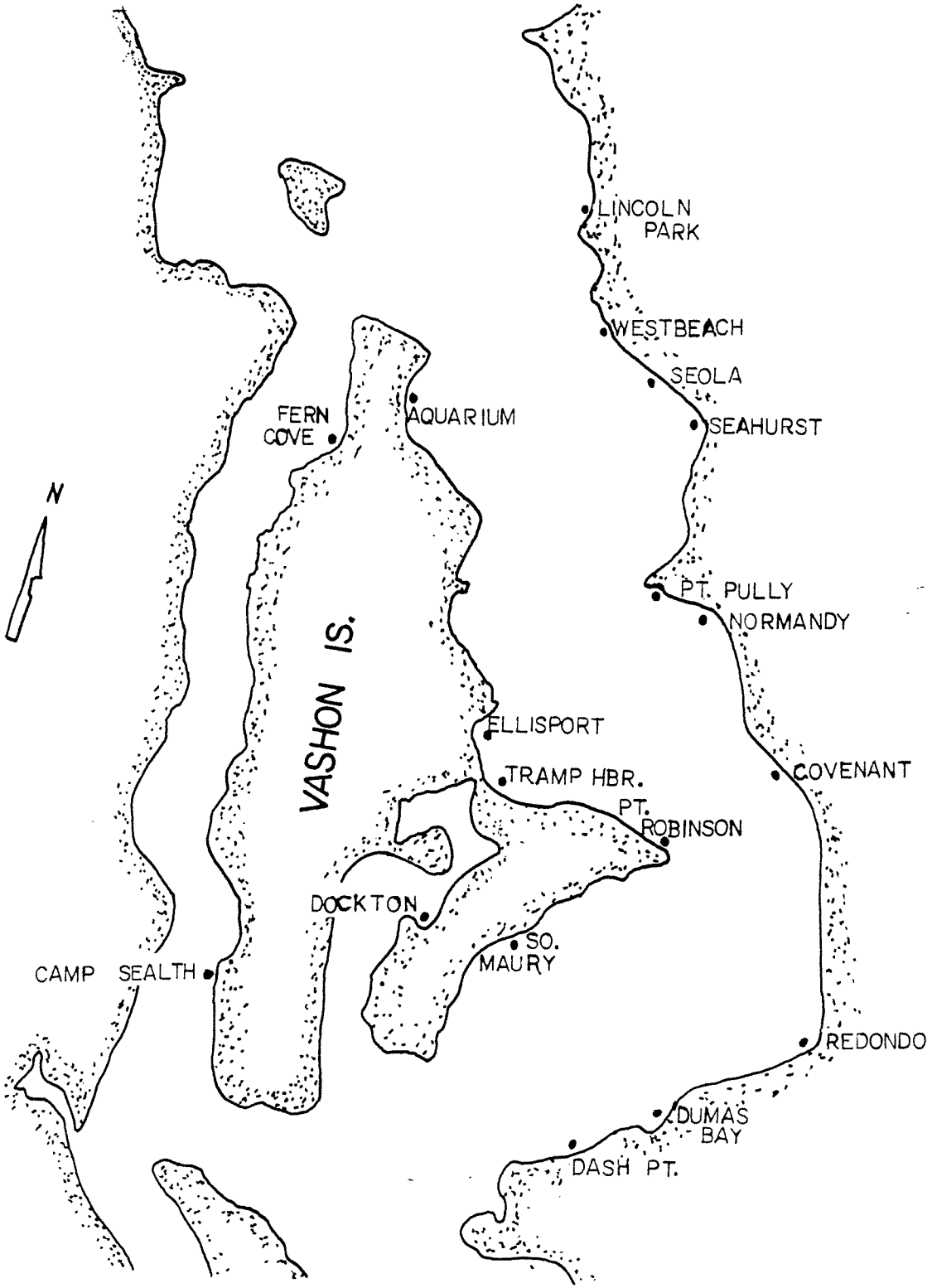



Figure 6.1. Intertidal study sampling locations

There are at least three sewage outfalls in the region. These are located at Seola, Redondo, and Dumas Bay. Information regarding the exact location of each outfall and the nature of the effluent is currently being compiled.

## 6.3 Materials and Methods

### 6.3.1 Habitat Distribution and Characterization

Eighteen beaches representative of the intertidal environment were chosen for the habitat study (Figure 6.1). Collections were made at a total of 30 sites. The sites were located in a representative portion of the major habitats (ie. sand, mud, cobble, eelgrass) at each beach. The location and description of each site were presented earlier (Thom et al. 1983). Three core samples (core size = 625 $cm^2$ x 30 cm deep) were collected by digging at each site. The sediment was immediately sieved through 0.5 inch (12.5 mm) mesh screens, and the bivalves retained on the screen were placed in labeled plastic bags, transported to the lab, and frozen. Cylindrical core samples (core size = 23.76 $cm^2$ x 10 cm deep) were removed from two random locations at each site. These samples were placed in labeled jars and preserved with 10% buffered formalin. Following preservation, the samples were sieved through a 1 mm mesh sieve. The animals retained on the screen were then placed in vials containing 70% ethanol. The percentage cover of macroalgal, eelgrass, and sessile macroinvertebrate species was sampled by taking photographs of 5-10 random 0.1 $m^2$ areas at each site. A general collection of algal species was also made in the habitat.

Duplicate epibenthic zooplankton samples were collected at high tide at each site using a modified suction pump which was designed for this purpose (Figure 6.2). The hydraulic suction pump system has been used extensively in

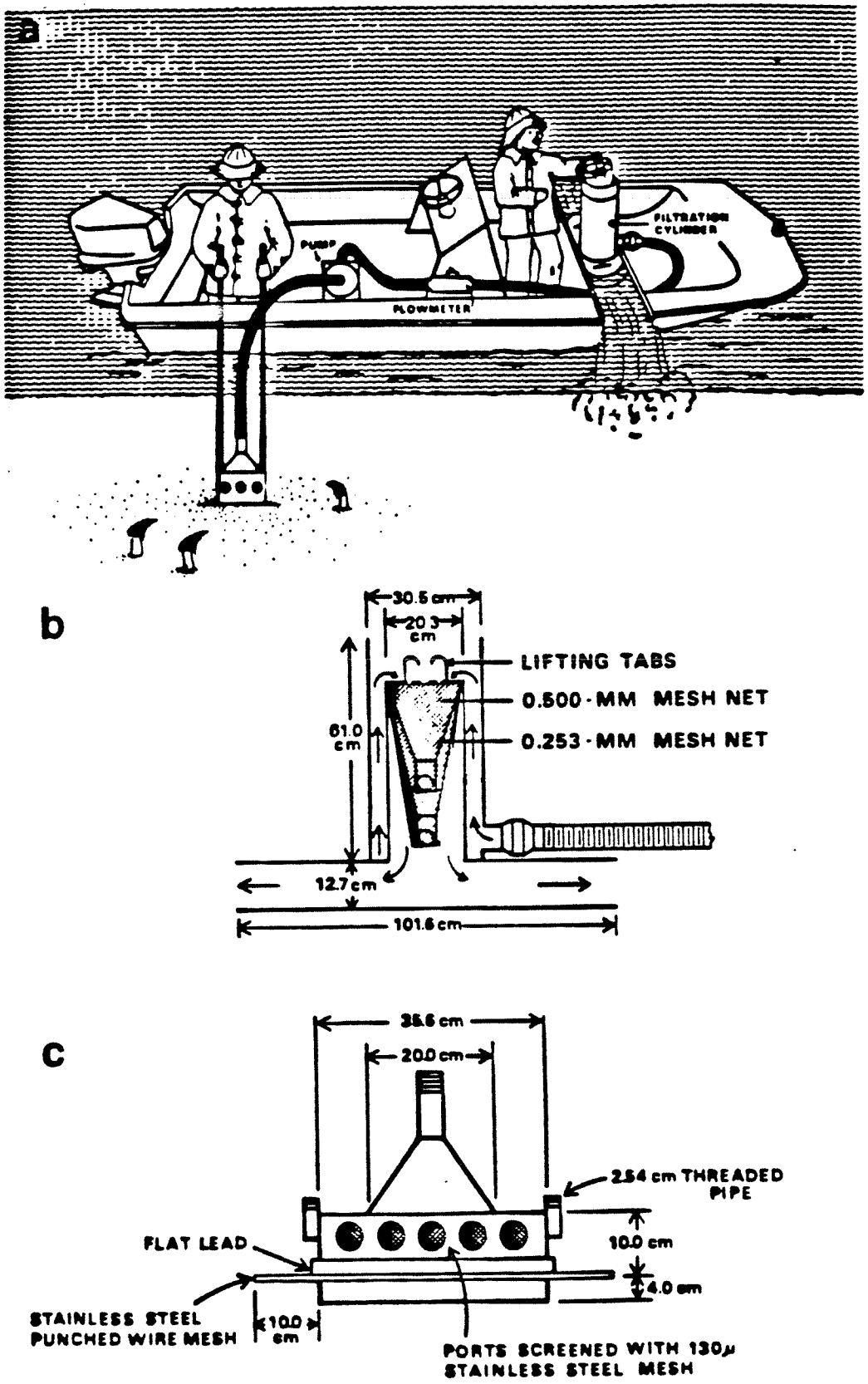



Figure 6.2. Hydraulic suction pump utilized to quantitatively sample epibenthic meiofauna and zooplankton.

studies of these assemblages in the Columbia River Estuary (Houghton, et al. 1981), Grays Harbor (Simenstad and Eggers 1981; Cordell and Simenstad, 1981), the Strait of Juan de Fuca (Simenstad, et al. 1980), and various locations in Puget Sound (Simenstad, et al. 1980b; Simenstad and Cordell 1980, 1982). The pump drew water and associated organisms from within a ported sampling cylinder firmly pressed against the substrate. The samples passed from the pump through a flowmeter and into a double-walled filtration cylinder in which two conical plankton nets were suspended. The nets were 0.500 mm and 0.253 mm mesh. At least 0.1 $m^3$ of water, over three times the volume of the sampling cylinder, was filtered in order to ensure total evacuation of organisms within the sampling cylinder. The sampling time was reduced if, due to clogging of the port screens, the pump's suction began to lift bottom sediment. The volume of the sampling cylinder was 0.025 $m^3$ and subsequent sample analyses were interpreted as standing stock values per $m^3$ of epibenthic habitat within 25 cm of the bottom. These values (number/$m^3$) may be converted to areal estimates ($m^2$) by dividing by 4.

Finally, sediment core samples were taken for analysis of biochemical oxygen demand (BOD), percent volatile solids, sulfides, total organic carbon and nitrogen, and grain size. The methods for these analyses are provided in the analytical chemistry section (Sec. 13.0).

All organisms in the infauna and bivalve samples were identified by species, enumerated and weighed. Slides of the photographic samples were projected onto a grid of 50 random points. The organisms occurring under the points were identified and assigned a percentage cover value which was determined by the number of points at which they occurred. Taxa not at a point, but within the quadrant, were assigned a nominal score of 0.2 percent.

Samples of epibenthic zooplankton were preserved in 5% buffered formalin

immediately upon removal from the sampling nets. After five or more days of fixation in the formalin solution, the samples were sieved to remove the formalin and extraneous sediment and then preserved in 45% Isopropanol in labeled vials. Rose Bengal dye was added to the 0.253-mm fraction sample at this time in order to facilitate sorting; this fraction was also panned to remove extraneous sediment prior to sorting.

If necessary to accomodate excessively large numbers of organisms, the 0.253-mm fractions were systematically subsampled. The subsampling method usually involved successively dividing the sample in a quartered petri dish. In the case of extremely high numbers, subsamples were withdrawn from the whole sample using a Hensen-Stempel pipette. The entire 0.500-mm fraction and the 0.253-mm fraction subsample of each duplicate were identified, enumerated, and weighed (to the nearest mg). Organisms were sorted and identified to the lowest level possible considering the state of the literature. For example, mysids and gammarid amphipods were assigned to species given existing taxonomic descriptions while many harpacticoid copepods were identified only to genus or higher level. In addition to taxonomic identification, organisms were also sorted, enumerated, and weighed according to life history stage e.g. larval stages, reproductive stage, and sex.

6.3.2 Long-Term Study Site Selection

The habitat study provided an excellent indication of the distribution of intertidal habitats. Further, the samples taken allowed determination of which habitats contained the most abundant plant and animal assemblages. Five major habitats were chosen for long-term investigations based on consideration of the habitat study data and the criteria outlined in Sec. 6.2 above. The habitats included high and low intertidal cobble/sand, low intertidal and shallow subtidal sand, and subtidal eelgrass. High intertidal cobble/sand

habitat study sites chosen for study were located at Seola Beach, Seahurst Park, and Aquarium. Low intertidal cobble/sand sites were located at Seahurst Park, Normandy Beach, Covenant Beach, and Tramp Harbor. Low intertidal sand sites were established at Seola Beach, Seahurst Park, Aquarium and Tramp Harbor. Subtidal sand and eelgrass sites were located at Seola Beach, Seahurst Park, Aquarium and Tramp Harbor (Fig. 6.1). These sites have been described earlier (Thom, et al. 1983).

6.3.3 Parameter Selection

The parameters chosen for study met three criteria. First, the parameter must be a measure of assemblage structure or function commonly used in the ecological literature for the types of habitats with which we are dealing. Second, the parameter must be relatively easy to measure in a repeatable manner. Finally, changes in values of the parameter must be a sensitive measure of changes in the assemblage structure or function. In the intertidal sand habitat, the parameters measured were pigment concentrations (chlorophyll *a*, phaeopigments) and primary production of sediment associated algae. Biomass, species abundances and diversity (measured by both species richness and the Shannon-Wiener H' value) of small infauna and epibenthic zooplankton were also measured. In low intertidal cobble habitats where clams and macroalgae are abundant, the parameters measured were macroalgal productivity, cover, biomass, species abundance and diversity; clam species abundance, biomass, and length-weight relationships; small infaunal and epibenthic zooplankton species abundances, biomass and diversity. In high intertidal cobble habitats, where clams are not abundant, the measured parameters included all of the parameters of the low intertidal cobble habitats except those related to the clam fauna. Small infauna and epibenthic zooplankton species abundance, biomass, and diversity were measured for both the shallow

subtidal habitats (i.e. sand and eelgrass). Eelgrass density was also recorded along with average blade length in the eelgrass habitat. Taxa biomass were recorded for plant material collected in the algal drift line.

6.3.4 Prestudy

The purpose of the prestudy was to determine the number of replicate samples required to compile adequate estimates of the mean values for the parameters measured. Several factors entered into the decision regarding the adequacy of an estimate. First, sampling frames (i.e. either cores or quadrats) were chosen that were of a size to be efficient, unencumbering in the field, and large enough to sample at least a moderate number of species of each assemblage within each habitat. Past investigations in Puget Sound (i.e. Armstrong, et al. 1976, Thom, et al. 1979, Zeh, et al. 1981) were helpful in making decisions on sampler sizes. Next, the degree of change in mean parameter values to be detected was determined. Zeh et al. (1981) suggested that detecting a change of 50% in mean value was a reasonable level for intertidal assemblages. As is discussed below, a level much higher than 50% represents a very gross change (e.g. a 100% change would mean that the mean value either doubled or went to zero). In contrast, in view of the relatively great variation associated with the parameters, a level much below 50% would require an inordinate number of replicate samples and a very costly effort. Associated with the degree of change is the level of statistical confidence applied to test for differences. Dr. Conquest's work (Conquest 1982) and her suggestions were of great help in deciding that changes should be tested at an $\alpha\,(_{2\text{-tailed}})\ \beta = 0.10$ and $(_{1\text{-tailed}}) = 0.20$. Her formula (Conquest 1982) was used to calculate the number of replicates for each parameter.

6.3.4.1 Macroalgal Assemblage

The cover of the sessile biota (ie. macroalgae and sessile animals) was

sampled at two cobble sites at Seahurst Park on 11 May 1982. Color photographs were taken of 20 random 0.1 $m^2$ areas within each habitat. The slides made from the photographs were projected onto a grid of 50 random points and treated as in the habitat study (Sec. 6.3.1). Algal biomass was then sampled by collecting all attached algae from within 0.06 $m^2$ areas at the first 10 random sampling locations. The samples were bagged separately, frozen, and later sorted to species. Each species was dried at 70 $^{o}C$ and weighed to the nearest mg.

6.3.4.2 Microalgal Assemblage

It was initially proposed that species abundances of the sediment associated microflora would be estimated. However, upon testing the published methods for doing this, a significant problem was discovered. Identification of diatom species requires very high magnification, which, in turn, requires separation of the diatoms from the sediment. Adequate removal methods (i.e. boiling in nitric acid) destroy pigments, which makes it difficult to distinguish cells alive when collected from those that were dead when collected. Attempts to remove intact cells yielded incomplete results. It was, therefore, decided that pigments (chlorophyll a and phaeopigments) in the sediments be sampled instead. Pigment concentration is a quantitative and easily measured parameter of the benthic microalgal assemblage. Ten replicate cores (3.14 $cm^2$ x 0.5 cm deep) were collected on 18 August from the sand habitat at Seahurst Park. Chlorophyll a and phaeopigments were analyzed from 90% acetone extracts using a fluorometer (Holm-Hansen, et al. 1965).

6.3.4.3 Algal Productivity

Specimens of the 13 most abundant algal taxa (12 macroalgal taxa plus 1 specimen of tufted diatom) and sediment cores were collected at Seahurst Park on 17 August 1982. Portions (0.014 - 0.198 g. dry wt.) of each species were

added to 300 ml. BOD bottles containing 150 microns filtered seawater from Seahurst. Two light bottle and two dark bottle replicates for each species were incubated in a water bath at ambient seawater temperature and ambient light (clear skies) for approximately 2 hours. Seawater only blanks were also incubated to account for plankton metabolism. Initial and final DO were measured using an oxygen probe, and the flux in $O_2$ was converted to carbon fixation per unit area of algal thallus and per unit dry weight following the methods of Littler and Murray (1974).

6.3.4.4 Eelgrass Density

The number of turions in 20 random 0.06 $m^2$ quadrats was recorded by divers at the Seahurst Park subtidal eelgrass habitat on 22 August 1982.

6.3.4.5 Drift Assemblage

On 19 July 1982, six non-selective 0.06 $m^2$ samples of plant material were collected from the approximate center of the algal drift line at the Seahurst Park drift algae study site. The samples were bagged separately, frozen, and later sorted to major group (e.g. green algae, terrestrial plants) and the dry weight recorded to the nearest mg.

6.3.4.6 Small Infauna

Twenty small infauna core samples (core size = 23.76 $cm^2$ x 10 cm deep) were collected in each of two habitats (cobble and sand) at Seahurst Park. Samples were collected and processed identically to small infaunal samples collected during the habitat study. The number of taxa, biomass and number of individuals were determined for each core sample.

A total of 15 small infaunal core samples were collected to a depth of 15 cm in four habitats (cobble, sand, gravel, and eelgrass) at Seahurst Park to determine the optimal depth to which core samples should be collected. Each core sample was divided into 3 depth strata of 5 cm intervals each, which were

placed in separate labeled jars. Each 5 cm strata was then processed as a separate sample and analyzed as to infaunal abundance and species composition. Results were used to compare the data obtained for core samples of 5 cm depth, 10 cm depth (the 0-5 cm and 5-10 cm strata combined), and 15 cm depth (all three strata combined).

6.3.4.7 Large Infauna

Ten large infaunal core samples (core size = 625 $cm^2$ x 30 cm deep) were collected in each of three habitats (high cobble, low cobble, and sand) at Seahurst Park. Samples were immediately washed through a 0.5 inch (12.5 mm) sieve. All clams retained in the sieve were processed and the data analyzed in the same manner as large infaunal samples collected during the habitat study.

6.3.4.8 Epibenthic Zooplankton Assemblage

The epibenthic pump was used to collect 2 replicate samples from all habitat study sites in May 1982. The results from these samples were used to calculate sample sizes.

6.3.5 Long-Term Studies

The study sites presented in Sec. 6.3.2 above were sampled during July-August, November-December 1982 and January-February 1983, which represent the first three quarters of seasonal sampling. Additional samplings were conducted for some parameters and these are detailed in the appropriate sections below. The sampling design within a habitat is shown in Figure 6.3.

6.3.5.1 Macroalgal Assemblage

The cover of macrobenthic assemblages was sampled at 30 random 0.1 $m^2$ areas at each cobble habitat each quarter. An additional sampling consisting of 15 random 0.1 $m^2$ areas was conducted at the Seahurst Park high and low intertidal cobble sites on 14 September 1982 in conjunction with the collection of specimens for primary production experiments. Samples were

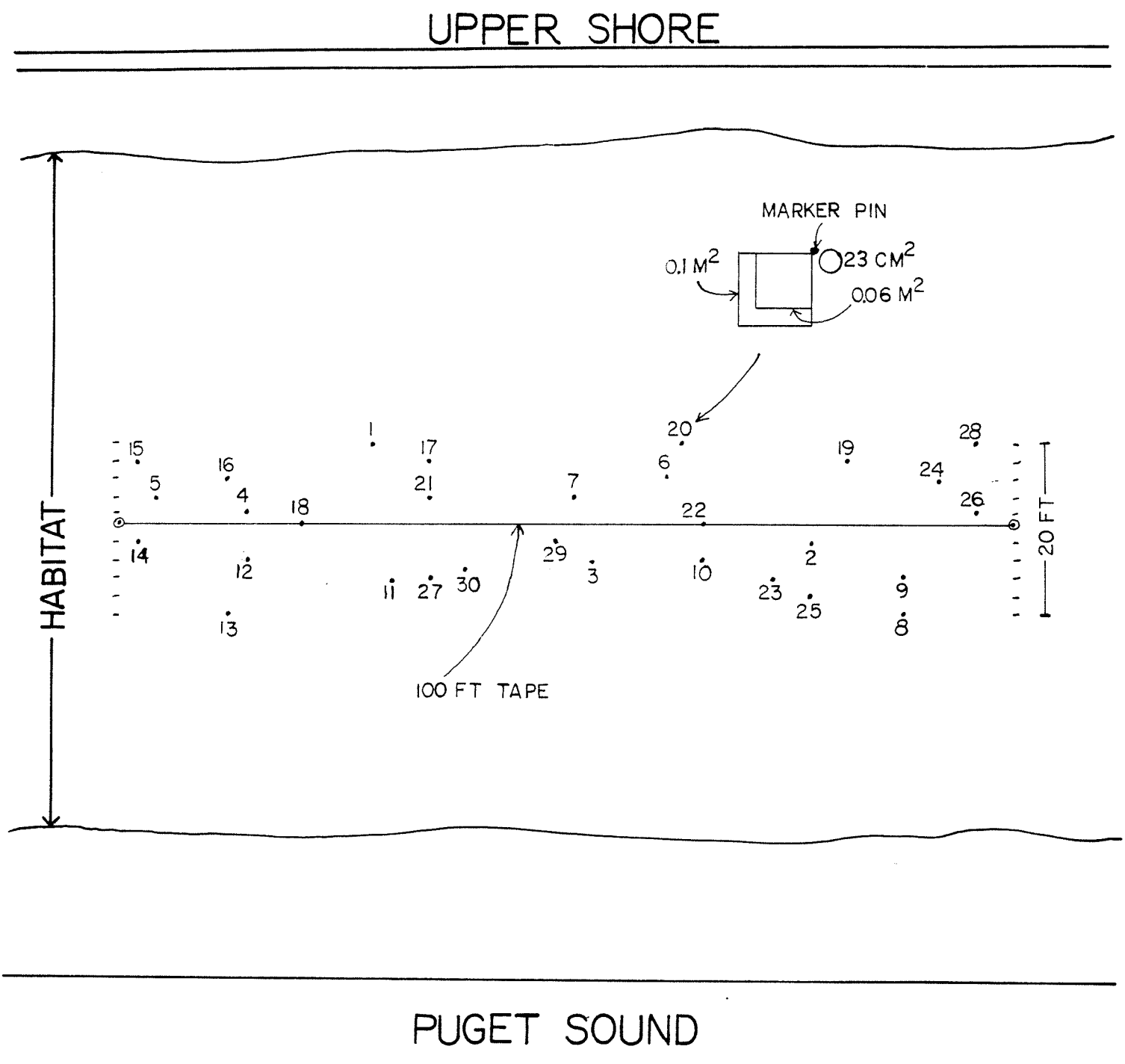



Figure 6.3. Plan view of a typical sampling pattern within a habitat. Thirty random points (numbered 1-30) are located within the sampling area each season. See text for explanation of the sampling plan.

processed as outlined in the habitat study section. For biomass determinations, macroalgae were collected from within 0.06 $m^2$ quadrats at the first 15 random areas at each site during the first quarter. Subsequently, algal biomass was sampled using 0.1 $m^2$ quadrats to allow direct correlations between cover and biomass to be determined. Processing methods were described above.

6.3.5.2 Microalgal Assemblages

Microalgal pigments were sampled using 3-10 replicate core samples at the Seahurst sand habitat on 18 August, 14 September, 15 November, and 29 November 1982. These methods are described above.

6.3.5.3 Algal Productivity

Algal productivity was measured on the most abundant taxa occurring at Seahurst Park on 17 August, 15 September, 30 November 1982 and 11 January 1983. Methods are outlined above. Data on sunlight during the experiments was recorded using a PANLUX electronic light meter (Grossen).

6.3.5.4 Eelgrass Density

The density of eelgrass was recorded at the shallow subtidal sites on 22 August and 21 November 1982 at Seahurst Park, 22 August and 21 November 1982 at Seola Beach, 30 July and 5 December 1982 at Aquarium, and 29 July and 2 December 1982 at Tramp Harbor. Twenty random 0.06 $m^2$ quadrats were sampled at each site as described above. In addition, the average length of the blades was also estimated during each visit.

6.3.5.5 Drift Assemblage

Drift material was collected using six non-selective replicate 0.06 $m^2$ quadrats at each beach. Samples were collected at Seahurst Park on 19 July, 14 September, and 3 November 1982, and 26 January 1983; at Seola Beach on 5 August and 1 November 1982, and 25 January 1983; at Normandy Beach on 5 August

and 1 November 1982, and 25 January 1983; at Covenant Beach on 21 July and 2 November 1982, and 27 January 1983; at Aquarium on 20 July and 4 November 1982, and 28 January 1983; and at Tramp Harbor on 20 July and 4 November 1982, and 28 January 1983.

6.3.5.6 Small Infauna

6.3.5.6.1 Intertidal

Intertidal small infaunal core samples (core size = 23.76 $cm^2$ x 10 cm deep) were collected during low tide from randomly located points along a permanent transect in each of the intertidal habitats selected for long-term study. Samples were collected on a quarterly basis. A total of 12 core samples were collected in each habitat type each quarter. Core samples were placed in labeled jars, then preserved in 10 percent buffered formalin as soon after collection as possible. Samples were left in the formalin for a minimum of 24 hours. Samples were then sieved and processed in the same manner as samples collected in the habitat study.

6.3.5.6.2 Subtidal

Subtidal small infaunal core samples were collected by SCUBA divers using hand-held core samplers. The core size used and number of replicates collected were identical to those for the intertidal small infaunal sampling. Samples were collected on a quarterly basis from randomly selected locations along a permanent transect at each site. Core samples were placed in labeled plastic bags and sealed underwater. As soon as possible following collection, the samples were transferred to glass or plastic jars and preserved in 10 percent buffered formalin. Samples were then processed in the same manner as all other small infaunal samples.

6.3.5.7 Large Infauna

Large infaunal core samples were collected during low tide at four of the

intertidal sites selected for long-term study. The substrate type at all four beaches consisted of cobble, gravel, and sand. Samples were collected on a quarterly basis from randomly selected locations along a permanent sampling transect located in the lower intertidal region (between -1.0 and 0.0 feet MLLW) in each habitat. Sample core size was 625 $cm^2$ x 30 cm deep. The number of replicates collected in each habitat varied according to the time available for sampling during low tide. We attempted to obtain a minimum of 10 replicates each time a site was sampled. The maximum number of replicates was 15. Samples were processed and analyzed in the same manner as large infaunal samples collected for the habitat study and the pre-study.

6.3.5.8 Epibenthic Zooplankton Assemblage

Duplicate hydraulic pump samples, as described in the habitat section (Sec. 6.3 above), were collected at all sites sampled for small infauna except the high intertidal cobble sites. Collections were made on 2-3 August and 1-2 November 1982, and 2-3 February 1983. Samples were processed as described above.

6.3.5.9 Water Characteristics

Duplicate samples for analysis of water characteristic parameters were gathered twice monthly during neap tides, from the six beaches. Samples were collected at approximately 0.3 m depth in hip-deep water using a hand-held Van Dorn water sampler. Water temperature was measured at the point where water samples were taken using a hand-held mercury thermometer. Water samples were transferred to glass-stoppered bottles, placed on ice in the dark, and transported to the Analytical Chemistry Laboratories at the University for analysis of salinity, dissolved oxygen, $OPO_4$, $SiO_4$, $NO_3$, $NO_2$, and ammonia.

6.3.5.10 Sediment Characteristics

Single samples of sediment were taken using the small infauna coring tube

when small infauna were sampled. The samples were analyzed by the Analytical Chemistry Section at the School of Fisheries for biochemical oxygen demand (BOD), volatile solids, dry to wet weight ratio, total organic carbon, total nitrogen, and sulfide. Sixteen trace metals were also analyzed in sediments from the habitat sites.

### 6.3.6 Additional Studies

#### 6.3.6.1 Clam Mortality

During September 1982, possible large-scale clam mortalities at Seahurst Park, Normandy Cove, and Covenant Beach were reported. The initial feelings of those who reported the mortalities were that the butter clam (Saxidomus gigantus) was the primary species involved. In view of the recreational value of butter clams in central Puget Sound, and potential implications of a die-off to interpretation of data both now and during future monitoring studies, it was deemed necessary to immediately investigate this reported mortality.

On September 17, 1982, a visit to Normandy Cove was made to look for signs of recent clam mortalities. Prior sampling at Normandy Cove had revealed the presence of a large population of butter clams. Eight 0.06 $m^2$ samples were collected to a depth of 30 cm approximately 40-50 m north of the quarterly sampling transect at the 0-0.5 foot tide level. Samples were washed through a 0.5 inch sieve.

One of the clam samples collected was given to Dr. Richard Kocan of the School of Fisheries for pathological analysis. The remaining seven samples were analyzed for clam species composition, abundance, biomass, length frequencies, and length-weight relationships. The results were contrasted with data obtained before the reported mortalities from the August 5 quarterly sampling.

As a follow-up to the September 17 visit to Normandy Cove, Jack Word, Ron

Thom, and Rick Albright of the U.W. School of Fisheries met Steve Saunders of METRO at Seahurst Park on September 29 to look for evidence of clam mortalities at that site. Digging for clams occurred at the water line during low tide (+1.2 feet relative to MLLW) in the area between the public parking area and the Highline School District Occupational Skills Center to the north.

Finally, results of the November 1982 quarterly sampling were compared to the August quarterly samples for Seahurst Park, Normandy Cove, and Covenant Beach. Comparisons were based upon clam abundance, biomass, and species composition.

## 6.4 Results and Discussion

### 6.4.1 Habitat Distribution and Characterization

The twenty sites containing attached macrobenthic organisms were clustered using percent cover data, the Bray-Curtis coefficient of dissimilarity, and the group average sorting strategy (Fig. 6.4). The most discernible group is that comprised by eelgrass sites (Site Group X). In general, one or two taxa resulted in the separation of the other site groups (Table 6.1). Site Group I (Fern Cove gravel) contained a relatively high cover of mussels (Mytilis edulis). Salt Water State Park high cobble (Site Group II) was distinguished by a high cover of barnacles. Site Group III and IV had a high proportion of Ulva lactuca. Site Group V was distinguished as a prime habitat for Enteromorpha linza. Ulva fenestrata comprised the highest cover in Site Group VI and U. expansa and Gracilaria verruosa distinguished Site Group VII. Enteromorpha linza was in greatest abundance at the gravel site at Salt Water State Park (Site Group VIII). Aquarium high cobble (Site Group IX) contained a large number of taxa in low abundance.

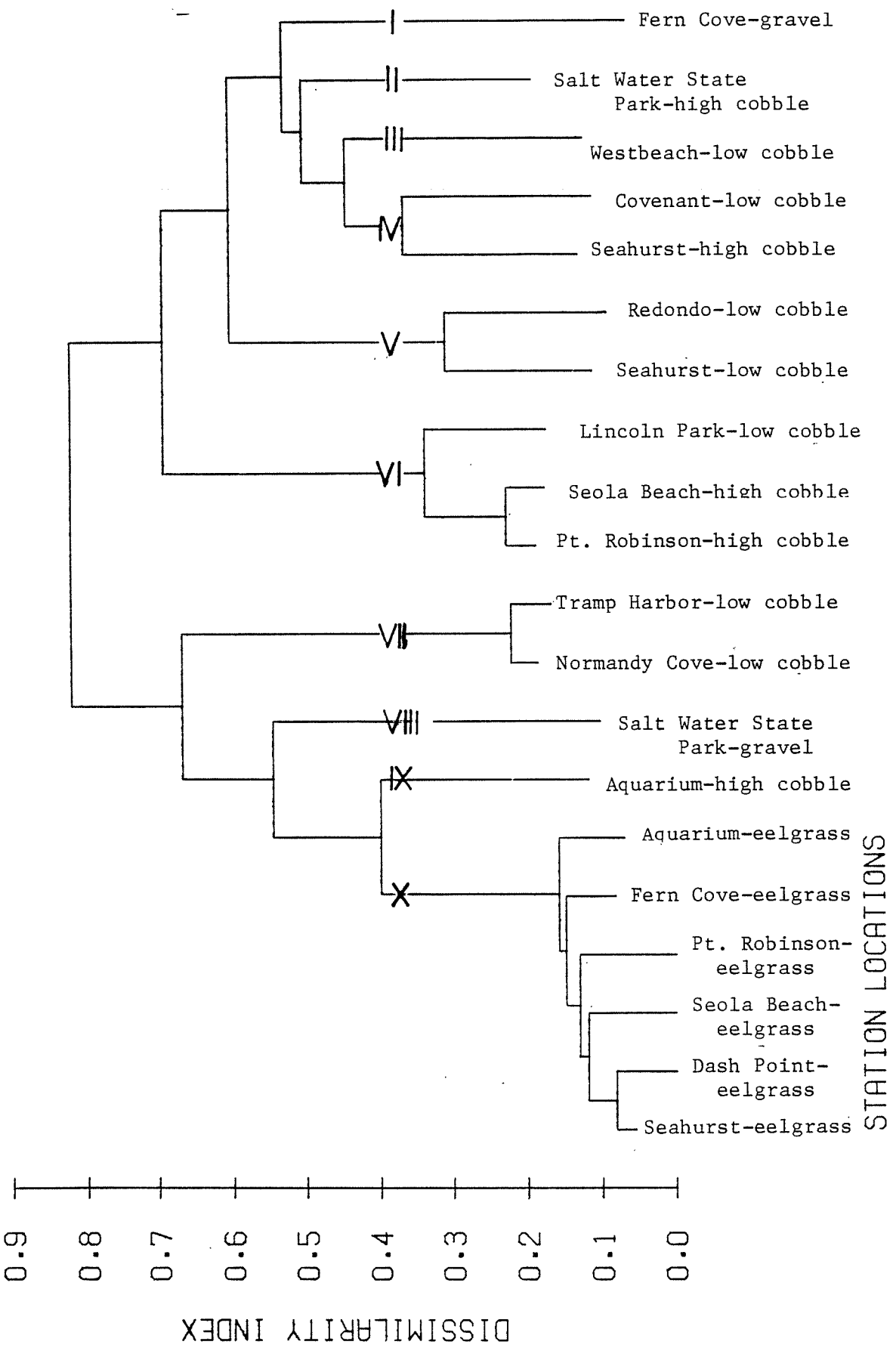



Figure 6.4. Dendrogram showing results of cluster analysis for algal percent cover data obtained during the habitat distribution study.

Table 6.1. Mean percent cover of algal and animal taxa within the fingerprint site groups.

| TAXA | SITE GROUPS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Ulva lactuca | 2.6 | .7 | 94.4 | 20.7 | 11.1 | 5.9 | | | 8.8 | |
| Mytilus edulis | 6.8 | .1 | .04 | .8 | | .1 | | | .1 | |
| Balanus crenatus | 3.6 | 22.4 | 1.9 | 13 | 1.6 | 2.1 | .5 | | .1 | |
| B. cariosus | .2 | .9 | .1 | | | .1 | | | | |
| Porphyra sanjuanensis | .02 | 1.2 | .1 | .2 | | 1 | .7 | | .01 | |
| Gigartina papillata | .1 | .04 | .02 | | .02 | .3 | | | .04 | |
| Anthopleura elegantissima | | .02 | .04 | .2 | .01 | .1 | .01 | | | |
| Littorina sp. | | .02 | .02 | | | | | | | |
| Hildenbrandia prototypus | | | .02 | | | .03 | .01 | | | |
| Iridea heterocarpa | | | .02 | | | .1 | | | | |
| I. cordata | | | .4 | | | 2.2 | | | | |
| Spongomorpha saxatilis | | | .2 | .1 | .01 | 1.8 | | | | |
| Enteromorpha linza | | | .02 | .01 | 59.2 | | | 2 | .2 | |
| E. intestinalis | | | | .5 | 1.4 | .1 | .7 | 4.6 | .01 | |
| Petalonia fascia | | | | | .01 | | | | .01 | |
| Ulva fenestrata | | | | | 2 | 77.3 | | | | |
| Collisella strigella | | | | | .01 | | | | | |
| diatoms | | | | | .01 | .04 | .03 | | | |
| Ralfsia sp. | | | | | .01 | .7 | | | | |
| Gigatina exasperata | | | | | | .01 | | | | |
| Fucus distichus | | | | | | .9 | | | .01 | |
| Polysiphonia sp. | | | | | | .1 | | .04 | .01 | |
| Odonthalia floccosa | | | | | | .5 | | | | |
| Laminaria saccharina | | | | | | .7 | | | | |
| Porphyra miniata | | | | | | .01 | | | .01 | |
| Leathesia difformis | | | | | | .01 | | | | |
| Cryptosiphonia woodii | | | | | | .2 | | | .01 | |
| Ceramium pacificum | | | | | | .01 | | | | |
| Ulva expansa | | | | | | | 64.8 | .01 | | 2.3 |
| Gracilaria verrucosa | | | | | | | 8 | | | |
| Ceramium spp. | | | | | | | .01 | | .01 | |
| Sargassum muticum | | | | | | | .1 | | | |
| Zostera marina | | | | | | | | | | 72.7 |
| Smithora naidum | | | | | | | | | | .3 |

There were no apparent gradients by latitude or tidal elevation in the percent cover data. The most important factor appears to be substrata. Sand habitats with eelgrass are obviously distinguished from the other sites. Site Groups III - VII contained relatively large proportions of algal cover (Table 6.2). The sites within these groups represent habitat of relatively stable substrata or low littoral habitats where large standing stocks of ephemeral algae (e.g. Ulva spp.) can develop in early summer. The other sites are either unstable or are disturbed by shifting sand, which inhibits the development of a high algal standing stock. Both Seahurst cobble sites are relatively stable.

Abundances of small infauna organisms at the 31 sites sampled ranged from 600 to 25,000 individuals $m^{-2}$. Mean abundance throughout the study area was 8200 $m^{-2}$. In general, mud and muddy-sand habitats had the highest abundance of small infauna, with a mean of 18,000 organisms $m^{-2}$, followed by eelgrass and cobble habitats, with 9,400 and 8,900 organisms $m^{-2}$, respectively (Fig. 6.5). Sand habitats had the lowest abundances with 4,300 organisms $m^{-2}$. Excluding the Dash Point sand site, which contained 48 percent of the total number of organisms collected at the 9 sand sites, mean abundance was only 2,500 organisms $m^{-2}$ for the remaining sand habitats.

Biomass was highest at beaches which provided suitable habitat for larger clam species such as butter (Saxidomus giganteus), littleneck (Protothaca staminea), and macoma (Macoma inquinata or M. secta) clams. Butter, littleneck, and one of the macoma clams (M. inquinata) preferred mixed substrates composed of cobble-gravel and sand (called cobble beaches). Although collected in low numbers, these bivalves contributed heavily to total biomass at beaches composed of this substrate. Annelids also had high biomass in this habitat type, sometimes equalling or even exceeding bivalve biomass. As a result, cobble beaches had much higher biomass than other habitat types

Table 6.2. Range in mean percent cover of animals, algae, and eelgrass within the fingerprint site groups.

| Site group | Range of cover (%) values | | | |
|---|---|---|---|---|
| | Animals | Eelgrass | Algae | Total |
| I | 10.6 | 0 | 2.8 | 13.4 |
| II | 23.5 | 0 | 1.9 | 25.4 |
| III | 2.1 | 0 | 95.4 | 97.5 |
| IV | 10.6-20.8 | 0 | 18.2-29.2 | 28.8-50.0 |
| V | 0.1-3.0 | 0 | 61.2-92.2 | 64.2-92.3 |
| VI | 3.4-10.6 | 0 | 18.2-89.3 | 28.8-93.0 |
| VII | 0.1-1.0 | 0 | 54.8-92.6 | 55.8-92.7 |
| VIII | 0 | 0 | 6.7 | 6.7 |
| IX | 0.2 | 0 | 9.0 | 9.2 |
| X | 0 | 53.2-99.8 | 0-8.8 | 57.0-99.8 |

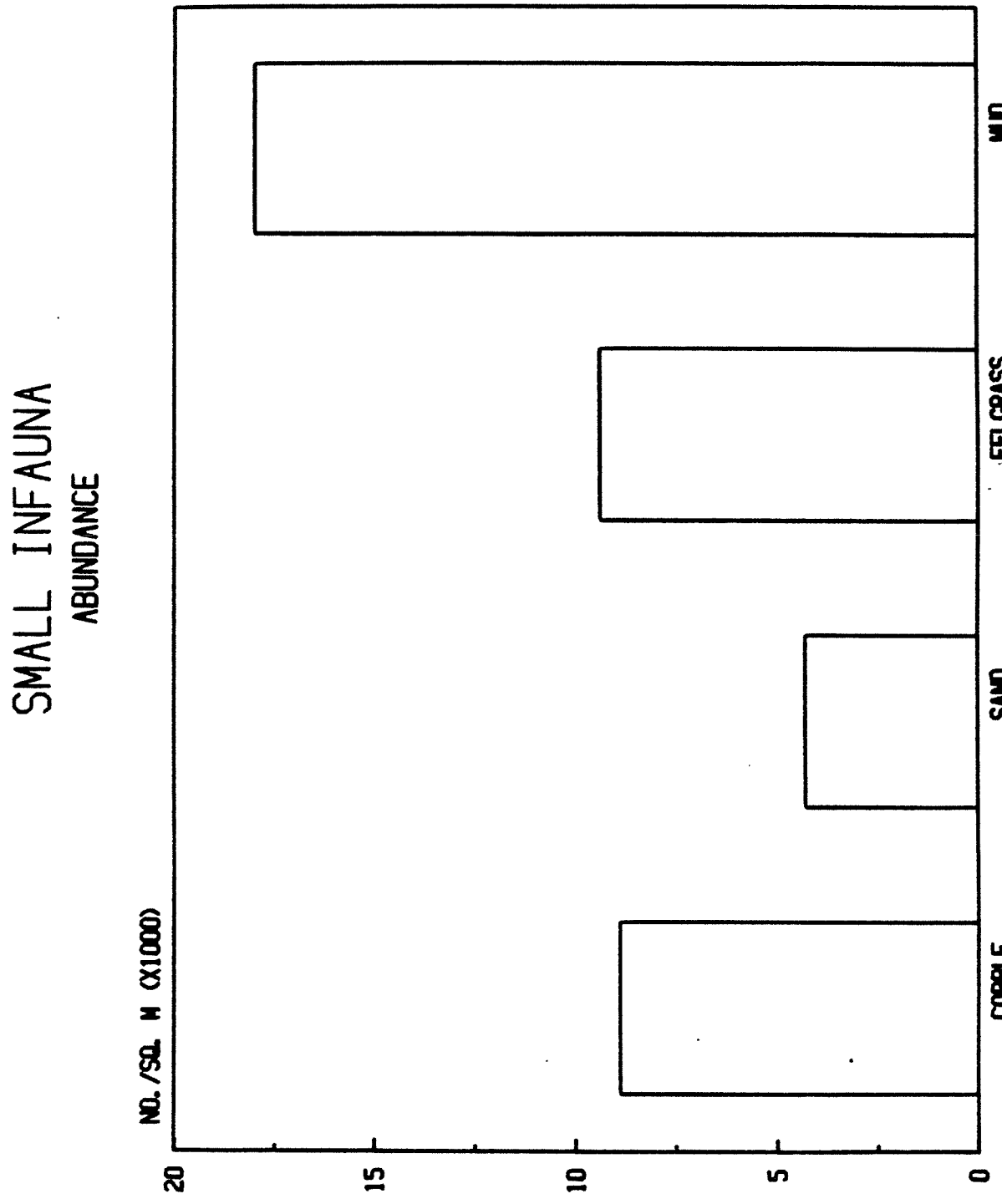



Figure 6.5. Mean small infaunal abundances for the major habitat types observed during fingerprint sampling, June 1982.

(158 g $m^{-2}$), followed by eelgrass, mud, and sand habitats with 96, 58, and 39 g $m^{-2}$, respectively (Fig. 6.6).

A total of 98 taxa of small infauna were identified during the habitat study. Polychaetes were the most diverse faunal group (44 taxa), followed by crustaceans (33 taxa), and molluscs (14 taxa). The remainder of the taxa were comprised of an assortment of faunal groups (e.g., nematodes, nemerteans, and insects). The number of taxa present at each site varied from two (at the Seola Beach sand habitat) to 25. Sand habitats generally had the lowest species richness, with a mean of 5.7 taxa per site (Fig. 6.7). This was expected considering the lower densities of organisms in sand habitats. Mud and eelgrass habitats had highest species richness, with 17.5 and 15.2 taxa per site, respectively. Cobble habitats averaged 11.1 taxa per site.

Species compositions of small infaunal communities were compared for the 31 habitat sampling sites by computing Bray-Curtis dissimilarity values. Sites were clustered using the group average method. Results were plotted in the form of a dendrogram (Fig. 6.8).

Dissimilarity values were generally high between sites, indicating that few sites had small infaunal communities of similar composition. As a result, site groups also had high dissimilarity values, and were difficult to separate out. If a dissimilarity value of 0.75 is used to separate site groups, however, 5 groups, only one of which contains a single site, result (Fig. 6.8). This appears to be the best level at which to analyze site groupings, as at lower dissimilarity values, the number of groups containing single sites is so high that, in effect, clustering is not accomplished. At higher dissimilarity values, groupings become too coarse to allow meaningful interpretation.

Site Group A contains 12 sites, nine of which had cobble-gravel

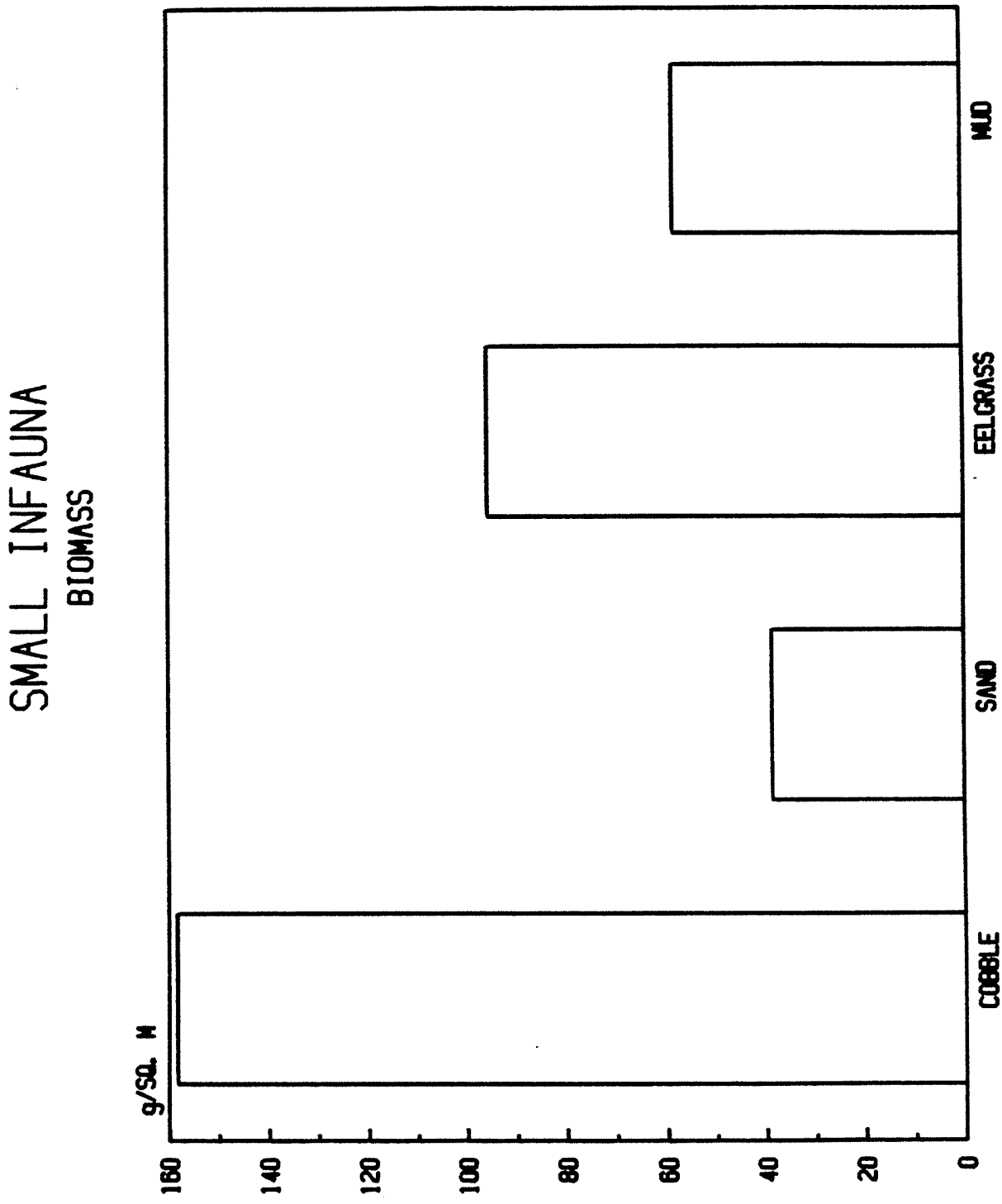



Figure 6.6. Mean small infaunal biomass by habitat type for fingerprint sampling, June 1982.

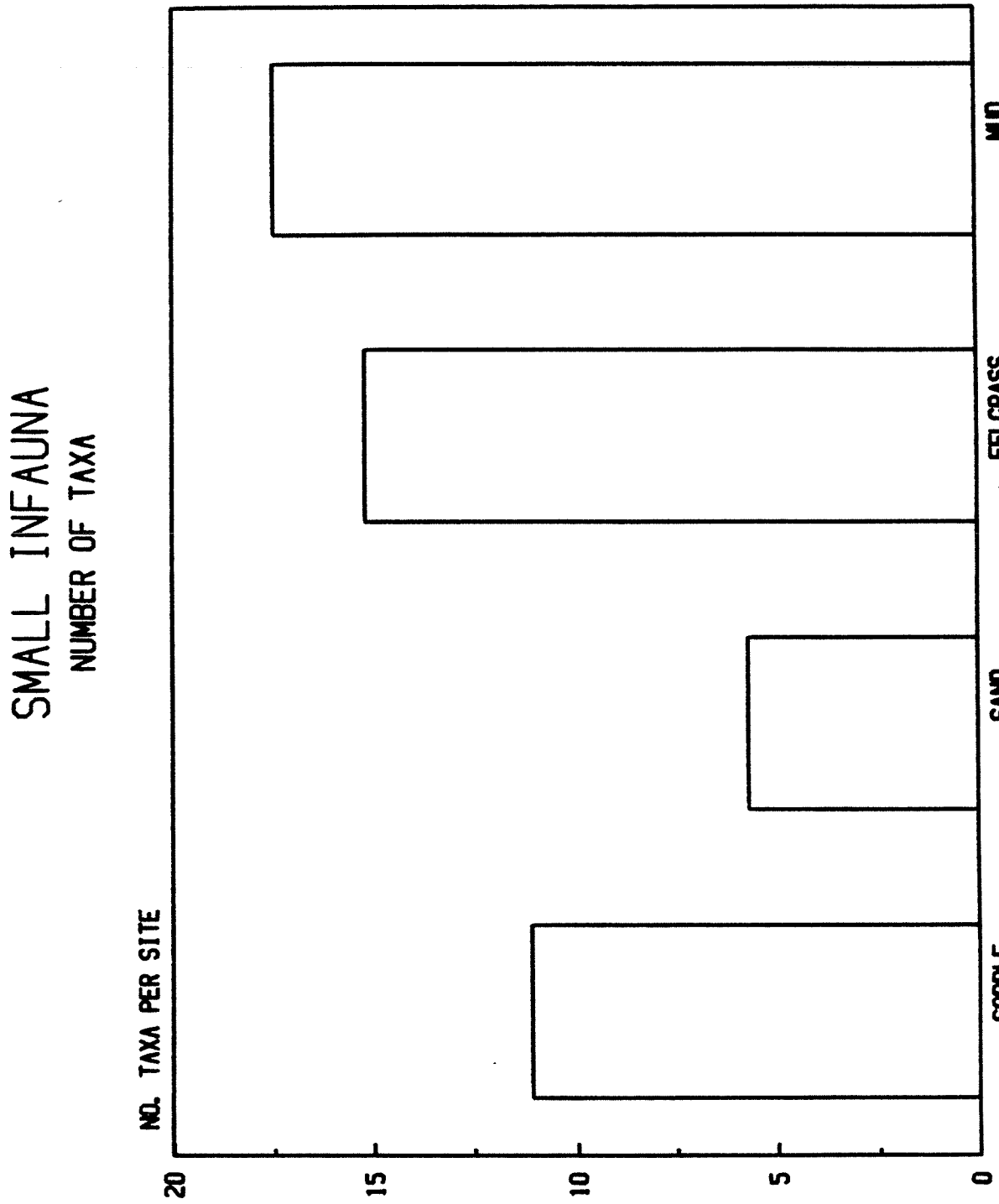



Figure 6.7. Mean number small infauna of taxa observed per site for each major habitat during fingerprint sampling, June 1982

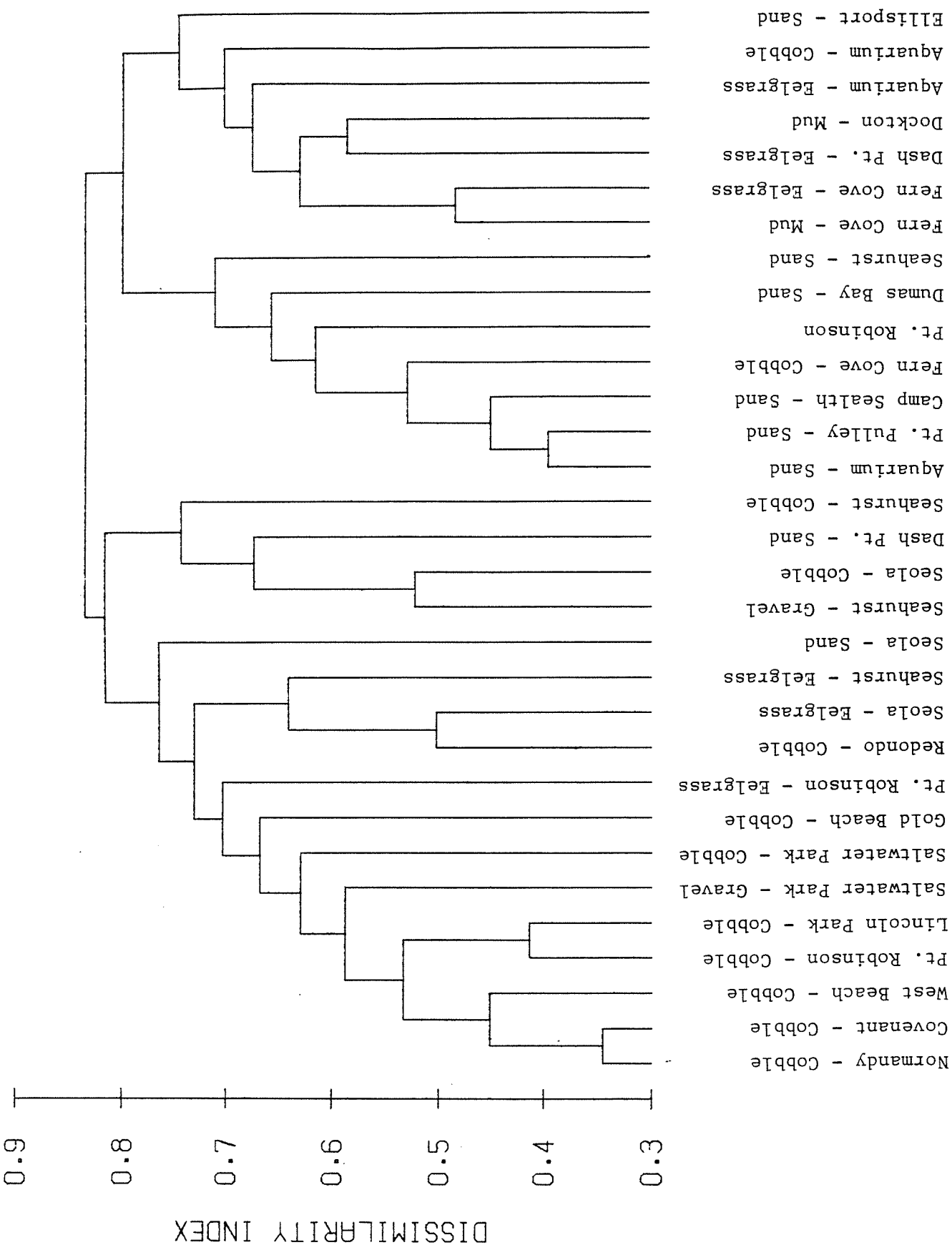



Figure 6.8. Site groupings based on results of small infaunal sampling during the habitat study, June, 1982. Dissimilarity values were computed using the Bray-Curtis dissimilarity index.

substrates. The remaining three stations were eelgrass habitats. Sites in this cluster group were characterized by the presence of the polychaetes Mediomastus sp. and Notomastus tenuis (Table 6.3). Other species present were the polychaetes Barantolla americana, Hemipodus borealis, and juvenile Nereidae.

Site Group B contains only one site, the sand habitat at Seola Beach. Only three organisms were collected at this site, two of which were the polychaete Scoloplos armiger, which was not a major component of the infauna at any other site.

Group C contained four sites, three with cobble-gravel substrate and one with sand substrate. Species characteristic of this group were the gammarid amphipod Corophium salmonis and oligochaete worms.

Site Group D included seven sites, six of which had sand substrate. The remaining site had a gravel-cobble substrate. Sites in this cluster group were characterized by the presence of the polychaetes Malacocerus glutaeus, Heteropodarke heteromorpha, and Hemipodus borealis.

Site Group E also contained seven sites, with a mixture of habitat types represented. Three eelgrass, two mud, one cobble, and one sand site were included. Species characteristic of sites within this group were the polychaete Malacocerus glutaeus and the cumacean Cumella vulgaris. Nematodes, the amphipod Corophium acherusicum, and the tanaid Leptochelia dubia were also associated with these sites.

Results of the cluster analysis indicated that small infaunal communities could not be predicted or characterized solely on the basis of substrate type present. This is in part due to an overlap in substrates present in the various habitat types. For example, organisms typically occurring in sand could also be found in pockets of sand within cobble-gravel substrates or sand

Table 6.3. Species characteristic of the various site groups resulting from cluster analysis of habitat distribution study small infaunal data, June 1982 (P = polychaete worm, C = crustacean).

| Group | Site | Habitat type | Characteristic species |
|---|---|---|---|
| A | Normandy Cove | Cobble | |
| | Covenant Beach | Cobble | *Mediomastus* sp. (P) |
| | West Beach | Cobble | *Notomastus tenuis* (P) |
| | Point Robinson | Cobble | Also present: |
| | Lincoln Park | Cobble | *Barantolla americana* (P) |
| | Salt Water State Park | Gravel | *Hemipodus borealis* (P) |
| | Salt Water State Park | Cobble | Nereidae, juv. (P) |
| | Gold Beach | Cobble | |
| | Point Robinson | Eelgrass | |
| | Redondo Beach | Cobble | |
| | Seola Beach | Eelgrass | |
| | Seahurst Park | Eelgrass | |
| B | Seola Beach | Sand | *Scoloplos armiger* (P) |
| C | Seahurst Park | Gravel | |
| | Seola Beach | Cobble | *Corophium salmonis* (C) |
| | Dash Point | Sand | Oligochaete worms |
| | Seahurst Park | Cobble | Also present: |
| | | | Nereidae, juv. (P) |
| D | Aquarium | Sand | |
| | Point Pulley | Sand | *Malacocerus glutaeus* (P) |
| | Camp Sealth | Sand | *Heteropodarke heteromorpha* (P) |
| | Fern Cove | Cobble | *Hemipodus borealis* (P) |
| | Point Robinson | Sand | Also present: |
| | Dumas Bay | Sand | *Mediomastus* sp. |
| | Seahurst Park | Sand | |
| E | Fern Cove | Mud | *Malacocerus glutaeus* (P) |
| | Fern Cove | Eelgrass | *Cumella vulgaris* (C) |
| | Dash Point | Eelgrass | Also present: |
| | Dockton | Mud | Nematodes |
| | Aquarium | Eelgrass | *Corophium acherusicum* (C) |
| | Aquarium | Cobble | *Leptochelia dubia* (C) |
| | Ellisport | Sand | |

present within an eelgrass bed. In addition, many intertidal species inhabit a range of substrata types, thus obscuring differences in community types. As a result, cluster groups did not fall out strictly according to substrate type, indicating that other environmental factors also strongly influence small infaunal community structure.

A correlation matrix was constructed to compare three biological parameters (abundance, biomass, and number of taxa) with sediment chemistry parameters (Table 6.4). Both abundance and number of taxa correlated with the same sediment chemistry parameters (BOD, percent volatile solids, carbon, sulfide, percent silt, and percent clay). Abundance correlated most closely with sulfide and percent volatile solids, while number of taxa correlated most closely to BOD and percent volatile solids. The significant correlations between these biological parameters and the percent clay in the sediment is of interest as percent clay correlated with many other sediment parameters. Percent clay thus may provide an indication of the values for a large number of physical and biological parameters. The lack of any significant correlations between biomass and the sediment chemistry data reflects the high variation of small infaunal biomass in the study area. In particular, the presence of one large clam was usually enough to raise the total biomass at a site from a low or moderate value to one of the highest values.

Large infaunal (i.e., bivalve) sampling was performed to determine the distribution, abundance, and biomass of bivalve populations. Clam abundances ranged from 0-507 clams $m^{-2}$. Abundance was highest at sites with cobble/gravel/sand substrates, but was also high in eelgrass habitats compared to mud and sand habitats (Figure 6.9). Thus, substrate type appeared to be an important environmental factor affecting clam distribution and abundance. Elevation was also an important environmental factor controlling clam

Table 6.4. Correlations between small infaunal abundance, biomass, and number of taxa and sediment chemistry parameters for the habitat distribution study. Underlined values are significant at $\alpha = 0.01$.

| Sediment parameter | Abundance | Biomass | Number of taxa |
|---|---|---|---|
| BOD | 0.495 | 0.185 | 0.712 |
| % VS | 0.558 | 0.271 | 0.657 |
| Dry:Wet | -0.256 | 0.011 | -0.137 |
| TOC | 0.504 | 0.368 | 0.469 |
| N | 0.138 | 0.127 | 0.048 |
| $H_2S$ | 0.571 | -0.036 | 0.456 |
| % Gravel | -0.124 | 0.207 | 0.124 |
| % Coarse sand | -0.288 | 0.105 | -0.174 |
| % Fine sand | 0.069 | -0.207 | -0.158 |
| % Silt | 0.484 | 0.078 | 0.475 |
| % Clay | 0.454 | -0.145 | 0.449 |
| % $H_2O$ | 0.329 | -0.044 | 0.145 |

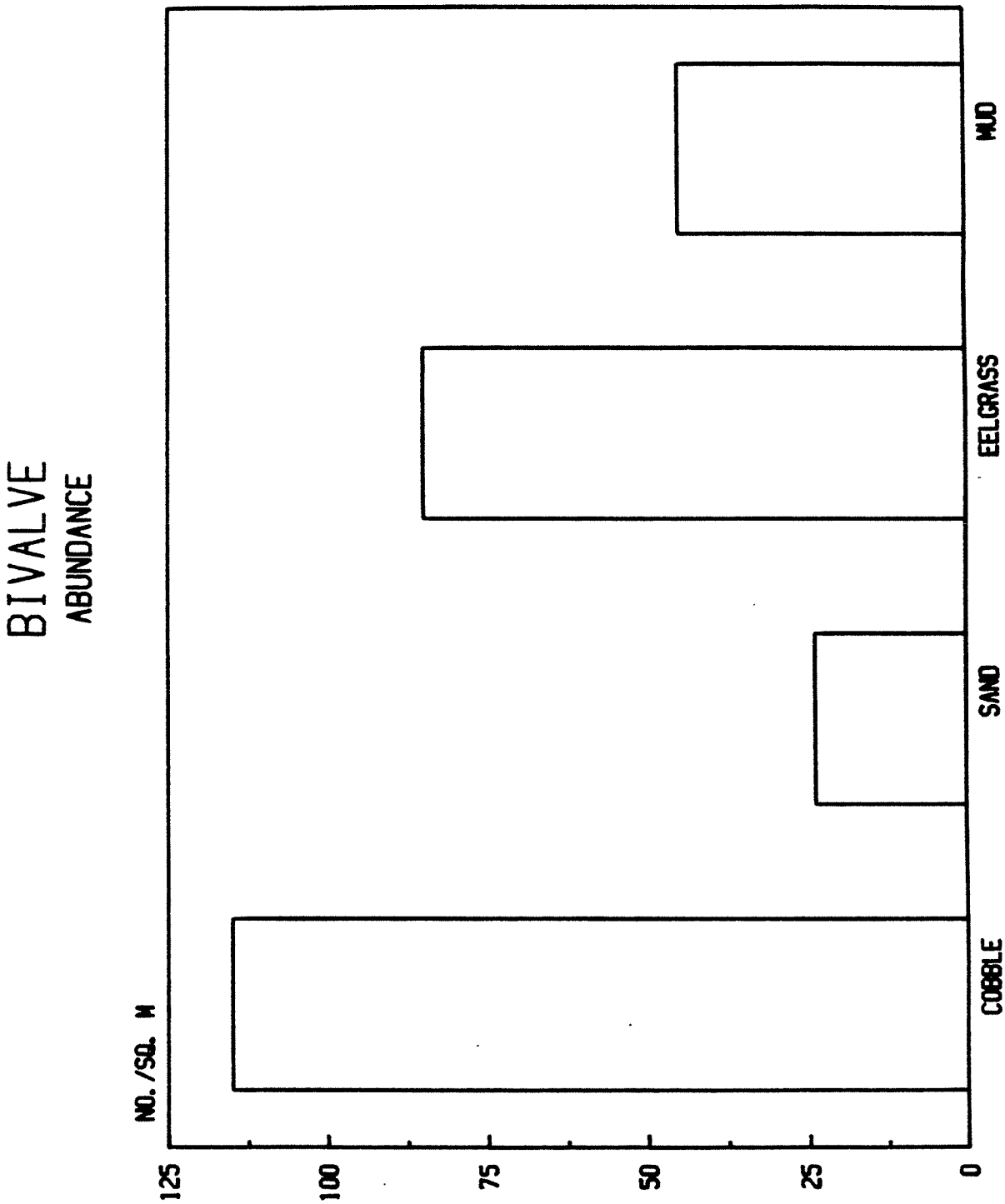



Figure 6.9. Mean clam abundance ($m^{-2}$) by habitat type observed during habitat distribution study, June 1982.

abundance. Only three of the 16 habitat distribution study sites with cobble/gravel/sand substrate contained no clams, and all three were sampled at an elevation of +3.0 feet (relative to mean lower low water) or higher. All sites with cobble/gravel/sand substrates occurring below this elevation had clams present in varying numbers.

Clam biomass was also considerably greater in cobble/gravel/sand habitats than in other habitats, with a mean of 917 g $m^{-2}$ (Fig. 6.10). The high biomass was due both to the large number of clams in this habitat type and the predominance of species which are large in size, such as butter clams (Saxidomus giganteus). Eelgrass habitats had the second highest biomass of clams, with 572 g $m^{-2}$, while mud and sand habitats both had relatively low clam biomass (194 and 172 g $m^{-2}$, respectively) (Figure 6.10).

Eelgrass habitats had the greatest species richness, with a mean of 5.8 clam species per site (Fig. 6.11). Cobble and mud habitats had comparable numbers of species per site, with means of 3.3 and 3.0 species, respectively. Sand habitats had a very limited clam fauna, with a mean of only 0.8 species per site.

Cluster analysis was performed on the data obtained from the large infaunal samples collected during the habitat distribution study. Results of the cluster analysis for the 27 sites where clams were present are displayed in a dendrogram indicating dissimilarity levels (Fig. 6.12). If a dissimilarity value of 0.5 is chosen to separate clusters, six clusters are apparent. Comparisons of the dominant bivalve species at each site within a cluster indicated that certain dominant species were characteristic of (and probably responsible for the placement of) all sites in the cluster (Table 6.5). Another "cluster group" not present in Figure 6.12 could be considered to exist which includes all sites lacking bivalves.

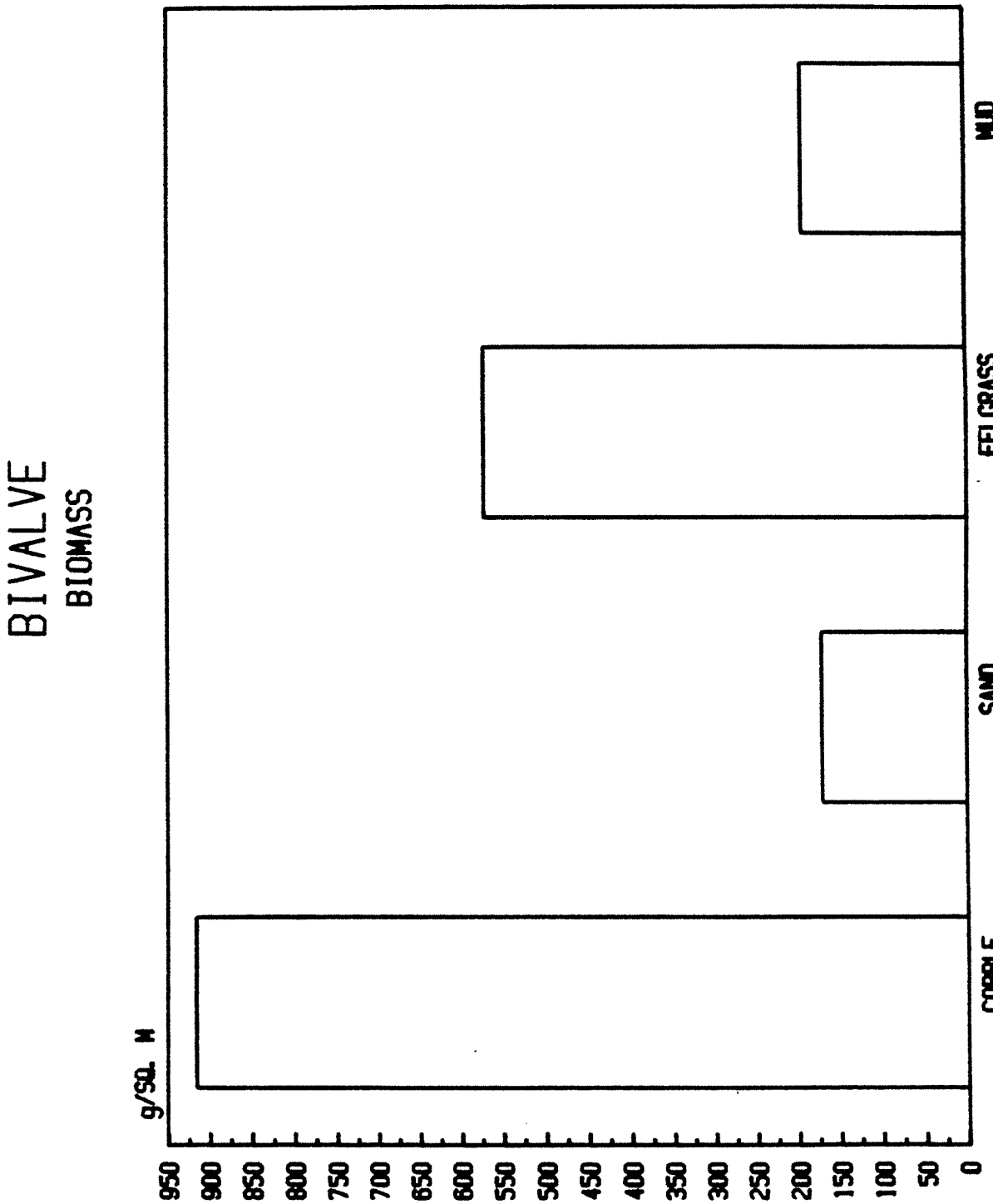



Figure 6.10. Mean clam biomass ($g \cdot m^{-2}$) by habitat type observed during habitat distribution study, June 1982.

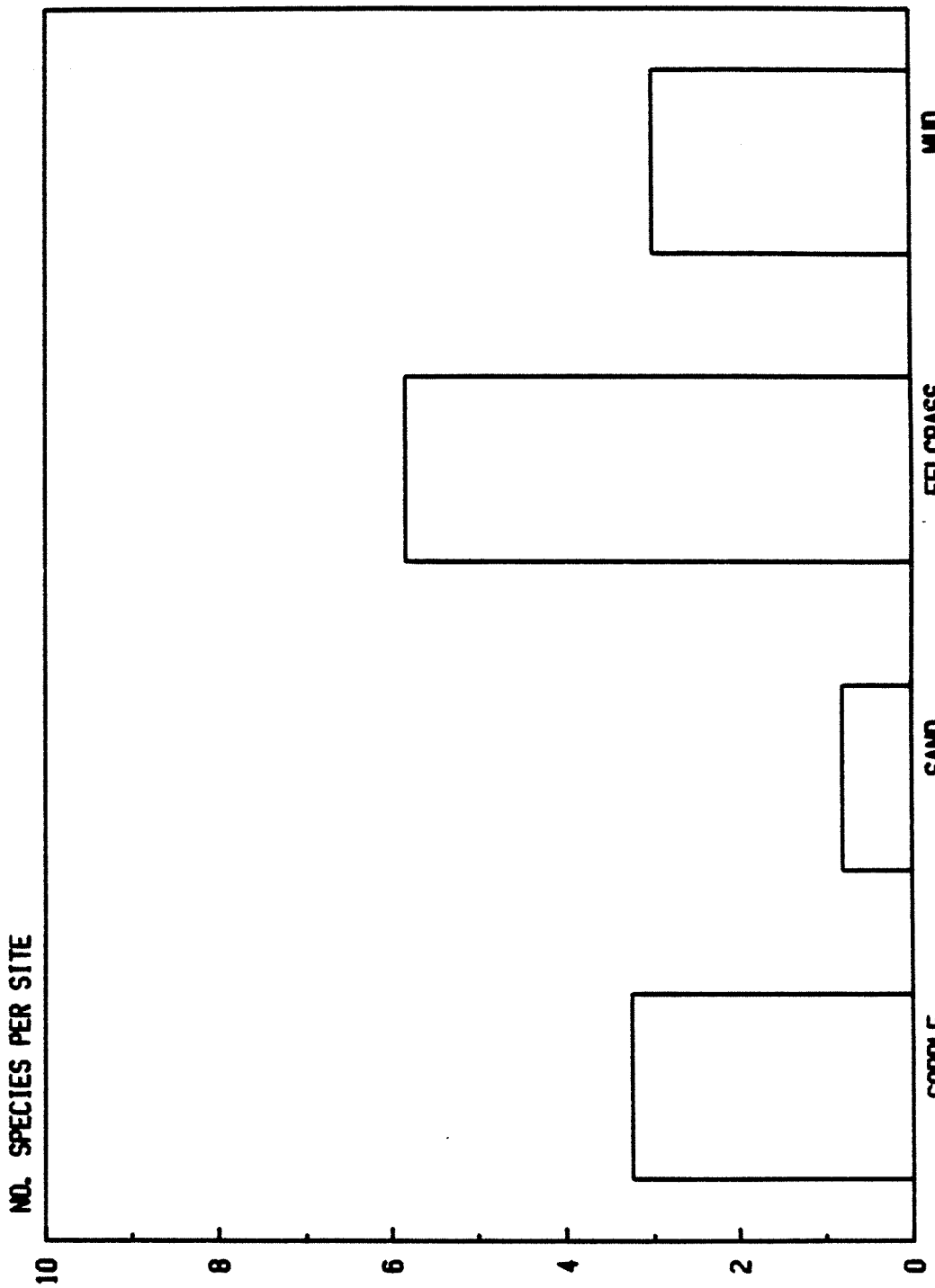



Figure 6.11. Mean number of clam species per site for each habitat type observed during habitat distribution study, June 1982.

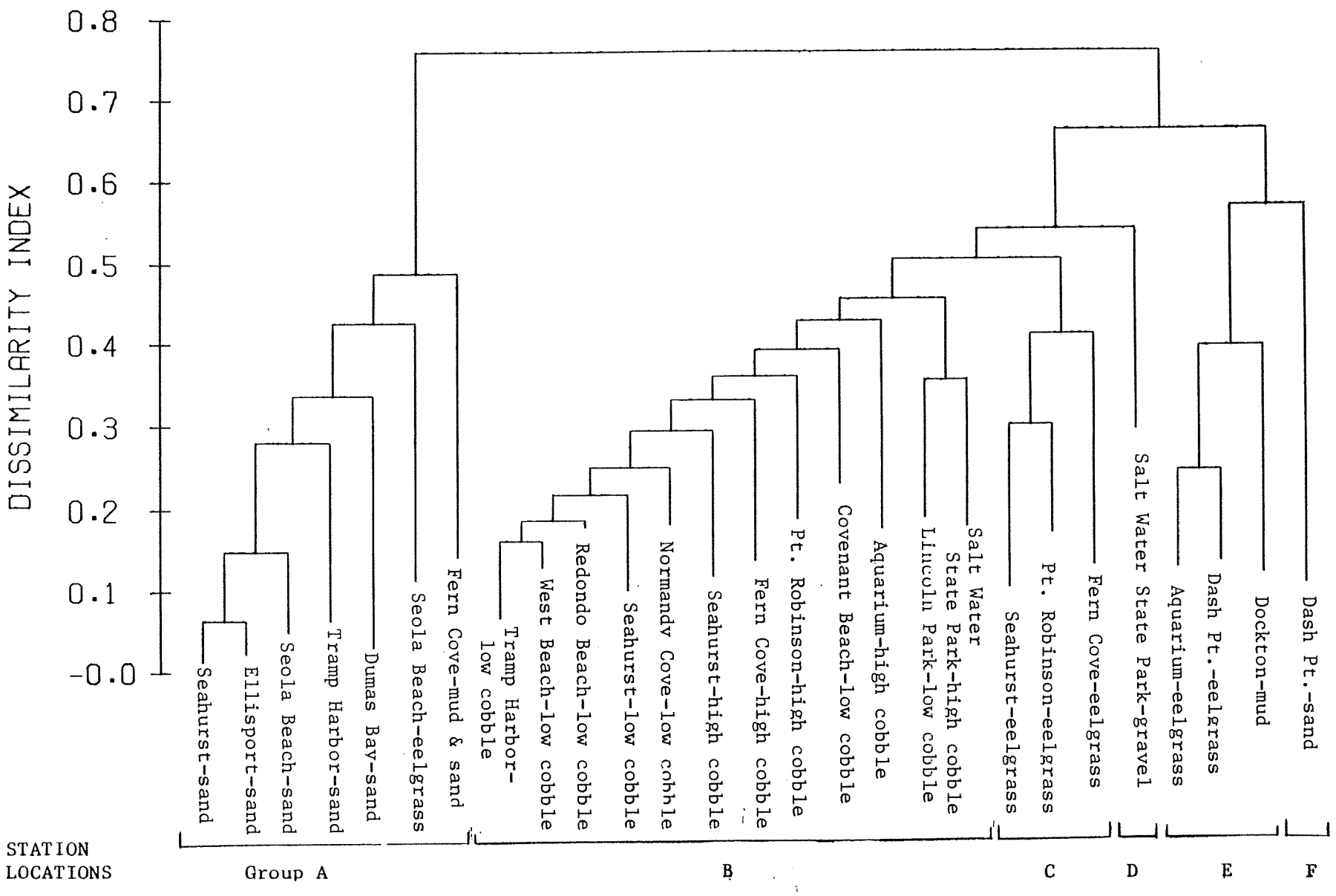



Figure 6.12. Dendrogram showing results of cluster analysis for bivalves collected in large infaunal samples during habitat distribution sampling. Only those locations where clams were present were included in the analysis.

Table 6.5. Dominant bivalve species characteristic of sample site cluster groups.

| Cluster Group | Characteristic Species |
|---|---|
| A | *Macoma secta* |
| B | *Protothaca staminea*-*Macoma inquinata* |
| C | *Macoma nasuta*-*Macoma inquinata* |
| D | *Saxidomus giganteus* |
| E | *Macoma nasuta*-*Lucinoma acutilineata* |
| F | *Lucinoma acutilineata*-*Macoma balthica* |

The various clusters generally represent specific habitat types. All sand habitats fell into cluster groups A and F. Both high and low cobble habitats (high and low refer to intertidal elevation) fell exclusively into group B. Intertidal eelgrass was the least consistent habitat type, with stations falling into any of three cluster groups.

Cobble habitats appear to provide the most valuable habitat for large bivalves in terms of both abundance and biomass. In addition, the four species of recreationally valuable clam species (butter clam, Saxidomus giganteus; native littleneck, Protothaca staminea; horse clam, Tresus capax; and Japanese littleneck, Tapes philippinarum) present in the study area occurred primarily in cobble habitats. Based upon this information and the results of the pre-study large infaunal sampling (see Sec. 6.4.3), it was decided that studies of large infauna would be restricted to cobble habitats. Four sites (Seahurst Park, Tramp Harbor, Normandy Cove, and Covenant Beach) were chosen for long-term monitoring.

The results of the cluster analysis strongly validated the choice of large infaunal sample locations for the long-term quarterly sampling. The four low cobble sites chosen for study all lie within the same cluster group, and are related by low dissimilarity values. This indicates the pre-outfall bivalve populations are similar in species composition. Post-outfall analyses of changes in bivalve populations can, therefore, be much more accurately and easily assessed using comparisons of data from the four sample locations.

Results of the sediment chemistry measurements were summarized by habitat type (Table 6.6). Mean values for BOD, percent volatile solids, carbon, carbon:nitrogen ratios, sulfide, percent water, and percent silt and clay were generally higher in mud and eelgrass habitats than cobble or sand habitats. Intertidal sand had the lowest mean values for BOD, percent volatile solids,

Table 6.6. Mean sediment chemistry measurements by habitat type during habitat distribution study.

| Parameter | Habitat type | | | |
|---|---|---|---|---|
| | Cobble | Sand | Eelgrass | Mud |
| BOD | 596 | 271 | 937 | 922 |
| Volatile solids | 1.112 | 0.817 | 1.275 | 1.650 |
| Dry Wt:Wet Wt | 0.809 | 0.797 | 0.749 | 0.757 |
| TOC | 2.14 | 1.57 | 2.65 | 4.19 |
| N | 0.96 | 0.51 | 0.72 | 0.39 |
| C/N | 2.23 | 3.06 | 3.68 | 10.74 |
| $H_2S$ | 0.001 | 0.003 | 0.008 | 0.037 |
| % Gravel | 34.58 | 8.19 | 6.23 | 0.7 |
| % Coarse sand | 18.04 | 12.00 | 3.85 | 6.10 |
| % Fine sand | 43.63 | 77.97 | 81.88 | 69.30 |
| % Silt | 2.71 | 2.82 | 7.77 | 20.80 |
| % Clay | 1.06 | 1.21 | 1.67 | 2.70 |
| % $H_2O$ | 15.02 | 19.81 | 24.88 | 27.50 |

and carbon. These results suggest possible correlations between the finer grain sizes (silt and clay) and other sediment chemistry parameters.

A correlation matrix was constructed from results of the habitat study sediment chemistry measurements (Table 6.7). Results indicate that percent clay correlates significantly with a large number of other sediment parameters (BOD, percent volatile solids, ratio of dry:wet weight, carbon, sulfide, percent silt, and percent water). Nitrogen measurements did not correlate well with any other sediment parameters.

The results of the habitat study revealed no longitudinal gradients in benthic intertidal assemblages. Study sites located on the extreme north and south ends of the study region were related closely faunistically and floristically. The major determiner of benthic assemblage, composition, and structure was habitat (i.e., substrata). The major habitats encountered in the study region were sand flats, mud flats, cobble (in various mixtures with sand), and eelgrass beds. Tidal elevation, although resulting in some difference among assemblages within a habitat, was not as important in causing changes in assemblages as were substrata differences.

Eelgrass beds are common at low intertidal-shallow subtidal depths in the study region. They are well developed in the Seahurst bight and, thus, form an important ecological condition in the area. The importance of eelgrass beds to higher trophic levels is well documented (Dawes 1981).

### 6.4.2 Prestudy

Data on minimum detectable changes (C) in assemblage parameter mean values for each sample type are given in Table 6.8. It appears that estimates of the mean number of species for most assemblages shows the least variation, and biomass has the highest variation. The criteria of C = 50% is approximately met in most cases. There was a large range in C for some

Table 6.7. Correlation matrix for sediment chemistry parameters. Underlined values are significant at $\alpha < 0.01$.

| Parameter | % VS | Dry:wet | TOC | N | $H_2S$ | Gravel % | C. sand % | F. sand % | Silt % | Clay % | $H_2O$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BOD | 0.828 | -0.497 | 0.624 | -0.072 | 0.352 | -0.88 | -0.298 | C.021 | 0.431 | 0.501 | 0.323 |
| % VS | | -0.370 | 0.798 | -0.132 | 0.528 | 0.030 | -0.064 | -C.191 | 0.643 | 0.550 | 0.284 |
| Dry:wet | | | -0.308 | 0.024 | -0.391 | 0.648 | -0.648 | -C.589 | -0.430 | -0.589 | -0.723 |
| TOC | | | | -0.194 | 0.423 | -0.126 | -0.100 | -C.041 | 0.618 | 0.467 | 0.337 |
| N | | | | | -0.142 | 0.103 | -0.024 | -C.056 | -0.150 | -0.205 | -0.108 |
| Sulfide | | | | | | -0.312 | -0.244 | C.124 | 0.706 | 0.736 | 0.384 |
| % Gravel | | | | | | | 0.607 | -C.877 | -0.334 | -0.445 | -0.847 |
| % C. sand | | | | | | | | -C.779 | -0.302 | -0.361 | -0.626 |
| % F. sand | | | | | | | | | 0.143 | 0.311 | 0.763 |
| % Silt | | | | | | | | | | 0.616 | 0.554 |
| % Clay | | | | | | | | | | | 0.572 |

Table 6.8. Range in minimum percent detectable change (C) in mean values of parameters based on prestudy samples using the method of Conquest (1982)[1]. ($\alpha_{(2)}$ = 0.10 and $\beta_{(1)}$ = 0.20). N = number of replicates chosen for sampling. Sample sizes are in parentheses under each sample type.

| Sample Type | Parameter | N | C |
|---|---|---|---|
| Macroalgal Biomass ($0.1\ m^2$) | Biomass | 15 | 39-91 |
| | No. Taxa | 15 | 18-27 |
| | Spp. Diversity | 15 | 32-64 |
| Macroalgal Cover ($0.1\ m^2$) | Cover | 30 | 26-30 |
| | No. Taxa | 30 | 13-15 |
| | Spp. Diversity | 30 | 21-22 |
| Macroalgal (0.014 - 0.198 g) | Net Productivity | 3 | 3-191 |
| Sediment Microalgae (2 ml) | Chlorophyll a | 10 | 17 |
| Drift ($0.06\ m^2$) | Biomass | 6 | 165-179 |
| Eelgrass ($0.06\ m^2$) | Density | 20 | 46-83 |
| Small Infauna: | | | |
| Sand habitat ($28\ cm^2$ x 10 cm deep) | No. Taxa | 12 | 52 |
| | Abundance | 12 | 53 |
| | Biomass | 12 | 168 |
| Cobble habitat ($28\ cm^2$ x 10 cm deep) | No. Taxa | 12 | 60 |
| | Abundance | 12 | 111 |
| | Biomass | 12 | 211 |
| Large Infauna: | | | |
| High cobble habitat ($0.06\ m^2$ x 30 cm deep) | No. Taxa | 15 | 102 |
| | Abundance | 15 | 148 |
| | Biomass | 15 | 187 |
| Sand habitat ($0.06\ m^2$ x 30 cm deep) | No. Taxa | 10 | 80 |
| | Abundance | 10 | 104 |
| | Biomass | 10 | 122 |

Table 6.8. (cont'd)

| Sample Type | Parameter | N | C |
|---|---|---|---|
| Large Infauna: | | | |
| Low cobble habitat ($0.06\ m^2$ x 30 cm deep) | No. Taxa | 10 | 47 |
| | Abundance | 10 | 37 |
| | Biomass | 10 | 91 |
| Epibenthos ($0.1\ m^2$) | | | |
| sand habitat | Abundance | 2 | 282 |
| cobble habitat | Abundance | 2 | 159 |
| eelgrass habitat | Abundance | 2 | 63 |

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[1]Conquest, L.L. 1982. Assessing the statistical effectiveness of ecological experiments: utility of the coefficient of variation. Int. J. Environmental Studies (in press).

parameters (eg. macroalgal productivity) in cases with more than one estimate. The number (N) of replicates was chosen to minimize C while considering cost and time constraints.

In general, the original (i.e., pre-prestudy) predictions on replication were low (see DETAILED WORK PLAN, PHASE I, 30 April 1982). The original estimates of the time required to collect and process samples was somewhat low for most sample types. These two factors have resulted in a significant increase in workload during Phase I.

Species area curves for cover and biomass of attached macrobiota are shown in Figures 6.13 and 6.14. Both curves level off at approximately 8-10 random replicate quadrat samples. It appears that, based on prestudy data, the number of taxa within the Seahurst low cobble habitat will be well sampled with 30 replicate samples for cover and 15 replicate samples for algal biomass.

Species-area curves were constructed for large infaunal samples collected in three habitats at Seahurst Park (one sand and two cobble habitats). The sand habitat contained only one species of clam (Macoma secta) collected in large infaunal samples, thus the species-area curve was of little value in determining necessary sample sizes. The species-area curve for the low cobble habitat (elevation 0.0 feet MLLW) indicated that a sample size greater than or equal to 7 should be adequate to sample the number of clam taxa present (Fig. 6.15). The curve for the high cobble habitat (+2.0 feet) did not include enough replicates for the curve to reach a plateau, indicating that more than 10 replicates are necessary to adequately sample clam species richness (Fig. 6.16).

Evaluation of the coefficients of variation for the large infaunal samples indicated that an unrealistically large number of replicates (as well

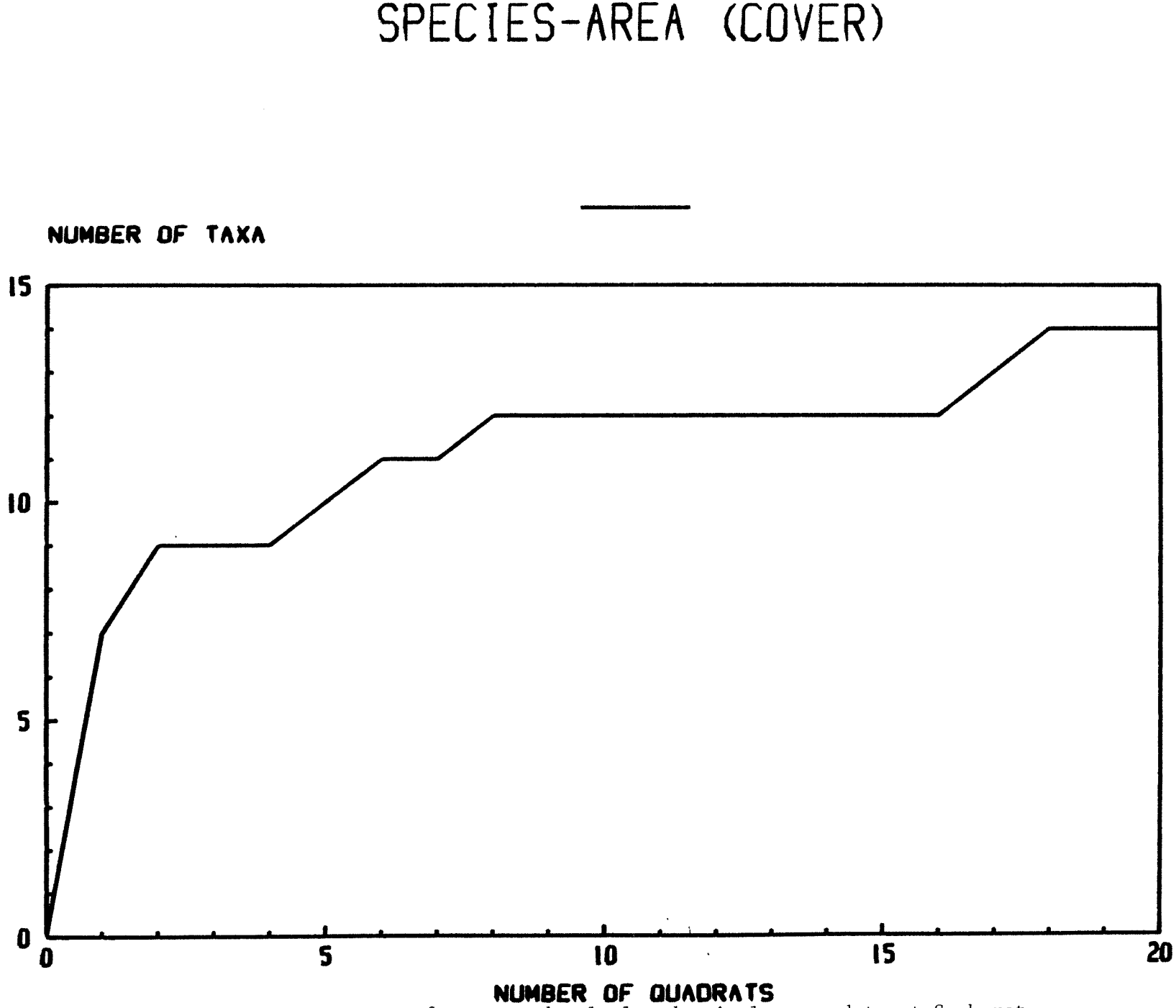



Figure 6.13. Species area curve for prestudy algal and animal cover data at Seahurst

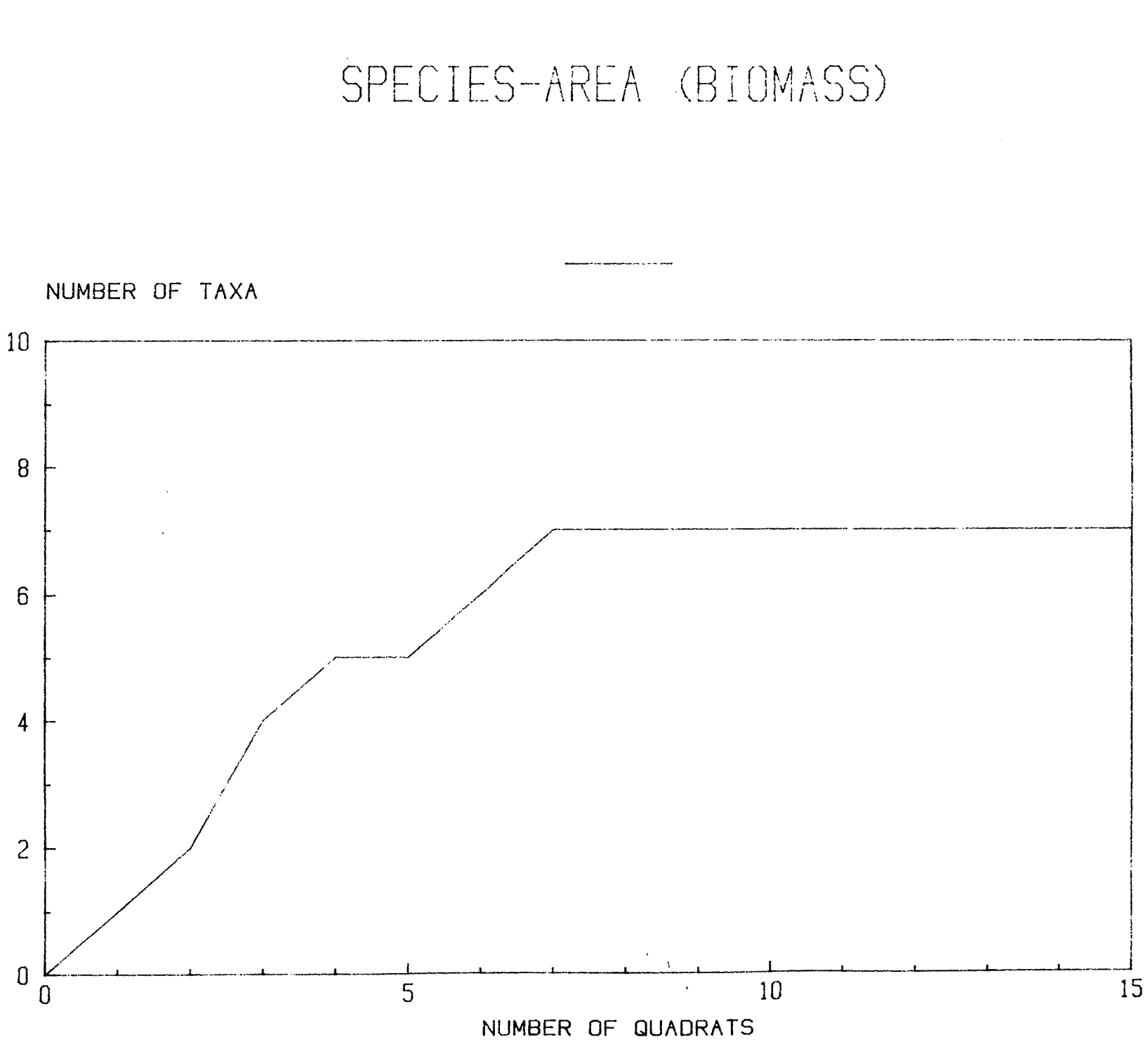



Figure 6.14. Species area curve for algal biomass at Seahurst.

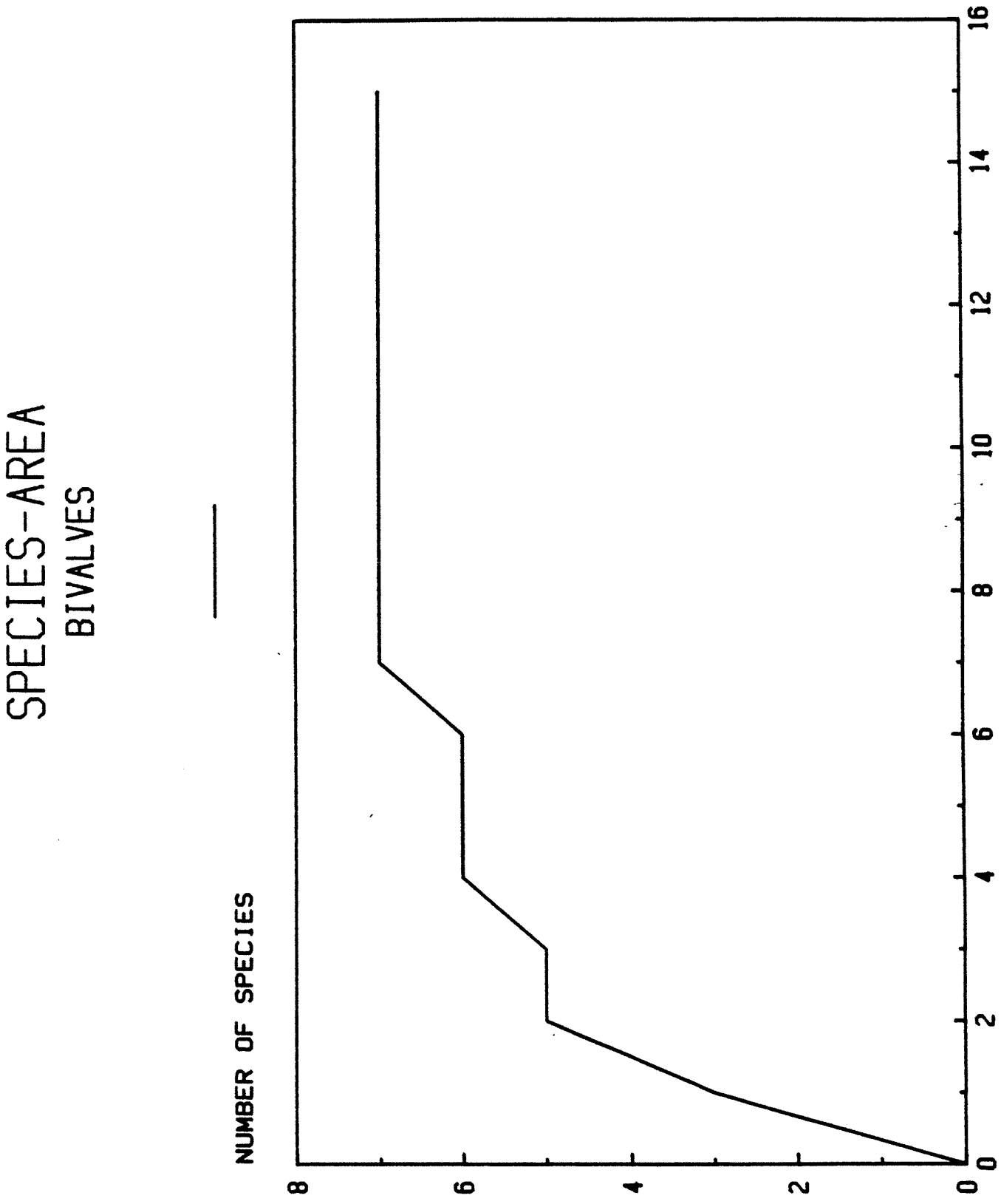



Figure 6.15. Species-area curve for Seahurst low cobble habitat, July 1982.

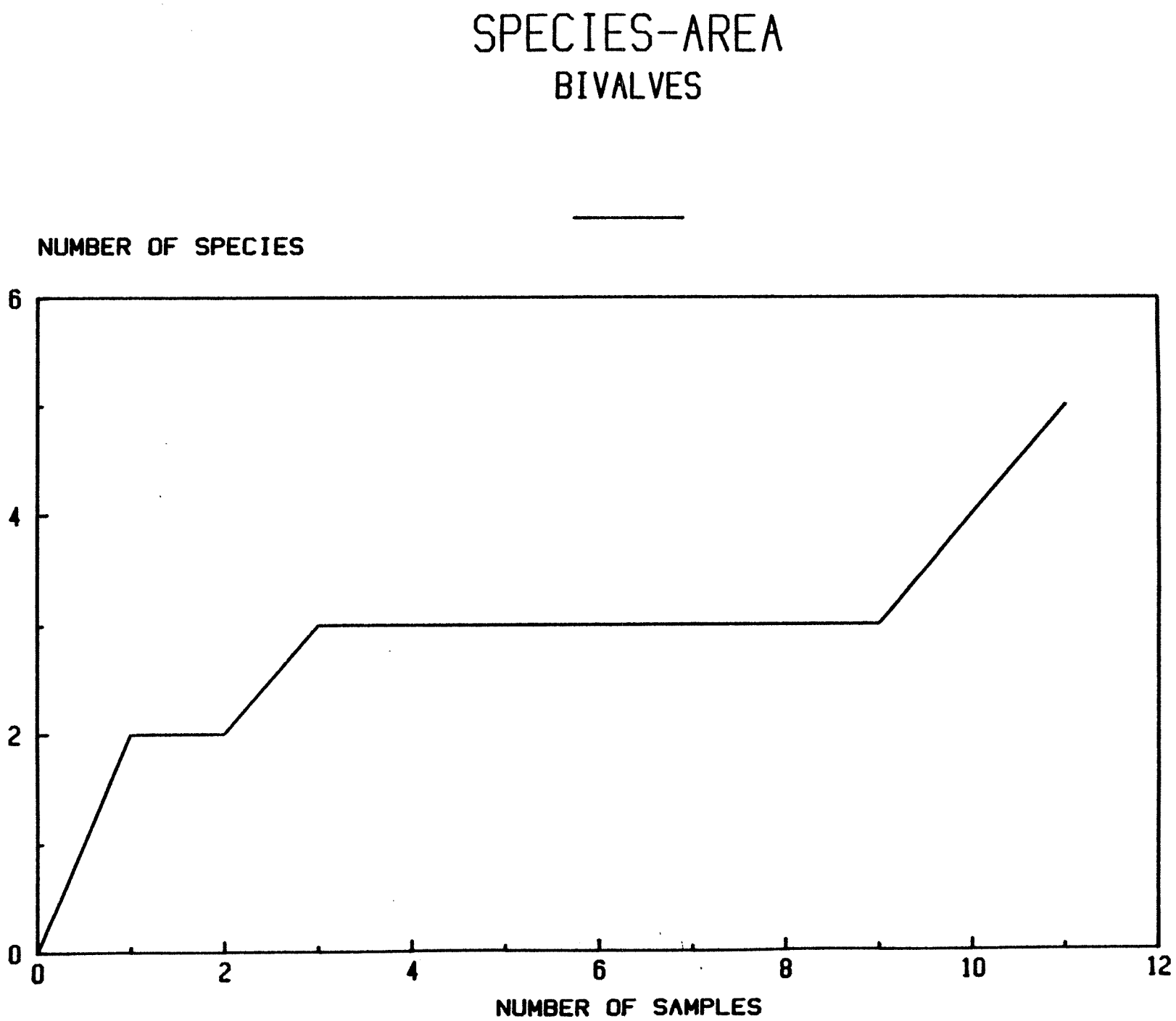



Figure 6.16. Species-area curve for Seahurst high cobble habitat, May 1982.

as a great destruction in habitat) were necessary in both the high cobble and sand habitats to observe changes in clam community structure. Therefore, these habitats were dropped from further study. Collection of ten or more replicates in the low cobble habitat, however, should be sufficient to detect changes of 50 percent in the number of taxa, 40 percent in abundance, and 90 percent in biomass.

Species-area curves for small infauna from the Seahurst Park cobble and sand habitats were also constructed. The species-area curve for the cobble habitat showed a definite leveling off after nine samples (Fig. 6.17), at which point 93 percent of the total number of taxa collected had been observed. This suggests that a minimum of nine samples are necessary for each sample collection in cobble habitats to obtain a representative number (>90%) of taxa present. The species-area curve for the sand habitat did not reach an obvious plateau (Fig. 6.18). This is apparently due to the low density of small infaunal organisms in this habitat, resulting in very few taxa collected in each core sample. This suggests that a larger sample size is necessary in sand habitats than cobble habitats to obtain a representative number of taxa present.

Coefficients of variation were used to calculate the number of replicates necessary to detect various levels of changes in small infaunal community parameters (Table 6.8), according to the method of Conquest (1982). These calculations indicate that a sample size of 12 would permit detection of changes of 50-110 percent in abundance, 170-210 percent in biomass, and 50-60 percent in number of taxa for comparisons of small infaunal community assemblages between sample dates and locations.

Pre-study core samples were also used to determine the minimal depth to which core samples should be collected. Results indicate that a core depth of

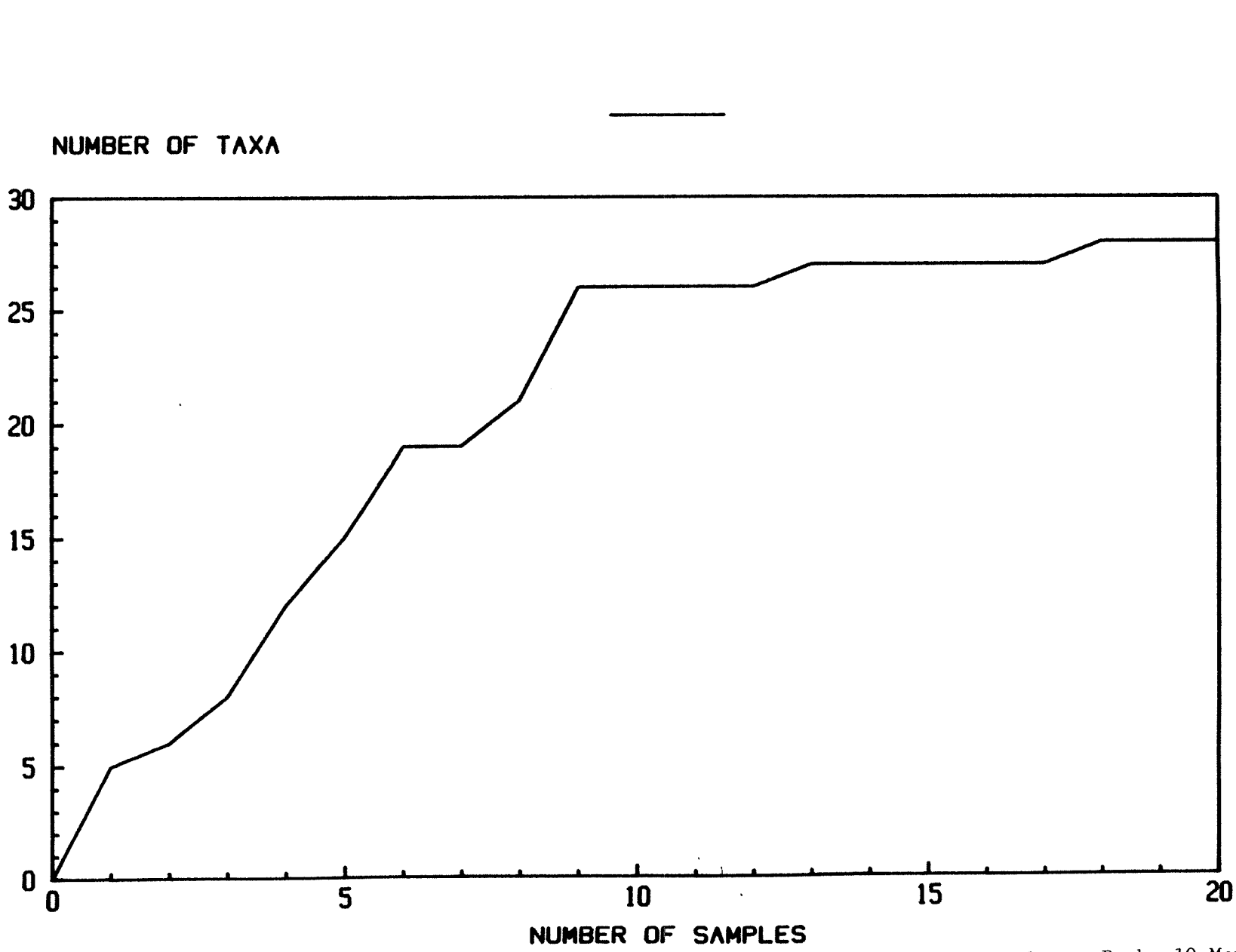



Figure 6.17. Species-area curve for small infauna in high cobble habitat at Seahurst Park, 10 May 1982.

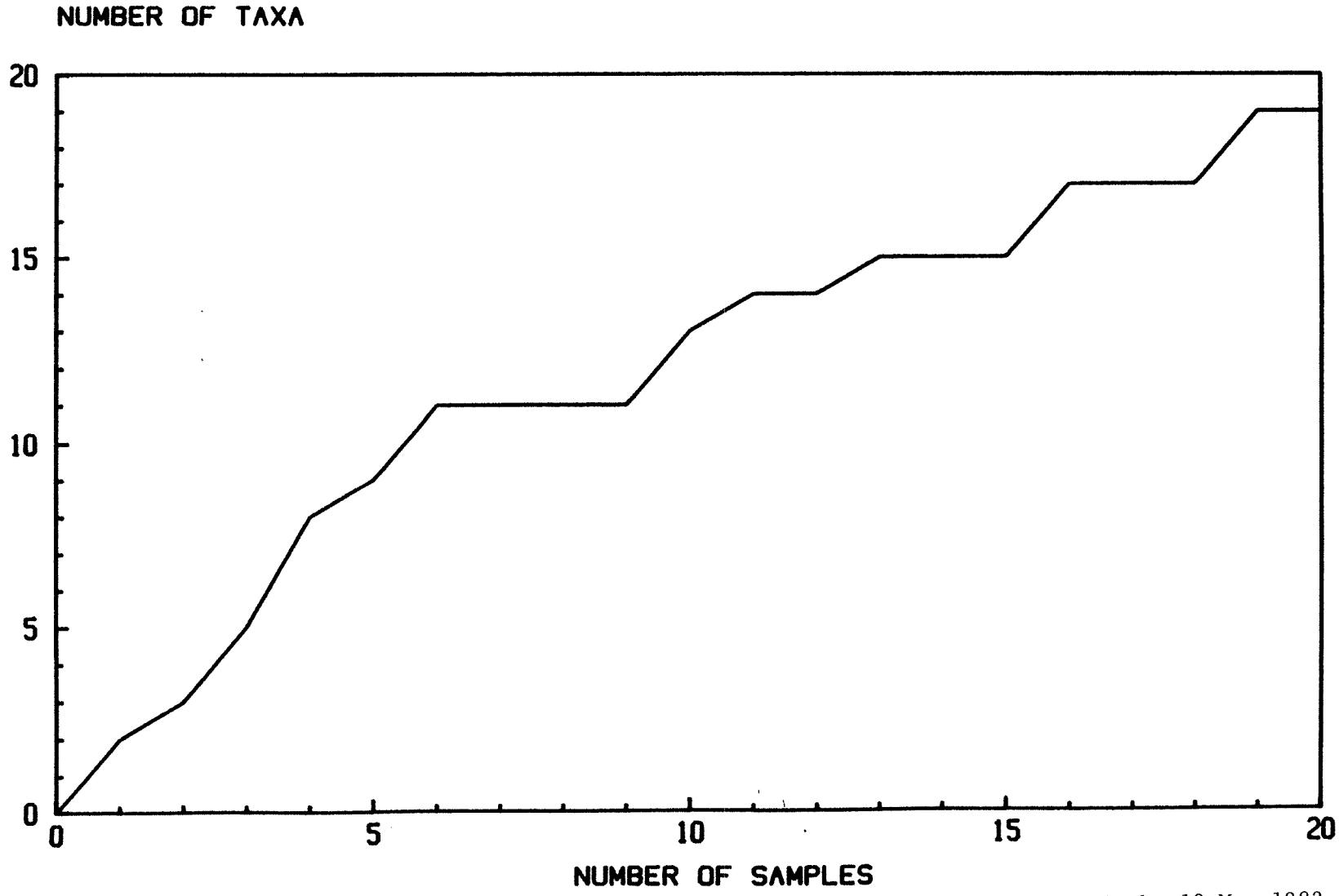



Figure 6.18. Species-area curve for small infauna in sand habitat at Seahurst Park, 10 May 1982.

10 cm collects 96 percent of the taxa and 91 percent of the number of organisms present in the top 15 cm of substrate (Figures 6.19 and 6.20). In addition, all species present between 10 and 15 cm depth also occurred in the top 10 cm, suggesting that no unique taxa occurred only between the 10 and 15 cm depths. It was then decided that collection of small infaunal core samples to a depth of 10 cm adequately sampled the small infaunal assemblages.

The degree of replication chosen was based on considerations of parameter variance, sample collection methods, degree of detectable change over time, level of significance in testing for changes, and amount of habitat destruction required for sampling. Habitat destruction is virtually non-existent and sample collection is relatively easy and repeatable for percent cover. Hence, 30 replicate samples are taken in the appropriate habitats. Algal biomass is somewhat more destructive and 15 replicates are taken. Small and large infauna sample collection requires considerable habitat destruction, especially for large infauna samples. Consequently, 12 and 10-15 replicates, respectively, were chosen for study. These levels of sample replication, and those for other sample types, provide estimates which conform to the original criteria without unduly taxing the environment. Fewer replicates would provide poorer estimates and more replicates, although desirable quantitatively, would lead to increased habitat destruction and/or unnecessary increases in cost.

### 6.4.3 Long-Term Studies

Long-term studies commenced at six selected beaches in June 1982 with initial water characteristic sampling. The first (summer) quarter sampling of benthic biota took place in July-August, and the second (autumn) quarter sampling was conducted in November-December 1982. The third quarter sampling occurred in January-March 1983.

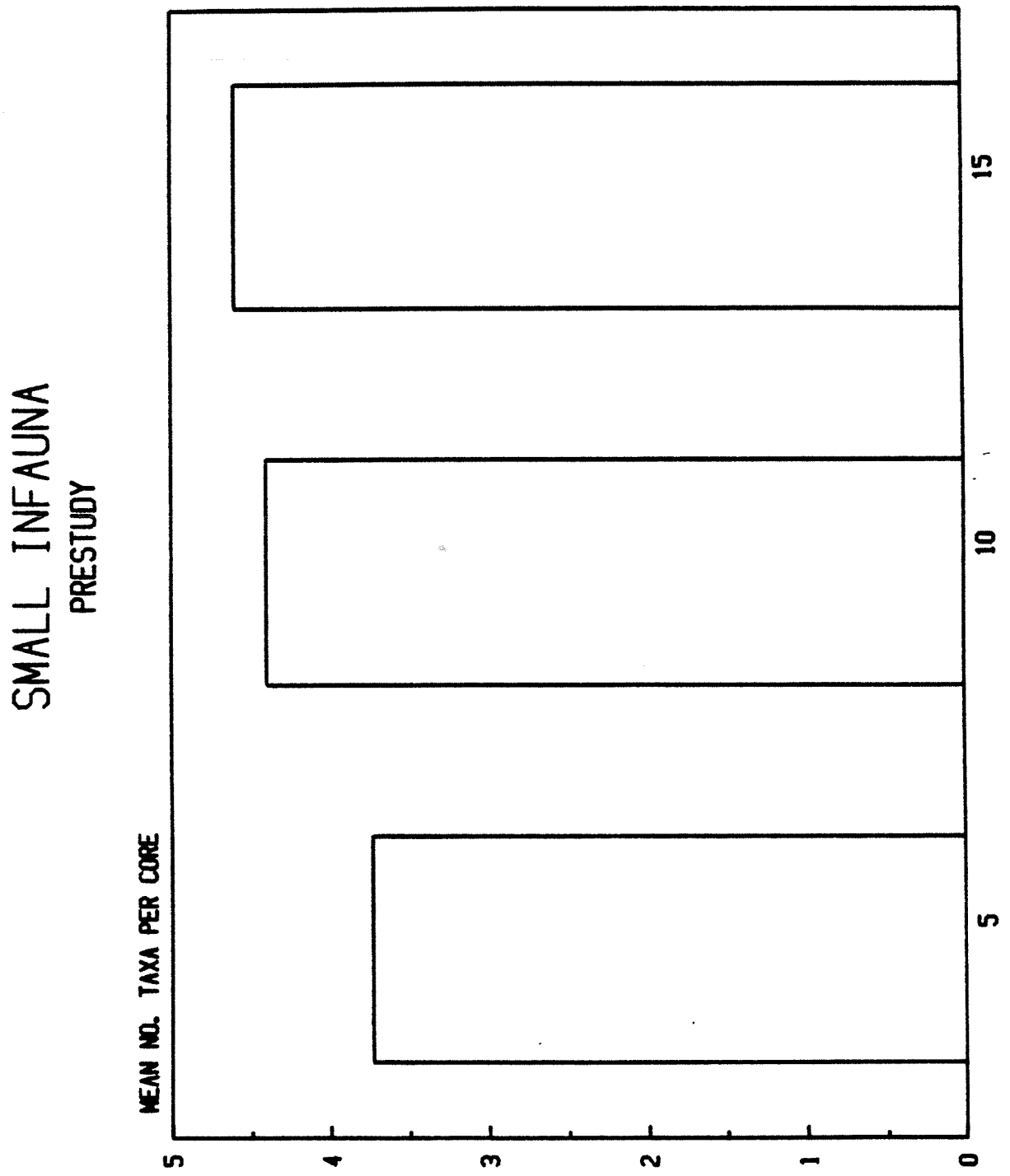



Figure 6.19. Comparison of mean number of small infaunal taxa collected using core samples of 5, 10, and 15 cm depth.

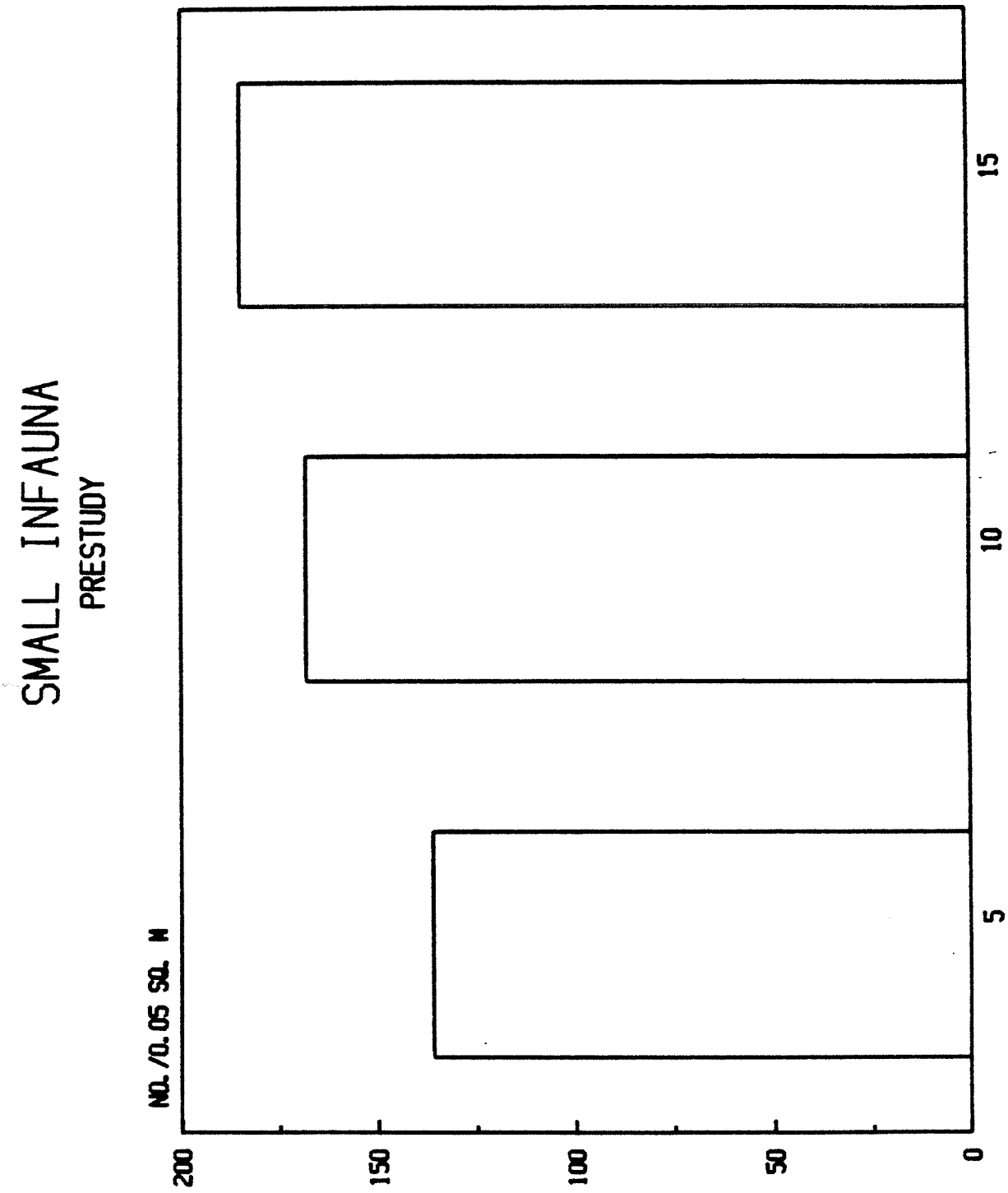



Figure 6.20. Comparison of number of small infaunal organisms collected using core samples of 5, 10, and 15 cm depth.

6.4.3.1 Water Characteristics

Water temperature averaged approximately 15 C during the summer (June-August) and was highly variable among the six beaches (Figure 6.21). There was a pronounced peak at most beaches on 8 September which coincided with a warm dry period. Water temperature declined between the 8 September and 8 December samplings. Average water temperature was between 8-9 C between 8 December and 4 February and showed relatively little variation among the six beaches.

Salinity, at most beaches, ranged between 27-30 ppt between 16 June and 23 December (Fig. 6.22). Covenant Beach was an exception to this pattern, where salinity ranged between 16-30 ppt. A stream flows over the intertidal zone very near the sampling site. Drops in salinity at Covenant Beach can largely be explained by increased runoff during rainy periods. On 5 January, the largest range (18-29 ppt) in salinity values occurred among the other five beaches. Analysis of this large among beach variation has not yet revealed any causitive factors.

Dissolved oxygen (DO) showed larger mean values and greater among beach variation during the summer samplings as compared to the late fall and winter sampling (Fig. 6.23). The values ranged between 7-19 mg/l over the entire period and showed a peak at most beaches on 8 September. Field observations on that date indicated that there was a very dense bloom of phytoplankton occurring nearshore. DO averaged about 11 mg/l during summer and 9 mg/l during the autumn and winter.

Most water column inorganic nutrients (i.e. $OPO_4$, Si, $NO_3$) showed a general pattern of increasing concentration between summer and winter (Figures 6.21 - 6.26). Phosphate concentration ranged between 1 - 3.5 micromole during the entire period and was similar (i.e. within 1 micromoles) among beaches for each sampling. Silicate concentration ranged between 10-170 micromoles and

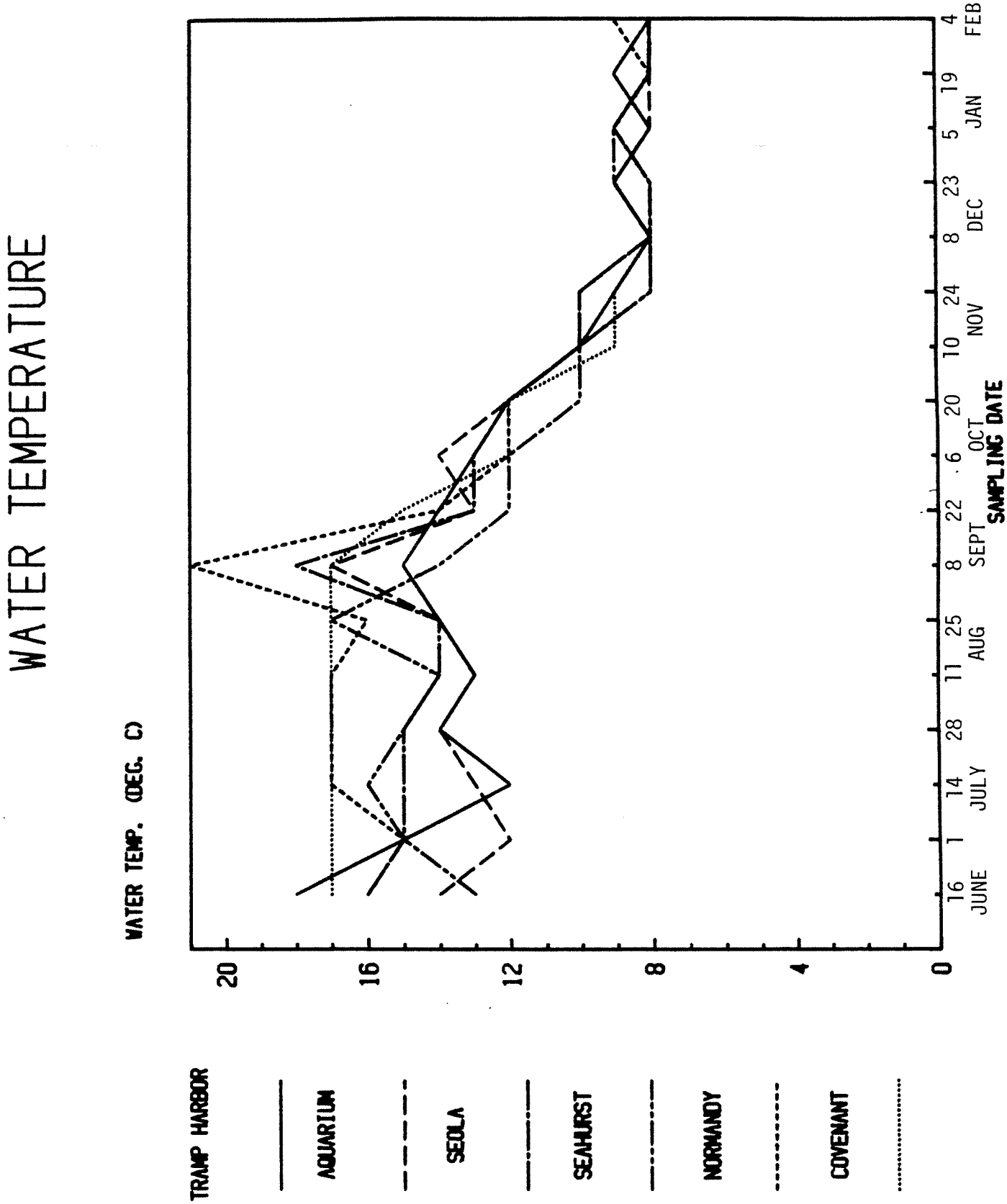



Figure 6.21. Water temperature at the six beaches.

# SALINITY

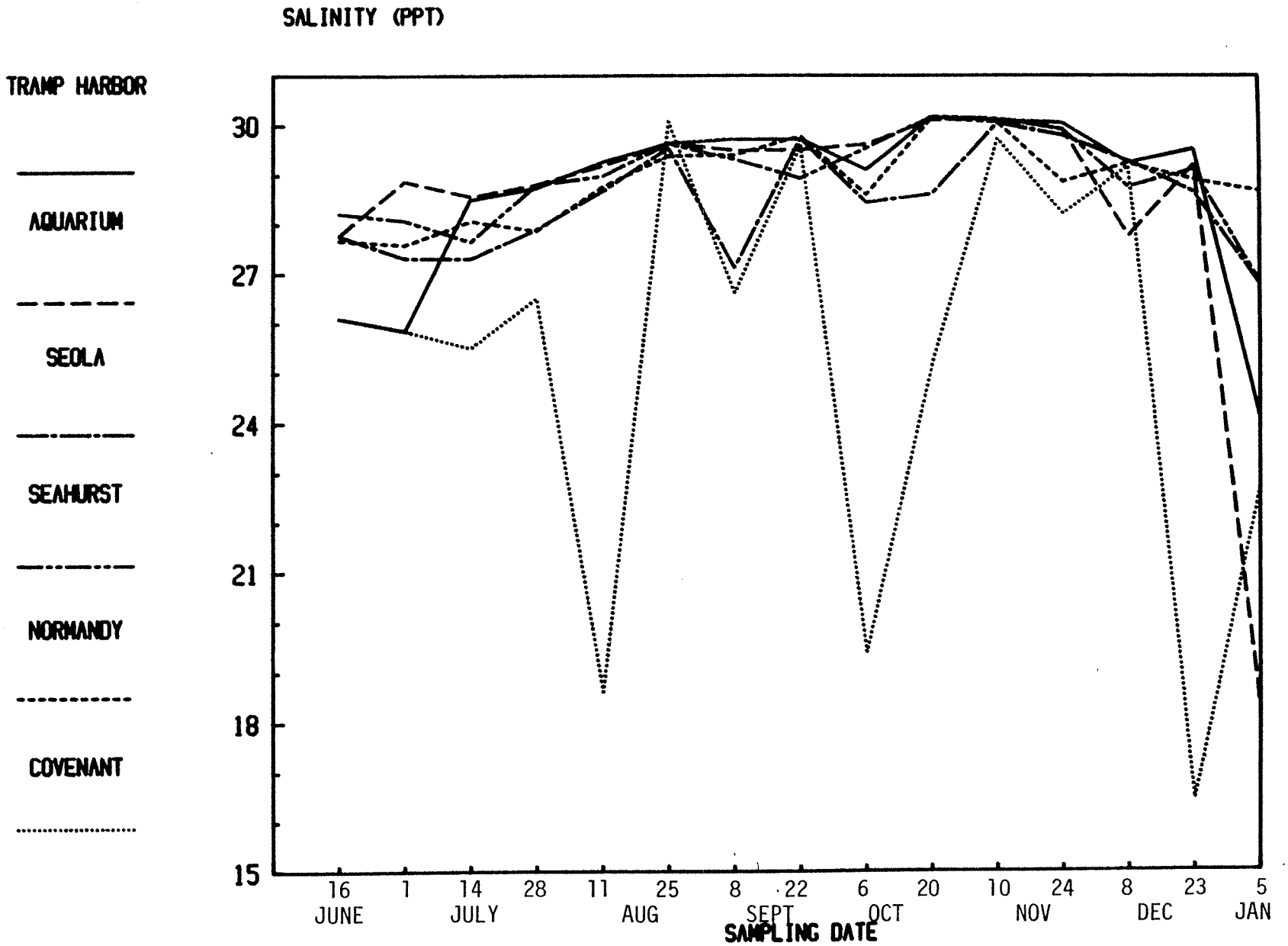



Figure 6.22. Salinity at the six beaches.

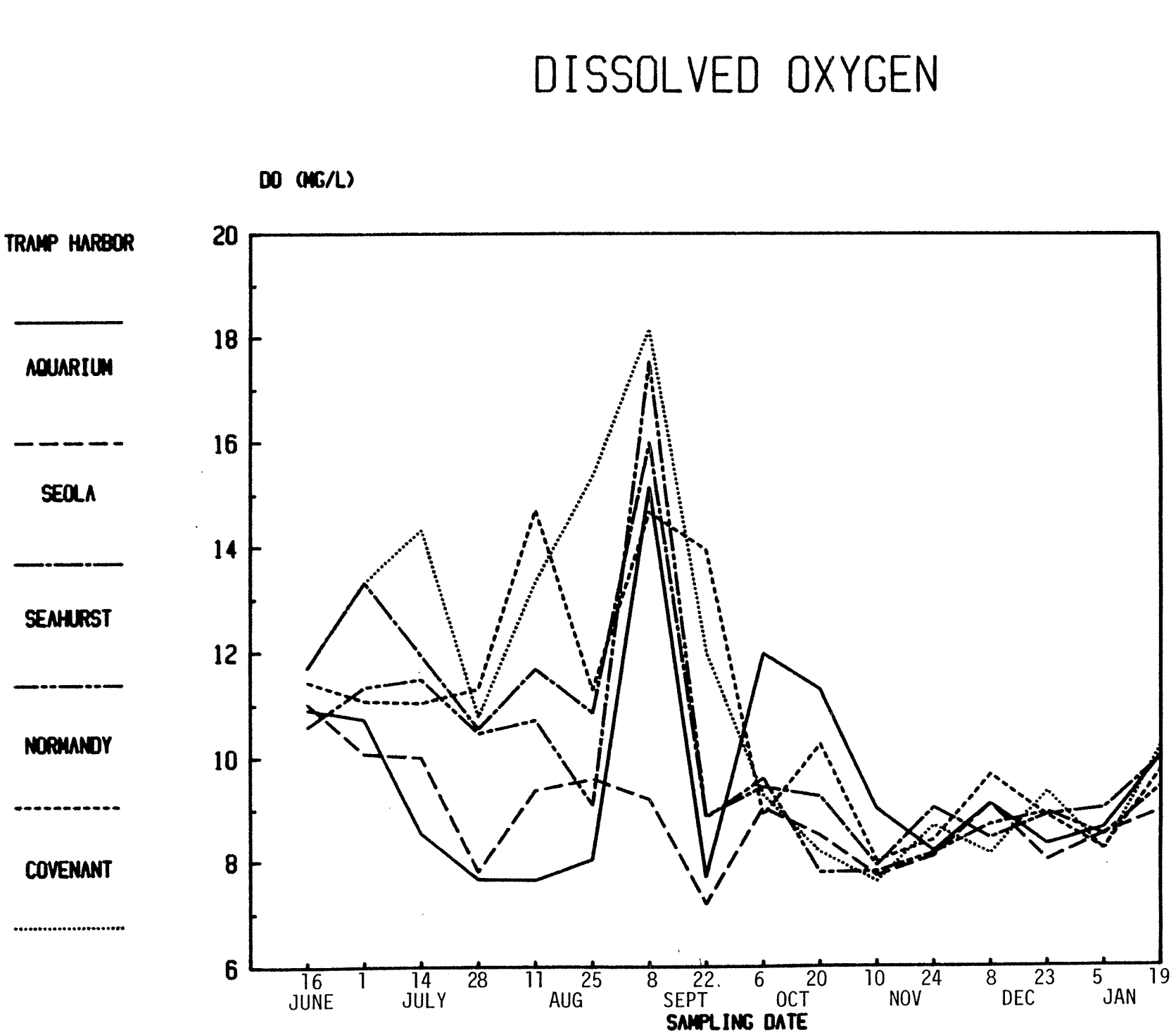



Figure 6.23. Dissolved oxygen concentration at the six beaches

# PHOSPHATE

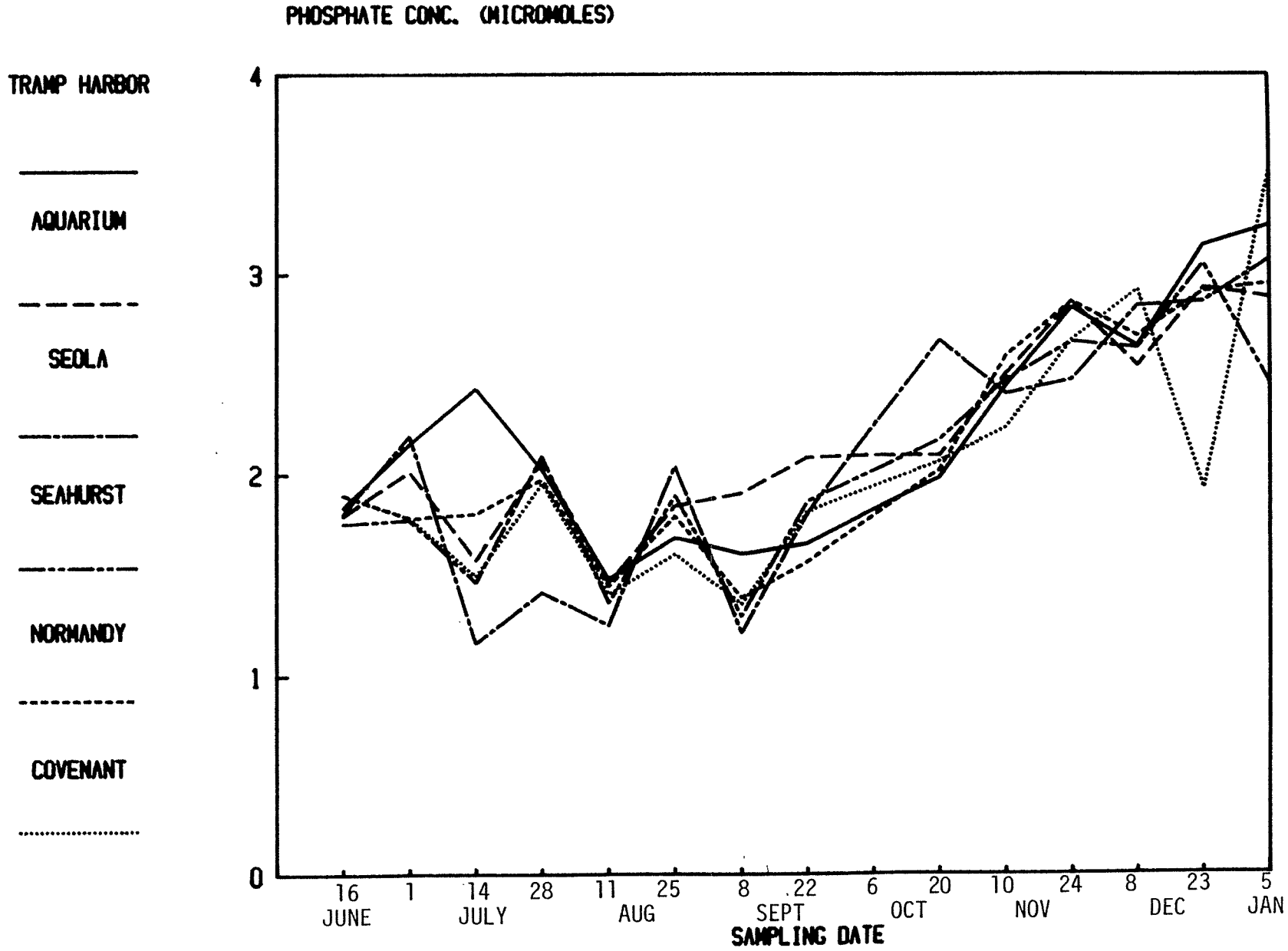



Figure 6.24. Phosphate concentration at the six beaches.

# SILICATE

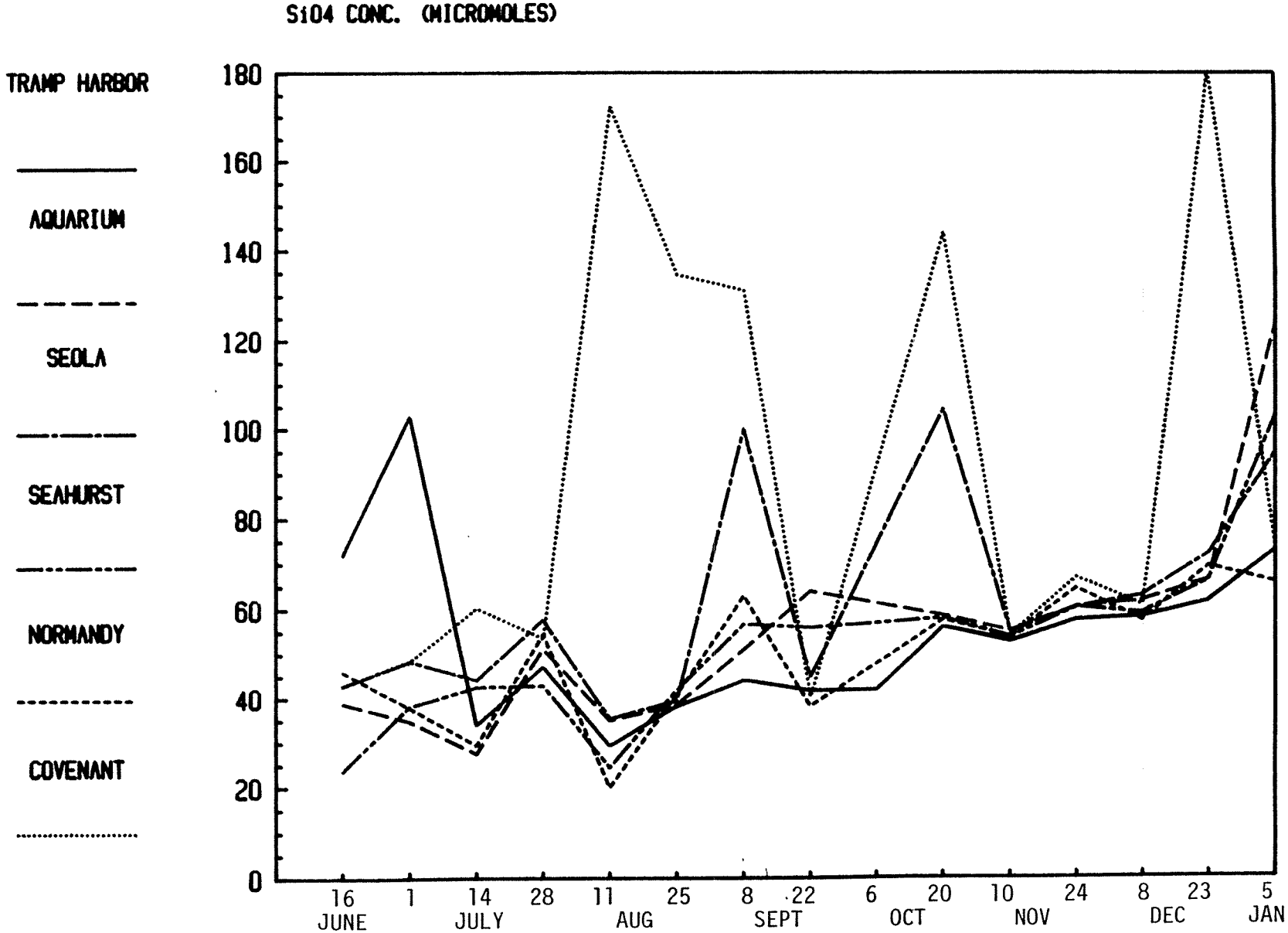



Figure 6.25. Silicate concentration at the six beaches.

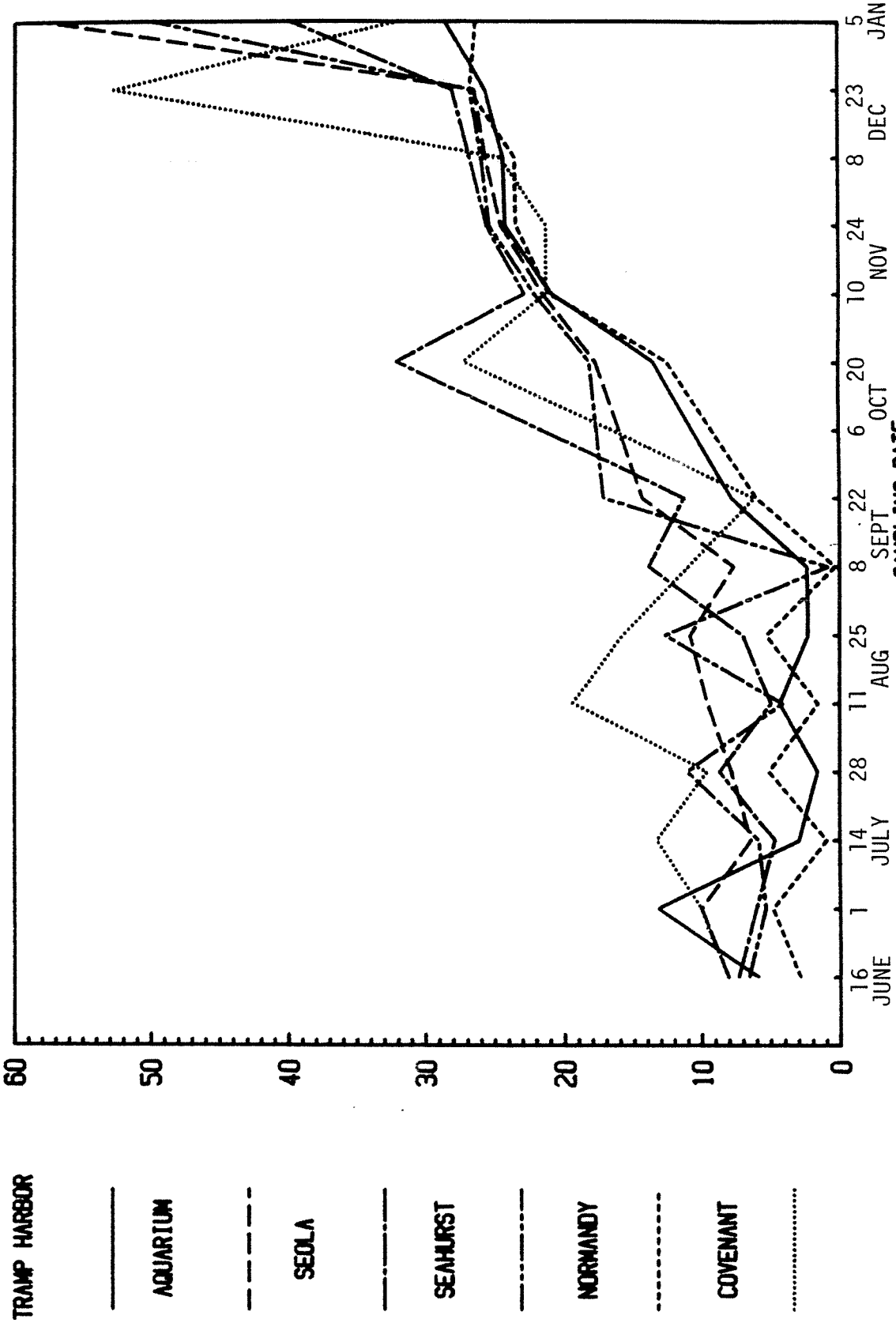



Figure 6.26. Nitrate concentration at the six beaches.

showed widest variation with time at Covenant Beach. The increases in $SiO_4$ at Covenant correspond to the decreased salinity concentrations (Fig. 6.22), which indicates that silicon is being input in significant quantities from the stream. Nitrate concentration ranged between 1 - 58 micromoles (Figure 6.26). There was marked variation among sites for all samplings except those from 10 November - 8 December. The greatest mean value calculated over all sites occurred in January. The general trend of increasing concentration of phosphate, silicate and nitrate, and the marked variation during the summer months, indicate that metabolism of aquatic plants may be important in controlling the concentrations of these nutrients.

Nitrite remained at low concentration (i.e., below 1 micromole) from 16 June - 5 January (Figure 6.27). There was, however, a peak in concentration at all sites beginning on 6 October and extending to 10 November, which reached a maximum on 20 October. This peak closely follows the cessation of the September phytoplankton bloom and may indicate the release of nitrogenous molecules and the rapid metabolism of these compounds to nitrite.

Ammonia concentration (Fig. 6.28) was quite stable over the study period and, except for one high concentration, ranged from less than one to nine micromoles. The peak in concentration at Normandy Beach on 8 September may have resulted from ammonia being released due to the decay of phytoplankton. Field observations indicate that a considerable odor was noted during sampling at this beach.

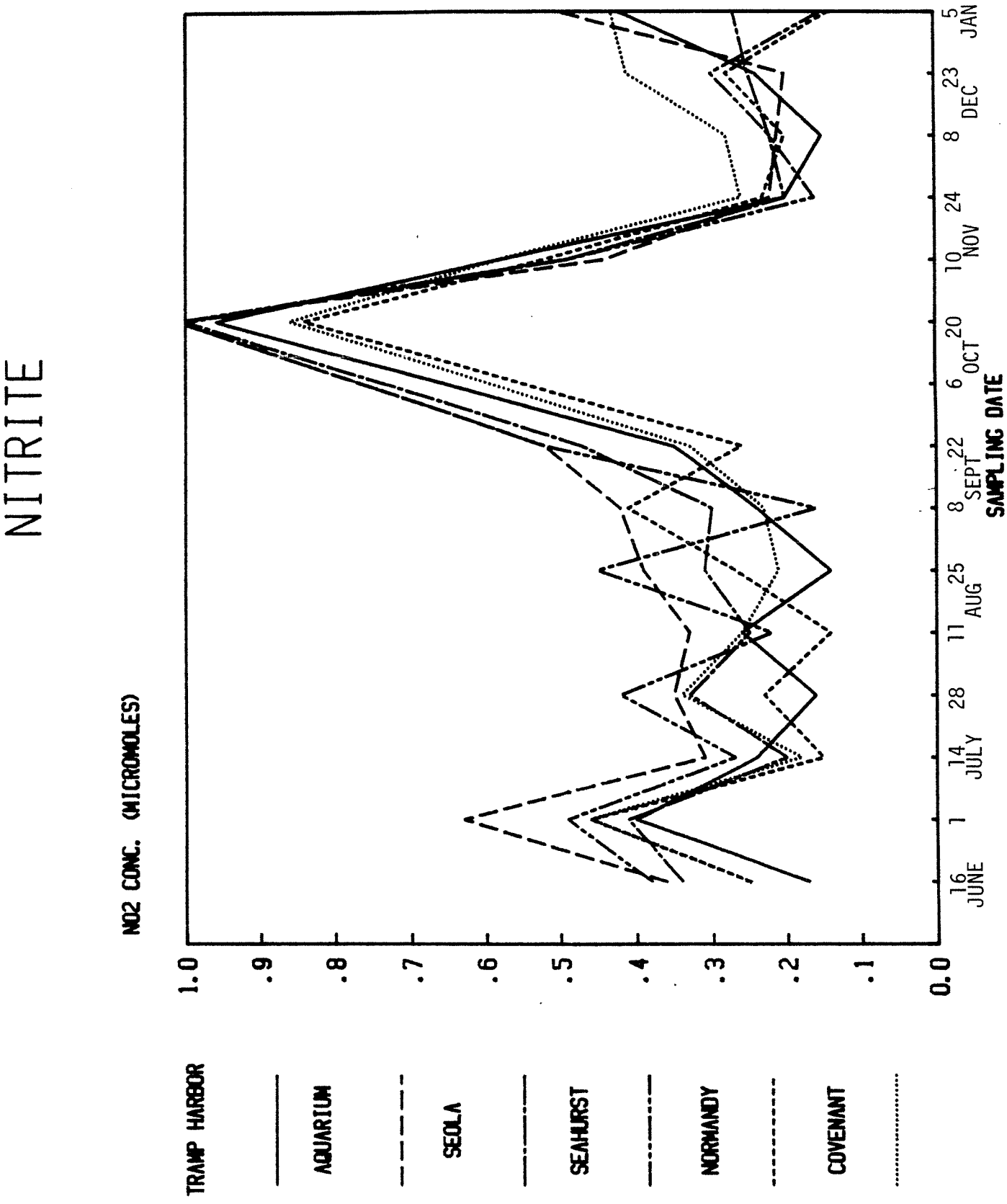



Figure 6.27. Nitrite concentration at the six beaches.

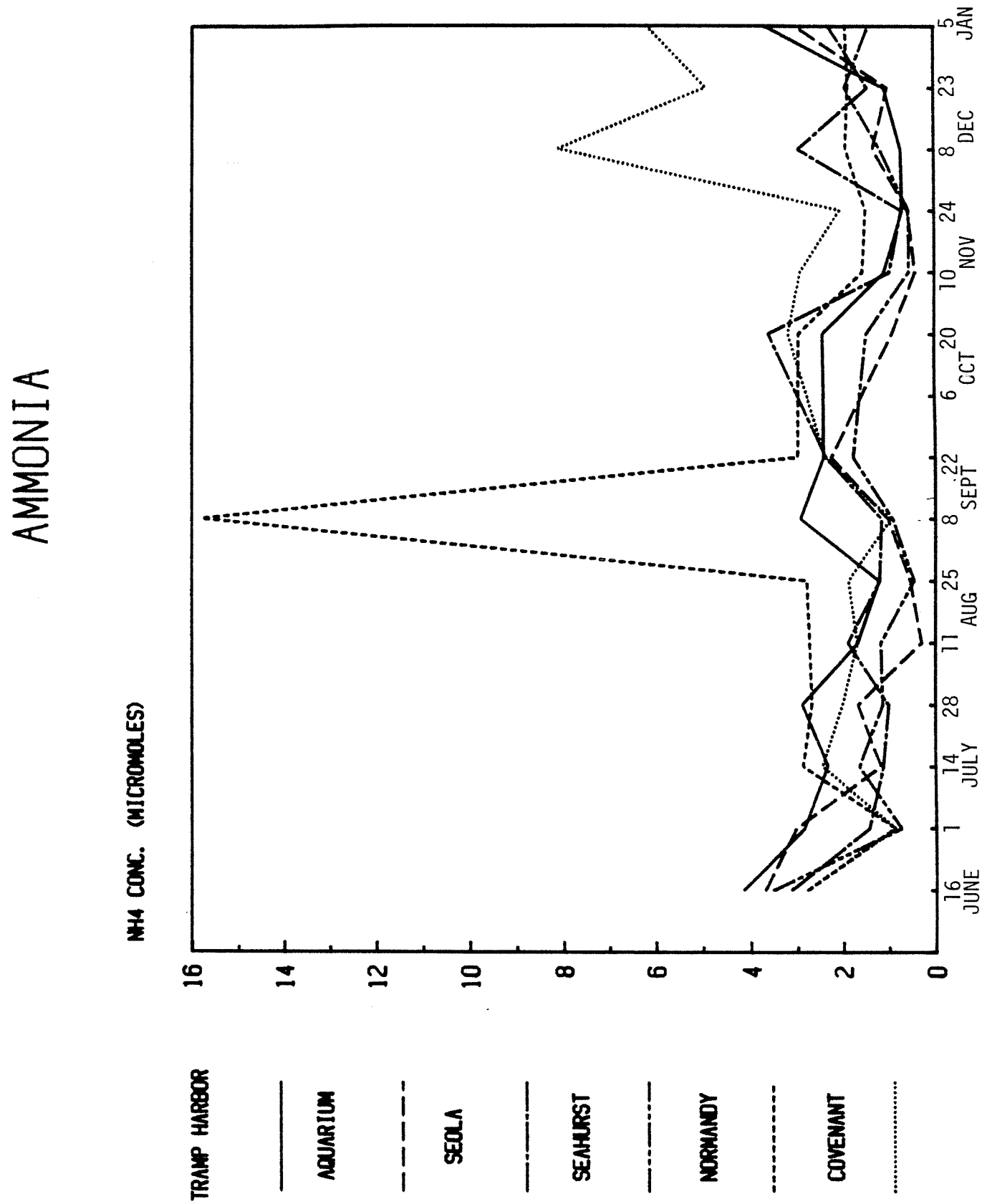



Figure 6.28. Ammonia concentration at the six beaches.

6.4.3.2 Macroalgal Assemblage

To date, a total of 68 taxa have been noted in the percent cover and algal biomass samples. This total includes 10 animal and 57 algal taxa and one eelgrass taxon. Of the 57 algal taxa, 31 are red algae, 16 are green algae, nine are brown algae and one designates macroscopically evident diatom tufts and filaments.

Mean percent cover declined (Tables 6.9, 6.10) between summer (grand mean = 80.7%) and autumn (grand mean = 18.6%). This change was related primarily to a loss of algal cover (summer grand mean = 79.6%; autumn grand mean = 15.5%). Based on three samplings at the two Seahurst Park sites, the decline primarily took place between September and November (Fig. 6.29). Algal biomass showed a concordant decline between the two seasons (Tables 6.9 - 6.10). The high intertidal site at Aquarium and the low intertidal site at Normandy Beach contained the lowest algal standing stocks during both seasons.

The total number of taxa and the total number of algal taxa recorded in the quadrats did not change appreciably between August and November (Tables 6.9, 6.10). The decline in algal standing stock was related to a general loss of large green algae (e.g. Ulva spp), which were replaced in autumn by a number of small red and green algal species (e.g. Pterosiphonia bipinniata, Ceramium spp, Cladophora spp). Although algal species diversity changed somewhat at all sites between seasons, the mean H' value over all sites was not appreciably different (summer mean H' = 0.37; autumn mean H' = 0.39).

The patterns seen are typical of central Puget Sound algal assemblages (Thom 1978). The ephemeral green algae of summer grow to large size, reproduce and begin to fray and decay during summer and early autumn. Turbulent wave action in autumn detaches the remaining plant material. Lower light conditions and cooling temperatures appear favorable to the development

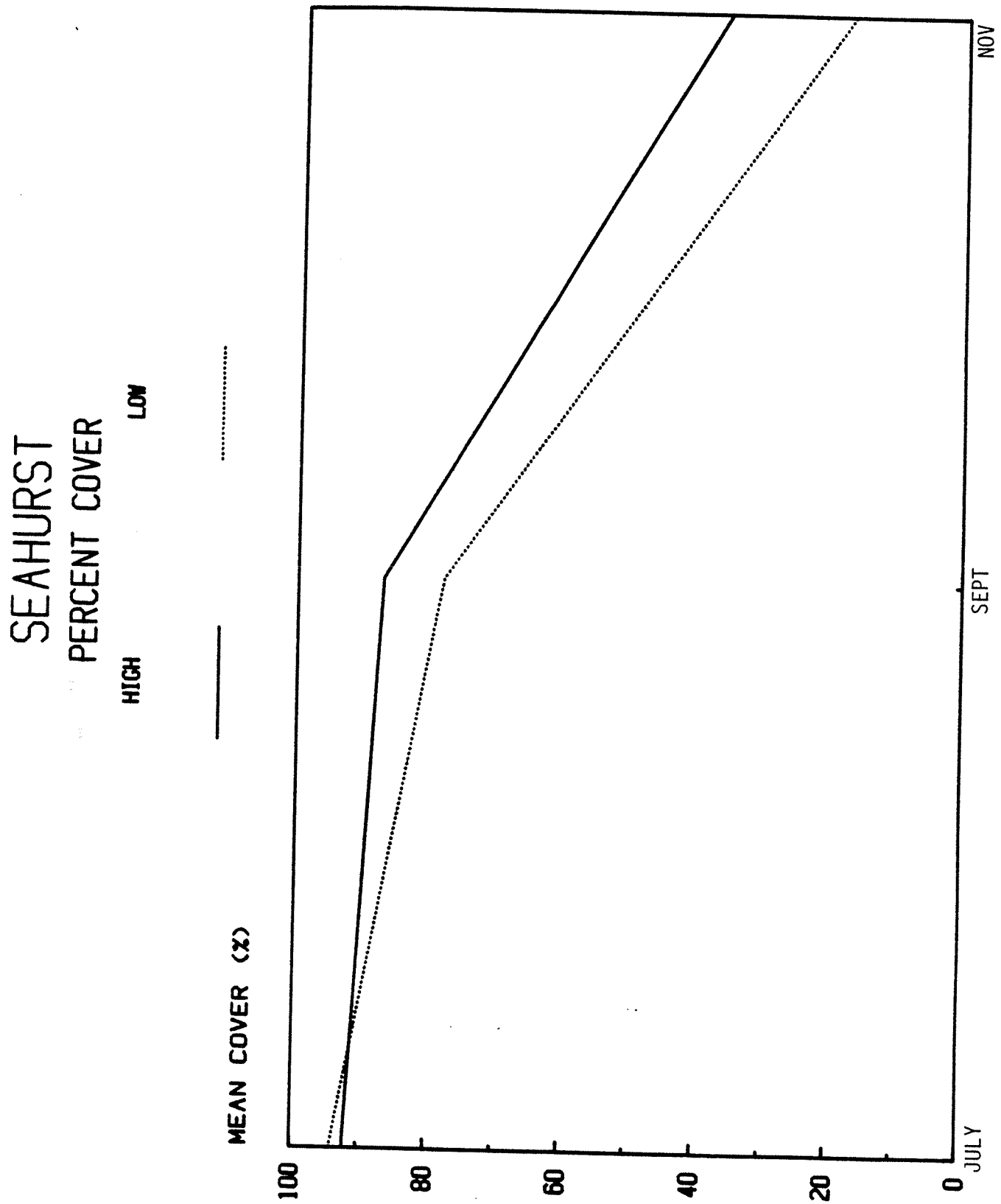



Figure 6.29. Mean percent cover of animals and algae at the Seahurst Park intertidal sites.

Table 6.9. Summary of data on surface dwelling organisms at sites in July-August 1982. H' based on biomass data; animal species richness from cover data; algal species richness from biomass data.

| Site | $\bar{x}$ Cover (%) | | | Algal biomass ($g/m^2$) | | Species Richness (Total No.Recorded) | | | Algal diversity (H') | Drift biomass ($g/m^2$) | | Eelgrass density ($No./m^2$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Animals | Algae | Total | $\bar{x}$ | SD | Animals | Algae | Total | | $\bar{x}$ | SD | $\bar{x}$ | SD |
| Seola | 2.2 | 88.4 | 90.6 | 176.208 | 102.672 | 4 | 9 | 13 | 0.43 | 143.296 | 165.904 | 51.2 | 31.5 |
| Seahurst: | -- | -- | -- | -- | -- | -- | -- | -- | -- | 87.184 | 62.957 | 57.6 | 58.9 |
| High | 2.6 | 88.9 | 91.5 | 122.502 | 89.036 | 7 | 7 | 14 | 0.39 | -- | -- | -- | -- |
| Low | 0.4 | 92.2 | 92.6 | 159.917 | 91.613 | 3 | 7 | 10 | 0.18 | -- | -- | -- | -- |
| Normandy | < 0.1 | 72.3 | 72.3 | 51.969 | 40.638 | 1 | 9 | 10 | 0.47 | 597.936 | 655.216 | -- | -- |
| Covenant | 0.6 | 85.4 | 86.0 | 91.844 | 48.789 | 3 | 6 | 9 | 0.23 | 241.635 | 235.988 | -- | -- |
| Aquarium | 1.9 | 37.6 | 39.5 | 37.061 | 46.148 | 6 | 8 | 14 | 0.39 | 205.539 | 190.326 | 89.6 | 51.8 |
| Tramp Harbor | 0.1 | 92.5 | 92.6 | 128.255 | 93.838 | 2 | 16 | 18 | 0.51 | 72.555 | 81.721 | 116.8 | 92.8 |

Table 6.10. Summary of data on surface dwelling organisms at sites in autumn (November 1982). H' based on biomass data; animal species richness from cover data; algal species richness from biomass data.

| Site | $\bar{x}$ Cover (%) | | | Algal biomass ($g/m^2$) | | Species richness (Total No.Recorded) | | | Algal diversity (H') | Drift biomass ($g/m^2$) | | Eelgrass density ($No./m^2$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Animals | Algae | Total | $\bar{x}$ | SD | Animals | Algae | Total | | $\bar{x}$ | SD | $\bar{x}$ | SD |
| Seola | * | -- | -- | 19.673 | 13.386 | -- | 2 | -- | 0.01 | 3.632 | 3.587 | 44.8 | 44.6 |
| Seahurst | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.432 | 8.259 | 48.0 | 52.4 |
| High | 7.7 | 28.4 | 36.1 | 41.993 | 50.564 | 5 | 6 | 11 | 0.27 | -- | -- | -- | -- |
| Low | 2.2 | 14.7 | 16.9 | 18.410 | 16.694 | 3 | 10 | 13 | 0.38 | -- | -- | -- | -- |
| Normandy | * | -- | -- | 1.787 | 1.449 | -- | 9 | -- | 0.71 | 14.123 | 18.454 | -- | -- |
| Covenant | 1.4 | 6.2 | 7.6 | 20.577 | 14.235 | 3 | 11 | 14 | 0.40 | 3.125 | 1.349 | -- | -- |
| Aquarium | 2.5 | 9.3 | 11.8 | 10.770 | 10.695 | 4 | 9 | 13 | 0.61 | 9.229 | 14.172 | 116.8 | 72.2 |
| Tramp Harbor | 1.5 | 18.9 | 20.4 | 52.012 | 5.341 | 3 | 6 | 9 | 0.33 | 95.104 | 117.140 | 41.6 | 74.4 |

*Camera failure during two attempts to sample these sites resulted in loss of photographic samples.

of a rich filamentous red algal flora (Thom 1980).

The Seahurst sites had relatively high algal standing stocks and species richness and diversity values which were comparable with other sites. No major species discrimination existed between the Seahurst sites and other sites.

6.4.3.3 Microalgal Assemblages

Sediment associated microalgae at the Seahurst Park sand site showed marked temporal variations as indicated by pigment concentrations (Figure 6.30). There was a significant bloom of sediment microalgae in mid November. Phaeopigments remained at relatively the same level through time (approximately 1.5 micrograms $cm^{-2}$), except for the sampling at the end of November where the value increased to 3.6 micrograms $cm^{-2}$.

A visible brown film was evident at the Seahurst sand site during all samplings. Microscopic examination of this brown coloration indicates the presence of an abundant microfloral assemblage consisting primarily of diatoms.

6.4.3.4 Algal Productivity

Net productivity rates of major algal taxa at Seahurst Park are shown in Figure 6.31 A-D for four experiments. Variation among taxa in productivity is evident during experiments. Temporal changes are best illustrated by rates for Ulva fenestrata, which was present during all experiments. The maximum rate occurred during September and the minimum rate measured was in November. The experiment in November was conducted under a dense overcast and light may have limited productivity then. The sediment microflora was consistently the least productive taxon on a per unit area basis for the first three experiments.

Productivity rates were extrapolated to total productivity within the low cobble study site (195 $m^2$) for each season by multiplying the rates by the

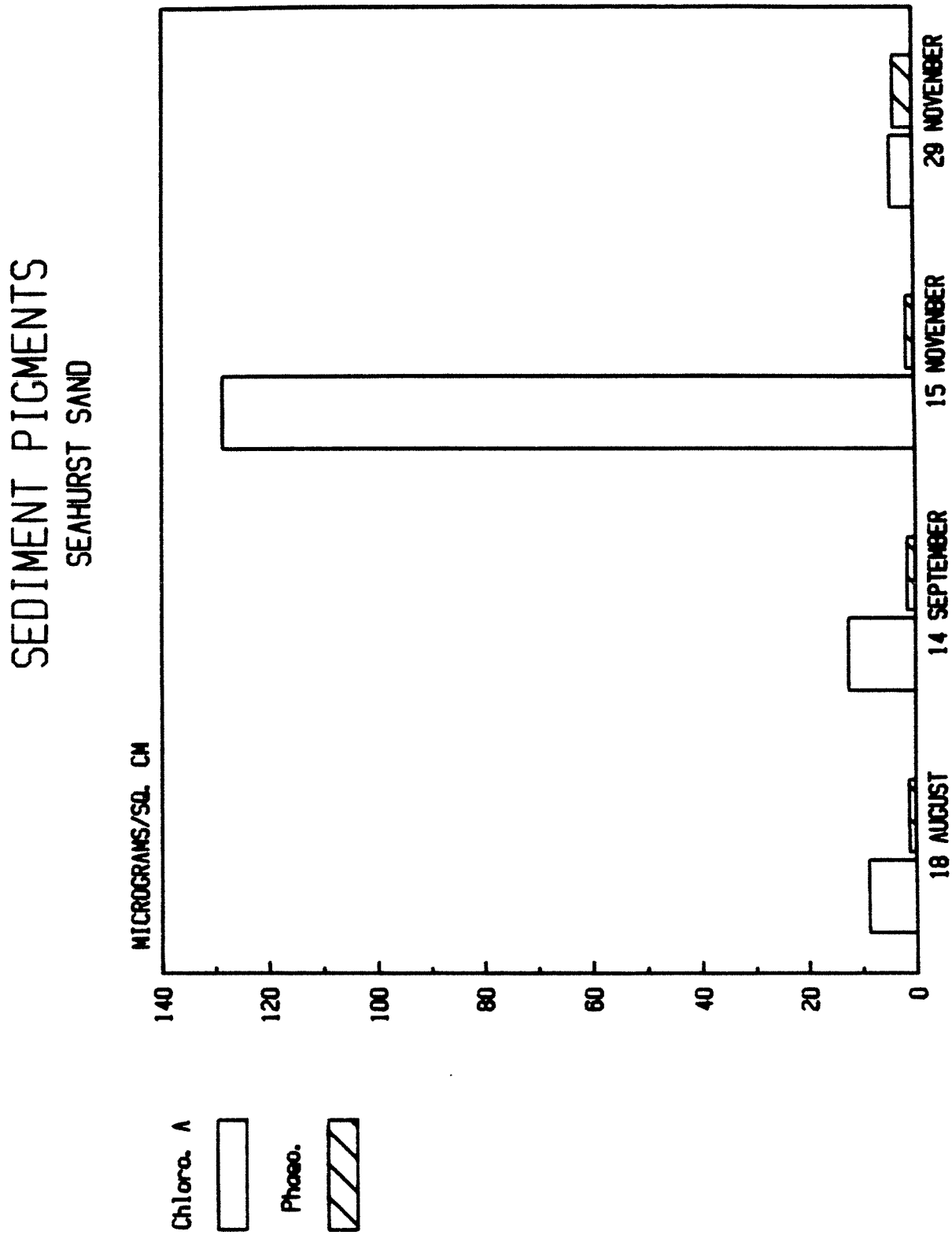



Figure 6.30. Pigment concentrations in sediment from the Seahurst Park sand habitat.

# ALGAL NET PRODUCTIVITY
## AUGUST 1982

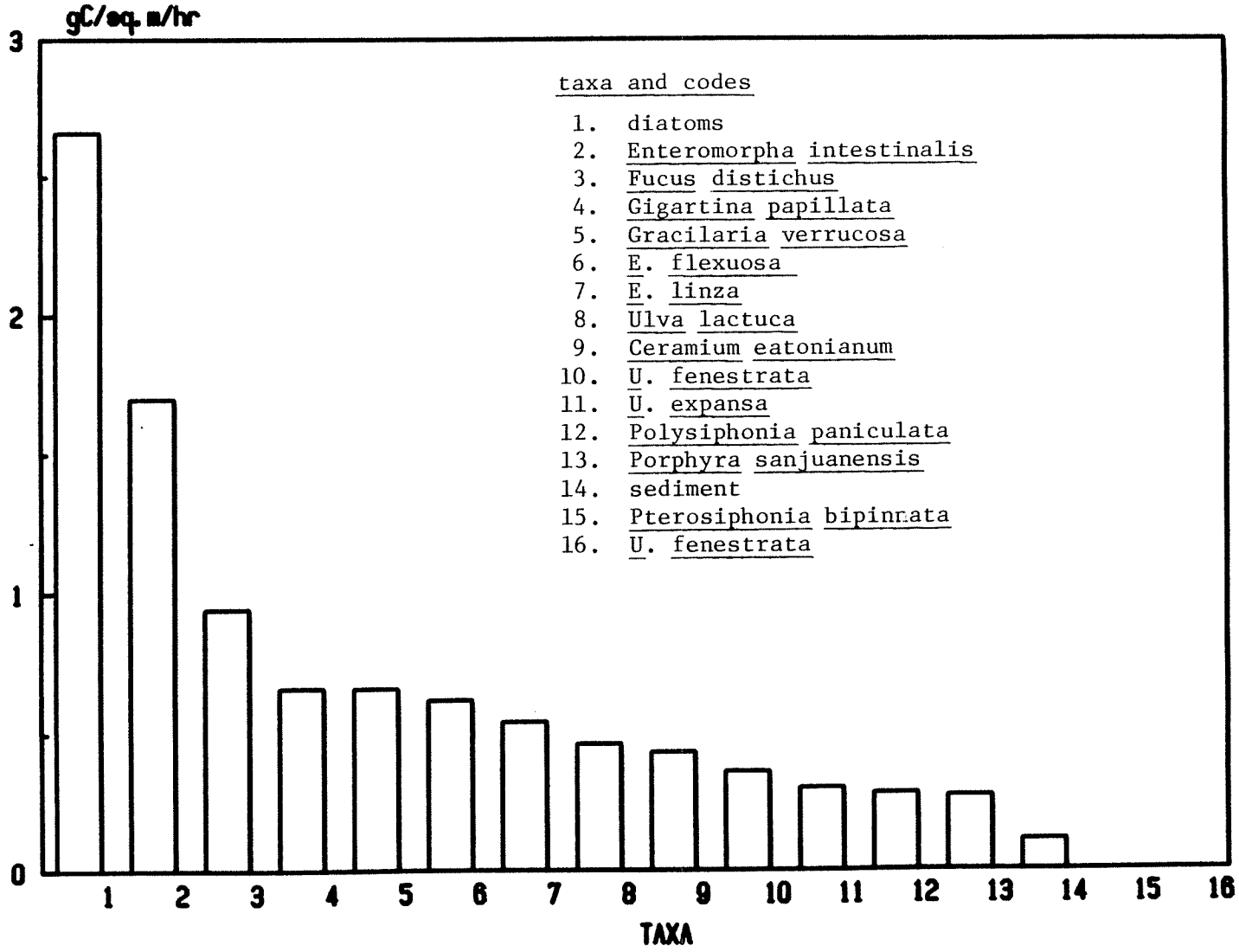



Figure 6.31A. Mean net productivity rates for major algal taxa at Seahurst Park.

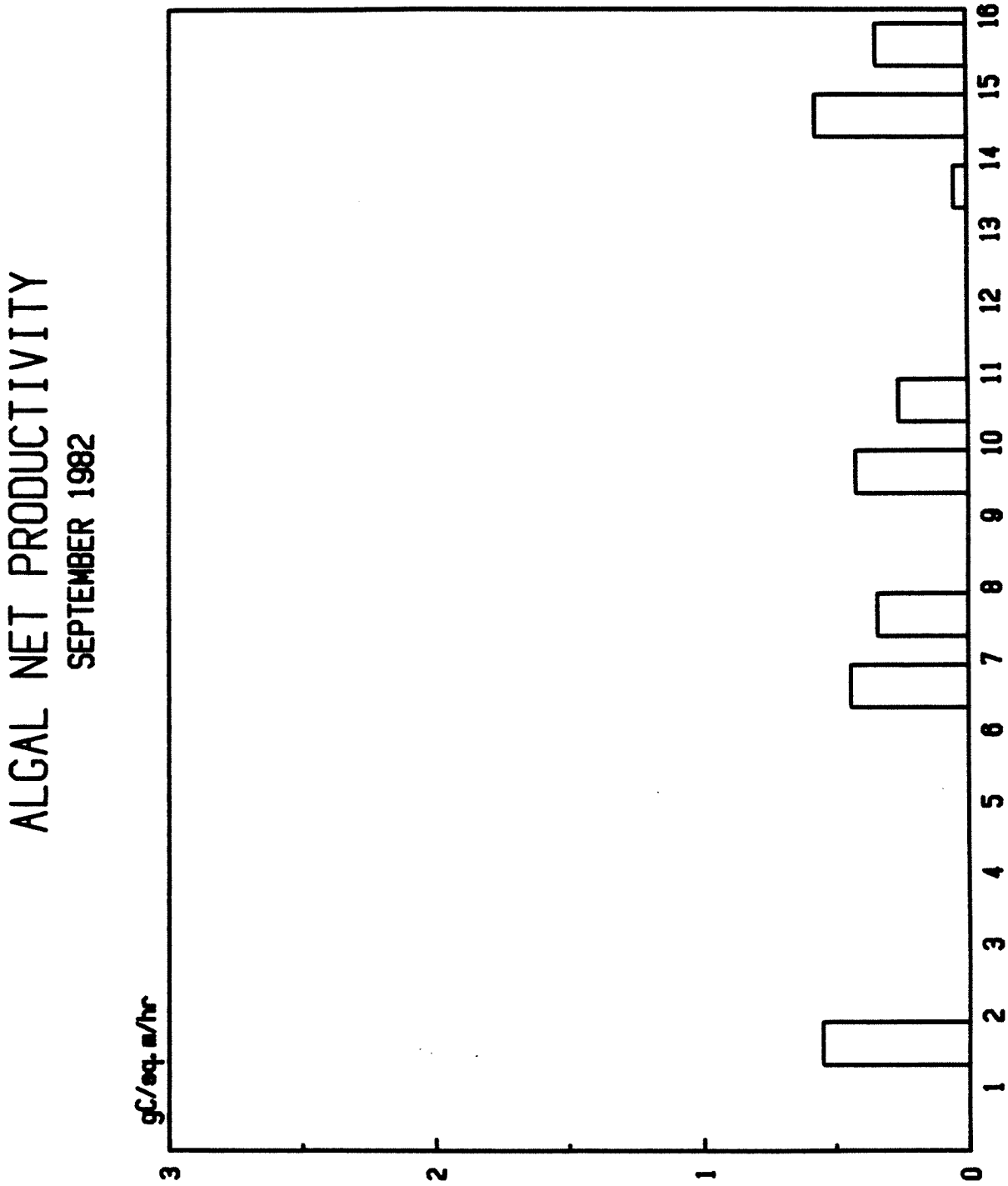



Figure 6.31B. Mean net productivity rates for major algal taxa at Seahurst Park.

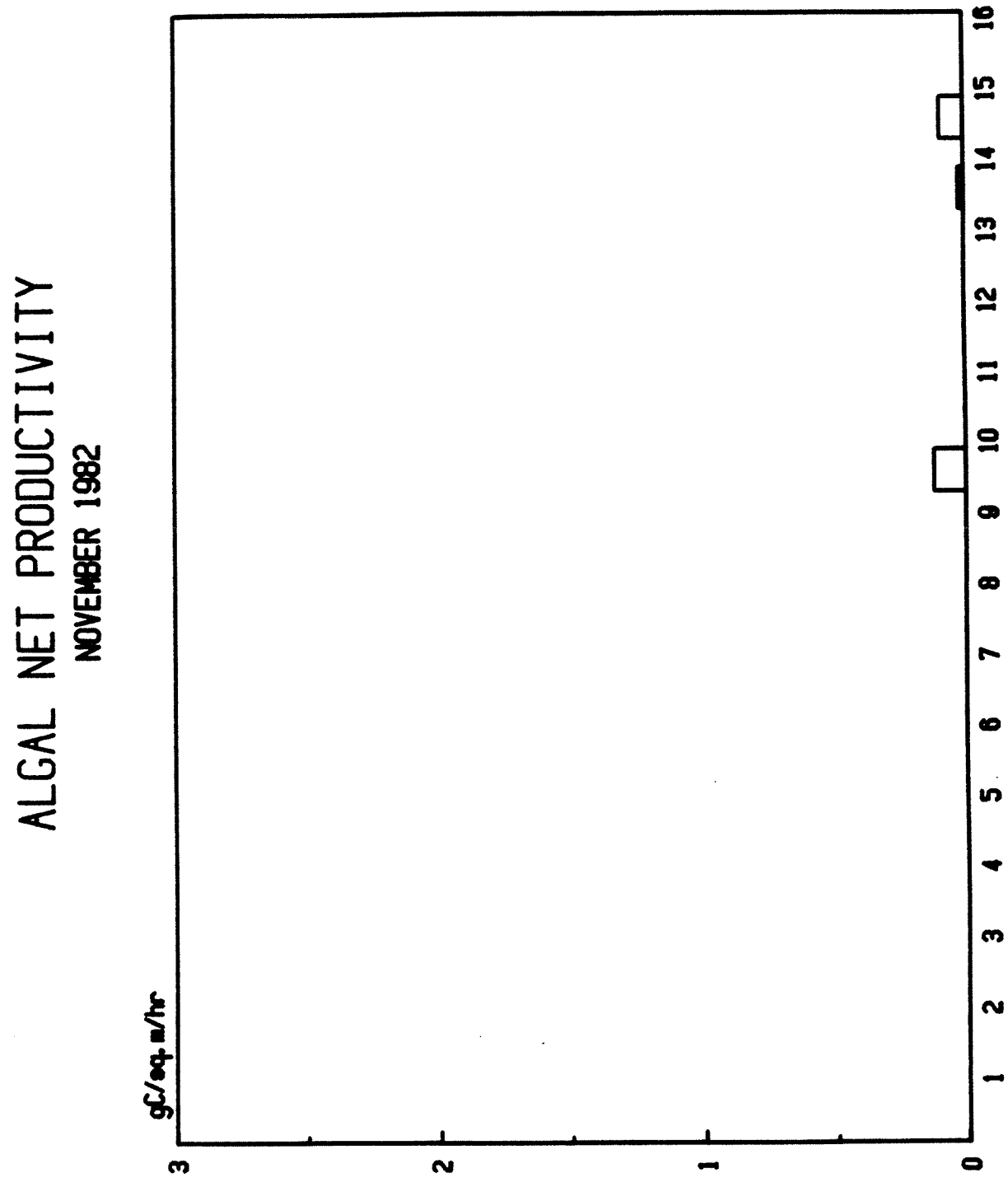



Figure 6.31C. Mean net productivity rates for major algal taxa at Seahurst Park.

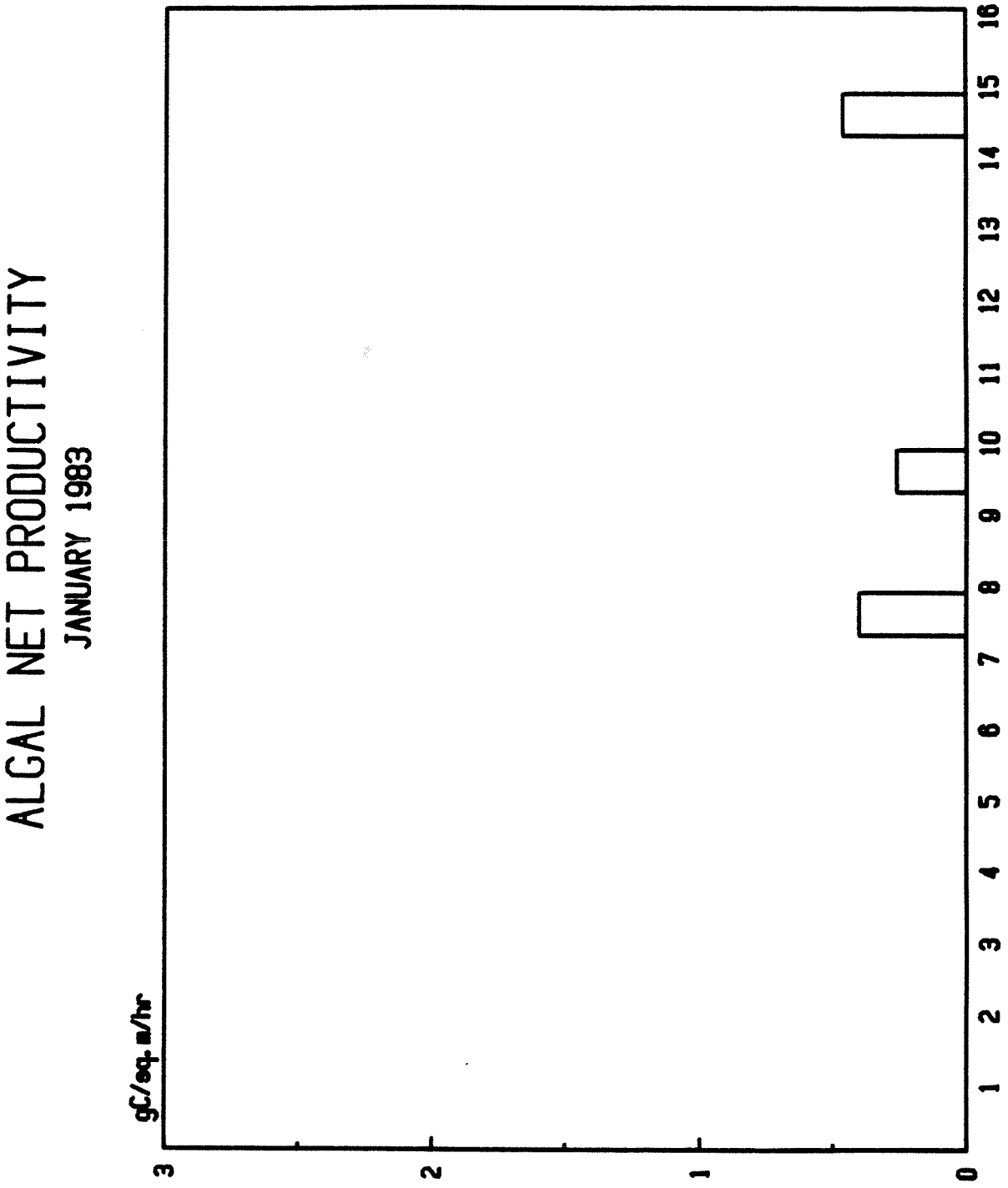



Figure 6.31D. Mean net productivity rates for major algal taxa at Seahurst Park.

amount of surface area covered by each taxon using percent cover measurements. A dramatic change in total production among months is evident (Table 6.11). Further, the contribution of a taxon to total production varied among months. For example, sediment microflora accounted for 0.4, 3.3, and 87.8% of total production for August, September, and November, respectively. This is in contrast to the fact that sediment microalgae exhibited minimum production per unit area in November. The shift in level of contribution to total carbon fixation may have effects on the quality of food available to consumers.

6.4.3.5 Eelgrass Density

Eelgrass density at shallow subtidal sites varied among the sites during August and November 1982 (Tables 6.9, 6.10). Field observations indicated that the beds at Seahurst Park and Tramp Harbor were patchy, whereas beds at Seola Beach and Aquarium formed a continuous cover. The tallest (1-2 m) and most robust plants were observed at the Seola Beach site. The plants at all sites showed a decrease in frond length between August and November. Typically, frond length decreased by one-half between the two samplings. Dead and decaying fronds were noted at the sites in November.

6.4.3.6 Drift Assemblage

Field observations indicated that two primary drift lines exist at the beaches. An accumulation of large logs and tree branches occurs very high on the beach. The accumulation appears to be quite stable. The second line occurs lower on the beach and consists primarily of drift algae, eelgrass and terrestrial leaf litter. This line is much less persistent than the log line and can migrate daily with the fluctuating tides. Because this material may cause noxious conditions and because algal material is a more labile source of energy to primary consumers, the algal drift line material is being monitored.

Plant material in the algal drift line consisted primarily of green

Table 6.11. Total net productivity of taxa at the low cobble study area (195 $m^2$) at Seahurst Park.

| Taxon | Total Net Productivity (gC/hr) August | September | November |
|---|---|---|---|
| diatoms | 0.01 | 0 | 0 |
| Enteromorpha intestinalis | 9.48 | 10.70 | 0 |
| Fucus distichus | 0.04 | 0 | 0 |
| Gigartina papillarta | 0.01 | 0 | 0 |
| Gracilaria verrucosa | 0.01 | 0 | 0 |
| E. flexuosa | 0.01 | 0 | 0 |
| E. linza | 72.97 | 0.01 | 0 |
| Ulva lactuca | 14.50 | 5.60 | 0 |
| Ceramium eatonianum | 0.01 | 0 | 0 |
| U. fenestrata | 2.73 | 1.10 | 0.39 |
| U. expansa | 0.01 | 34.63 | 0 |
| Polysiphonia paniculata | 0.01 | 0 | 0 |
| Porphyra sanjuanensis | 0.01 | 0 | 0 |
| sediment | 0.37 | 1.82 | 2.80 |
| Pterosiphonia bipinnata | 0 | 1.49 | <0.01 |
| Total | 100.17 | 55.35 | 3.19 |

algae, eelgrass, and terrestrial material at most sites in August. The exception was Tramp Harbor, where the red alga Gracilaria verrucosa was abundant in the drift. In general, the drift assemblage reflected the attached algal assemblage at the site. Drift biomass decreased at all sites between August and November (Tables 6.9, 6.10), except Tramp Harbor. This latter site contains a high abundance of perennial taxa (G. verrucosa, Sargassum muticum) which tend to enter the drift over a longer period of time than the highly ephemeral green algae.

6.4.3.7 Sediment Chemistry

Results of sediment chemistry analyses for the long-term study sites were summarized by habitat type (Table 6.12). During the summer and fall of 1982, the intertidal sand habitats generally had lower BOD, percent volatile solids, and nitrogen values than the other habitat types. Total organic carbon (TOC) was high in the intertidal sand habitat, due solely to one high value. Excluding this single high value, the mean value for TOC in the intertidal sand habitat dropped to 0.99, which was lower than for any other habitat type.

Mean carbon:nitrogen ratios were in the range of 5.3 - 6.7 for all habitats except for the intertidal sand habitat. Once again, the high ratio for this habitat (15.3) resulted from a single high value. Excluding this single value, the carbon;nitrogen ratio for this habitat dropped to 5.5, which fit in well with values for the other habitats.

Sediment grain size and percent water were extremely similar for the low and high cobble habitats. Grain size and percent water were similar for the intertidal and subtidal sand and subtidal eelgrass habitats.

Seasonally, grain size, percent volatile solids, and TOC did not appear to fluctuate in a consistent manner. BOD, however, decreased at 16 of the 19 sites between summer and fall. The ratio of dry:wet weight of the sediments

Table 6.12. Summary of sediment chemistry data at long-term study sites during summer and fall, 1982. Data are presented as mean values, with ranges in parentheses.

| | | | | | | | | GRAIN SIZE (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Habitat | BOD | %VS | DRY: WET | TOC | N | TOC/N | $H_2S$ | Cobble | Gravel | Coarse Sand | Fine Sand | Silt | Clay | $\%H_2O$ |
| Intertidal: Low cobble | 963 (384-3200) | 1.10 (.81-1.64) | .79 (.74-.75) | 1.98 (1.10-2.78) | .34 (.14-.57) | 5.82 | 9.08 (0-55.44) | 0 (-) | 30.4 (18.0-50.1) | 19.9 (3.4-25.4) | 47.6 (28.9-64.6) | 7.6 (.5-36.8) | 1.7 (.9-2.8) | 17.5 (13.2-22.8) |
| High cobble | 408 (211-913) | 1.15 (.76-1.54) | .80 (.76-.83) | 1.90 (.60-2.70) | .36 (.18-.53) | 5.27 | 1.02 (0-4.646) | 0 (-) | 30.9 (12.0-60.7) | 10.9 (3.9-18.7) | 50.1 (29.6-80.2) | 6.0 (1.8-12.0) | 2.1 (1.1-3.5) | 17.2 (11.5-22.3) |
| Sand | 310 (117-790) | .85 (.71-1.07) | .78 (.75-.81) | 2.75 (.51-15.10) | .18 (.12-.28) | 15.28 | .97 (0-7.603) | 0 (-) | 1.3 (0-7.0) | 3.2 (.1-14.8) | 91.2 (74.4-98.7) | 3.0 (.4-8.5) | 1.3 (.9-1.8) | 20.5 (13.9-22.7) |
| Subtidal: Eelgrass | 542 (253-842) | 1.08 (.74-1.93) | .76 (.71-.81) | 2.47 (1.09-5.89) | .37 (.18-64) | 6.68 | .79 (0-5.60) | 0 (-) | .8 (0-2.6) | 7.2 (.6-33.1) | 85.9 (62.3-95.6) | 4.4 (.9-9.7) | 1.5 (.7-1.9) | 23.8 (19.7-31.6) |
| Sand | 449 (202-694) | 1.14 (.63-3.19) | .76 (.72-.82) | 2.00 (.97-4.56) | .37 (.19-.58) | 5.41 | .24 (0-.78) | 0 (-) | .8 (0-3.5) | 5.7 (1.2-15.8) | 88.9 (80.8-96.9) | 2.3 (.3-6.1) | 1.6 (1.1-2.4) | 21.6 (17.9-28.0) |

decreased at the same 16 sites at which BOD decreased.

The low values for BOD, percent volatile solids, and nitrogen found in the intertidal sand are of interest. These results correlate well with results of the small infaunal sampling, which showed that the intertidal sand habitat characteristically had low abundance, biomass, and species richness relative to other habitat types. If one extremely high value is excluded, TOC was also low in the intertidal sand habitat relative to other habitats, strengthening this correlation. Exclusion of this high value appears reasonable based on its extreme variation relative to the other values obtained for sand, and the closeness of the resulting carbon:nitrogen ratio to ratios for the other habitats after exclusion. The carbon:nitrogen ratios are in the same range, although slightly lower, than values recently obtained in Hood Canal (C. Simenstad, unpublished data).

Results of the sediment chemistry from the habitat study indicated that organic material was high in the finest sediments (i.e., those with a high proportion of silt and clay). Carbon:nitrogen ratios ranged between 2.2 - 10.7 with most values between 2.2 - 3.7. These values indicated that most organic material in the sediments is from Puget Sound algal sources as opposed to terrestrial sources.

6.4.3.8 Small Infauna

The abundances and number of taxa for small infauna varied widely between sites during summer of 1982. Abundances ranged from a low of 1,390 $m^{-2}$ (at the Tramp Harbor sand site) to 43,300 $m^{-2}$ (at the Normandy Cove low cobble site). The number of taxa varied from 10 (at Seola Beach sand) to 41 (Normandy Cove low cobble and Tramp Harbor subtidal sand). Biomass also varied greatly, ranging from 6 g $m^{-2}$ (at Seahurst sand) to nearly 900 g $m^{-2}$ (at Aquarium subtidal eelgrass). The high biomass at the Aquarium subtidal sand site was

primarily due to the presence of a single specimen of Macoma nasuta. Excluding this one clam, the biomass at this site dropped to less than 200 g $m^{-2}$, with the highest biomass then occurring at the Seahurst high cobble site (390 g $m^{-2}$).

Low cobble habitats had the highest abundance (21,000 $m^{-2}$) and number of taxa per site (35.3) of the habitats sampled (Table 6.13). Abundance at the Normandy Cove low cobble site was far higher than at any other site, due primarily to large numbers of capitellid polychaetes (18,000 $m^{-2}$) and the amphipod Corophium acherusicum (12,000 $m^{-2}$). When the high abundance of infauna from Normandy Cove was excluded, abundance in the low cobble habitats was still twice as high as in any other habitat. Biomass was highest in the subtidal eelgrass habitat. However, if the one large Macoma nasuta from the subtidal eelgrass habitat at Aquarium is excluded, the low cobble habitat also had the highest biomass. The intertidal sand habitat possessed a rather impoverished fauna in terms of abundance (1,600 organisms $m^{-2}$), biomass (11 g $m^{-2}$), and number of taxa per site (14.8). The subtidal sand habitat also had low biomass.

The total number of taxa found in each habitat type (i.e. the number of taxa when taxa for all sites within a habitat type were combined) was considerably higher in the low cobble, subtidal eelgrass, and subtidal sand habitats relative to the total number of taxa present in the high cobble and intertidal sand habitats.

Calculations of Shannon-Wiener diversity values, H' (Table 6.13), indicated that the subtidal habitats had slightly higher H' values than the intertidal habitats and that sand habitats had slightly lower H' values than other habitats. However, variation of H' values within habitat types was generally greater than variation between habitat types, which suggested that

Table 6.13. Small infaunal abundance (no. per $m^2$) number of taxa (no. per site) and species diversity ($H'$) during the summer quarterly sampling, 1982.

| | HABITAT TYPE | | | | |
|---|---|---|---|---|---|
| | Intertidal | | | Subtidal | |
| | High Cobble | Low Cobble | Sand | Eelgrass | Sand |
| Mean abundance/$m^2$ | 6,580 | 21,054 | 1,610 | 5,293 | 3,914 |
| Mean no. taxa/site | 21.7 | 35.3 | 14.8 | 28.0 | 27.5 |
| Biomass ($g/m^2$) | 142.7 | 186.5 | 10.9 | 288.7* | 15.5 |
| Total # taxa | 47 | 74 | 36 | 70 | 66 |
| $H'$ | 1.079 | 1.0578 | .914 | 1.118 | 1.108 |

* 113.8 if a single large Macoma nasuta is excluded from the calculation.

differences in H' values between habitats were not significant.

The Seahurst sample sites were generally comparable in abundance and species richness to other sites of similar habitat type. The only exception was the subtidal eelgrass habitat, where small infaunal abundance was one-fourth that of other subtidal eelgrass habitats, and the number of taxa present was one-half the number present at other sites. The reason for this may be the relatively patchy distribution of eelgrass at Seahurst.

6.4.3.9 Large Infauna

Results of the large infauna sampling indicated that the four low cobble habitats surveyed (Seahurst Park, Tramp Harbor, Normandy Cove, and Covenant Beach) have substantial populations of clams; including recreationally valuable species. Abundance found during the summer and fall quarterly sampling ranged from 137 - 218 clams $m^{-2}$, with a mean of 193 clams $m^{-2}$. All sites had comparable abundance (Figure 6.32) of clams, with the exception of Tramp Harbor, which had a mean over both seasons of only 151 clams. Analysis of variance by ranks using the Kruskal-Wallis test, however, indicated that the abundance of clams at Tramp Harbor was not significantly lower ($\alpha = 0.05$) than abundances at other beaches. Biomass was more variable, ranging from 1.1 - 7.9 kg $m^{-2}$ (Figure 6.33). Mean clam biomass was 3.7 kg $m^{-2}$.

Numerical dominance by species (Fig. 6.34) and total clam biomass appeared to reflect the intensity of recreational clam digging at the various beaches. The most heavily dug beaches, Seahurst Park and Tramp Harbor, are public, and had 1-2 kg of clams (dry wt) $m^{-2}$ during summer and fall. The most abundant clams at these beaches were macoma (Macoma inquinata) and native littleneck (Protothaca staminea) clams. Recreational clam digging at Normandy Cove is somewhat restricted as the sample transect occurs on a private community beach. Mean biomass at Normandy Cove was 5.1 kg (dry wt) $m^{-2}$ during

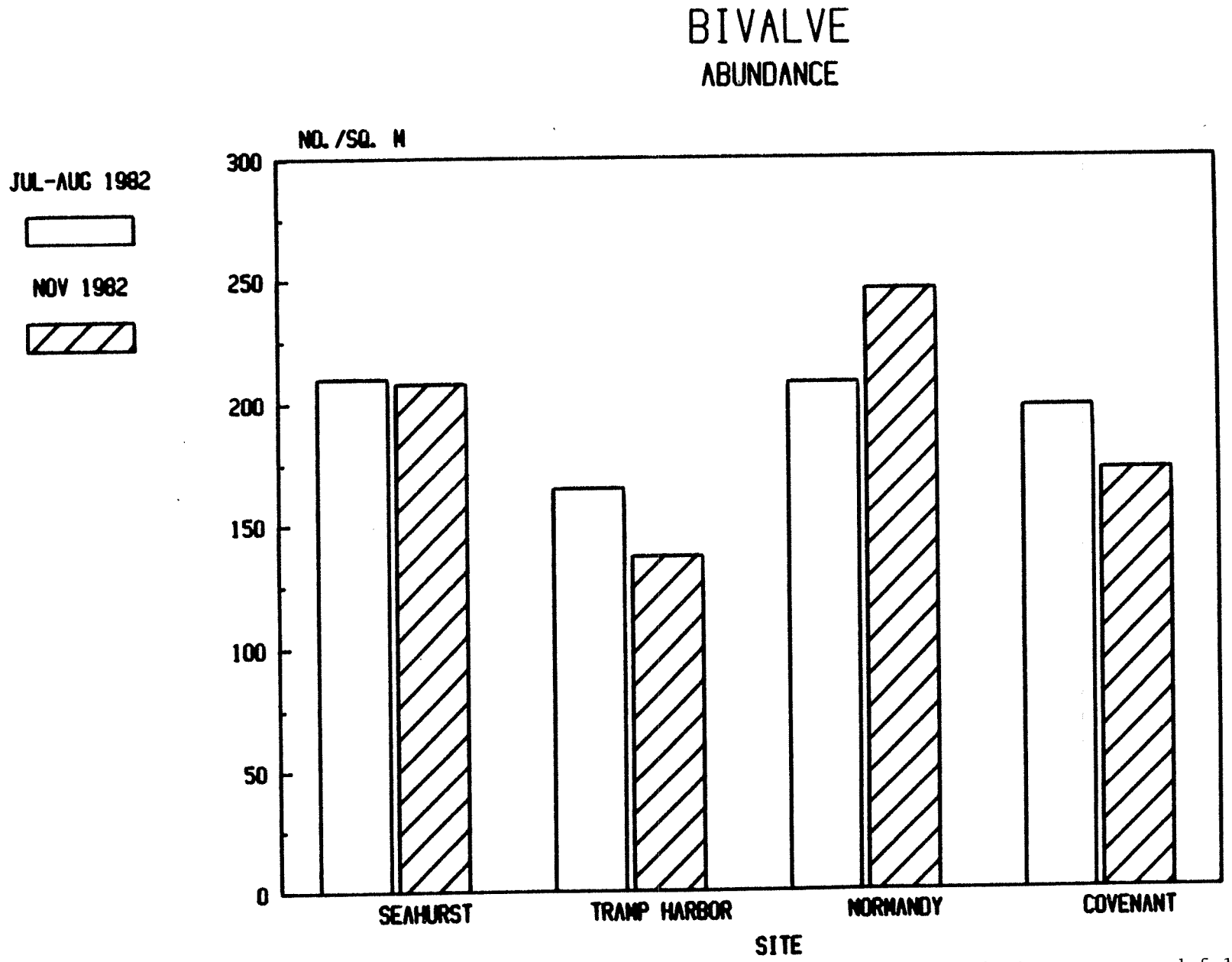



Figure 6.32. Clam abundance at the low cobble habitats during summer and fall, 1982.

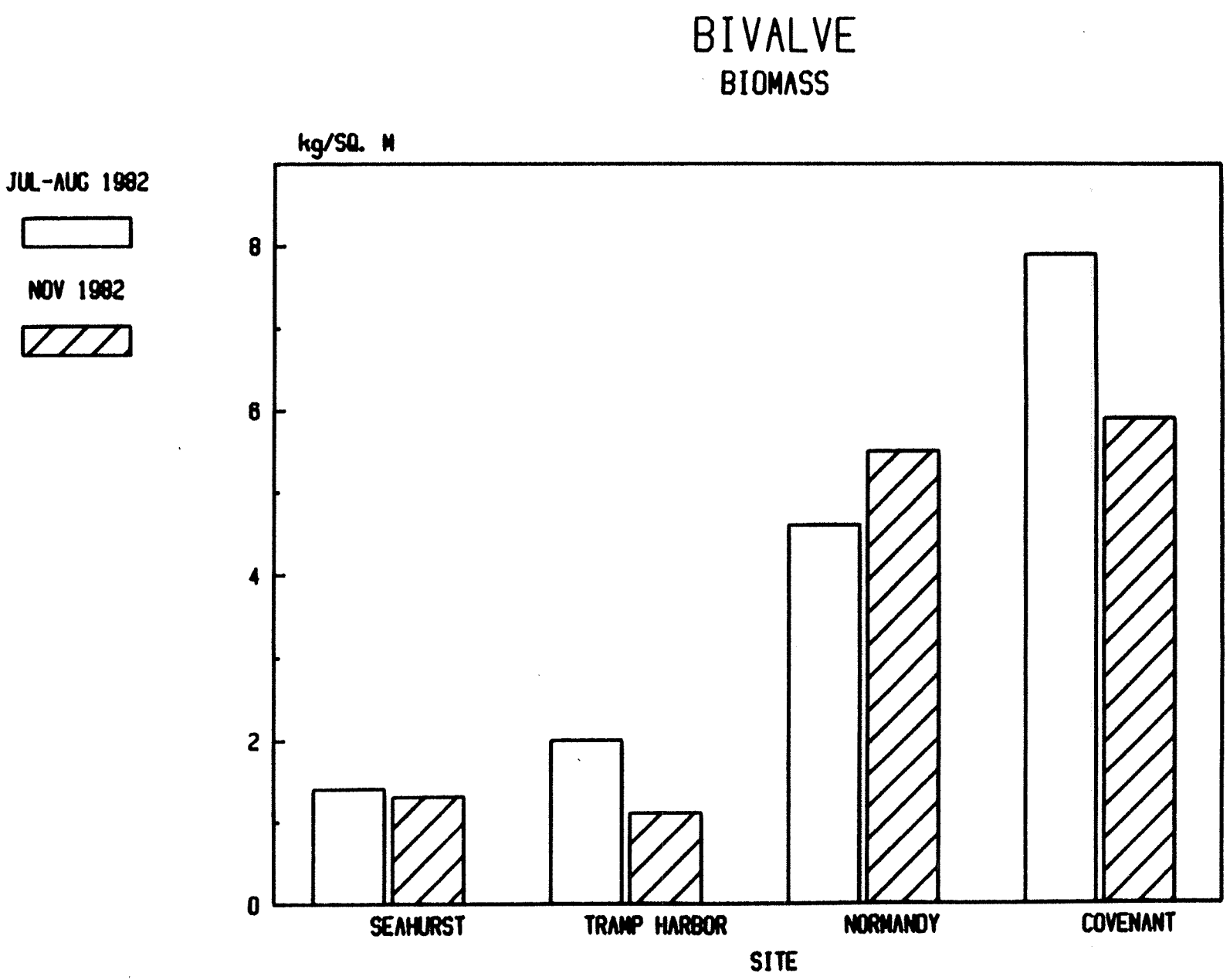



Figure 6.33. Total clam biomass at the low cobble habitats during summer and fall, 1982.

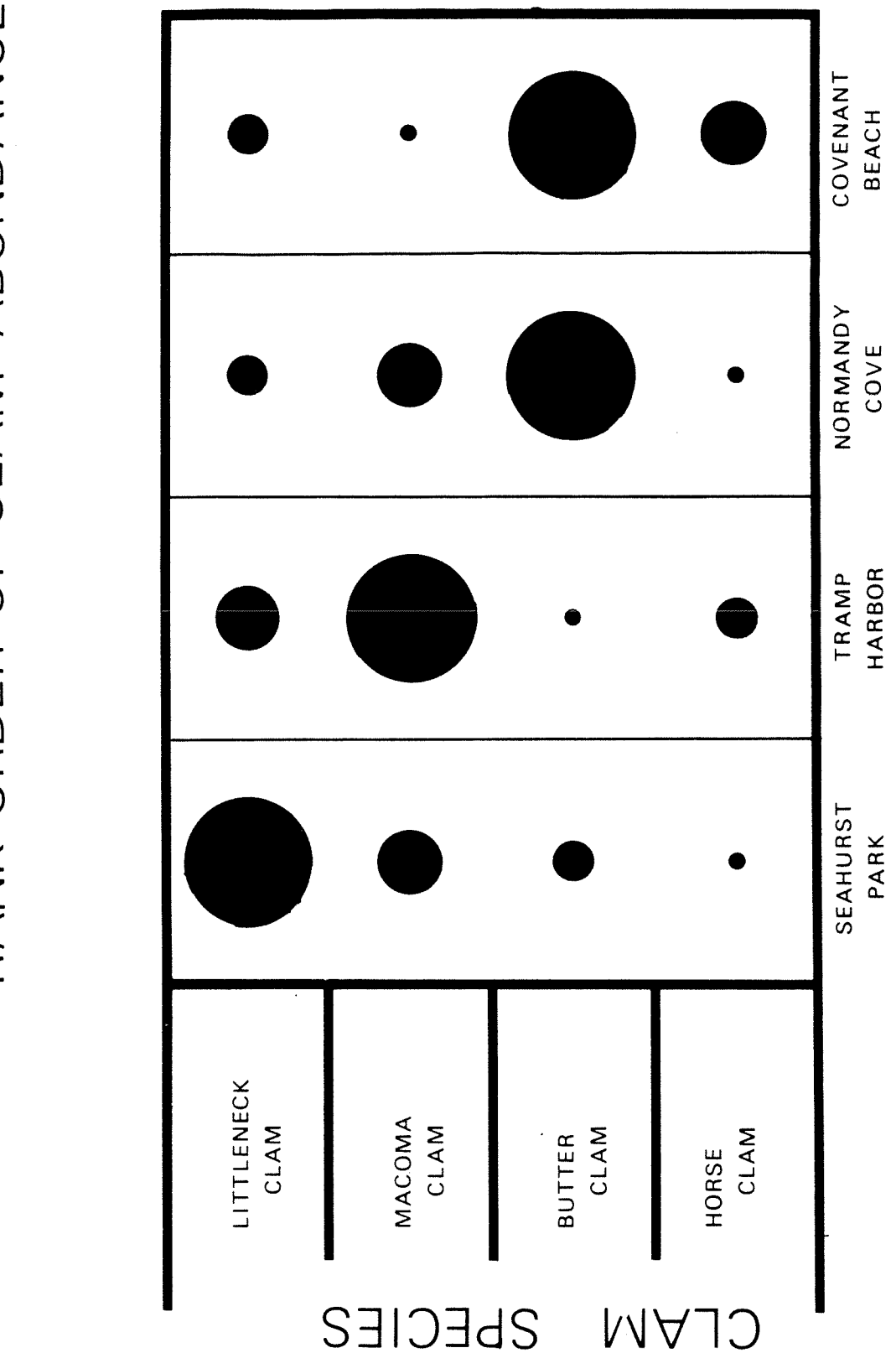



Figure 6.34. Rank order of clam abundance in the low cobble habitats during summer, 1982.

the summer and fall quarterly sampling. Butter clams (Saxidomus giganteus) were the most abundant clam sampled. Covenant Beach, which is rarely affected by recreational clamming, had a mean biomass of 7 kg $m^{-2}$ during the summer and fall sampling. Butter and horse (Tresus capax) clams were the most abundant species present.

6.4.3.10 Epibenthic Zooplankton

Of the eighteen sites sampled during the spring habitat distribution study, only six (12 microhabitats) were completely processed. These corresponded to the sites chosen for further seasonal sampling except in the case of the Ellisport site, which was subsequently changed to an adjacent site at Tramp Harbor (Figure 6.1). The latter site offered a greater diversity of microhabitats than did the first site.

At the finest resolution of taxonomic and life history stage determination, approximately 450 categories of epibenthic zooplankton have been identified. Table 6.14 itemizes the familial (or phylogenetically higher) composition of all taxa, indicating that harpacticoid copepods (14 families), gammarid amphipods (12), polychaete annelids (12), and calanoid copepods (9) accounted for most of the taxa richness in the samples. The relative contribution of harpacticoids and gammarids is magnified, however, by the fact that polychaetes are predominantly benthic and calanoids are pelagic organisms and should not be considered actual components of the epibenthos. Taxa richness is also extremely high at the species level for harpacticoids (at least 46 species) and gammarids (at least 18 species).

Numerically, harpacticoids comprise over half (51.78%) of all organisms, and gravimetrically almost 38%. Prominent taxa include the families Harpacticidae (11.55% of total density and 14.36% of total standing crop, primarily Harpacticus spinulosus and Zzus sp.); Tisbidae (10.77% and 8.81%;

Table 6.14. Taxa (family or phylogenetically higher) composition of epibenthic zooplankton sampled in central Puget Sound, June, August, November, 1982; data does not include eggs of these taxa.

| | LIFE HISTORY STAGE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Larva | Juvenile | Adult | % Total Density | (Super-Totals) | % Total Standing Crop | (Super-Totals) |
| Rhizopodea-foraminiferida | | x | x | 1.12 | | 0.49 | |
| Siphonophora | | x | x | <0.01 | | <0.00 | |
| Turbellaria | | x | x | 0.49 | | 0.30 | |
| Nemertea | | x | x | <0.01 | | 0.04 | |
| Nematoda | x | x | x | 9.42 | | 1.06 | |
| Polychaeta | x | x | x | 0.69 | (1.02) | 0.84 | (3.81) |
| Polynoidae | | x | x | 0.63 | | 0.11 | |
| Phyllodocidae | | x | | <0.01 | | 0.01 | |
| Hesionidae | | x | x | 0.08 | | 0.08 | |
| Syllidae | | x | | 0.01 | | 0.04 | |
| Nereidae | | x | x | 0.06 | | 0.48 | |
| Nephtyidae | | x | x | 0.01 | | 0.86 | |
| Glyceridae | | x | x | 0.01 | | 0.01 | |
| Orbiniidae | | x | x | <0.01 | | 0.01 | |
| Spionidae | x | x | x | 0.04 | | 0.09 | |
| Opheliidae | | x | x | 0.08 | | 0.24 | |
| Capitellidae | | x | | 0.01 | | 0.02 | |
| Ampharetidae | x | | | <0.01 | | <0.01 | |
| Oligochaeta | x | x | x | 4.62 | | 5.80 | |
| Gastropoda | | | | | (0.10) | | (0.54) |
| Mesogastropoda | x | x | x | 0.03 | | 0.05 | |
| Lacunidae | | x | x | 0.07 | | 0.49 | |
| Rissoidae | | x | x | <0.01 | | <0.01 | |
| Entomotheaniata | | x | x | <0.01 | | 0.11 | |
| Opisthobranchia | | x | | <0.01 | | <0.01 | |
| Bivalvia | | x | x | 1.33 | (1.34) | 4.11 | (5.38) |
| Mytilidae | | x | | <0.01 | | 0.01 | |
| Montacutidae | | | x | <0.01 | | 0.11 | |
| Cardiidae | | x | x | <0.01 | | 0.07 | |
| Tellinidae | | x | x | 0.01 | | 0.86 | |
| Veneridae | | x | x | <0.01 | | 0.22 | |

Table 6.14. (page 2)

| | Larva | Juvenile | Adult | % Total Density | (Super-Totals | % Total Standing Crop | (Super-Totals) |
|---|---|---|---|---|---|---|---|
| Cephalopoda | | x | | 0.08 | | 0.01 | |
| Acarina | | x | x | 0.02 | | 0.04 | |
| Halacaridae | | x | x | 0.03 | | 0.09 | |
| Crustacea | x | | | 0.02 | | 0.01 | |
| Cladocera | | | | | | | |
| Polyphemidae | | | x | <0.01 | | 0.01 | |
| Cychoridae | | | x | <0.01 | | <0.01 | |
| Ostracoda | | | | | (2.08) | | (1.97) |
| Myodocopa | | | | | | | |
| Philomedidae | x | x | x | 0.01 | | 0.20 | |
| Podocopa | x | x | x | 2.07 | | 1.77 | |
| Copepoda | x | | | 1.91 | | 0.34 | |
| Calanoida | x | | | 1.77 | (2.65) | 0.44 | (1.38) |
| Calanidae | | x | x | 0.01 | | 0.05 | |
| Paracalanidae | | x | x | 0.61 | | 0.54 | |
| Pseudocalanidae | | x | x | 0.01 | | 0.02 | |
| Aetideidae | | x | x | <0.01 | | 0.01 | |
| Scolecithricidae | | x | x | 0.05 | | 0.07 | |
| Temoridae | | x | x | 0.13 | | 0.11 | |
| Pontellidae | | x | | 0.01 | | 0.02 | |
| Acartiidae | x | x | x | 0.06 | | 0.11 | |
| Tortanidae | | | x | <0.01 | | 0.01 | |
| Harpacticoida | x | x | x | 4.41 | (51.78) | 0.71 | (37.97) |
| Porcellidiidae | | x | x | 0.04 | | 0.09 | |
| Longipediidae | | x | x | 0.05 | | 0.13 | |
| Ectinosomatidae | | x | x | 4.38 | | 1.81 | |
| Harpacticidae | | x | x | 11.55 | | 4.36 | |
| Tisbidae | | x | x | 10.77 | | 8.81 | |
| Tachidiiae | | x | x | 0.09 | | 0.10 | |
| Laophontidae | x | x | x | 1.66 | | 0.98 | |
| Ameridae | | x | x | 0.07 | | 0.10 | |
| Tetragonicipitidae | | | x | <0.01 | | <0.01 | |
| Cletodidae | | x | x | 7.49 | | 7.01 | |

Table 6.14. (page 3)

| | Larva | Juvenile | Adult | % Total Density | (Super-Totals) | % Total Standing Crop | (Super-Totals) |
|---|---|---|---|---|---|---|---|
| Diosaccidae | | x | x | 9.84 | | 12.42 | |
| Canthocamptidae | | x | x | 0.26 | | 0.31 | |
| Thalestridae | | x | x | 0.99 | | 1.12 | |
| Parastenheliidae | | | x | 0.18 | | 0.02 | |
| Cyclopoida | | x | x | 0.03 | (7.99) | 0.08 | (1.73) |
| Corycaeidae | | x | x | 7.49 | | 1.30 | |
| Clausiidae | | | x | <0.01 | | <0.01 | |
| Oithonidae | | x | x | 0.05 | | 0.10 | |
| Cyclopinidae | | x | x | 0.42 | | 0.25 | |
| Caligoida | | x | | <0.01 | | 0.01 | |
| Branchiura | | x | x | <0.01 | | <0.01 | |
| Balanomorpha | x | | | 0.34 | | 0.41 | |
| Mysida | | x | x | 0.02 | | 0.41 | |
| Mysidae | | x | x | 0.01 | | 0.43 | |
| Cumacea | | | | | | | |
| Lampropidae | | x | x | 0.22 | | 1.04 | |
| Diastylidae | | x | x | 0.03 | | 0.19 | |
| Nannastacidae | | x | x | 0.47 | | 1.04 | |
| Tanaidacea | | x | | <0.01 | (0.01) | <0.01 | (0.06) |
| Dikonophora | | x | x | 0.01 | | 0.01 | |
| Tanaidae | | x | x | <0.01 | | <0.01 | |
| Paratanaidae | | x | x | 0.01 | | 0.04 | |
| Isopoda | | x | | <0.01 | (0.44) | <0.01 | (2.65) |
| Cirolanidae | | x | x | <0.01 | | <0.01 | |
| Sphaeromatidae | | x | x | 0.15 | | 1.46 | |
| Idoteidae | | x | | 0.01 | | 0.72 | |
| Munnidae | | x | x | 0.26 | | 0.41 | |
| Bopyridae | | x | x | 0.02 | | 0.06 | |
| Gammaridea | | x | x | 0.03 | (4.95) | 0.06 | (23.70) |
| Ampithodae | | x | x | <0.01 | | 0.15 | |
| Aoridae | | x | x | 0.49 | | 3.05 | |
| Calliopiidae | | x | x | 0.34 | | 1.70 | |
| Corophiidae | | x | x | 0.53 | | 1.57 | |
| Eusiridae | | x | x | 1.14 | | 8.97 | |
| Gammaridae | | x | x | 0.17 | | 1.34 | |

Table 6.14. (page 4)

| | Larva | Juvenile | Adult | % Total Density | (Super-Totals) | % Total Standing Crop | (Super-Totals) |
|---|---|---|---|---|---|---|---|
| Hyalidae | | x | x | 0.04 | | 1.64 | |
| Isaeidae | | x | x | 1.13 | | 1.95 | |
| Ischyroceridae | | x | x | 0.53 | | 2.73 | |
| Oedicerotidae | | x | x | 0.18 | | 0.51 | |
| Pleustidae | | x | x | 0.01 | | 0.02 | |
| Stenothoidae | | x | x | <0.01 | | 0.01 | |
| Hyperiidea | | | | | (0.02) | | (0.03) |
| Hyperiidae | | x | | 0.02 | | 0.03 | |
| Caprellidea | | | | | | | |
| Caprellidae | | x | | 0.43 | | 3.75 | |
| Decapoda | | | | | | | |
| Caridea | | x | x | <0.01 | (0.07) | 0.11 | (4.02) |
| Hippolytidae | x | x | x | 0.07 | | 3.76 | |
| Cragonidae | | x | | <0.01 | | 0.04 | |
| Paguridae | x | x | | <0.01 | | 0.11 | |
| Brachyura | x | | | <0.01 | (0.02) | <0.01 | (0.15) |
| Pinnotheridae | x | | | 0.02 | | 0.15 | |
| Insecta | | x | | <0.01 | (0.02) | 0.01 | (0.10) |
| Ephemeroptera | | x | | <0.01 | | <0.01 | |
| Trichoptera | | x | | <0.01 | | <0.01 | |
| Diptera | | x | | <0.01 | | 0.01 | |
| Chironomidae | | x | | 0.02 | | 0.08 | |
| Gymnolaemata | | x | | <0.01 | | 0.01 | |
| Echinodermata | | | | | | | |
| Strongylocentrotidae | | x | | 0.01 | | 0.09 | |
| Chaetognatha | | x | | <0.01 | | 0.15 | |
| Oikopleuridae | | x | x | <0.01 | | 0.01 | |

Tisbe sp.), Diosaccidae (9.84% and 12.42%; Amonardia perturbata and Diosaccus spinatus), Cletodidae (7.49% and 7.01%; Huntemannia jadensis), and Ectinosomatidae (4.38% and 1.81%; Ectinosoma sp and Halectinosoma sp). Gammarid amphipods were also prevalent, although more on the basis of standing crop (23.70% of total) than on density (4.95%). Prominent families included Eusiridae (1.14% of total density and 8.97% of total standing crop; including primarily Pontogeneia sp.), Aoridae (0.49% and 3.05%; Aoroides columbiae), Ischyroceridae (0.53% and 2.73%; Ischyrocerus sp.), Isaeidae (1.13% and 1.95%; Photis lacia), Corophiidae (0.53% and 1.57%; Corophium ascherusicum, C. salmonis, and C. insidiosum), Calliopiidae (0.34% and 1.70%; Paracalliopiella pratti), Hyalidae (0.40% and 1.64%; Allorchestes angusta), and Gammaridae (0.17% and 1.34%; Anisogammarus pugettensis).

Other numerically or gravimetrically abundant epibenthic taxa included cladocerans and ostracods. Although often prominent in the samples, calanoid and cyclopoid copepods constituted immigrants from pelagic habitats and nematodes, oligochaetes, and bivalves constituted contamination of the samples from benthic infauna in near-surface sediments.

The total density of epibenthic organisms fluctuated dramatically as a function of site, microhabitat, and season (Table 6.15). Overall, densities averaged 37,289 $\pm$ 45,757 organisms $m^{-3}$, reflecting a broad range (640 to 217,360 $m^{-3}$) and high coefficient of variation (1.23).

During the spring habitat distribution study period, highest densities occurred at the Seola Beach (91,447 $\pm$ 47,483 $m^{-3}$), Seahurst Park (48,940 $\pm$ 53,409 $m^{-3}$) and Aquarium (46,087 $\pm$ 27,310 $m^{-3}$) sites, with almost an order of magnitude lower densities at the other sites. Within sites, the shallow subtidal sand/eelgrass microhabitat tended to have the higher densities although the maximum density (141,320 $m^{-3}$) originated from the intertidal

Table 6.15. Total standing stock (density, no. $m^{-3}$, standing crop, g $m^{-3}$, ± 1 s.d.) of epibenthic organisms sampled in central Puget Sound during three seasons (June, August, November, 1982).

| SAMPLING PERIOD | MICROHABITAT | STANDING STOCK | |
|---|---|---|---|
| | | Density (no. $m^{-3}$) | Standing Crop (g $m^{-3}$) |
| Spring Fingerprint | | | |
| Ellisport | -1.0 sand | 7,060 ± 5,233 | 0.40 ± 0.34 |
| Aquarium | +0.6 cobble | 45,180 ± 40,249 | 2.90 ± 2.96 |
| | -0.1 sand | 42,120 ± 45,029 | 1.32 ± 1.31 |
| | -0.1 sand/eelgrass | 50,960 ± 1,018 | 4.72 ± 1.09 |
| Covenant Beach | +0.5 sand-cobble | 3,640 ± 339 | 0.10 ± 0.01 |
| Seola Beach | +0.9 cobble | 120,220 ± 29,840 | 3.47 ± 1.28 |
| | 0.0 sand | 53,700 ± 63,498 | 1.24 ± 1.50 |
| | -0.9 sand/eelgrass | 100,420 ± 41,040 | 0.77 ± 0.30 |
| Seahurst Park | +0.6 cobble | 18,040 ± 6,166 | 0.68 ± 0.09 |
| | -0.2 sand | 81,360 ± 90,906 | 0.88 ± 0.74 |
| | -0.5 sand/eelgrass | 47,420 ± 44,095 | 1.84 ± 1.74 |
| Normandy Park | +0.3 sand-gravel | 8,340 ± 5,119 | 0.17 ± 0.05 |
| OVERALL MEAN | | 48,205 ± 47,137 | 1.53 ± 1.69 |
| Summer | | | |
| Tramp Harbor | -0.3 sand-cobble | 26,460 ± 3,705 | 1.98 ± 1.79 |
| | +0.6 sand | 50,967 ± 13,058 | 0.83 ± 0.14 |
| | -1.2 sand | 6,600 ± 5,940 | 0.27 ± 0.21 |
| | -1.2 sand/eelgrass | 40,660 ± 44,208 | 1.46 ± 1.43 |
| Aquarium | 0.0 sand | 87,000 ± 118,596 | 1.49 ± 1.94 |
| | -1.3 sand | 21,980 ± 9,249 | 1.25 ± 0.05 |
| | -1.3 sand/eelgrass | 54,993 ± 9,626 | 1.82 ± 0.91 |
| Seola Beach | -1.7 sand | 33,860 ± 26,106 | 0.51 ± 0.34 |
| | -1.7 sand/eelgrass | 46,300 ± 15,981 | 2.19 ± 1.32 |
| Seahurst Park | -0.3 cobble | 97,680 ± 54,193 | 2.53 ± 1.61 |
| | 0.0 sand | 146,340 ± 100,437 | 2.20 ± 0.11 |
| | -1.3 sand | 137,940 ± 26,333 | 3.05 ± 0.59 |
| | -1.3 sand/eelgrass | 51,680 ± 29,133 | 2.06 ± 0.09 |
| Normandy Park | 0.0 gravel-cobble | 45,760 ± 18,554 | 1.10 ± 0.61 |
| Covenant Beach | 0.0 sand-gravel | 13,340 ± 3,536 | 0.34 ± 0.11 |
| OVERALL MEAN | | 57,444 ± 53,141 | 1.54 ± 1.09 |

Table 6.15. (page 2)

| SAMPLING PERIOD | MICROHABITAT | STANDING STOCK | |
|---|---|---|---|
| Fall | | Density (no. $m^{-3}$) | Standing Crop (g $m^{-3}$) |
| Tramp Harbor | -0.3 sand-cobble | 16,820 ± 3,592 | 0.88 ± 0.11 |
| | +0.6 sand | 1,100 ± 198 | 0.10 ± 0.00 |
| | -1.2 sand | 680 ± 57 | 0.04 ± 0.01 |
| | -1.2 sand/eelgrass | 29,660 ± 27,860 | 3.30 ± 3.30 |
| Aquarium | 0.0 sand | 1,120 ± 113 | 0.08 ± 0.02 |
| | -1.3 sand | 1,240 ± 283 | 0.13 ± 0.07 |
| | -1.3 sand/eelgrass | 2,260 ± 1,669 | 0.21 ± 0.21 |
| Seola Beach | -1.7 sand | 1,560 ± 339 | 0.08 ± 0.00 |
| | -1.7 sand/eelgrass | 3,260 ± 3,140 | 0.46 ± 0.36 |
| Seahurst Park | -0.3 cobble | 22,740 ± 17,961 | 1.37 ± 1.09 |
| | 0.0 sand | 6,460 ± 1,273 | 0.32 ± 0.03 |
| | -1.3 sand | 13,780 ± 8,344 | 1.32 ± 0.11 |
| | -1.3 sand/eelgrass | 26,333 ± 28,317 | 2.82 ± 3.07 |
| Normandy Beach | 0.0 cobble | 3,160 ± 2,659 | 0.15 ± 0.14 |
| Covenant Beach | 0.0 cobble | 4,760 ± 4,752 | 0.51 ± 0.55 |
| | 0.0 sand-cobble | 33,840 ± 46,160 | 1.77 ± 2.30 |
| OVERALL MEAN | | 11,371 ± 17,255 | 0.93 ± 1.24 |

cobble microhabitat at Seola Beach.

Summer collections produced only slightly higher densities (averaging 57,444 ± 53,141 $m^{-3}$) compared to the spring collections (averaging 48,205 ± 47,137 $m^{-3}$). The summer sampling was not directly comparable due to the shift to more subtidal collections and the change from the Ellisport site to Tramp Harbor. Densities of epibenthic organisms at Seahurst Park, averaging 108,410 ± 60,775 $m^{-3}$, were considerably higher than at any other site, followed by Aquarium (54,691 ± 60,801 $m^{-3}$), and Tramp Harbor (31,172 ± 25,042 $m^{-3}$). No trend was discernible among microhabitats within sampling sites.

Epibenthic zooplankton densities were measurably depressed by the time of the fall collections averaging 11,371 ± 17,255 $m^{-3}$. Seahurst Park again had the highest density values, averaging 20,620 ± 18,036 $m^{-3}$, only 20% of the summer average. Due to the maximum sample density of 66,480 $m^{-3}$, Covenant Beach had approximately the same average density, followed by Tramp Harbor (12,065 ± 16,704 $m^{-3}$).

Unfortunately, such total density values are inadequate indicators of true epibenthic zooplankton standing stock, due to the often insignificant introduction of pelagic or benthic organisms into the samples. Given the prominence of harpacticoid copepods and gammarid amphipods in the assemblages, we have separately estimated their densities and proportional contributions (Table 6.16) as more representative comparisons of the microhabitat, site and seasonal differences in assemblage densities. Only the intertidal cobble microhabitat at Ellisport indicated densities less than $1 \times 10^4$ $m^{-3}$ in the late spring. Essentially all densities were close to or significantly above that level during the summer. The maximum density overall was that of the intertidal sand microhabitat at Seahurst Park, which soared to over $1.1 \times 10^5$ $m^{-3}$. Most harpacticoid assemblages illustrated declining densities between

Table 6.16. Standing stock (density, no. $m^{-3}$; standing crop, g $m^{-3}$) and percent contribution of total epibenthos (in parentheses) of harpacticoid copepods and gammarid amphipods in central Puget Sound during three seasons (June, August, November, 1982).

| Sampling Period | Site | Microhabitat | HARPACTICOID COPEPODS Density no. $m^{-3}$ (%) | HARPACTICOID COPEPODS Standing Crop g $m^{-3}$ (%) | GAMMARID AMPHIPODS Density no. $m^{-3}$ (%) | GAMMARID AMPHIPODS Standing Crop g $m^{-3}$ (%) |
|---|---|---|---|---|---|---|
| Spring Fingerprint | | | | | | |
| | Ellisport | -1.0 sand | 3,520 (49.9) | 0.05 (14.5) | 14.0 (2.0) | 0.29 (40.6) |
| | Aquarium | 0.6 cobble | 34,480 (77.9) | 1.56 (53.5) | 3,080 (6.8) | 0.58 (19.8) |
| | | -0.1 sand | 25,720 (61.1) | 0.70 (53.9) | 960 (2.3) | 0.32 (24.4) |
| | | -0.1 sand/eelgrass | 39,320 (72.9) | 2.82 (59.6) | 4,000 (7.8) | 1.35 (28.6) |
| | Seola Beach | +0.9 cobble | 27,820 (23.0) | 0.85 (24.6) | 1,660 (1.4) | 0.11 (3.1) |
| | | 0.0 sand | 34,480 (64.2) | 0.92 (74.7) | 160 (0.3) | 0.02 (1.3) |
| | Seahurst Park | +0.6 cobble | 600 (3.3) | 0.03 (4.2) | 260 (1.5) | 0.05 (7.5) |
| | | -0.2 sand | 17,980 (21.1) | 0.86 (49.9) | 220 (0.3) | 0.02 (2.3) |
| | | -0.5 sand/eelgrass | 24,640 (52.0) | 0.88 (48.4) | 780 (1.6) | 0.48 (13.2) |
| | Normandy Park | +0.3 sand-gravel | 2,340 (28.1) | 0.02 (18.5) | 40 (0.5) | <0.01 (3.1) |
| | Covenant Beach | +0.5 sand-cobble | 1,160 (39.0) | 0.03 (31.7) | 100 (2.8) | 0.01 (9.8) |

Table 6.16. (page 2)

| Sampling Period | Site | Microhabitat | HARPACTICOID COPEPODS Density no. $m^{-3}$ (%) | HARPACTICOID COPEPODS Standing Crop g $m^{-3}$ (%) | GAMMARID AMPHIPODS Density no. $m^{-3}$ (%) | GAMMARID AMPHIPODS Standing Crop g $m^{-3}$ (%) |
|---|---|---|---|---|---|---|
| Summer | | | | | | |
| | Tramp Harbor | -0.3 sand-cobble | 12,260 (46.3) | 0.21 (10.9) | 560 (2.1) | 0.05 (2.9) |
| | | +0.6 sand | 34,500 (67.7) | 0.37 (46.8) | 226.7 (0.4) | 0.02 (2.3) |
| | | -1.2 sand | 4,380 (66.4) | 0.11 (50.5) | 360 (11.2) | 0.02 (14.3) |
| | | -1.2 sand/eelgrass | 25,380 (62.4) | 0.70 (49.7) | 1,420 (3.5) | 0.13 (9.1) |
| | Aquarium | 0.0 sand | 67,680 (77.7) | 1.07 (72.3) | 80 (0.1) | <0.01 (0.5) |
| | | -1.3 sand | 9,860 (44.9) | 0.10 (8.5) | 420 (0.1) | 0.14 (11.8) |
| | | -1.3 sand/eelgrass | 28,867 (52.5) | 0.48 (28.1) | 3,693 (6.7) | 0.49 (26.8) |
| | Seola Beach | -1.7 sand | 18,780 (55.5) | 0.24 (48.4) | 660 (2.0) | 0.06 (11.6) |
| | | -1.7 sand/eelgrass | 27,960 (60.4) | 1.03 (47.2) | 5,580 (12.1) | 0.28 (12.8) |
| | Seahurst Park | -0.3 cobble | 52,760 (54.0) | 1.10 (43.5) | 1,780 (1.8) | 0.39 (15.5) |
| | | 0.0 sand | 114,480 (78.2) | 1.64 (74.8) | 280 (0.2) | 0.04 (2.0) |
| | | -1.3 sand | 71,660 (51.9) | 1.96 (64.6) | 9,340 (6.8) | 0.64 (20.9) |
| | | -1.3 sand/eelgrass | 32,660 (63.2) | 1.09 (54.3) | 2,060 (4.0) | 0.25 (12.3) |

Table 6.16 (page 3)

| Sampling Period | Site | Microhabitat | HARPACTICOID COPEPODS Density no. $m^{-3}$ (%) | HARPACTICOID COPEPODS Standing Crop g $m^{-3}$ (%) | GAMMARID AMPHIPODS Density no. $m^{-3}$ (%) | GAMMARID AMPHIPODS Standing Crop g $m^{-3}$ (%) |
|---|---|---|---|---|---|---|
| Summer, cont'd. | | | | | | |
| | Normandy Park | 0.0 gravel-cobble | 22,020 (48.1) | 0.43 (39.9) | 1,800 (3.9) | 0.09 (8.3) |
| | Covenant Beach | 0.0 sand-gravel | 7,740 (58.0) | 0.04 (16.5) | 300 (2.3) | 0.02 (6.8) |
| Fall | | | | | | |
| | Tramp Harbor | -0.3 sand-cobble | 13,280 (79.0) | 0.26 (29.5) | 2,180 (13.0) | 0.47 (52.5) |
| | | +0.6 sand | 620 (56.4) | 0.01 (16.7) | 120 (10.9) | 0.92 (54.8) |
| | | -1.2 sand | 320 (47.1) | 0.01 (59.3) | 0 (0) | 0 (0) |
| | | -1.2 sand/eelgrass | 20,280 (68.4) | 0.54 (16.4) | 7,920 (26.7) | 1.84 (56.2) |
| | Aquarium | 0.0 sand | 560 (50.0) | 0.02 (30.6) | 40 (3.6) | <0.01 (5.6) |
| | | -1.3 sand | 600 (48.4) | 0.02 (15.0) | 120 (9.7) | 0.02 (20.0) |
| | | -1.3 sand/eelgrass | 1,520 (67.2) | 0.03 (17.0) | 200 (8.8) | 0.03 (15.9) |
| | Seola Beach | -1.7 sand | 280 (18.0) | 0.01 (15.0) | 60 (3.8) | 0.02 (30.0) |
| | | -1.7 sand/eelgrass | 900 (27.6) | 0.03 (5.7) | 1,680 (51.5) | 0.32 (70.0) |

Table 6.16. (page 4)

| Sampling Period | Site | Microhabitat | HARPACTICOID COPEPODS Density no. $m^{-3}$ (%) | HARPACTICOID COPEPODS Standing Crop g $m^{-3}$ (%) | GAMMARID AMPHIPODS Density no. $m^{-3}$ (%) | GAMMARID AMPHIPODS Standing Crop g $m^{-3}$ (%) |
|---|---|---|---|---|---|---|
| Fall, cont'd. | | | | | | |
| | Seahurst Park | -0.3 cobble | 11,660 (51.3) | 0.14 (10.3) | 5,400 (23.8) | 0.93 (68.2) |
| | | 0.0 sand | 1,160 (18.0) | 0.03 (10.0) | 360 (5.6) | 0.07 (24.7) |
| | | -1.3 sand | 4,660 (33.8) | 0.06 (4.8) | 2,700 (19.6) | 0.59 (45.8) |
| | | -1.3 sand/eelgrass | 20,120 (51.0) | 0.44 (10.5) | 12,060 (30.5) | 2.52 (71.1) |
| | Normandy Park | 0.0 cobble | 440 (13.9) | 0.01 (10.8) | 140 (4.4) | 0.03 (20.0) |
| | Covenant Beach | 0.0 cobble | 1,400 (29.4) | 0.02 (33.6) | 900 (18.9) | 0.09 (19.1) |
| | | 0.0 sand-cobble | 16,160 (47.8) | 0.31 (17.4) | 6,120 (18.1) | 0.68 (37.9) |

summer and fall, although the declines were less extreme in several Seahurst Park microhabitats and several increases occurred at Tramp Harbor and Covenant Beach.

There was no consistent ranking in total density of harpacticoid copepods among the respective microhabitats although the subtidal sand/eelgrass microhabitat often sustained the higher density values, particularly in the fall.

Gammarid amphipod densities were considerably more variable than harpacticoid copepod densities but were obviously correlated more with particular microhabitats (Table 6.16). Specifically, the highest densities occur in association with eelgrass or cobble microhabitats. Maximum densities of over 12 x $10^3$ $m^{-3}$ (Seahurst Park subtidal sand/eelgrass, Fall) and densities over 1 x $10^3$ $m^{-3}$ occurred commonly through the fall sampling period. Except for the one incidence of over 9 x $10^3$ $m^{-3}$ amphipods in the subtidal sand microhabitat at Seahurst, the presence of macrophytes (eelgrass or attached algae on cobbles) correlated well with amphipod densities regardless of the season and site.

Total standing crop estimates, also provided in Table 6.15, generally mirror density estimates and were typically less variable (lower coefficient of variation values) within duplicate samples, indicating that meiofaunal organisms were probably the source of most of the numerical variation within microhabitats.

Mean total standing crop over the three sampling periods was 1.30 $\pm$ 1.44 g $m^{-3}$ and ranged between 0.04 and 6.34 g $m^{-3}$. Similar to density patterns, overall mean standing crop remained constant (approx. 1.54 g $m^{-3}$) between spring and summer but declined, although not as precipitously, between summer and fall sampling periods. During the habitat study sampling, standing crop

maxima occurred at the Aquarium (ranging between 1.32 and 4.72 g $cm^{-3}$) and Seola Beach sites (0.77 to 3.47 g $m^{-3}$); in the summer, Seahurst Park (2.06 to 3.05 g $m^{-3}$) and Aquarium collections (1.25 to 1.82 g $m^{-3}$) were the highest; and, in the fall, Seahurst Park (0.32 to 2.82 g $m^{-3}$) continued to have the highest average standing crop, although the subtidal sand/eelgrass microhabitat at Tramp Harbor illustrated the maximum overall (3.30 $\pm$ 3.30 g $m^{-3}$).

Although a tendency existed for sand/eelgrass microhabitats to maintain high standing crops of epibenthic zooplankton through the fall sampling period, no discernible ranking in mean total standing crop existed among microhabitats.

Except for a few exceptions (i.e. Harpacticus, Tisbe, Diosaccus, Amonardia), most harpacticoid copepods fall in the same general biomass range, producing patterns in standing stock which reflect those patterns of harpacticoid density (Table 6.16). Discrepancies are usually due to high abundances of such species as Diosaccus and Amonardia (i.e. subtidal collections at Tramp Harbor in summer, when diosaccid harpacticoids alone comprised between 18 to 26 percent of the total density and 19 to 30 percent of the standing crop). Given the typically larger sizes and size ranges of gammarid amphipods, the standing crop and percent contribution by gammarid amphipods often deviates significantly from patterns in gammarid densities (Table 6.16). Standing crop maxima still tend to be associated with sand/eelgrass microhabitats.

Epibenthic zooplankton assemblages in intertidal and shallow subtidal environs of central Puget Sound most closely resemble those sampled previously along the Strait of Juan de Fuca (Simenstad et al. 1980a) and Hood Canal (Simenstad et al. 1980b) and depart from assemblages documented in more dynamic, estuarine habitats such as the Columbia River estuary (Houghton et al. 1981) and Grays Harbor (Simenstad and Eggers 1981; Cordell and Simenstad 1981) or highly modified estuaries such as Commencement Bay, just south of the METRO Seahurst Baseline Study sites (Simenstad and Cordell 1980,1982).

Although dramatically more taxa rich than the estuarine assemblages, the central Puget Sound assemblages also possessed measurably more epibenthic taxa than were documented either along the Strait of Juan de Fuca or in Hood Canal. Given our improvement in taxonomy of harpacticoid, copepod and other epibenthic crustaceans since these earlier studies, however, much of the apparent difference in taxa composition is probably due to finer resolution in sample processing.

Epibenthic zooplankton densities documented in the Strait of Juan de Fuca averaged 51 x $10^3$ $m^{-3}$ and standing crop 1.98 g $m^{-3}$. Simenstad et al. (1980a) indicated very similar assocations between standing stock maxima and sandy eelgrass microhabitats. Extensive studies of epibenthic zooplankton in an intertidal sand-gravel microhabitat in northern Hood Canal over three years (Simenstad et al. 1980b) indicated that mean total densities ranged from 23 to 30 x $10^3$ $m^{-3}$ and mean standing crop estimates between 1 and 2 g $m^{-3}$. Although considerably less diverse assemblages, epibenthic zooplankton in intertidal sand habitats in Grays Harbor also fell in a similar standing stock range, i.e. mean density of 46.5 x $10^3$ $m^{-3}$, although the mean standing crop of 0.27 g $m^{-3}$ was considerably lower than that of central Puget Sound.

Although epibenthic zooplankton assemblages in the even more dynamic

estuarine habitats of the Columbia River estuary were taxonomically very dissimilar (Houghton et al. 1981), standing stock estimates were an order of magnitude higher (mean density of 335.7 x $10^3$ $m^{-3}$; mean standing crop of 2.24 g $m^{-3}$) despite the lack of any macrophytes in the sampled habitats. The unpublished examinations by Simenstad and Cordell (1980,1982) of the epibenthos at two intertidal sites (City and Hylelbos waterways) in Commencement Bay, immediately south of the METRO Seahurst Baseline Study sites, also indicated divergent assemblages of very low taxa richness and, at least in Hylebos Waterway, often depressed standing stock, even in the presence of attached macrophytes (the alga Enteromorpha). Good evidence indicates that both sites have been significantly impacted by organic and inorganic pollutants and are not comparable to any of the other sites with respect to pollutant impact.

Epibenthic zooplankton collections were made within four microhabitats at eighteen sites in central Puget Sound. Extremely high taxonomic richness and relatively high standing crop estimates characterized the respective zooplankton assemblages, especially those associated with sand and sand/eelgrass microhabitats. Late June and early August collections were relatively comparable in terms of taxa richness, density, and standing crop, but these indicators of epibenthic zooplankton diversity and production had declined measurably by fall. Previous studies in the Pacific Northwest would suggest that these epibenthic assemblages are very comparable to other moderately-exposed, moderate-gradient, sand to cobble habitats with some macrophytic vegetation.

Continued seasonal documentation at the established quarterly sampling sites will provide better indications of the scope of seasonal variability; microhabitat assocations will be further elucidated through multivariate

analyses of the 1982-1983 annual dataset as soon as the winter data becomes available; and food web linkages to nearshore (fish) consumer organisms will be investigated through quantitative stomach analyses of epibenthic predators which were captured during 1983-1984 investigations.

Many conclusions concerning site, microhabitat, and seasonal variability in epibenthic zooplankton assemblage composition and standing stock are contingent upon an annual series of samples from established locations. As such, the changes in sites and microhabitats between the spring sampling period and the summer quarterly sampling period, as well as the lack of results from winter sampling, prevent thorough comparisons at this time.

Some trends are readily apparent relative to standing stock estimates within sites. Sand and sand/eelgrass microhabitats and those beaches with high proportions of these microhabitats (i.e. Seahurst Park) tend to support higher standing stock of epibenthic organisms, especially harpacticoid copepods and gammarid amphipods. In addition, the diversity of and contribution to, epibenthos standing stock by gammarid amphipods appears to be enhanced and perhaps seasonally sustained in gravel-cobble habitats which also possess benthic macrophytes.

6.4.4 Clam Mortality

The September visits to Seahurst Park and Normandy Cove resulted in finding no indication of any recent clam mortalities. Analysis of the summer and fall quarterly sample data strongly supported this conclusion (Tables 6.17-6.20). Comparison of results before and after the reported die-off showed no statistically significant decreases ($\alpha = 0.05$) in number of taxa, total abundance, or total biomass at either Seahurst Park or Normandy Cove. No statistically significant decreases in abundance or biomass of any of the major clam species existed between the summer and fall quarterly samplings.

Table 6.17. Clam species abundances (no./0.06 $m^2$) from Normandy Cove.

| Species | 5 August 1982 | | 17 September 1982 | | 1 November 1982 | |
|---|---|---|---|---|---|---|
| | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD |
| *Clinocardium nuttalli* | 0 | -- | 0 | -- | 0.15 | 0.38 |
| *Macoma inquinata* | 3.45 | 2.58 | 0.43 | 0.53 | 3.62 | 2.87 |
| *Macoma nasuta* | 0 | -- | 0.14 | 0.38 | 0 | -- |
| *Protothaca staminea* | 3.27 | 2.53 | 0.29 | 0.76 | 2.85 | 2.64 |
| *Saxidomus giganteus* | 6.00 | 3.66 | 5.29 | 2.14 | 8.54 | 4.94 |
| *Tapes japonica* | 0.09 | 0.30 | 0.14 | 0.38 | 0.15 | 0.38 |
| *Tresus capax* | 0.18 | 0.40 | 0.57 | 1.13 | 0.08 | 0.28 |
| Total Abundance | 13.00 | 6.03 | 6.86 | 3.29 | 15.38 | 9.24 |
| No. of species | 3.00 | 0.63 | 2.14 | 1.46 | 3.08 | 0.64 |

Table 6.18. Clam species biomass (g dry wt/0.06 $m^2$) from Normandy Cove.

| Species | 5 August 1982 | | 17 September 1982 | | 1 November 1982 | |
|---|---|---|---|---|---|---|
| | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD |
| *Clinocardium nuttallii* | 0 | -- | 0 | -- | 4.44 | 15.22 |
| *Macoma inquinata* | 6.50 | 5.73 | 1.01 | 1.98 | 7.89 | 8.02 |
| *Macoma nasuta* | 0 | -- | 0.30 | 0.80 | 0 | -- |
| *Protothaca staminea* | 34.64 | 21.79 | 5.08 | 13.45 | 32.32 | 29.50 |
| *Saxidomus giganteus* | 222.64 | 158.31 | 260.22 | 101.19 | 291.31 | 147.75 |
| *Tapes japonica* | 0.48 | 1.60 | 1.40 | 3.71 | 1.14 | 2.78 |
| *Tresus capax* | 27.04 | 60.19 | 76.45 | 130.70 | 6.12 | 22.09 |
| Total Biomass | 291.35 | 187.10 | 344.46 | 187.38 | 343.22 | 157.41 |

Table 6.19. Clam species abundances (no./0.06 $m^2$) from Seahurst Park low cobble habitat.

| Species | 19 July 1982 $\bar{X}$ | SD. | 3 November 1982 $\bar{X}$ | SD. |
|---|---|---|---|---|
| Clinocardium nuttallii | .27 | .46 | .36 | .50 |
| Macoma inquinata | 4.67 | 2.77 | 6.43 | 4.82 |
| Macoma nasuta | .20 | .41 | .07 | .27 |
| Macoma secta | 0 | -- | .07 | .27 |
| Macoma sp. | .33 | .72 | .14 | .36 |
| Prototaca staminea | 6.20 | 3.97 | 4.79 | 3.33 |
| Saxidomus giganteus | 1.13 | 1.41 | 1.14 | 1.10 |
| Topes japonica | .07 | .26 | 0 | -- |
| Tresus capax | .27 | .46 | .64 | 1.22 |
| Total abundance | 13.13 | 6.69 | 13.64 | 7.09 |
| No. species | 3.47 | .83 | 3.50 | .85 |

Table 6.20. Clam species biomass (g dry wt/0.06 $m^2$) from Seahurst Park low cobble habitat.

| Species | 19 July 1982 X | SD. | 3 November 1982 X | SD. |
|---|---|---|---|---|
| Clinocardium nuttallii | 1.47 | 2.80 | 1.49 | 3.21 |
| Macoma inquinata | 10.59 | 10.66 | 14.73 | 11.53 |
| Macoma nasuta | .60 | 1.39 | .82 | 2.99 |
| Macoma secta | 0 | -- | .72 | 2.70 |
| Macoma sp. | 1.09 | 2.72 | .80 | 2.21 |
| Protothaca staminea | 32.59 | 24.65 | 37.25 | 30.16 |
| Saxidomus giganteus | 42.06 | 63.80 | 25.12 | 46.50 |
| Topes japonica | .04 | .15 | 0 | -- |
| Tresus capax | .59 | 1.88 | 1.13 | 3.26 |
| Total Biomass | 87.47 | 68.48 | 82.12 | 60.65 |

The 17 September sampling at Normandy Cove did show significantly lower abundance and biomass for two species of clams (Protothaca staminea and Macoma inquinata) relative to the August sampling. However, these samples were collected in an area 40-50 m north of the quarterly sampling transect. The decreases in numbers and biomass likely resulted from patchiness in species distributions rather than recent mortalities.

Length-frequency histograms for butter clams were compared for the three sample dates from Normandy Cove (Figures 6.35-6.37). The histogram for the November data reflected that of a healthy population of butter clams. Once again, the data for September reflected site-specific differences in the population structure. Comparison of length-weight regressions for the three sample dates for Normandy Cove showed no statistically significant differences, suggesting that no unusual or severe stresses had occurred which reduced the condition of the butter clam population as a whole.

## 6.5 Conclusions

Recent data (URS Engineers, et al. 1983) indicate that shoreline impingement of the sewage field produced by a 200 foot deep discharge would occur >20% of the time. Most of this impingement would take place in late fall and winter when stratification of the water column is minimal. Dilution of the field at the beach would be on the order of 200 to 360 times (0.5 - 0.3% of effluent concentration). Conservative (i.e. turbidity, nutrients, trace contaminants, oil and grease, suspended solids) and other components (i.e. BOD, coliform bacteria) would undergo little if any additional dilution prior to contacting shallow subtidal and intertidal benthic populations. The effects of this impingement on benthic metabolism, organism health, and community

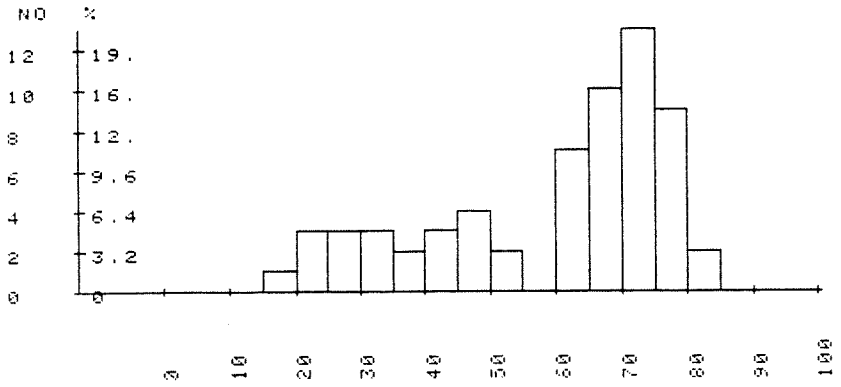



Figure 6.35. Length frequencies of butter clams at Normandy Cove in August, 1982.

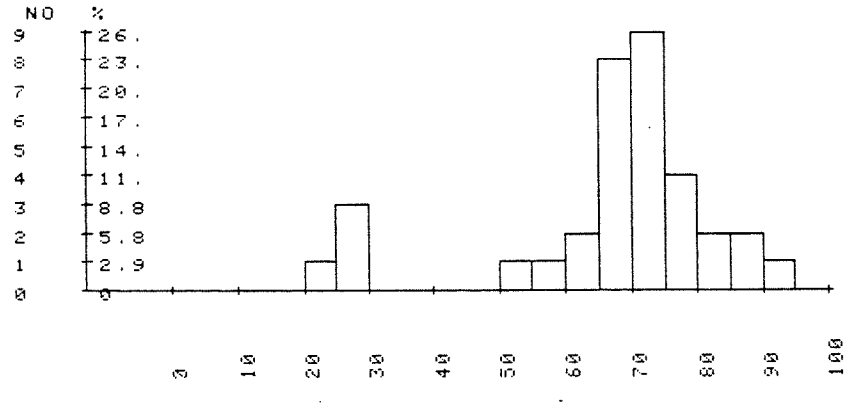



Figure 6.36. Length frequencies of butter clams at Normandy Cove in September, 1982.

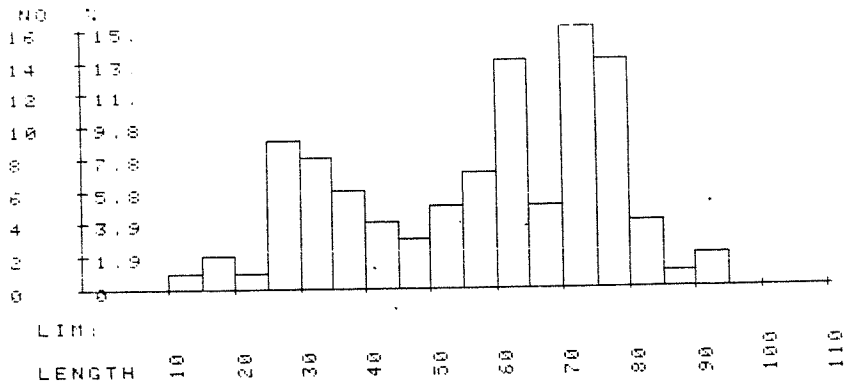



Figure 6.37. Length frequencies of butter clams at Normandy Cove in November, 1982.

structure is not known accurately, at this time, but is potentially significant.

The work on the intertidal/shallow subtidal biota has shown that the benthos in the Seahurst bight is very productive. Extensive stands of eelgrass exist in the Bight along with sand flats and cobble-boulder fields. Macroalgae are abundant and diverse on hard substrata. Epibenthic zooplankton and infauna populations are abundant and diverse in all habitats. Recreationally important clam beds exist in cobble areas at Seahurst Park.

There are significant changes with season in algal standing stock, drift algal material and eelgrass plant size. Decreasing light levels and water temperature may be important in causing declines in plant populations between summer and autumn. Clam populations were quite stable with regard to density and biomass between summer and autumn. There appears to be a direct correspondence between clam digging pressure and the abundance of recreationally preferred clams. Seahurst Park clam populations appear to be subject to relatively severe exploitation.

Total benthic algal production varies with season, primarily in response to changes in standing stock of primary producers. Sediment associated microalgae are present and showed a bloom in mid November. This bloom followed the autumn increase of phytoplankton and suggests that the sediment flora is shade adapted.

Low intertidal cobble habitats contained very diverse and abundant infaunal assemblages. Bivalves and small infauna reach highest abundance in this habitat as compared to sand and eelgrass.

The epibenthic zooplankton assemblage in the study region, which comprises a large proportion of the juvenile salmonid diet, is very abundant and diverse compared to other areas in the Pacific Northwest. The assemblage

resembles most closely that found in the Strait of Juan de Fuca.

## 6.6 Recommendations

Based on preliminary observations and data, it is recommended that the outfall be placed at the deepest (i.e. 600 feet) depth possible and as far into the main basin as possible. Important and productive benthic biological resources exist in the Seahurst Bight, and placement of the outfall at a location as far as possible from these resources would minimize the possibility of impact. An outfall at 200 feet would predictably have a measurable impact on the nearshore benthic biota.

Three important questions arise from the present study. First, what is the quantitative nature of the connection between the benthos and predators (e.g. fish, crabs) that inhabit the nearshore area? Second, what are the factors controlling primary and secondary production of the nearshore benthos? Finally, what is the impact of dilute Renton effluent on the benthos and, in turn, on higher trophic levels? Answers to these questions are required to predict possible ecosystem impact, and to design an efficient and meaningful monitoring program. Studies of effluent effects on algal metabolism begin to answer the third question. Data gathered in other areas of Puget Sound and in the present study can be used to answer the second question.

The lack of any stomach contents analyses from the littoral/shallow sublittoral fish collections during the METRO Seahurst Baseline Study limit the direct information about predator-prey relationships between epibenthic organisms and their principal predators. Similar information from northern Puget Sound and the Strait of Juan de Fuca (Simenstad et al. 1979), Hood Canal (Simenstad et al. 1980b), and Nisqually Beach in southern Puget Sound (Fresh

et al. 1979) indicates that many nearshore fishes are trophically linked to intertidal/shallow subtidal epibenthic zooplankton prey resources. This is particularly true for juvenile fishes which may utilize these habitats as nursery environs (i.e. chum, Onconhynchus keta, and pink salmon, O. gorbuscha; english sole, Parophrys vetulus; sand sole, Psettichthys melanosticulus) and fish assemblages which are particularly associated with eelgrass (including bay pipefish, Syngnathus leptorhynchus; shiner perch, Cymatogaster aggregata; tube-snout, Aulorhynchus flavidus; crescent gunnel, Pholis laeta) (see Figures 6.8 and 6.9, Simenstad et al. 1979). Confirmation of these functional relationships between nearshore fish utilization of intertidal/shallow subtidal microhabitats with characteristic epibenthic zooplankton assemblages at the Seahurst Park site is recommended during the 1983-1984 studies through analysis of fish stomach contents from catches provided by the study's nearshore fish investigators.

## 6.7 Summary

A summary of the results of the first nine months of investigations on the intertidal and shallow subtidal biota is as follows:

1. Collections of macroalgae, eelgrass, small and large infauna were made at 30 intertidal sites located in major habitats on Vashon Island the eastern shore of Puget Sound. This survey revealed the major habitats in the region which were sand flats, eelgrass beds, mud flats, and cobble fields.
2. Major intertidal and nearshore subtidal habitats were chosen for long term study (2 years) at six beaches which included Seola Beach, Seahurst Park beach, Normandy Beach, Covenant Beach, Tramp Harbor beach and Aquarium beach. There were at least two reference sites for each habitat sampled at Seahurst Park. The habitats chosen for

study were high and low intertidal cobble/sand, low intertidal and shallow subtidal sand and subtidal eelgrass.

3. A prestudy was performed to determine number of replicates required to adequately sample target parameters within the habitats. A high degree of spatial variability for most parameters necessitated taking more than the originally proposed number of replicate samples.

4. Nearshore water characteristics were monitored at two week intervals at all six beaches beginning in June 1982. Most parameters that reflect biological activity (e.g. dissolved oxygen, inorganic nutrients) showed very high among site and among sampling variations during the summer months. Nutrients generally increased from summer to winter. A phytoplankton bloom creating noxious conditions was evidenced by increased ammonia concentration.

5. Significant declines in macroalgal standing stock took place between summer and autumn. Algal species richness and diversity remained unchanged due to an increase in the number and kinds of small red and green algal species.

6. Microalgae are abundant in sand flats and exhibited a bloom in mid November. This followed the October bloom of phytoplankton and indicates that sediment associated algae are low-light adapted.

7. Eelgrass grows extensively in the low intertidal and shallow subtidal zones in the study region. Eelgrass density decreased slightly from summer to autumn and leaf length decreased by approximately one-half during the same period.

8. Plant material in the algal drift line declined from summer to autumn. The composition of the material reflects that found attached

at the adjacent beach. Eelgrass and bladed green algae were the most important components of the drift material.

9. Low littoral cobble habitats contained the highest abundance and biomass of small infauna during summer. Low intertidal sand habitats had the lowest small infauna abundances and biomass. Shannon-Wiener diversity values were similar among all habitats sampled.

10. All four sites sampled for large infauna (i.e. bivalve molluscs) had substantial populations of recreationally important clam species. Recreational clam digging has resulted in a decline in size and abundance of the butter clam at Seahurst Park beach. Total clam abundance was very similar among beaches and was very stable over time. A suspected clam mortality in the region was not evident at the study sites between August and November 1982.

11. Macroalgae appear to be nutrient limited in the Seahurst Bight and additions of dilute effluent stimulate productivity rates.

12. Recommendations from the initial nine months of study are that the Seahurst outfall diffuser should be sited as far as possible from shore to minimize the probability of effluent impingement on the productive intertidal benthic biota. Further, questions regarding impacts of effluent on energy flow to higher trophic levels should be investigated.

# 7.0 SUBTIDAL BIOLOGY

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## 7.1 Introduction

The primary purpose of the Subtidal Baseline Study is to establish an understanding of the present physical, chemical, and biological characteristics of the subtidal biology throughout the East Passage, with special emphasis placed on the Seahurst area. Establishment of this baseline information will allow examination of various siting options within the general area to assess the relative potential for minimizing effects of secondary effluents on the subtidal environment and to provide a data base that will allow the ultimate identification of alterations which may occur in the post-discharge monitoring environment.

Phase I of the subtidal baseline study was designed to concentrate on the biological attributes of sediment samples from water depths in excess of 185 m and to examine the gross chemical and physical properties of sediments throughout the entire sampling grid. This information was used to answer several biological and chemical questions pertaining to specific objectives. The basic objectives proposed for the first year were as follows: 1) to determine the number of replicate samples required to answer specific biological or chemical questions, 2) to identify any long term or seasonal trends in the biological or chemical properties of the sediments, 3) to examine the distribution of species abundances and physical and chemical measurements, 4) to determine the degree of similarity between stations using computer cluster analysis, 5) to assess the degree of differences observed in sediment samples between south central Puget Sound, Commencement Bay, Elliott

Bay, and the West Point area. A final objective during the first year of study has been to compare the costs of monitoring deep water and shallow water discharges.

## 7.2 Description of the Study Area

The main body of Puget Sound, including East and Colvos Passages was formed during the Pleistocene by glacial scouring (Crandell, et al. 1965). The glacier that performed this scouring has been estimated to have been 4,000 feet in thickness over the Puget Sound (Seattle) area (Ibid). The rapidly sloping bottom topography and the relatively wide basins of the area are the dominant features left to this environment by the glacial activity. In order to relate the types of benthic communities observed along each of the transects to these dominant features in the Sound a series of bathymetry contours are presented with the approximate location of each of the stations along the contours (Figures 7.1-7.5). In general, the sediments along the narrow, shallow shelf and the rapidly sloping regions grade from coarse sands and gravels to the finer silt and clay dominated sediments of the basins. Extreme changes in bottom slopes, or positioning of stations in areas of potential erosion by water movement (e.g. Three Tree Point), result in coarser substrates than would be predicted based upon the average sediment coarseness for a given water depth within Puget Sound. The chemical, physical, and biological groupings of stations are related to the types of slopes at each of the stations.

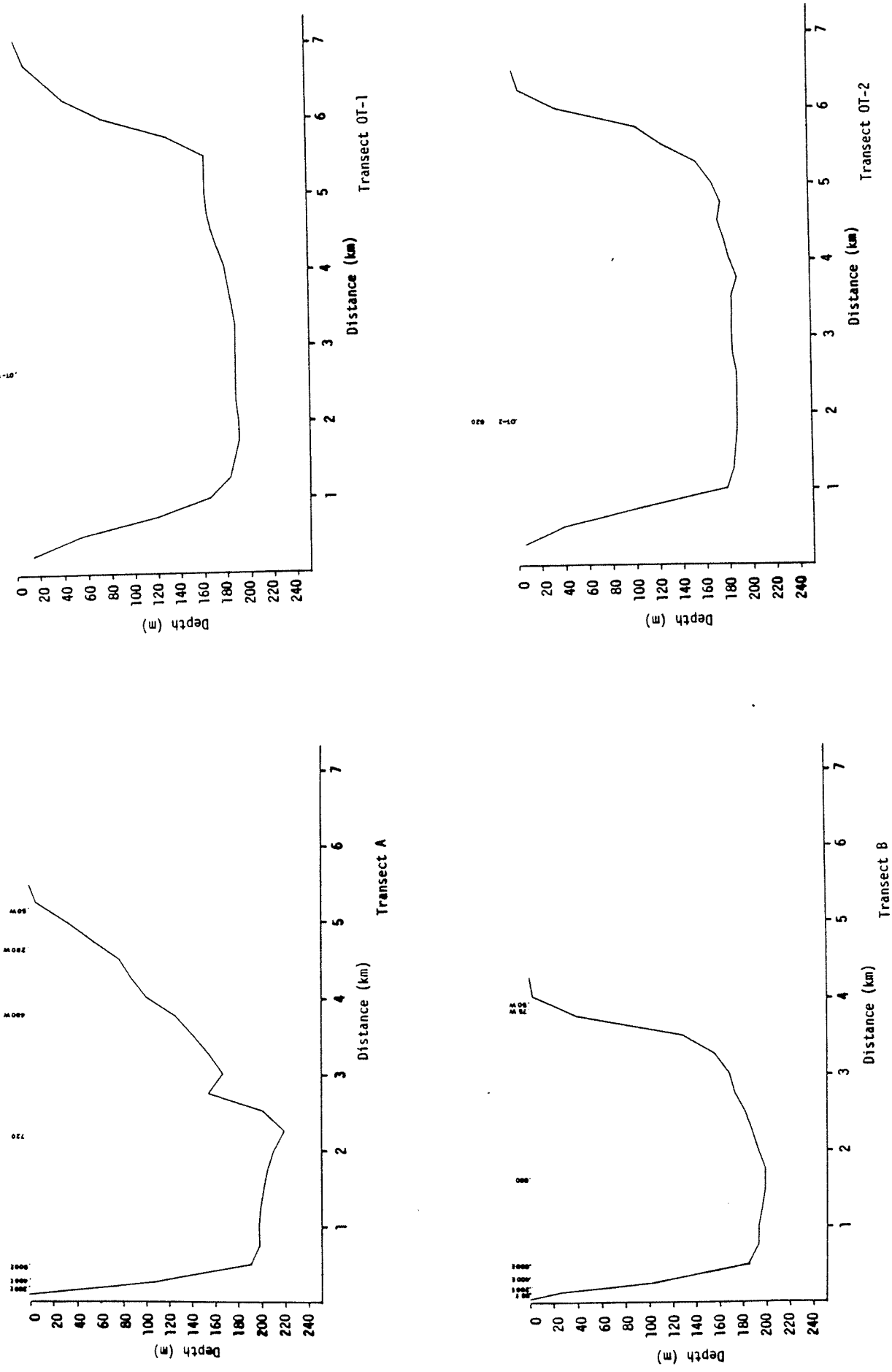



Fig. 7.1. Bathymetric contours for transects A, B, OT-1, OT-2

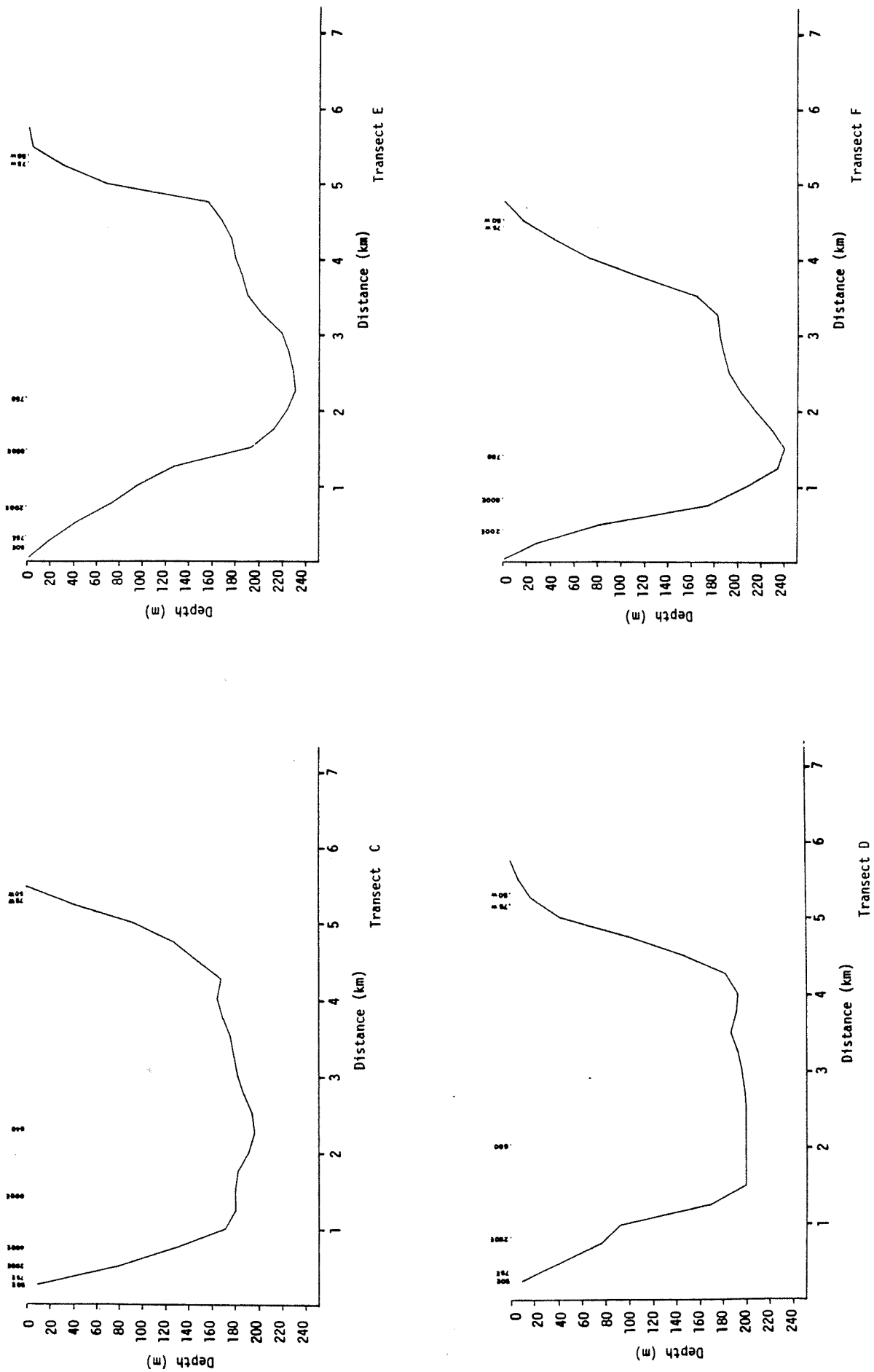
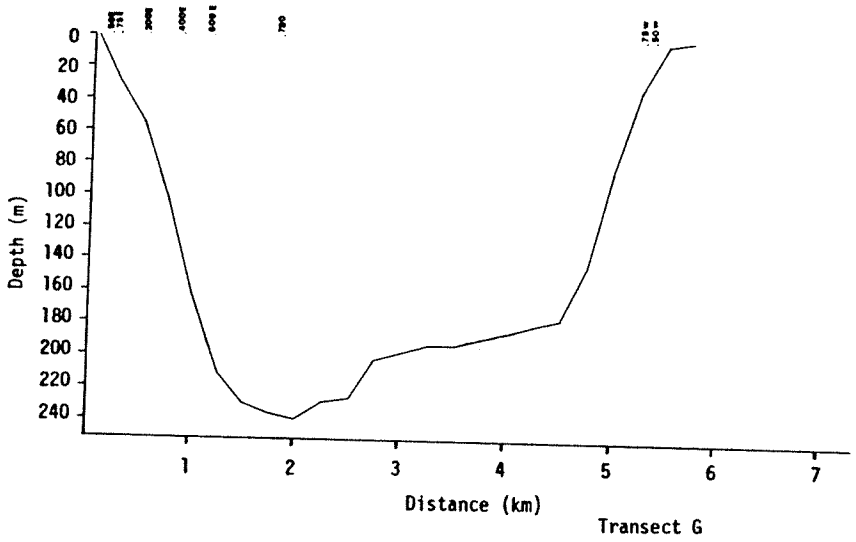
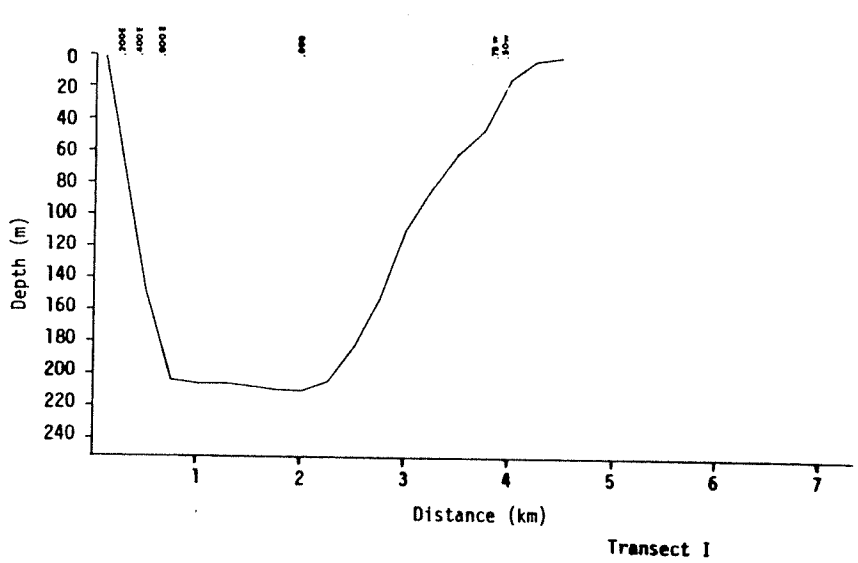
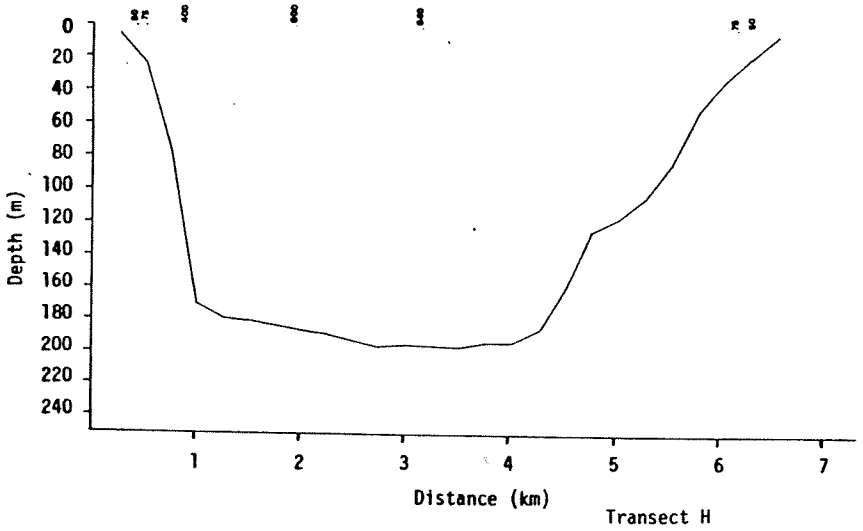



Fig. 7.2. Bathymetric contours for transects C, D, E, F



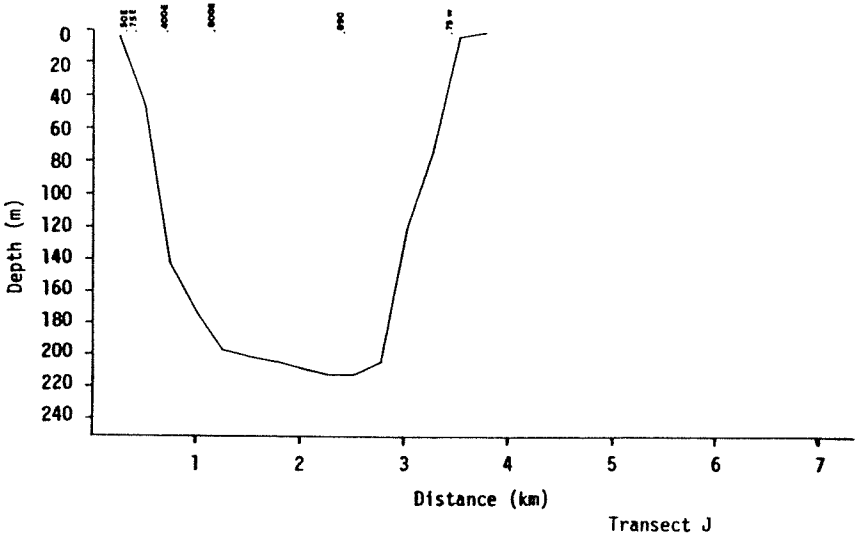
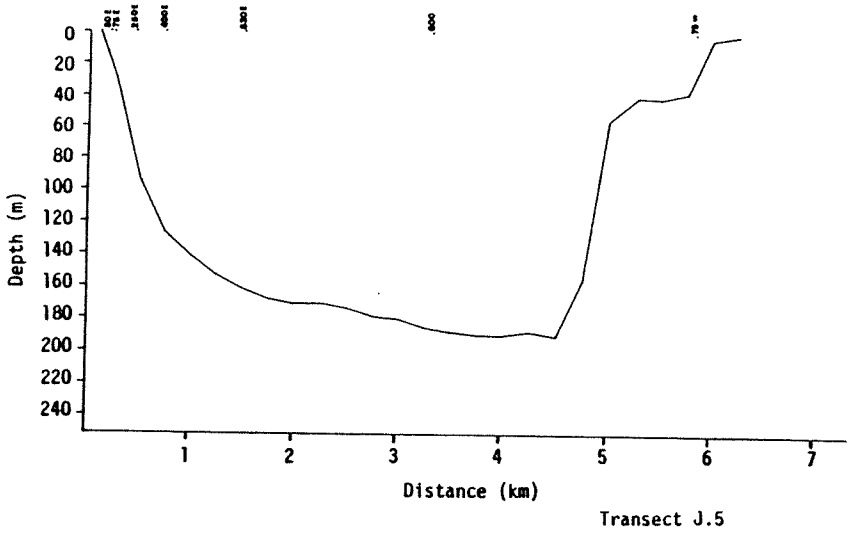
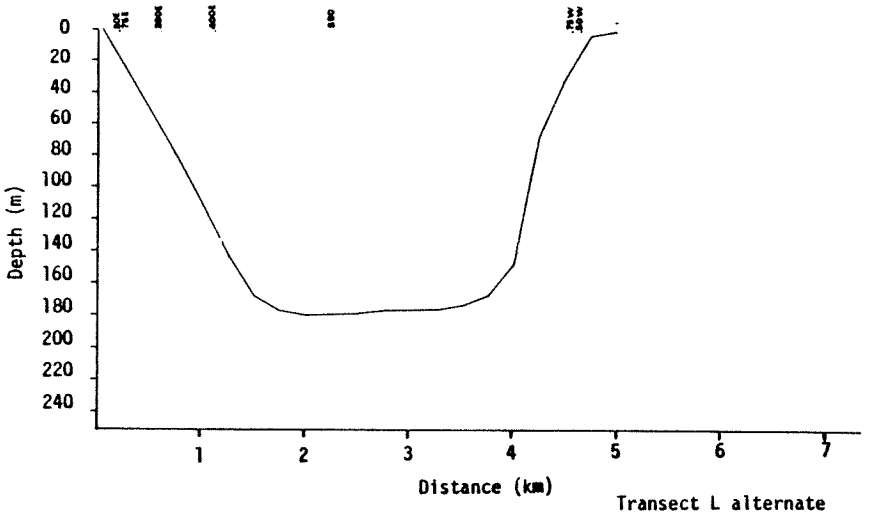
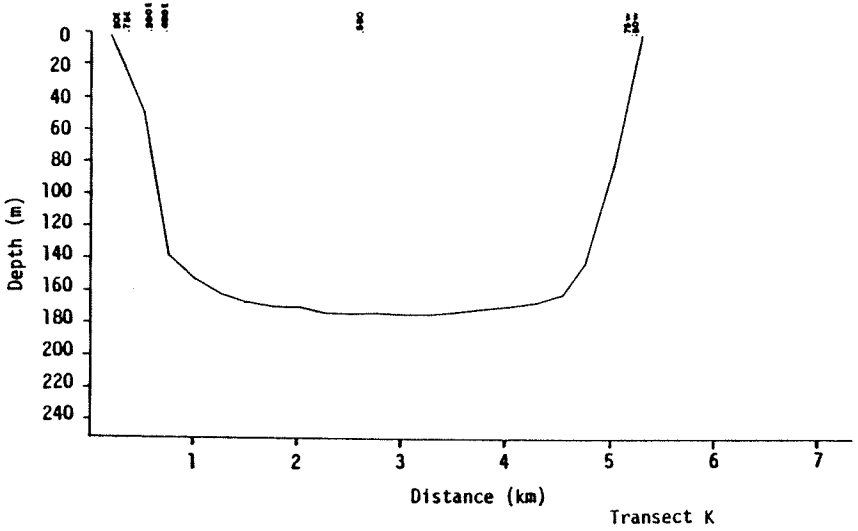






Fig. 7.3. Bathymetric contours for transects G, H, I, J



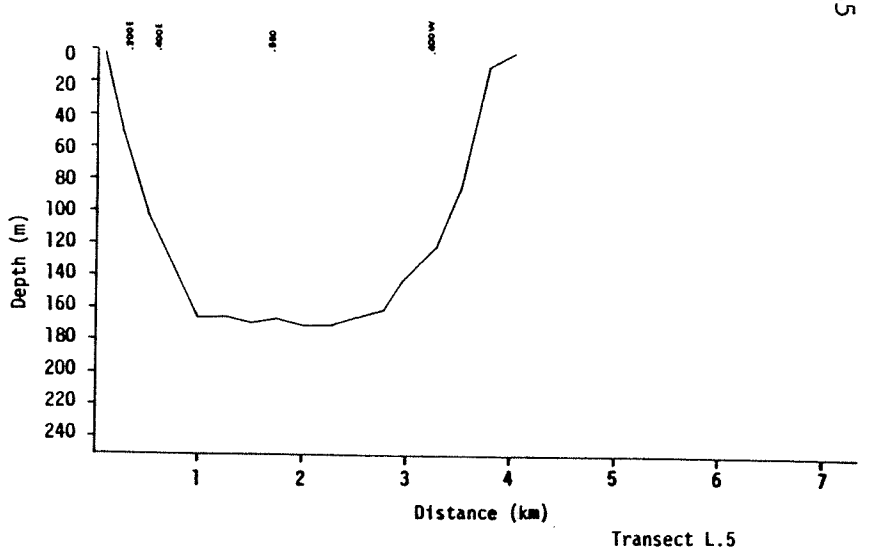
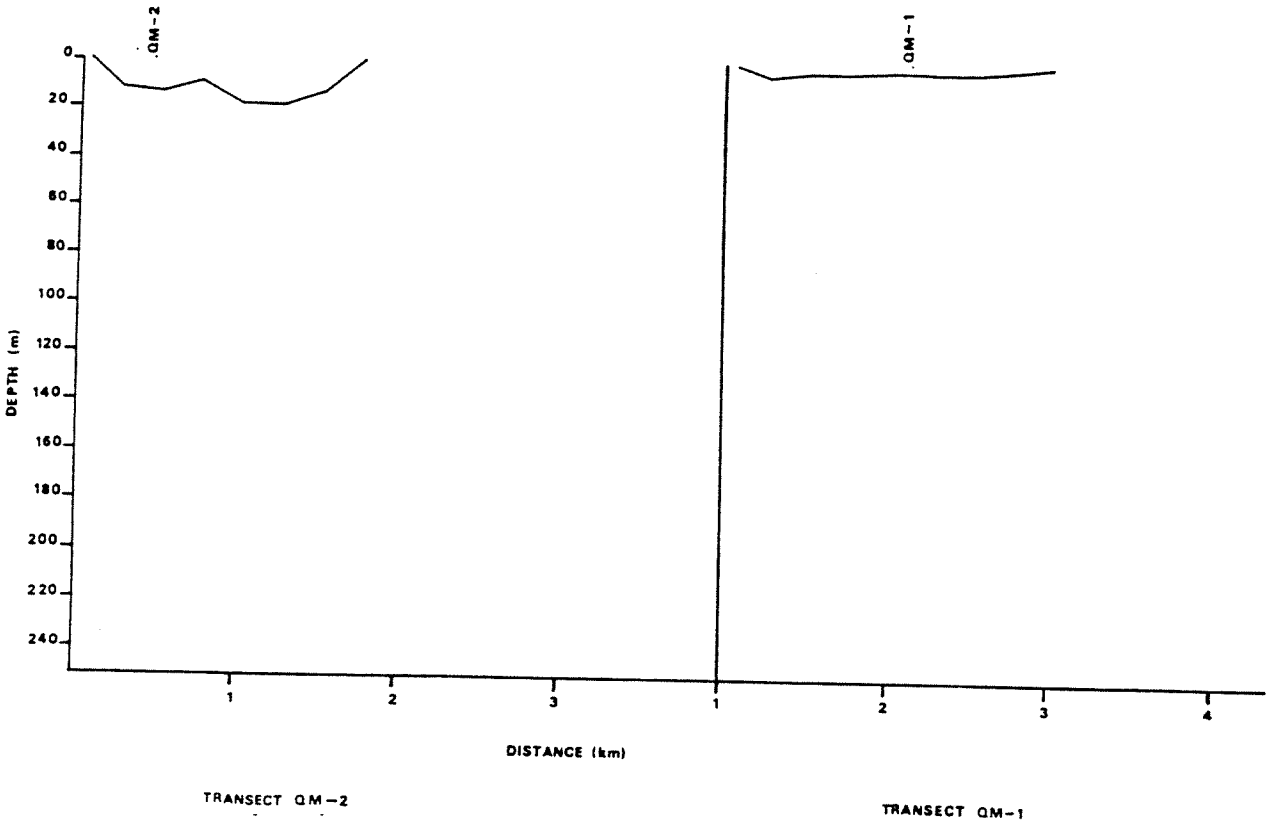
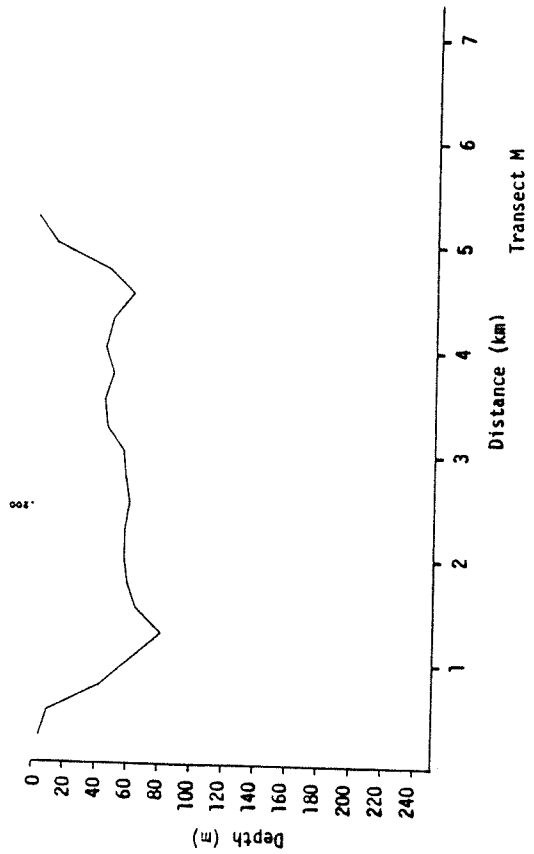




Figure 7.4. Bathymetric contours for transects J.5, K, Lalt, L.5.



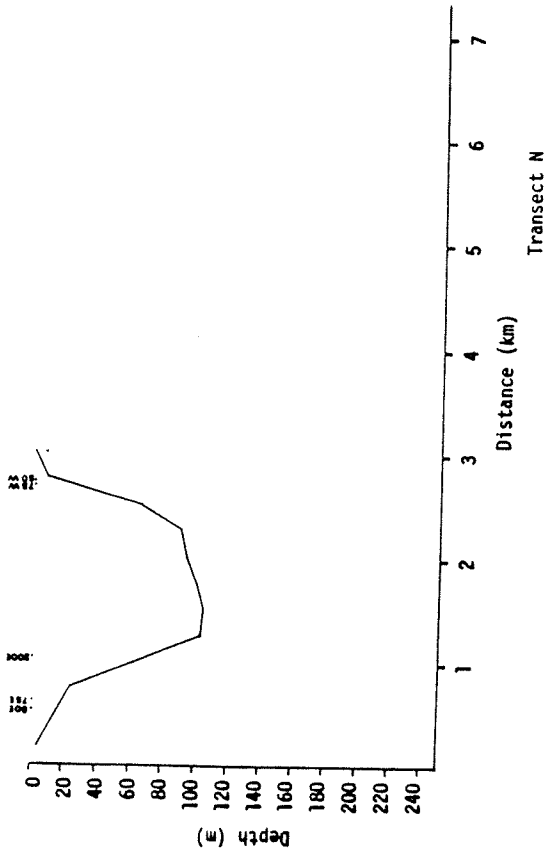




Fig. 7.5. Bathymetric contours for transects M, N, QM-1, QM-2

## 7.3 Methods and Materials

### 7.3.1 Sampling at Sea

The majority of baseline stations are situated along 16 transect lines that extend from the eastern to the western shoreline of East and Colvos Passages. Where possible stations have been established at depths of 15, 23, 62, 123, and 185 m on the eastern side of the passages, at the maximum depth on each transect line and at 15 and 23 m on the western side of the passages. The first transect line also includes stations at 62 and 123 m on the west side of the transect. In addition to this sampling grid four stations at 62 m have been established in Poverty Bay (PBI-4), two stations at a depth of 197 m near Seahurst (OT1 and OT2) and two stations in Quartermaster Harbor (QM1 and QM2). These stations and seasonal sampling distribution are shown in Figure 7.6. Stations were established by examination of fine scale bathymetry charts (NOAA, 1935) so that a distribution of potentially depositional and erosional sites would be examined throughout the baseline study. Once the stations were identified a combination of information from navigational aids were used in order to reoccupy the same location with a small degree of variation (Appendices 7.1-7.3). LORAN C coordinates were identified for each station, the depth of water at the site was also recorded, and any range fixes that could be established with shoreline objects were included as mechanisms for reoccupying each station. LORAN C navigational points are accurate to within 20 m and the maximum variation in the depth of replicate samples is 5 meters. Two biological and one chemical grab samples were taken at each station during all of the sampling periods, except at stations H640, D250E, OT1, and OT2, where five biological and one chemical sample were taken.

Subtidal benthic samples were collected using a modified van Veen grab

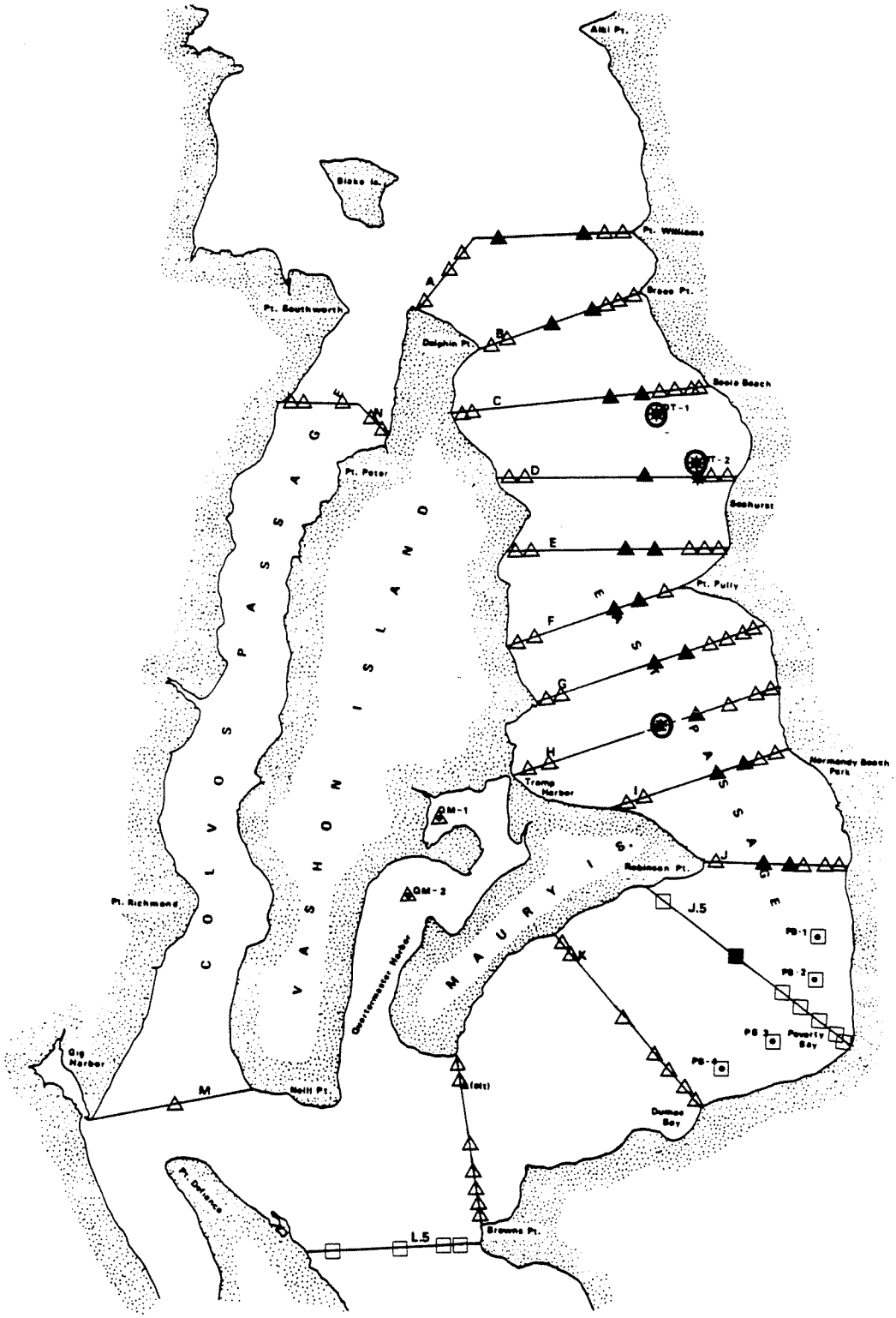



Figure 7.6. Location of quarterly baseline sample stations for the subtidal benthic program. △ indicates quarterly sampling occurred during June/July, September/October, and November/December 1982; □ indicates stations added during September/October; and * indicates stations that have been sampled with five replications during each quarter. ▲ or ■ or ⊛ indicates those stations biologically analyzed during the first three sampling quarters.

sampler of 0.1 sqm surface area (Word, 1976, 1977; Word et al. 1976; Thom et al. 1979; Malins 1980) during each quarterly sampling period. Ninety-one stations with 285 grab samples were taken between 15 June and 2 July (Summer, 1982), and 106 stations with 330 grab samples during the autumn and winter sampling periods (21 September - 8 October and 29 November - 11 December 1982). Each sample was described physically with regards to sediment texture, sediment color, odor strength and type, grab penetration depth, the degree of leakage or sediment surface disturbance, bottom water depth, and any obvious abnormalities of the sample (e.g., presence of large animals, wood debris, metal fragments, etc.) (Appendices 7.1-7.3). Samples that showed a leakage of sediments through openings in the grab, excessive disturbance of the upper layers of sediments, and samples that did not penetrate a minimum distance of 10 cm in silt, clay, or fine sand dominated sediments or 5cm in coarser sediments were rejected. These rejection criteria reflect information on the quantities of individuals and the numbers of species found at different depths within the sediments. Coarser substrates generally have few species or individuals burrowing deeper than 5 cm (Word et al. 1976).

When the qualitative description of the sediments was completed each sample was placed into a sieving station (Striplin and Maupin, in review) and carefully sieved through screens with a mesh diameter of 1 mm. The debris was then carefully washed into a sample container with internal and external labels and fixed with a mixture of 10-15% formalin, buffered with sodium borate and diluted with seawater to a concentration of 10-15 percent. After returning to the laboratory the samples remained in the formalin solution for a period that did not exceed two weeks. The fixed material was then resieved in the laboratory with fresh water, and the formalin mixture was replaced with 70% ethanol for long term preservation and storage.

7.3.2 Laboratory Methods and Quality Control of Biological Samples

Samples chosen for analysis were sorted in one of two manners. Coarse sediment debris often resulted in samples with nearly 4 liters of sortable material. The density of the coarse material allowed the initial separation of organisms from the sediments by a freshwater floatation technique and spillage of floatable materials and organisms onto a sieve. This material was sorted so that organisms were separated into major taxonomic elements (annelida, mollusca, arthropoda, echinodermata, and other taxa) through the use of dissecting microscopes with a minimum of 10X magnification. The remainder of the sediments that were not floated were then examined under magnification in large flat trays. Most of the remaining organisms were either mollusca or pieces of rocks with attached organisms. These were removed and sorted into higher taxonomic groupings as were the floated materials. Those samples that contained quantities of less dense materials (e.g., plant fibers, grasses, or fine less dense sediments) were sorted in the same manner as the floatable debris. Quality control of the sorting procedures was accomplished by resorting 10-20% of each sample. Any subsample that had more than five organisms present in the resort was considered a quality control failure and was completely resorted. Based on the final abundances present in the samples examined, this level of quality control indicated that at most only about 5% of the organisms would be missed through the sorting procedures.

Identification of organisms in the deeper than 185 m samples were all done at the complete taxonomic level rather than a portion being done at an incomplete level as originally proposed. This was possible during this first year of sampling because analyses were confined to those stations at depths in excess of or equal to 185 m (157 Baseline and 45 Nichols' stations). The

savings in the amount of time required for sorting each of the samples at these depths were due to the small number of samples with large quantities of gravel or plant material, and the relatively fewer numbers of species and individuals normally present at these depths in Puget Sound. This will not necessarily occur during the second year of the baseline program because efforts wil be concentrated at depths which generally have more sorting debris, higher species numbers, and total abundances.

Identification and enumeration of taxa from each of the samples was accomplished at the lowest possible taxonomic level through the use of dissecting and compound microscopic techniques, and by of the extensive taxonomic library available at this laboratory. Assurance of consistent identifications between different individuals within the laboratory was accomplished by the continuous interaction of individuals and by the use of specially developed in-house taxonomic keys of species that presented identification problems. Two literature source verifications of taxonomic characteristics or personal communication with other taxonomists were required for each identification.

7.3.3 Chemical Analysis and Collection Methods

Chemical samples were removed from one grab sample at each station through the use of a standardized cookie-cutter procedure developed by METRO which sampled the two surface centimeters of the grab. A single subsample was removed from the grab for total sulfide, organics (biochemical oxygen demand, volatile solids, organic carbon and nitrogen concentrations) and grain size analysis, and a third for metals determinations. The samples for organics, metals, and grain size determinations were placed on ice until returned to the laboratory while the sulfide samples were placed in a zinc acetate solution as a preservative. Specific methods for the determination of each of these

chemical and physical properties are contained in the chemistry section.

7.3.4 Selection of Replication Numbers

Replicate samples were taken at eight stations at water depths in excess of 185 m during two to three different periods in Puget Sound during 1982. Five of these stations were situated off West Point and were sampled twice (March and July 1982) with four samples taken at each station during each sampling period. Three other stations were occupied during three separate periods (June, September, and November, 1982) in the south central Puget Sound area near Seahurst Park and Three Tree Point. Five replicate samples were taken at each of these stations. All samples were collected and identified by the same biologists using the navigation techniques, sampling and identification procedures discussed previously.

Summary statistics (means, standard deviations, coefficient of variations,) were determined at each of these stations on the number of species, individuals in total, as well as, for each major taxa group: annelida, mollusca, arthropoda, echinodermata, and miscellaneous taxa. Shannon-Wiener's and Gleason's Diversities were also determined, as was an overall Infaunal Trophic Index value. Ninety percent confidence limits were determined for each of 1-5, 7, and 10 replications based upon the variability determined on each parameter ($X_A - X_B = Z \quad S^2_A/N_A + S^2_B/N_B$) (Diamond, 1982 pg. 53). Absolute percentage differences between mean values of each parameter and the maximum confidence level of differences were then determined for each potential replication.

The improvement between sample 1 and 2, 2 and 3, etc. was then determined by subtracting the percentages of detectable variations with each additional sample. This difference in percentages was then used as a measure for the improved quality of precision in estimating the natural inherent variation in

each of the biological parameters. These parameters of improved precision for estimating the inherent variability of a measurement were then compared with all the replication information on each of the biological characteristics of interest.

7.3.5 Long Term and Seasonal Comparisons

Three sets of biological information were examined for the purpose of demonstrating seasonal and long term cycles in benthic communities. All of these sets of information were collected with a van Veen grab sampler with a surface area of 0.1 sqm and the material was sieved with screens having a mesh diamter of 1.0 mm. All of the samples were identified by the same laboratory while the sorting was performed by the Department of Oceanography-Dr. F. C. Nichols and the present Subtidal Studies group. The number of replicate samples at each station varied between the different studies from 1-5 repeated samplings of the same stations (Table 7.1).

The number of species, individuals, Gleason's and Shannon-Wiener's Diversities in total and within each major taxanomic grop and the Infaunal Trophic Index was summarized from each sample. These values were used to determine the means, standard deviation, and coefficient of variation for each of the parameters at each station. The most abundant 30 taxa at each station were then tabulated and the percent of total abundance for each taxa were calculated for each grab sample. All of these parameters were examined seasonally in order to detect significant differences between stations, transects, regions within Puget Sound, and for long term trends.

7.3.6 Biological Data Analysis

Three major taxonomic groups of benthic infauna were examined in order to determine if there were significant groups of species that commonly occurred at depths in excess of 185 m in Puget Sound. These species groups were then

Table 7.1. Date, number of stations, replicates/station, and the number of samples from each survey used in this analysis.

| Survey | Sampling Period | No. Stations | Rep./ Station | No. of Samples |
|---|---|---|---|---|
| TPPS | Oct. 1981 | 15 | 1(1 W/ 3) | 17 |
| | March 1982 | 5 | 4 | 20 |
| | July 1982 | 5 | 4 | 20 |
| Baseline | Jun/July 1982 | 21 | 2(3 W/ 5) | 51 |
| | Sept/Oct 1982 | 22 | 2(3 W/ 5) | 53 |
| | Nov/Dec 1982 | 22 | 2(3 W/ 5) | 53 |
| Nichols | Monthly | | | |
| | Nov'69 - Apr'70 | 1 | 3 | 15 |
| | May'70 - Nov'70 | 1 | 5 | 30 |
| Totals | | 92 | | 259 |

examined in order to determine if there were important differences in the abundance of major species. Stations were then grouped together by an examination of the abundance of species at each station in order to detect major differences in communities within either of the two major areas of study (near West Point and in south central Puget Sound) or between the two areas.

The numerical abundance of each species were determined from 157 METRO/Baseline and 57 METRO/TPPS samples. Three of the METRO/Baseline stations were sampled with five replicate grabs during each of the three sampling periods (June/July, September/October, and November/December 1982) while 18 stations during the June/July sampling and 19 stations during the remaining two periods were sampled with two samples. The METRO/TPPS sampling occurred at 15 stations during March 1981 (single samples/site) and during March and July, 1982 at five stations with four replicate samples per site. All of these samples were taken at stations whose water depths exceeded 185 m (see Appendix 7.1 and Figure 7.1).

Analyses of overall trends in the data were first separated into groups based upon geographical location and equivalent sampling periods. METRO/TPPS samples were separated from the more southern regions and comparisons between the two areas were made only on samples taken within the same month. More detailed examination of the distribution of the species within each of these groups were made through the use of agglomerative hierarchical cluster analysis (Bray and Curtis, 1957) with a group average sorting strategy of the abundance of the individuals within each taxa (Sokal and Michener, 1958). These cluster techniques were applied separately to all stations during each of the Baseline and METRO/TPPS sampling periods and also in combination when both areas were sampled during the same month (eight separate clusters were performed on each taxonomic group). The groups of stations clustered together

based upon these analyses were then examined in order to determine those species that were most instrumental in forming the groups. These species were examined in detail to find patterns of groups of species that were apparently responding to water depth, geographical area, or bottom topography.

7.3.7 Chemical Data Analysis

The quantities of organic carbon, nitrogen, biochemical oxygen demand (five day), volatile solids (loss of weight by ignition), percentage by weight of five sediment grain size ranges [gravel (64-2 mm), coarse sand (2-0.5 mm), fine sand (0.5-0.062 mm) silt (0.062-0.004 mm), clay <0.004 mm)] and percentage of water in the sediments were determined by the methods described in the chemistry section of this annual report. Additionally the quantities of organic carbon to nitrogen (C/N) and the biochemical oxygen demand of the sediments to the volatile solids concentrations were determined. All of these measurements except nitrogen and C/N ratios were included in an analysis of the amount of dissimilarity between stations for the combination of all of these parameters through the computer cluster analytical technique described previously.

Through this procedure 93 stations sampled during June 1982 were grouped based upon the quantities of physical and chemical constituents of the sediments. These groups were ranked from low to high concentrations of organic materials and were then plotted on charts of the area in order to examine spatial patterns in Puget Sound. The potential for seasonal cyclings in sediment chemistry for altering the groupings of stations were examined by ANOVA between 28 stations sampled quarterly that were originally part of the first cruise series. Additionally stations not sampled during the first cruise were sampled on the second and third cruise in order to increase spatial coverage. If the seasonal changes in chemistry data showed that

that stations of the first cruise were not significantly different between each of the subsequent cruises, these new stations not sampled in June/July could be added to the charts of the groupings made during the first cruise. This procedure would then allow a greater degree of spatial coverage without requiring all chemical samples to be repeated for the second and third samplings with the resultant increase in the total costs to the Baseline Study.

Also added to these analyses was a comparison of north central sound (Alki Point north to Meadow Point METRO/TPPS) to the south central sound (Brace Point south to Commencement Bay METRO/Baseline). Cluster analysis were run on stations deeper than 185 m from both areas when the samples were collected during the same months (METRO/Baseline cruises 1 and 2 on TPPS cruises for Phase 2 and 3B).

## 7.4 Results and Discussion

### 7.4.1 Replication for Selection of Numbers

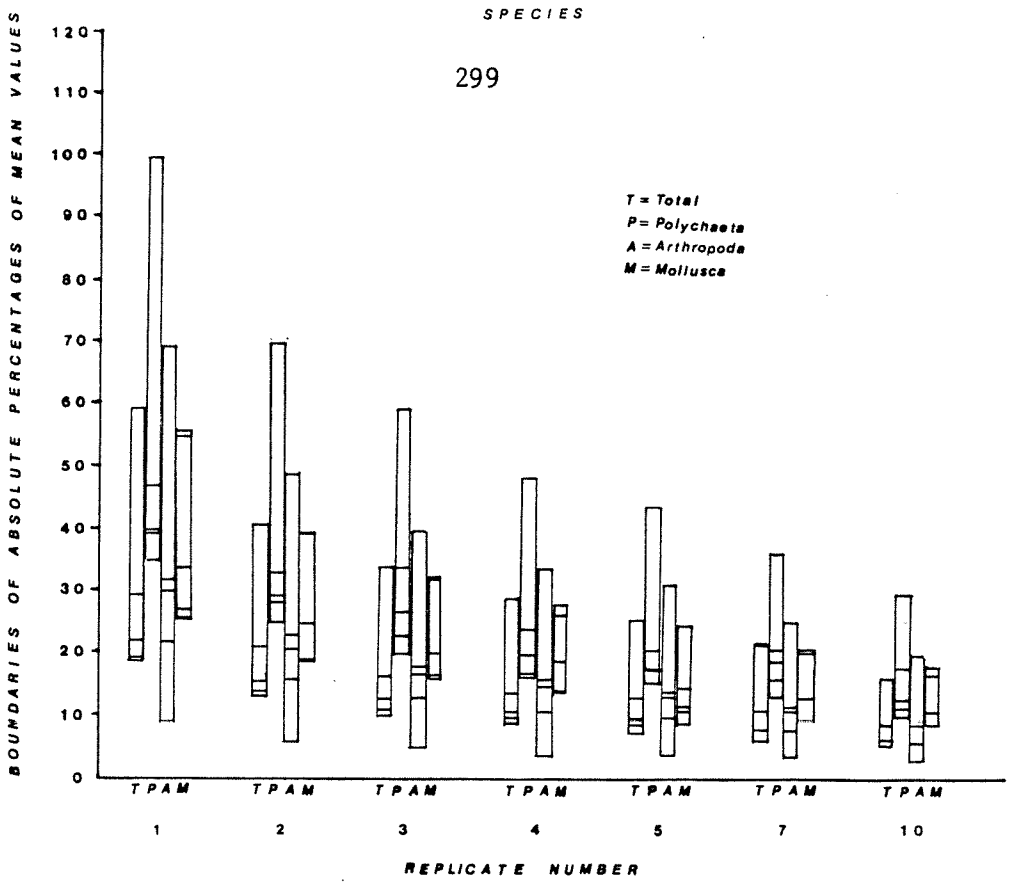
As the number of repeated measurements increase, the potential for establishing smaller statistically significant boundaries around the parameter of interest improves while the cost of the analytical program increases. Optimizing the amount of information improvement for each new repeated measure with the cost of obtaining that improvement should then become a primary concern in planning the sampling design and apportioning the generally limited number of biological measurements between stations.

There are inherent variabilities in biological parameters that will not necessarily be the same for each parameter or for the same parameter at a variety of stations. No matter what is done, replication cannot change these

inherent variabilities. It seems reasonable then to discuss the relative degree of improvement in the precision of estimates for each parameter rather than examine the absolute range of confidence limits with each new repeat measure. The approach towards determining the number of repeat measurements that would provide the best return for the investment of time and money involves examining the decrease in the absolute percentage of maximum confidence limits around the mean value resulting from additional replication (English 1964). This technique has been referred to as analysis of replication through the use of "trumpet" diagrams. The approach has been modified in this presentation by employing only one-half of the "trumpet" diagrams and to look at the improvement in percentage of detectable confidence limits rather than the absolute values at each replicate sample.

The inherent variability of the biological parameters of interest in this study showed ranges in the degree of detectable variation (Figures 7.7-7.11) The number of species of arthropods and the abundance of arthropods and molluscs showed the widest degree of inherent variation while the total numbers of species and individuals showed the lowest degree of variability during the July 1982 samplings off West Point (Figure 7.8). During the March 1982 samplings at these same stations the annelid species showed the most variability (Figure 7.7). In all cases the diversity measures and the Infaunal Trophic Index values at these stations showed much lower degrees of inherent variability (Table 7.2).

At the stations near Seahurst Park and Three-Tree point the range in inherent variability within the major and total taxa groups showed comparable degrees of variation with the West Point stations. During the June/July sampling period annelida and arthropoda species and annelida individuals showed the greatest range in variation (Figure 7.9). During the September and



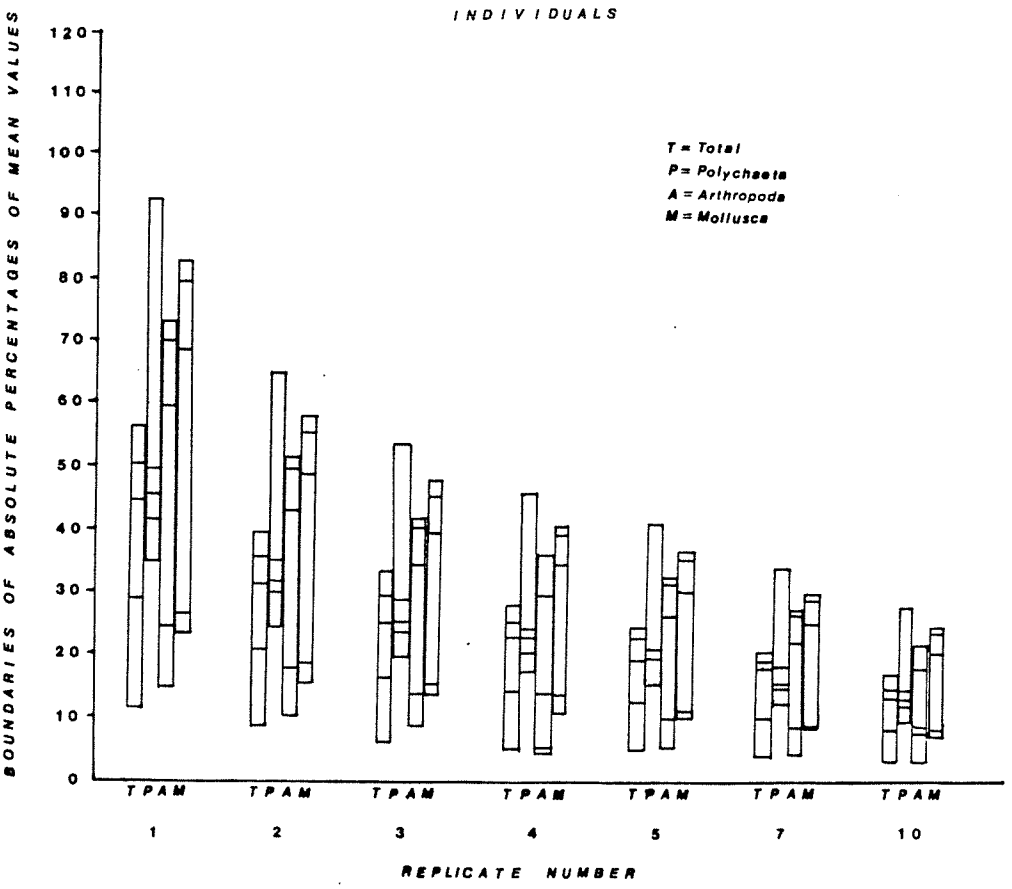




Fig. 7.7. Decrease in the absolute percentage of maximum confidence limits around the mean value resulting from additional replication. Data collected from the March METRO/TPPS sampling period.

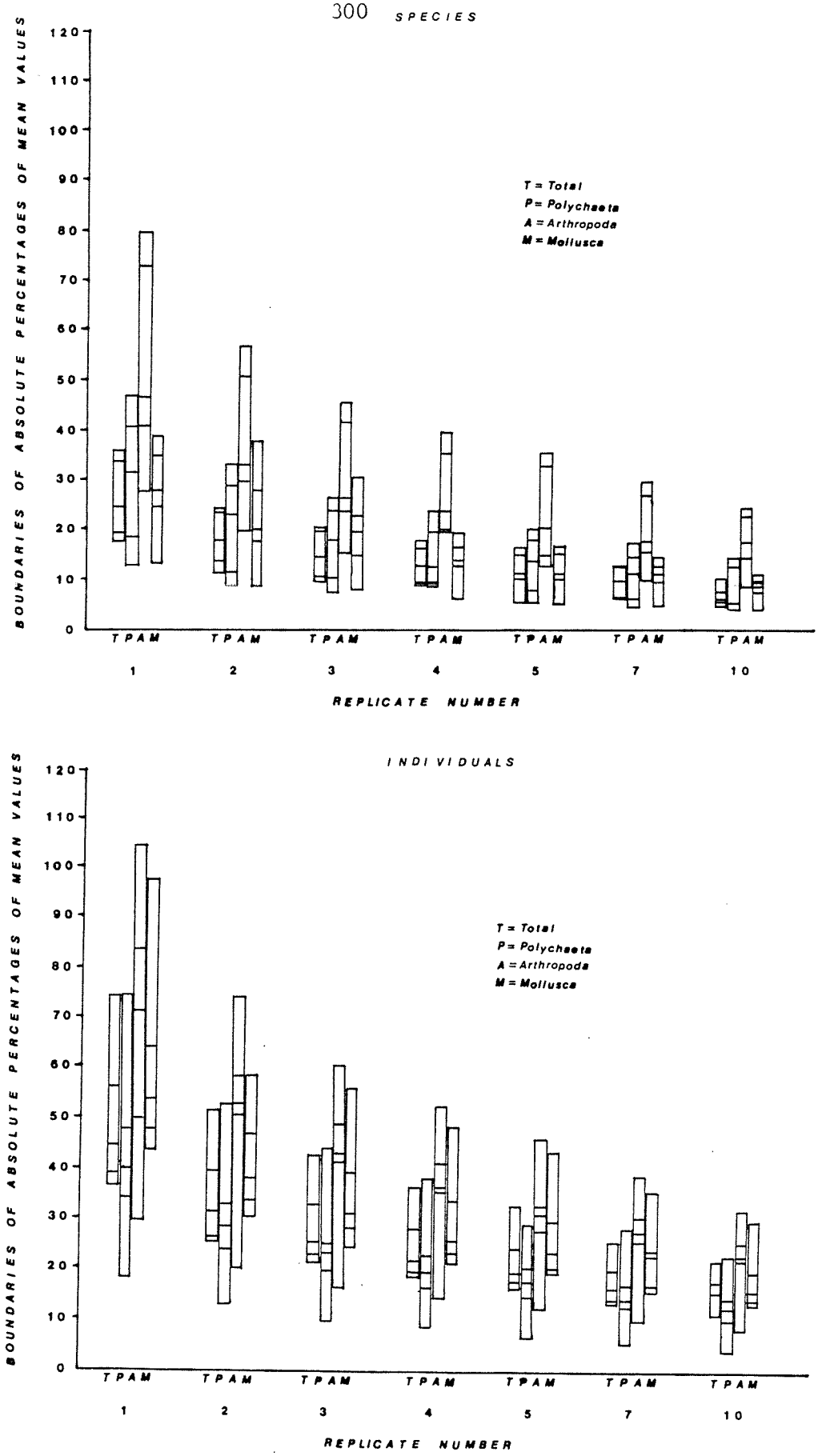



Fig. 7.8. Decrease in the absolute percentage of maximum confidence limits around the mean value resulting from additional replication. Data collected from the July METRO/TPPS sampling period.

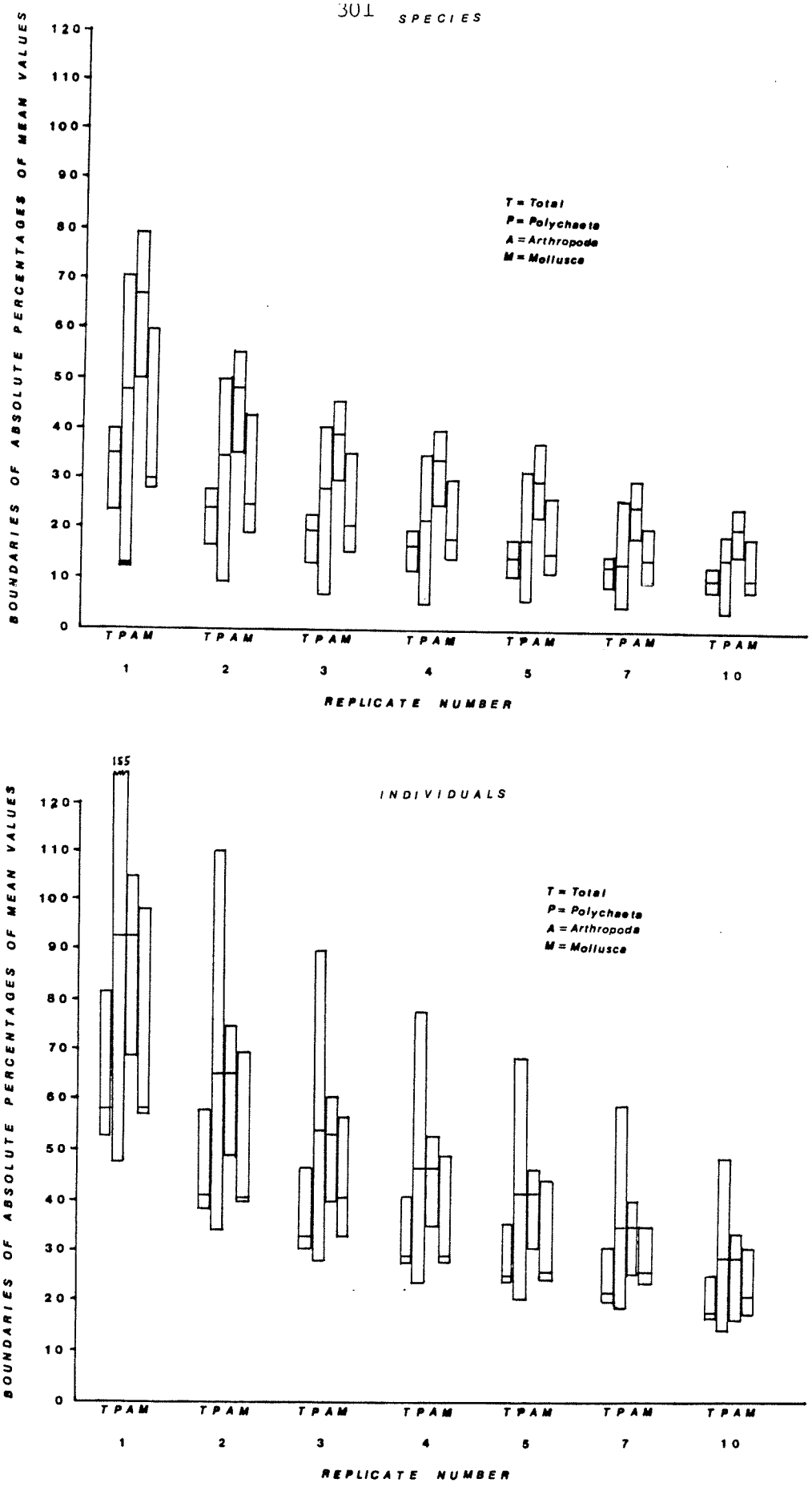



Fig. 7.9. Decrease in the absolute percentage of maximum confidence limits around the mean value resulting from additional replication. Data collected from METRO/Baseline stations H-640, OT-1 and OT-2 during the June/July sampling period.

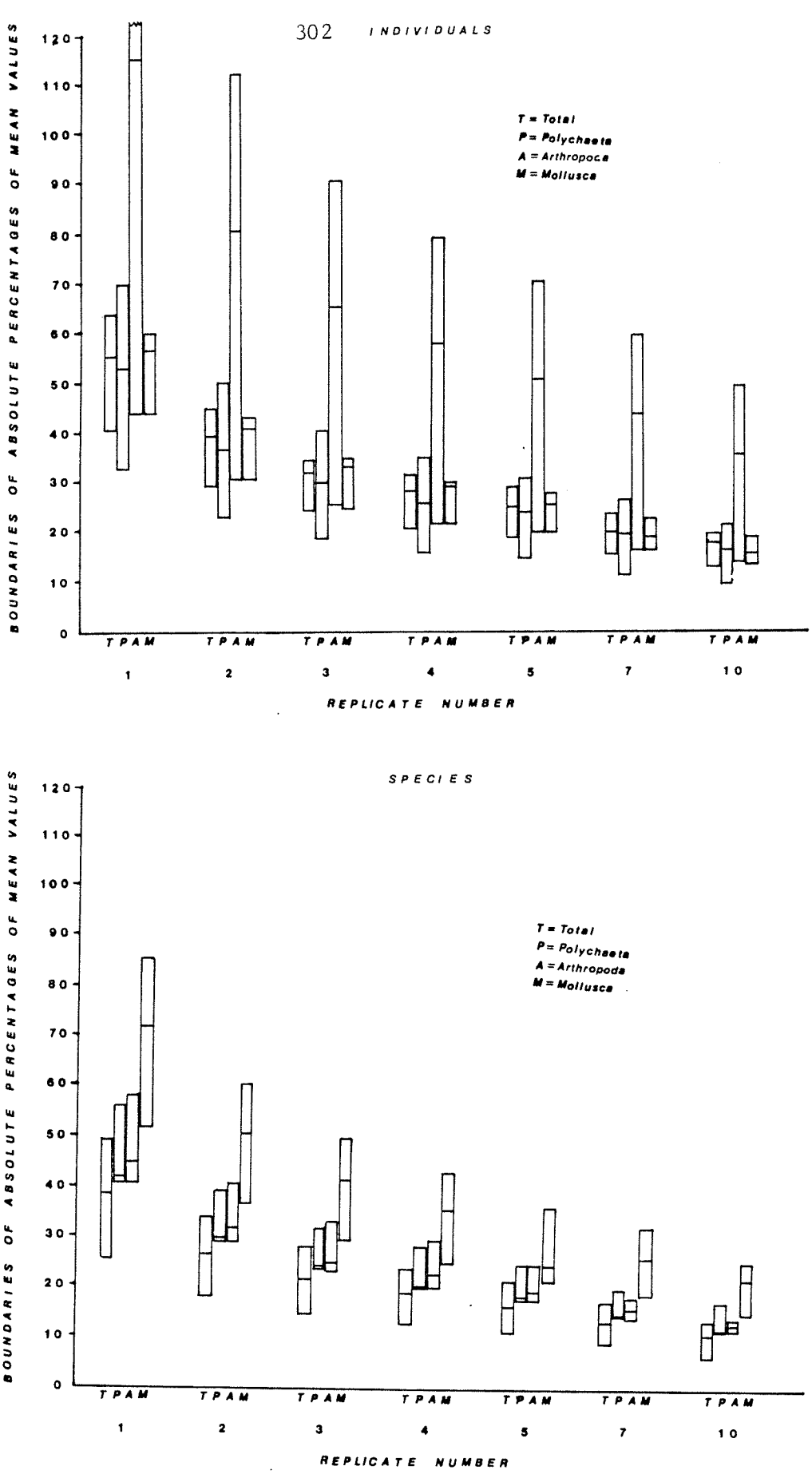
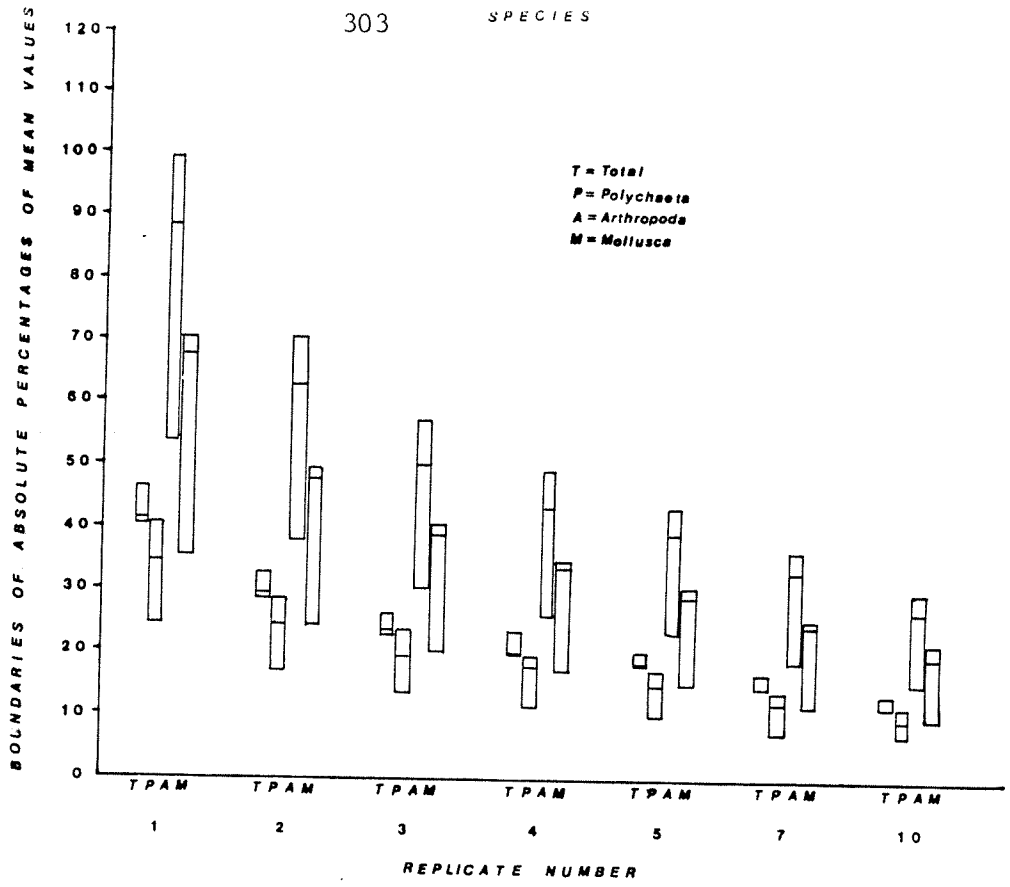



Fig. 7.10. Decrease in the absolute percentage of maximum confidence limits around the mean value resulting from additional replication. Data collected from METRO/Baseline stations H-640, OT-1, and OT-2 during the September/October sampling period.



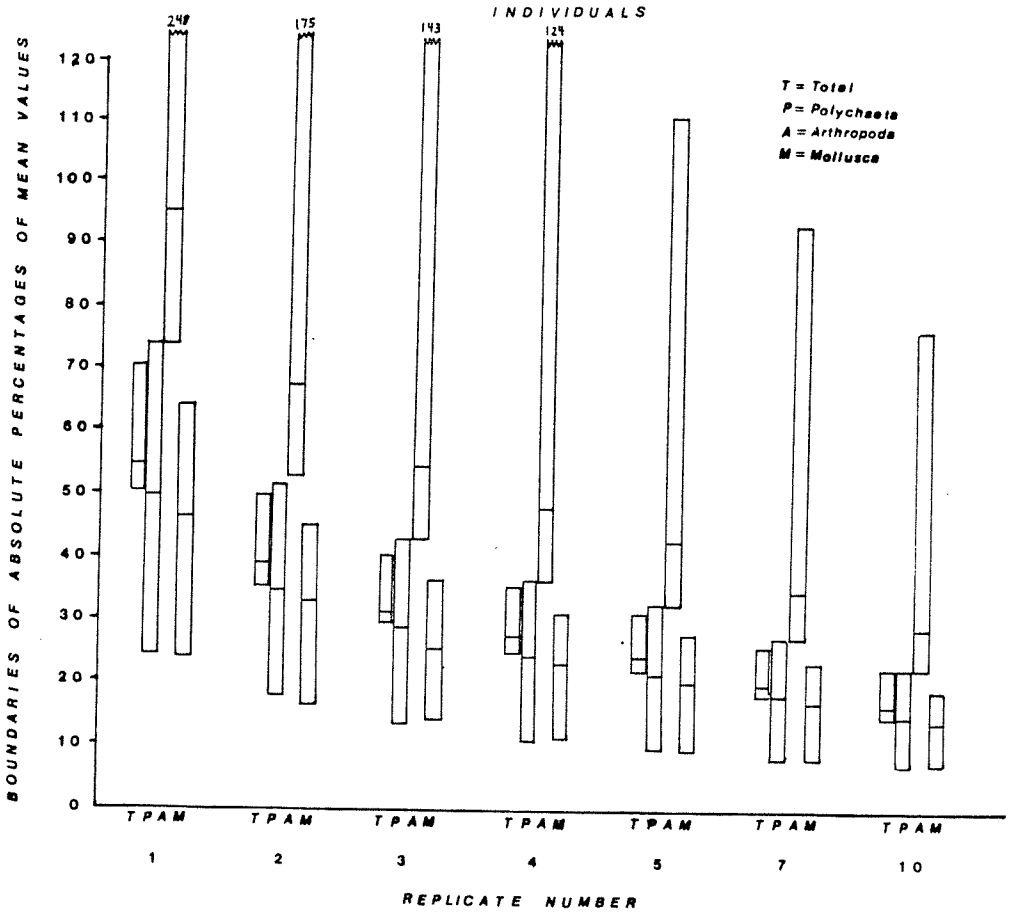




Fig. 7.11. Decrease in the absolute percentage of the maximum confidence limits around the mean value resulting from additional replication. Data collected from METRO/Baseline stations H-640, OT-1, and OT-2 during the November/December sampling period.

Table 7.2. Inherent variability in Shannon-Wiener's and Gleason's Diversity measures and The Infaunal Trophic Index at stations off West Point during March and July 1982. Values are the absolute percentage of the confidence limit range around the mean value.

JULY 82

Shannon-Wiener/Polychaeta

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| III - 750 | 23 | 17 | 14 | 12 | 11 | 9 | 7 |
| V - 750 | 28 | 20 | 16 | 14 | 13 | 11 | 9 |
| VII 750 | 33 | 24 | 19 | 17 | 15 | 13 | 11 |
| VIII - 750 | 15 | 11 | 9 | 8 | 7 | 6 | 5 |

Gleason's/Polychaeta

| | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| | 13 | 9 | 7 | 6 | 6 | 5 | 4 |
| | 47 | 33 | 27 | 24 | 21 | 18 | 15 |
| | 28 | 20 | 16 | 14 | 13 | 11 | 9 |
| | 39 | 28 | 23 | 20 | 17 | 15 | 12 |
| | 27 | 19 | 15 | 13 | 12 | 10 | 5 |

Shannon-Wiener/Arthropoda

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 22 | 16 | 13 | 11 | 10 | 8 | 7 |
| III - 750 | 14 | 10 | 8 | 7 | 6 | 5 | 5 |
| V 750 | 34 | 24 | 19 | 17 | 15 | 13 | 11 |
| VII 750 | 52 | 37 | 30 | 26 | 23 | 20 | 16 |
| VIII - 750 | 43 | 31 | 25 | 22 | 19 | 16 | 14 |

Gleason's/Arthropoda

| | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| | 37 | 26 | 21 | 18 | 17 | 14 | 12 |
| | 35 | 25 | 20 | 17 | 16 | 13 | 11 |
| | 87 | 62 | 50 | 44 | 39 | 32 | 28 |
| | 74 | 52 | 43 | 37 | 33 | 28 | 23 |
| | 63 | 47 | 39 | 34 | 30 | 25 | 21 |

Shannon-Wiener/Mollusca

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 18 | 13 | 10 | 9 | 8 | 7 | 6 |
| III - 750 | 35 | 25 | 20 | 18 | 16 | 13 | 11 |
| V - 750 | 55 | 39 | 32 | 27 | 25 | 21 | 17 |
| VII 750 | 26 | 18 | 15 | 13 | 12 | 10 | 8 |
| VIII - 750 | 34 | 24 | 19 | 17 | 15 | 13 | 11 |

Gleason's/Mollusca

| | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| | 30 | 21 | 17 | 15 | 14 | 11 | 10 |
| | 33 | 23 | 19 | 17 | 15 | 13 | 10 |
| | 40 | 28 | 23 | 20 | 18 | 15 | 13 |
| | 23 | 16 | 13 | 11 | 10 | 9 | 7 |
| | 15 | 11 | 9 | 8 | 7 | 6 | 5 |

Infaunal Trophic Index

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 17.3 | 12.3 | 10.0 | 8.7 | 7.8 | 6.6 | 5.5 |
| III - 750 | 12.6 | 8.9 | 7.3 | 6.3 | 5.6 | 4.8 | 4.0 |
| V - 750 | 19.1 | 13.5 | 11.0 | 9.5 | 8.5 | 7.2 | 6.1 |
| VII 750 | 23.5 | 16.6 | 13.6 | 11.7 | 10.5 | 8.9 | 7.4 |
| VIII 750 | 9 | 6 | 5 | 4.3 | 3.8 | 3.2 | 2.7 |

MARCH 1982

Shannon-Wiener/Polychaeta

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 26 | 19 | 15 | 13 | 12 | 10 | 8 |
| III - 750 | 20 | 14 | 12 | 10 | 9 | 8 | 6 |
| V 750 | 20 | 14 | 11 | 10 | 9 | 7 | 6 |
| VII - 750 | 32 | 24 | 19 | 17 | 15 | 13 | 11 |
| VIII - 750 | 37 | 27 | 18 | 19 | 17 | 14 | 12 |

Gleason's/Polychaeta

| | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| | 42 | 33 | 27 | 23 | 21 | 18 | 15 |
| | 33 | 22 | 19 | 17 | 15 | 13 | 10 |
| | 26 | 26 | 21 | 18 | 16 | 14 | 11 |
| | 39 | 28 | 23 | 20 | 17 | 15 | 12 |
| | 85 | 60 | 49 | 43 | 38 | 32 | 27 |

Shannon-Wiener/Arthropoda

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 36 | 26 | 21 | 18 | 16 | 14 | 11 |
| III - 750 | 37 | 26 | 21 | 18 | 16 | 14 | 12 |
| V - 750 | 30 | 21 | 17 | 15 | 13 | 11 | 10 |
| VII - 750 | 52 | 37 | 30 | 26 | 23 | 20 | 16 |
| VIII - 750 | 18 | 13 | 11 | 9 | 8 | 7 | 6 |

Gleason's/Arthropoda

| | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| | 30 | 21 | 17 | 15 | 13 | 11 | 9 |
| | 34 | 24 | 20 | 17 | 15 | 13 | 11 |
| | 18 | 13 | 11 | 9 | 8 | 7 | 6 |
| | 74 | 52 | 43 | 37 | 33 | 28 | 23 |
| | 34 | 24 | 20 | 17 | 15 | 13 | 11 |

Shannon-Wiener/Mollusca

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 27 | 19 | 16 | 14 | 12 | 10 | 9 |
| III - 750 | 13 | 10 | 8 | 7 | 6 | 5 | 4 |
| V - 750 | 36 | 26 | 21 | 18 | 16 | 14 | 11 |
| VII - 750 | 26 | 18 | 15 | 13 | 12 | 10 | 8 |
| VIII - 750 | 22 | 15 | 13 | 11 | 10 | 8 | 7 |

Gleason's/Mollusca

| | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| | 55 | 39 | 32 | 26 | 25 | 21 | 18 |
| | 31 | 24 | 19 | 17 | 15 | 13 | 11 |
| | 25 | 18 | 15 | 13 | 11 | 10 | 8 |
| | 33 | 16 | 13 | 11 | 10 | 9 | 7 |
| | 45 | 31 | 25 | 22 | 20 | 17 | 14 |

Infaunal Trophic Index

| STATION/REP | 1 | 2 | 3 | 4 | 5 | 7 | 10 |
|---|---|---|---|---|---|---|---|
| II - 750 | 27 | 19 | 15 | 13 | 12 | 10 | 8 |
| III - 750 | 11.1 | 7.8 | 6.4 | 5.6 | 4.9 | 4.2 | 3.5 |
| V - 750 | 12.0 | 8.5 | 6.9 | 6.0 | 5.4 | 4.6 | 3.8 |
| VII - 750 | 23.5 | 16.6 | 13.6 | 11.7 | 10.5 | 8.9 | 7.4 |
| VIII - 750 | 21 | 15 | 12 | 10 | 9 | 8 | 7 |

October cruises mollusca species and arthropoda individuals showed the greatest variability (Figure 7.10). During the November and December sampling cruises arthropod species and individuals showed the largest inherent variation (Figure 7.11).

Overall the annelida and arthropoda species and individuals showed the widest ranges and the greatest degree of variation throughout all stations and all sampling periods (Figure 7.12). The summary diversity measures and the Infaunal Trophic Index values showed the narrowest ranges in variation and were either less than or comparable to all other types of biological measures made during this study (Table 7.3).

The optimum number of replicate samples required to increase the precision of a measurement without inordinately increasing the number of replicate samples at the sake of spatial coverage is summarized in Figure 7.13. The maximum and minimum variability observed at all stations for each of the biological parameters studied indicated that an overall sample number of four per station would provide the optimum precision in all cases. Previous information at this site also indicated that the optimum number of replicates for certain measurements or stations could be reduced to two samples per site if by previous information it could be shown that the degree of improved precision with additional replication, although showing improvement, would not improve that precision greatly.

### 7.4.2 Seasonal and Long Term Comparisons

The effect of seasonal variation on the abundance and the numbers and types of species in an area needs to be understood prior to assessing the potential effects of a perturbation to the environment (e.g., effluent disposal). Juvenile recruitment of invertebrates to the sediments and the survival of those individuals are both important facets of these types of

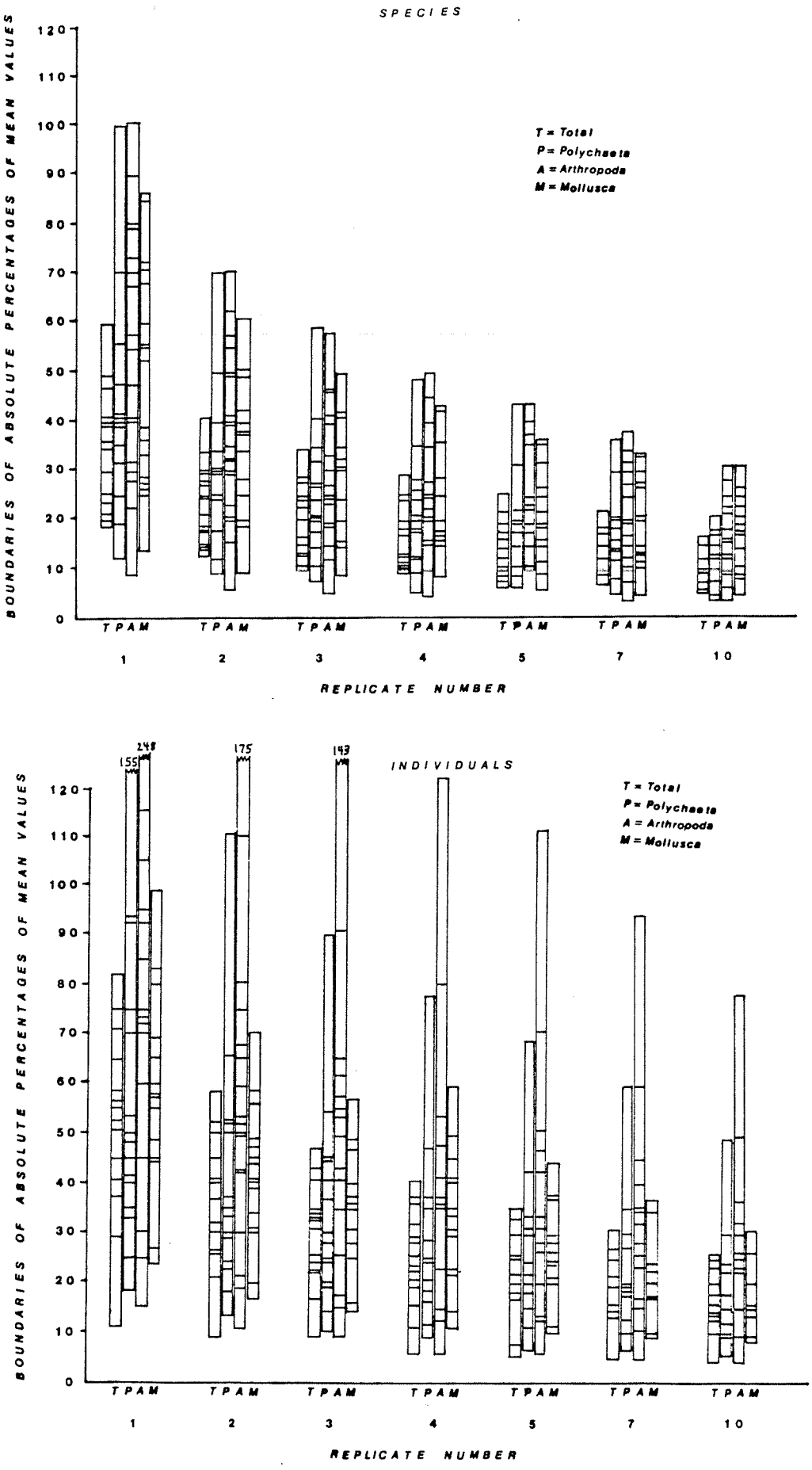



Fig. 7.12. Decrease in the absolute percentage of the maximum confidence limits around the mean value resulting from additional replications. Data collected from both METRO/TPPS and METRO/Baseline stations.

Table 7.3. Variability of diversities and infaunal trophic index values (mean/standard deviation).

| | II-750 | | | III-750 | | | V-750 | | | VII-750 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT |
| GLEASONS-DIVERSITY | | | ** | | | | | | ** | | | ** |
| Polychaeta | 3.51/.64 | 3.78/.21 | 3/82/.57 | 3/28/.46 | 4.39/1.09 | 3.18 | 4.19/.65 | 4.42/.54 | 3.04 | 3.14/.53 | 4/68/.93 | 3.52 |
| Mollusca | 1/51/.36 | 1.69/.22 | 1.58/.21 | 1.38/.20 | 1.90/.27 | 1.39 | 1.46/.16 | 1.64/.28 | 1.37 | 1.83/.18 | 2.12/.27 | 1.75 |
| Arthropoda | 2.66/.34 | 3.46/.55 | 2.71/1.05 | 2.10/.31 | 3.76/.56 | 3.60 | 3.07/.24 | 2.64/.99 | 1.71 | 2.30/.73 | 2.65/.41 | 2.95 |
| Echinodermata | -0- | .36/.72 | -0- | -0- | .86/.71 | -0- | .18/.36 | .82/.60 | -0- | .95/.34 | .67/.06 | -0- |
| Miscellaneous | -0- | .29/.24 | .41/.72 | -0- | 1.21/.90 | -0- | -0- | .72/.83 | 1.44 | .85/1.05 | 1.08/.72 | 1.44 |

| | VIII-750 | | | H-640*** | | | OT-1*** | | | OT-2*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAR | JULY | SEP/OCT | JUN/JUL | SEP/OCT | NOV/DEC | JUN/JUL | SEP/OCT | NOV/DEC | JUN/JUL | SEP/OCT | NOV/DEC |
| Polychaeta | 3.85/.41 | 3.74/.43 | 5.53 | 4.28/.71 | 4.05/.66 | 3.12/.23 | 3.56/.77 | 3.82/.60 | 3.51/.42 | 4.66/.27 | 4.46/.86 | 4.72/.72 |
| Mollusca | 1.16/.22 | 1.69/.11 | 2.24 | 1.69/.42 | 1.44/.45 | 1.36/.42 | 1.23/.19 | 1.05/.27 | 1.44/.20 | 1.31/.14 | 1/18/.50 | .94/.34 |
| Arthropoda | 2.30/.33 | 2.60/.75 | 2.26 | 4.15/1.07 | 2.35/.55 | 2.19/.63 | 3.19/.59 | 2.48/.45 | 2.27/.81 | 3.39/.83 | 2.67/.40 | 2.46/.35 |
| Echinodermata | 1.13/.37 | .12/.24 | -0- | .59/.37 | .41/.38 | .58/.79 | -0- | -0- | 1.22/.40 | .76/.52 | .65/.75 | .94/.59 |
| Miscellaneous | -0- | .90/.69 | 0.72 | .33/.45 | -0- | .12/.28 | -0- | -0- | .12/.28 | .50/.46 | -0- | .29/.64 |

| | II-750 | | | III-750 | | | V-750 | | | VII-750 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHANNON-WIENER | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT |
| | | | ** | | | | | | ** | | | * |
| Polychaeta | .987/.111 | 1.03/.005 | .880/.20 | .945/.082 | 1.07/.108 | 0.66 | 1.04/.088 | 1.04/.125 | 0.79 | .883/.127 | 1.15/.102 | 0.54 |
| Mollusca | .415/.049 | .378/.029 | .607/.031 | .450/.026 | .435/.055 | 0.36 | .450/.070 | .458/.108 | 0.53 | .555/.062 | .615/.095 | 0.58 |
| Arthropoda | .770/.120 | .883/.080 | .707/.154 | .580/.091 | .885/.066 | 0.91 | .673/.087 | .745/.108 | 0.74 | .640/.143 | .743/.132 | 0.85 |
| Echinodermata | -0- | .080/0.15 | -0- | -0- | .230/.150 | -0- | .08/.15 | .22/.14 | -0- | .21/.14 | .26/.05 | 0.30 |
| Miscellaneous | -0- | .07/.07 | .14/.24 | -0- | 0.30/.026 | -0- | -0- | .35/.09 | 0.3 | .19/.23 | .23/.15 | -0- |

| | VIII-750 | | | H-640*** | | | OT-1*** | | | OT-2*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAR | JULY | SEP/OCT | JUN/JUL | SEP/OCT | NOV/DEC | JUN/JUL | SEP/OCT | NOV/DEC | JUN/JUL | SEP/OCT | NOV/DEC |
| Polychaeta | 1.03/.167 | 1.01/.067 | 1.00 | 1.09/.07 | 1.09/.08 | .93/.04 | .96/.13 | 1.02/.08 | .96/.05 | 1.16/.04 | 1.09/.09 | 1.09/.11 |
| Mollusca | .555/.052 | .603/.087 | 0.45 | .68/.13 | .42/.06 | .45/.11 | .56/.04 | .30/.03 | .41/.08 | .81/1.2 | .22/.05 | .19/.02 |
| Arthropoda | .723/.057 | .732/.136 | 0.63 | 1.0/.07 | .81/.09 | .68/.11 | .88/.08 | .77/.13 | .76/.14 | .95/.11 | .81/.07 | .81/.07 |
| Echinodermata | .28/.23 | .06/.12 | -0- | .21/.13 | .14/.13 | .50/.21 | -0- | -0- | .34/.08 | .21/.12 | .19/.20 | .30/.19 |
| Miscellaneous | -0- | .21/.14 | 0.24 | .12/.16 | -0- | .04/.10 | .29/.04 | -0- | .06/.13 | .16/.15 | -0- | .06/.13 |

| | II-750 | | | III-750 | | | V-750 | | | VII-750 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT | MAR | JULY | SEP/OCT |
| ITI | | | ** | | | | | | ** | | | * |
| | 49.1 | 47.0 | 54.8 | 52.3 | 49.8 | 51.3 | 54.1 | 52.3 | 59.0 | 64.3 | 62.5 | 63.7 |

| | VIII-750 | | | H-640 | | | OT-1 | | | OT-2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAR | JULY | SEP/OCT | JUN/JUL | SEP/OCT | NOV/DEC | JUN/JUL | SEP/OCT | NOV/DEC | JUN/JUL | SEP/OCT | NOV/DEC |
| | | | * | | | | | | | | | |
| | 65.8 | 61.8 | 55.5 | 70.6 | 68.3 | 71.1 | 68.0 | 66.1 | 70.1 | 65.0 | 67.0 | 68.1 |

*** All stations with 5 reps Metro/Baseline
** II-880 3 reps, V-880 1 rep
* VII-800 1 rep, VIII-800 1 rep

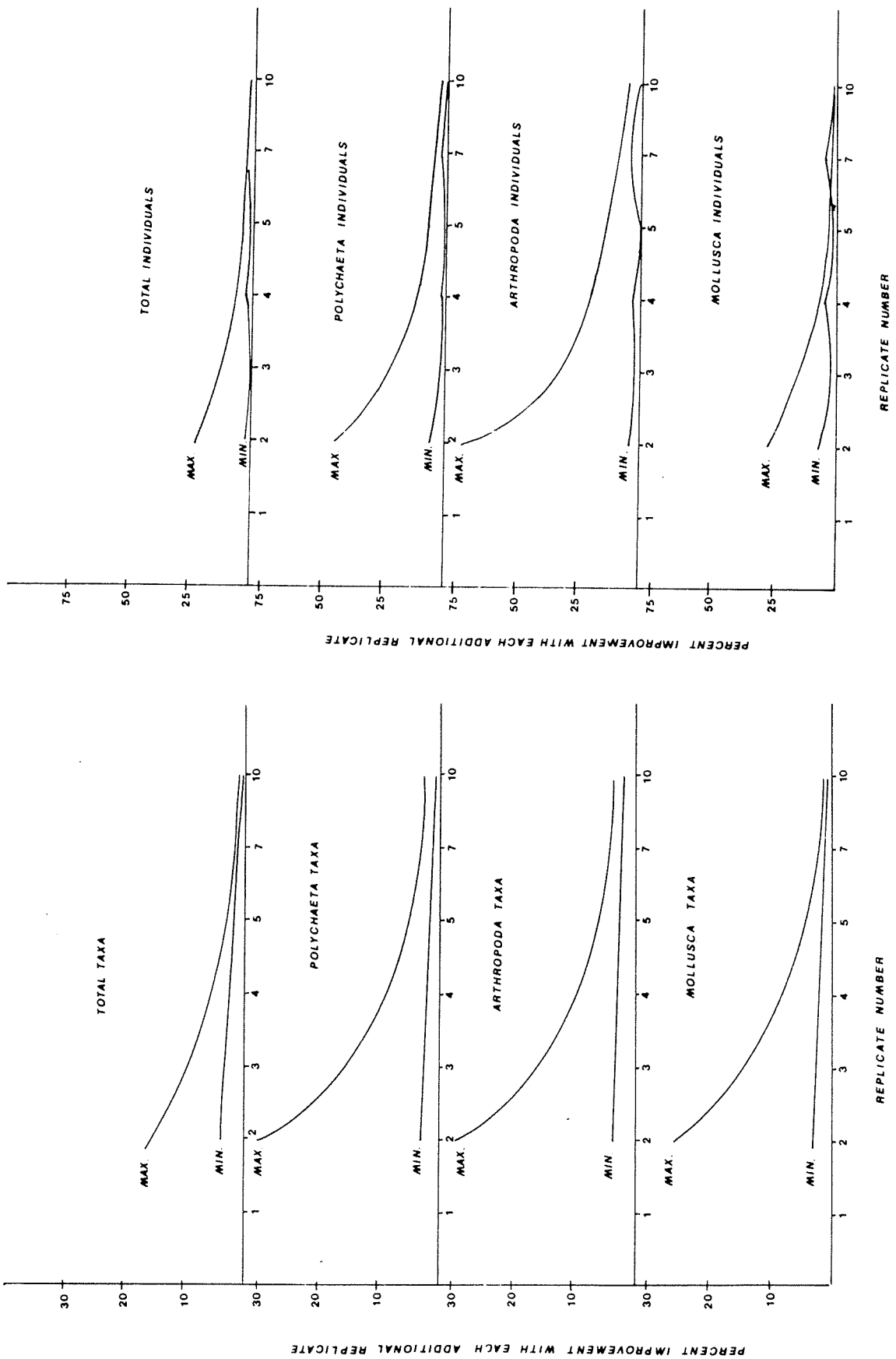



Figure 7.13. Percent improvement in decreasing variability with each additional replicate for the number of taxa and for the number of individuals.

studies. The Baseline survey has emphasized the latter of these two processes in its study of the south central Puget Sound area and as such has limited its examination of the sediments to the organisms collected on sieves with 1 mm mesh openings. It is recognized that sieves of smaller diameter will provide better estimates of juvenile settlement to a station but this selection also results in greater expense on a per sample basis. The greater per sample costs would limit the amount of spatial coverage of the study area which is believed to be necessary. Therefore, the analysis of the data presented during this first annual report will be based not on those organisms recruiting into the sediments but on those individuals that not only settled but survived that process and grew to a size that would allow their capture in the sieve sizes used.

In addition to the general question relating to seasonal cycles within a period of one year the Baseline program also examined the types of long term cycles through the use of a set of data collected by Dr. F. C. Nichols. His site, located just to the south of Three Tree Point was sampled between November 1969 and November 1970. These data allowed for a comparison between two specific points in time separated by nearly fifteen years.

The number of taxa and abundance in total and for each of the major taxonomic groups (annelida, arthropoda, mollusca) for the Nichols (1969-1970) study are summarized in Figure 7.14 b & b. The total number of taxa ranged from 17 in April to 29 in September and the abundance of organisms followed the same pattern with fewer individuals (30) in April and the most in September (127). The major taxonomic group responsible for the change in species through this time was the arthropoda. The abundance of organisms in the grab samples show a somewhat different trend in that the annelida show a statistically significant increase in abundance between July and September (a

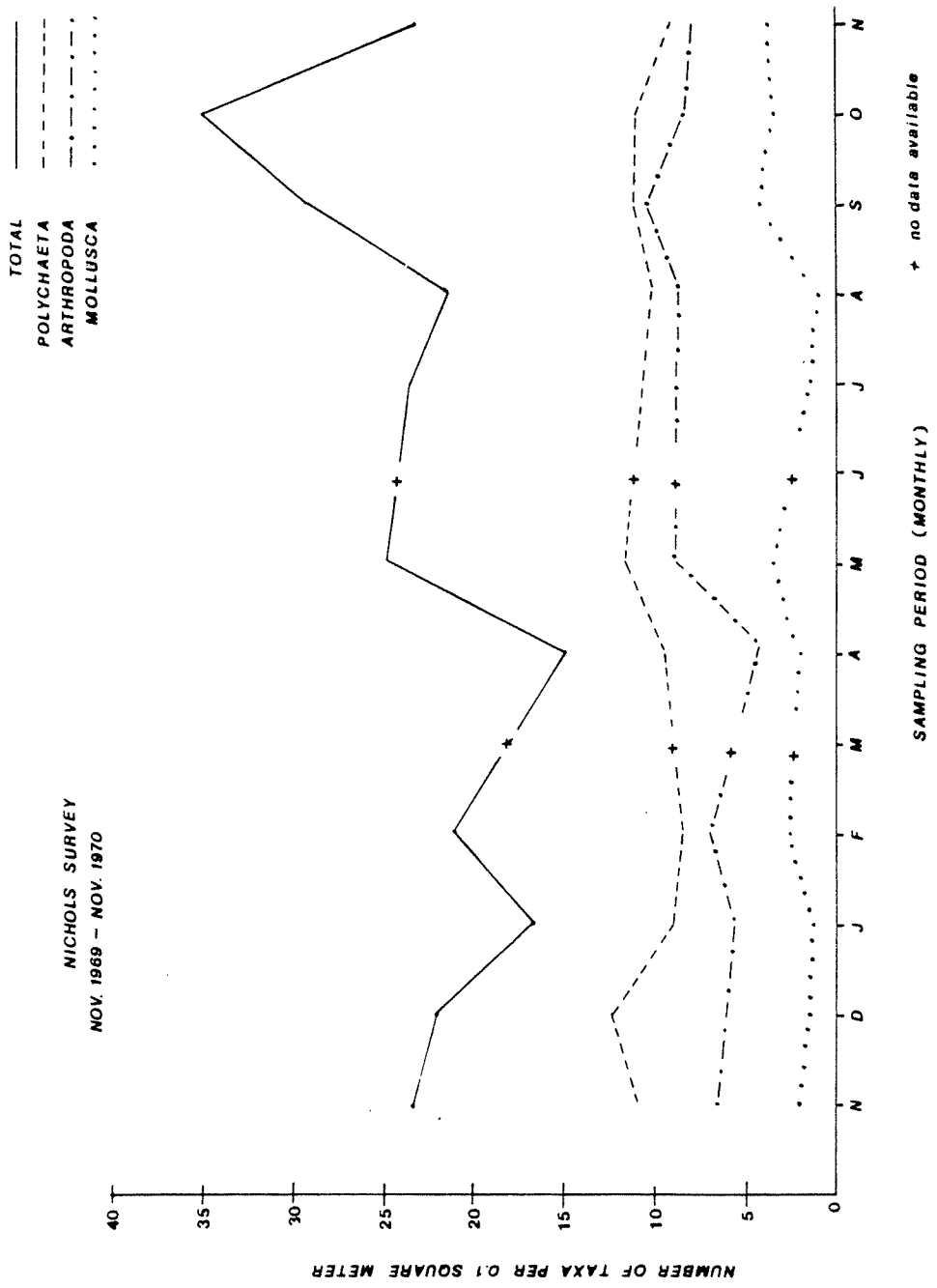



Figure 7.14a. Number of taxa in each major taxonomic group and for the total number of taxa for each sampling period.

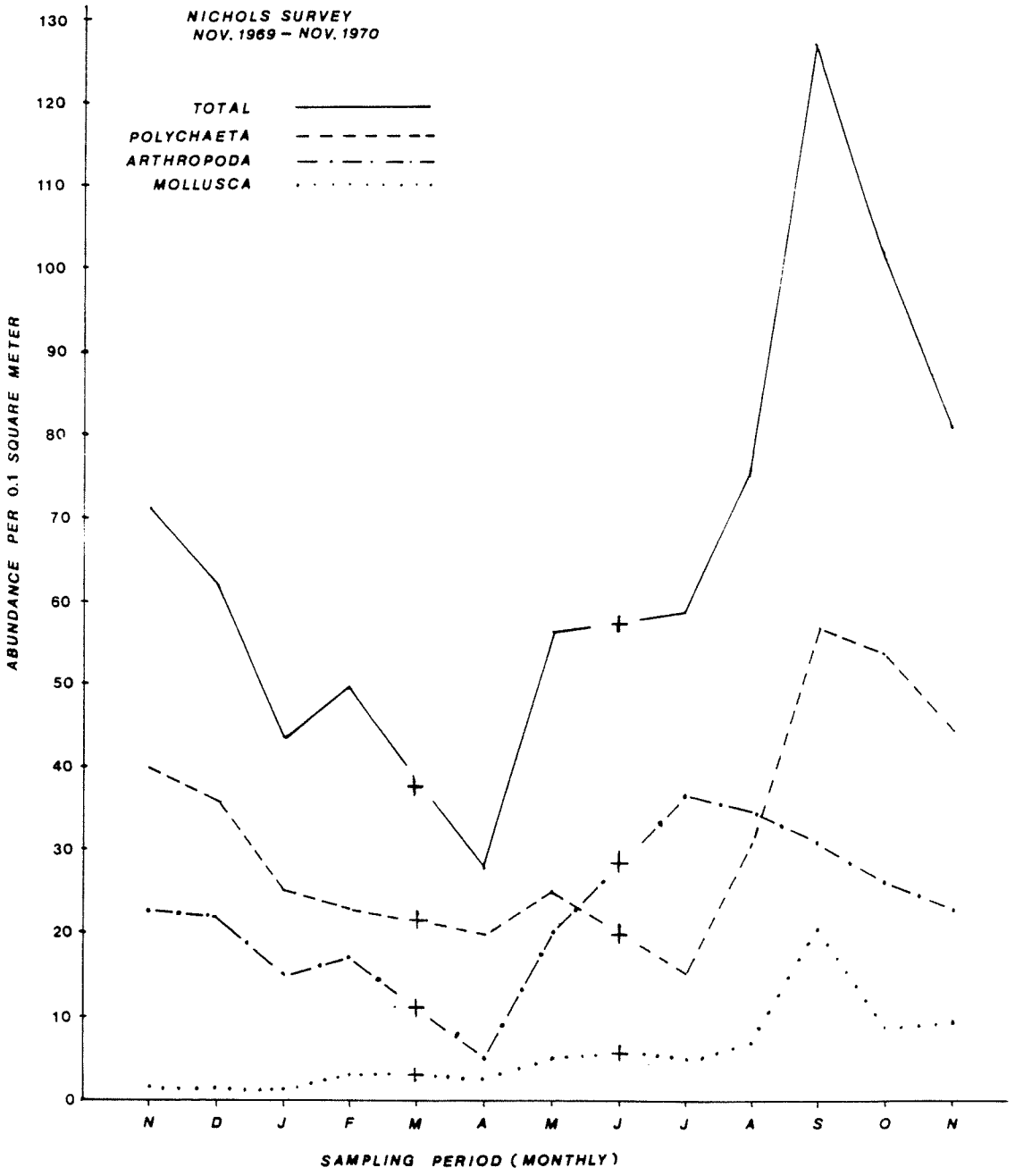



Figure 7.14b. Abundance of major taxonomic groups and for the total abundance for each sampling period.
+ no data available.

= 0.5, t = 6.8) as do the mollusca during the same period (a = .05, t = 5.7). The arthropoda show a different period of enhanced abundance with a gradual increase from April through July with decreases in abundance occurring after July. Infaunal Trophic Index values (Table 7.4) showed no statistically significant differences between the monthly sampling at this station. There was, however, a trend in the index values that indicate a decrease from highs during the summer to lows in the autumn (Figure 7.15).

Pectinaria californiensis (annelida) was the dominant organism during all but the July sampling period (Table 7.5). During this single period one of the normally less dominant, but still abundant arthropods, (Eudorellopsis integra) became most abundant. The dominant organisms show seasonal cyclings in relative abundance but the overall trends of the changes in total abundance of organisms at this station are the cycles in abundance of the annelid Pectinaria californiensis (Figure 7.16).

The Baseline sampling program reoccupied Nichols' original station in addition to sampling additional areas in south central Puget Sound. Baseline station H640 was located in the general vicinity of Nichols' station south of Three Tree Point. This station was sampled during June/July, Sept./Oct. and Nov./Dec., 1982 with five replications per sampling period. Table 7.6 presents the mean number of individuals and species for each of the major taxonomic units and the total number of species and individuals. The total number of species sampled during 1982 ranged from 45.8 in June/July to 28.4 in Nov/Dec which is a significant increase (a = .05, t = 6.25). The major taxa driving the increase in number of species are the arthropoda whose maximum species richness is in June and minimum in November, 1982 (Figure 7.17A). The figure on these results indicates that maximum species richness for arthropods occurs during the summer months with a fairly rapid decrease in species

Table 7.4. Infaunal trophic index values for the Nichols survey for each sampling period

| Date | ITI $\bar{x}$ | S.D. | C.V. | N |
|---|---|---|---|---|
| Nov. 69 | 70.9 | .78 | 1.10 | 3 |
| Dec. 69 | 71.2 | 2.15 | 3.02 | 3 |
| Jan. 70 | 72.5 | .64 | .89 | 3 |
| Feb. 70 | 70.6 | 1.32 | 1.87 | 3 |
| Apr. 70 | 73.2 | .14 | .19 | 2 |
| May 70 | 69.2 | 2.52 | 3.64 | 4 |
| Jul. 70 | 72.3 | 6.77 | 9.36 | 5 |
| Aug. 70 | 69.6 | 3.96 | 5.69 | 5 |
| Sept. 70 | 64.5 | 1.07 | 1.64 | 5 |
| Oct. 70 | 69.0 | 2.51 | 3.64 | 5 |
| Nov. 70 | 68.3 | 2.88 | 4.22 | 5 |

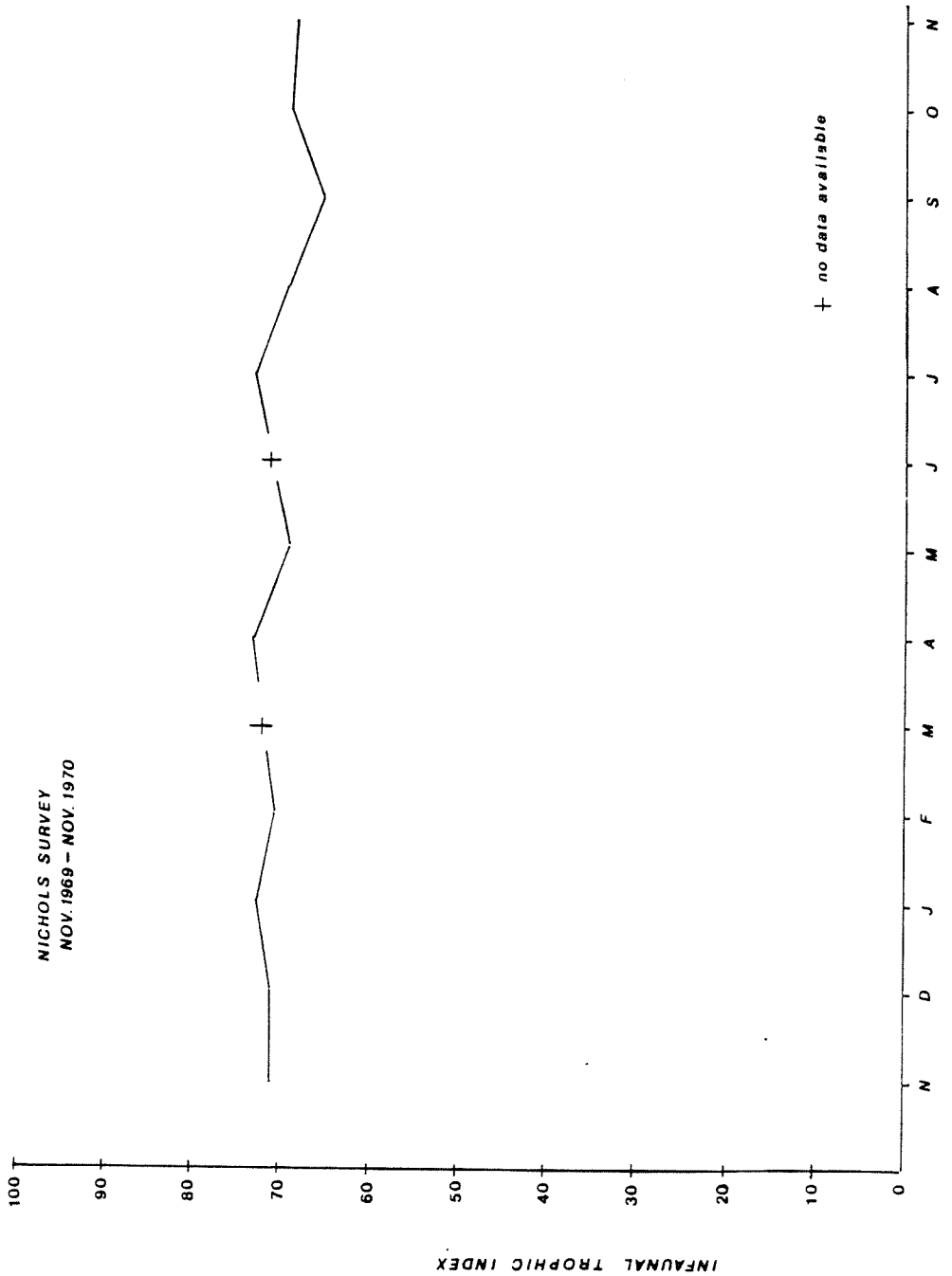



Figure 7.15. Graphical representation of I.T.I. values showing slight decrease from summer to fall.

Table 7.5. The four most abundant taxa for each sampling period, along with the mean abundance (see Table 7.1 for N values) and the percent of the total abundance each taxa represents.

| SAMPLING PERIOD | TAXA | MEAN ABUNDANCE | PERCENT OF TOTAL ABUNDANCE |
|---|---|---|---|
| NOV 69 | Pectinaria | 20 | 28.2 |
| | Eudorella | 9.3 | 13.1 |
| | Euphilomedes | 4 | 5.6 |
| | Prionospio cirrifera | 4 | 5.6 |
| DEC 69 | Pectinaria | 22 | 34.4 |
| | Euphilomedes | 8.7 | 13.6 |
| | Eudorella | 4.3 | 6.7 |
| | Paraphoxus | 3 | 4.7 |
| JAN 70 | Pectinaria | 11.3 | 25.1 |
| | Orchomene | 3.7 | 8.2 |
| | Euphilomedes | 3 | 6.7 |
| | Paraphoxus | 2.3 | 5.1 |
| FEB 70 | Pectinaria | 12 | 23.5 |
| | Euphilomedes | 5 | 9.8 |
| | Eudorellopsis | 2.7 | 5.3 |
| | Paraphoxus/Glycera | 2.3 | 4.5 |
| APR 70 | Pectinaria | 7.3 | 24.3 |
| | Glycera capitata | 2.7 | 9.0 |
| | Heterophoxus | 2 | 6.7 |
| | Euphilomedes | 1.5 | 5.0 |
| MAY 70 | Pectinaria | 11 | 19.6 |
| | Eudorellopsis | 5.5 | 9.3 |
| | Eudorella | 4 | 7.1 |
| | Euphilomedes | 3.3 | 5.9 |
| JUL 70 | Eudorellopsis | 8.8 | 14.4 |
| | Euphilomedes | 5.8 | 9.5 |
| | Eudorella | 5.2 | 8.5 |
| | Heterophoxus | 4.8 | 7.9 |
| AUG 70 | Pectinaria | 18.6 | 24.2 |
| | Euphilomedes | 8.8 | 11.4 |
| | Eudorella | 7.2 | 9.4 |
| | Macoma carlottensis | 6 | 7.8 |
| SEP 70 | Pectinaria | 41.2 | 32.4 |
| | Macoma carlottensis | 10.4 | 8.2 |
| | Euphilomedes | 8.6 | 6.8 |
| | Eudorella | 6.2 | 4.9 |
| OCT 70 | Pectinaria | 27.8 | 28.7 |
| | Euphilomedes | 8 | 8.3 |
| | Heterophoxus | 4.4 | 4.5 |
| | Protomedeia | 3.4 | 3.5 |
| NOV 70 | Pectinaria | 32.4 | 46.9 |
| | Macoma carlottensis | 6 | 8.7 |
| | Eudorella | 3.6 | 5.2 |
| | Heterophoxus | 3.2 | 4.6 |

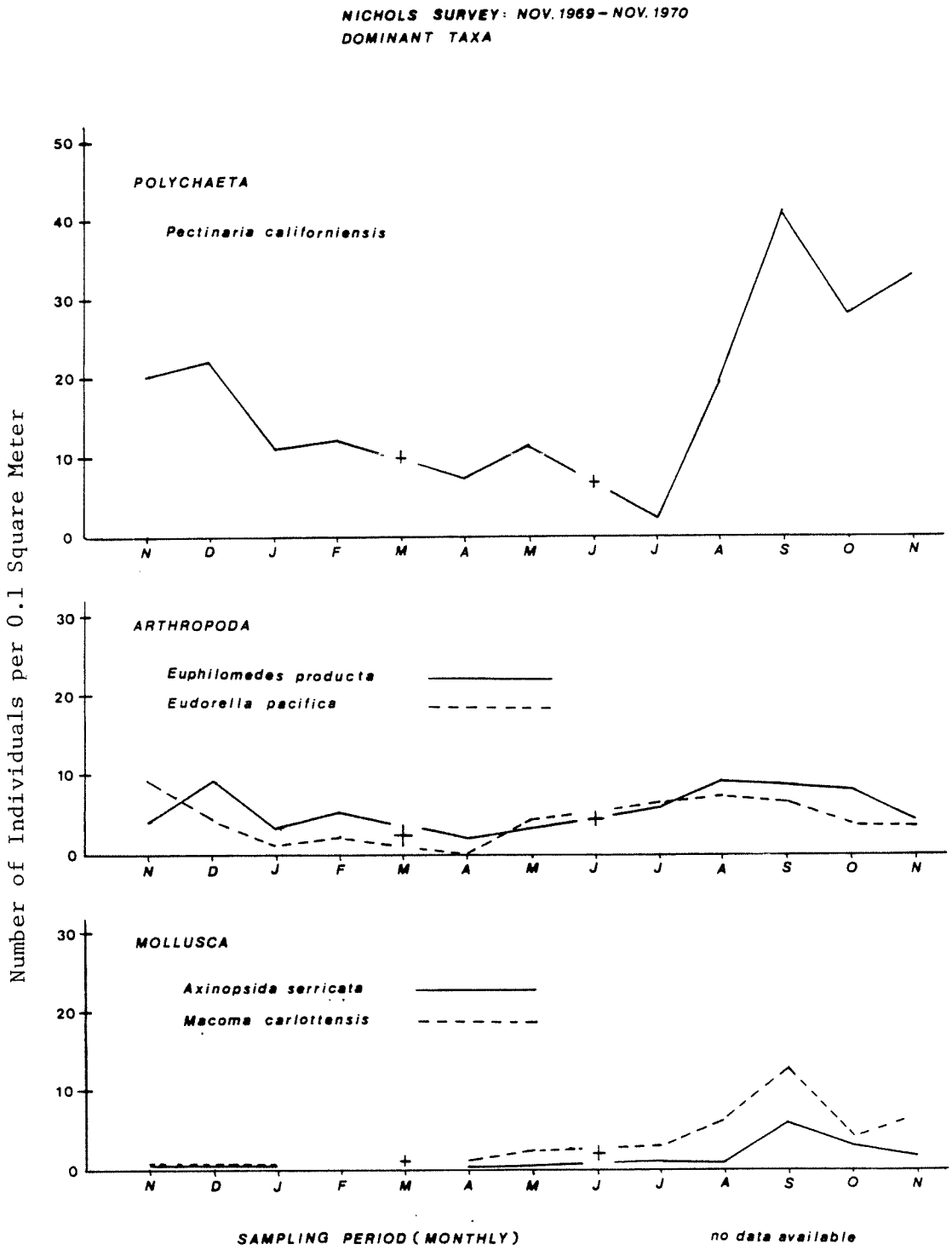



Figure 7.16. Abundance patterns of the dominant organisms in each major taxonomic group.

Table 7.6. Mean, S.D., C.V. of number of species and abundance for the total and major taxonomic groups at Metro/Baseline Station H-640. N = 5 in all cases.

| | June/July | | Sept./Oct. | | Nov./Dec. | |
|---|---|---|---|---|---|---|
| | Taxa | Abun. | Taxa | Abun. | Taxa | Abun. |
| Polychaeta | | | | | | |
| $\bar{x}$ | 17 | 49 | 15.6 | 37 | 12.2 | 37.6 |
| S.D. | 3.5 | 19.6 | 2.8 | 8.4 | 1.3 | 11.5 |
| C.V. | 21 | 28 | 17.9 | 22.6 | 11 | 31 |
| Arthropoda | | | | | | |
| $\bar{x}$ | 18.8 | 72.6 | 8.0 | 24.0 | 7.0 | 20.0 |
| S.D. | 6.4 | 32.9 | 2.0 | 16.3 | 3.0 | 21.3 |
| C.V. | 34 | 45 | 25 | 67.9 | 43 | 106 |
| Mollusca | | | | | | |
| $\bar{x}$ | 6.6 | 27.4 | 7.4 | 82.8 | 6.2 | 43.6 |
| S.D. | 1.7 | 6.6 | 2.3 | 15.6 | 1.8 | 12.1 |
| C.V. | 25 | 24 | 31.1 | 19 | 29 | 28 |
| TOTAL | | | | | | |
| $\bar{x}$ | 45.8 | 151 | 33.4 | 147.8 | 28.4 | 104.6 |
| S.D. | 6.8 | 34.7 | 7.02 | 40.5 | 5.0 | 32.1 |
| C.V. | 15 | 23 | 21.0 | 27.4 | 18 | 31 |

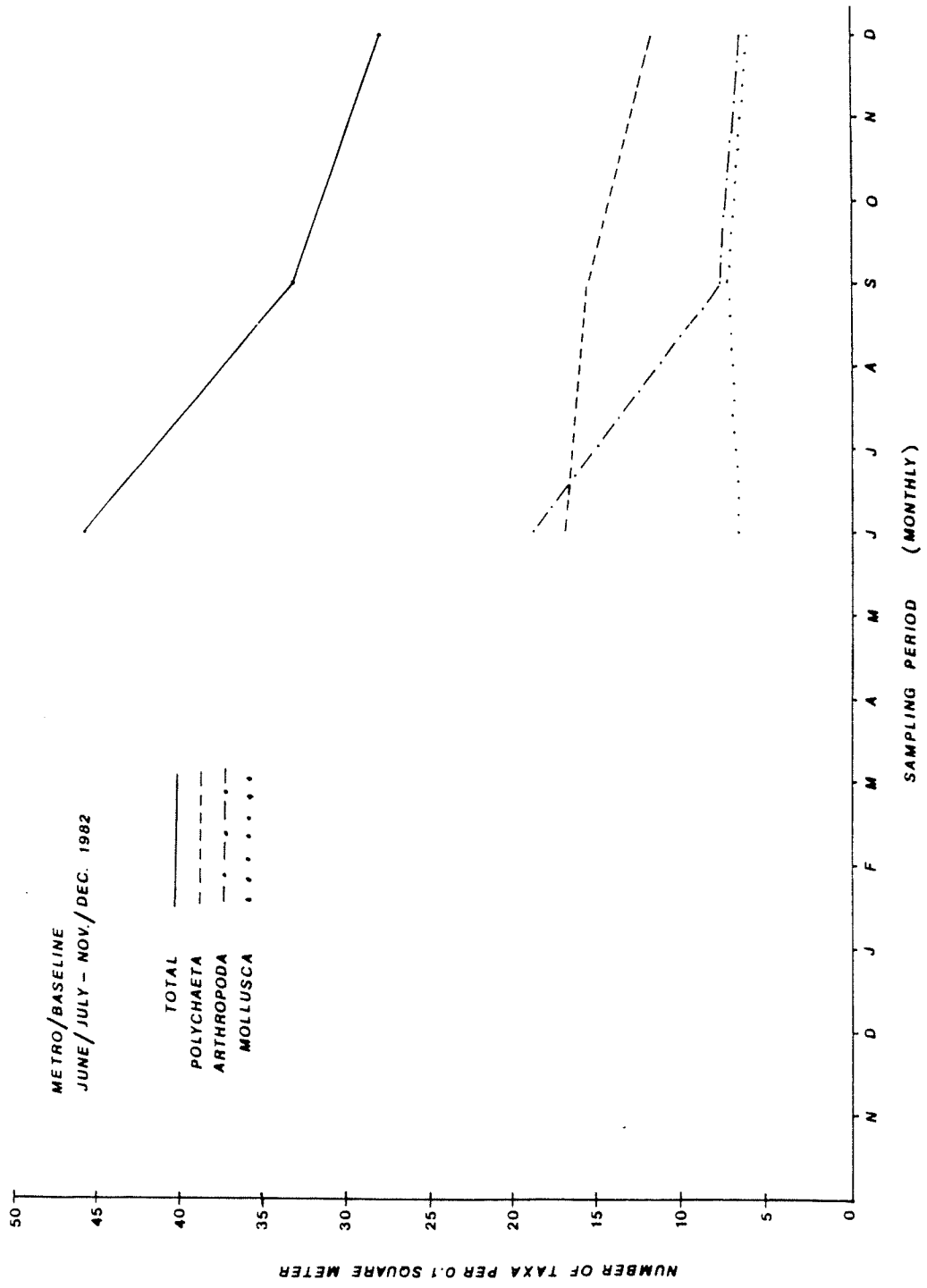



Figure 7.17a. Mean number of total taxa and the number of taxa in each major taxonomic group for Station H-640.

numbers during the autumn and winter.

The abundance of major taxa groups show somewhat different trends. Overall the maximum numbers of individuals at this station during 1982 occurred during the June through September periods of sampling with rapid declines decrease in total abundance by the Nov./Dec. sampling. The major taxa groups showed somewhat different trends. Mollusca were most abundant during the September samples while polychaetes and arthropods were most abundant during the summer periods (Figure 7.17b).

Table 7.7 provides data on three measures of community structure: the Infaunal Trophic Index, Shannon-Wiener's, and Gleason's Diversity measures. Both measurements of diversity show a downward trend from highs during June to lows during November. The Infaunal Trophic Index responds differently with low values during the autumn sampling period and comparable values during the summer and winter periods.

The most abundant organism during the June sampling period was a copepod of the genus Calanus (Table 7.8). Since these organisms are generally considered to be water column species it will not be considered in the rest of this presentation. Molluscs accounted for the majority of individuals in all sampling periods. During June an aplacophoran mollusc of the genus Chaetoderma represented the most abundant organism and accounted for 6% of the total number of individuals at this station, Axinopsida serricata, a small pelecypod accounted for 41.5 and 28.7% of the September and November samples, respectively. The most abundant polychaeta were Ampharete acutifrons in June and September, and Mediomastus spp. during the November/December samplings. The cumacean arthropods (Eudorellopsis and Eudorella) were most abundant in June and September while the amphipod Paraphoxus oculatus was the most dominant arthropod in November/December samples (Table 7.8).

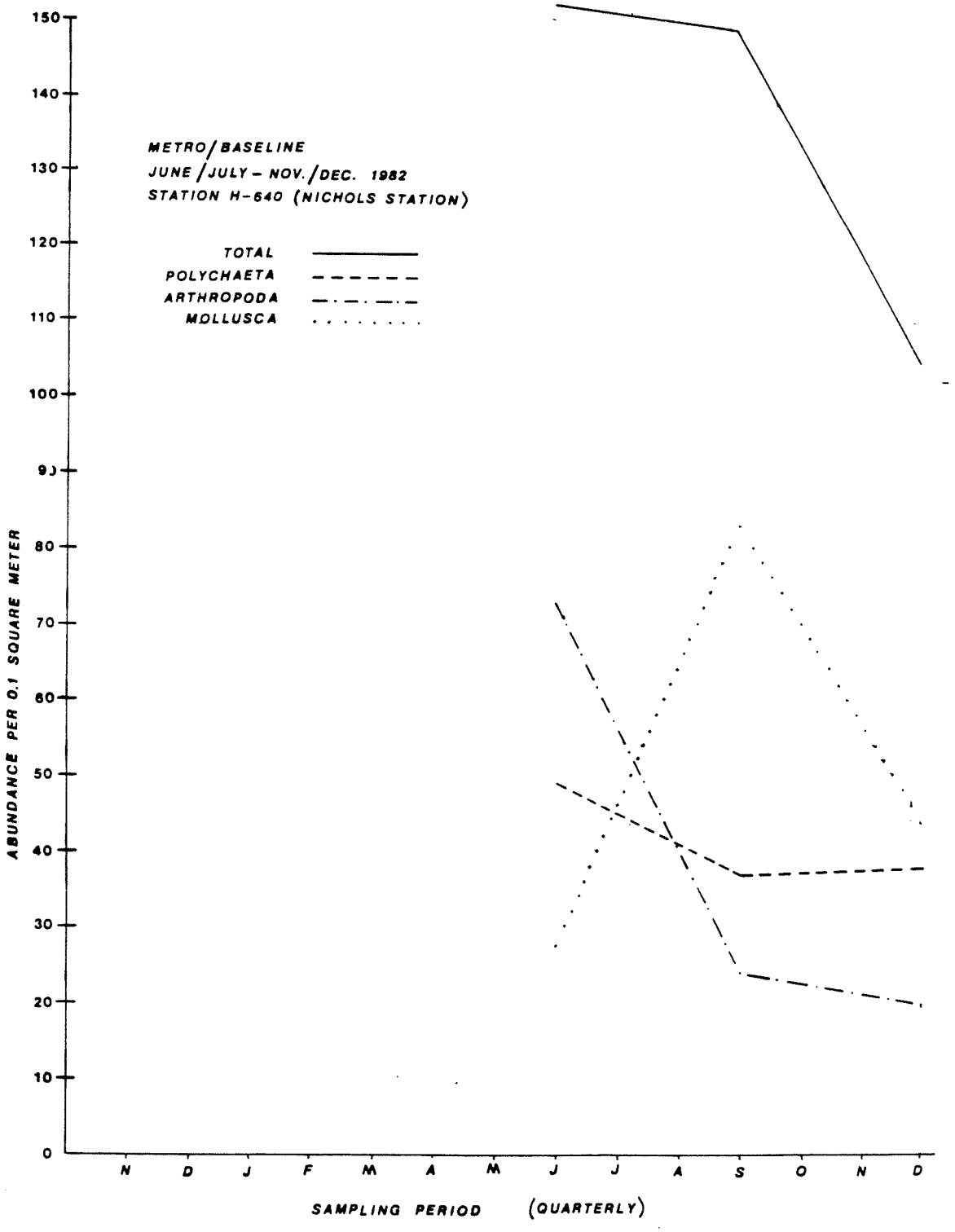



Figure 7.17b. Abundance: total and for each major taxa group at Station H-640.

Table 7.7. Infaunal trophic index values, Gleason's diversity and Shannon-Wiener's diversity for each sampling period of the METRO/Baseline Study.

| Measure | June | Sept. | Nov. |
|---|---|---|---|
| ITI | 70.6 | 68.3 | 71.1 |
| GLEASON'S DIVERSITY | | | |
| Polychaeta | 4.28 | 4.00 | 3.12 |
| Mollusca | 1.69 | 1.44 | 1.36 |
| Arthropoda | 4.15 | 2.35 | 2.19 |
| SHANNON-WIENER'S | | | |
| Polychaeta | 1.09 | 1.09 | .92 |
| Mollusca | .68 | .42 | .45 |
| Arthropoda | 1.02 | .81 | .68 |

Table 7.8. The four most abundant taxa for each sampling period along with the mean abundance and the percent of the total abundance each taxa represents (represents station H-640).

| Sampling period | Taxa | Mean abundance | Percent of total abundance |
|---|---|---|---|
| June 82 | Calanus* | 21 | 13.9 |
| | Chaetoderma | 9.4 | 6.2 |
| | Eudorellopsis | 8.4 | 5.6 |
| | Ampharete | 8.2 | 5.4 |
| | Tauberia | 7.4 | 4.9 |
| Sept. 82 | Axinopsida | 61.4 | 41.5 |
| | Ampharete | 7.2 | 4.9 |
| | Chaetoderma/Macoma carlottensis | 7 | 4.7 |
| | Eudorella | 5.8 | 3.9 |
| Nov. 82 | Axinopsida | 30 | 28.7 |
| | Mediomastus | 7.8 | 7.5 |
| | Paraphoxus/Spiophanes | 7.2 | 6.9 |
| | Ampharete | 5.6 | 5.4 |

The sampling design of the Baseline program not only included a replication of Dr. Nichols' station but also examined 21 other stations at depths exceeding 185 m (June 1982) and 22 stations at similar depths during the September and November periods. Three of these stations were replicated with five samples during each period while the others had two samples at each station during each period. This resulted in a total of 157 benthic samples to examine for the effects of seasonal variation during the first three quarters of sampling. The abundance and species richness in total and for each major taxonomic element are summarized in Table 7.9. In general the trends were for a decrease in species from June through Nov./Dec. (ANOVA P of F>3.71 is .029). The total abundance through time did not provide trends that were this clear. It is interesting to note that the maximum number of species during each of the sampling periods always occurred at station F600E which is situated on a rapidly sloping bottom offshore from Three Tree Point.

ANOVA tests were also run on the major taxa groups in order to determine which of the major groups were most responsible for the overall trends. The numbers of species of arthropods were most significant in showing different levels of species richness. They showed a highly significant decrease in abundance between June and Nov./Dec. sampling periods (P of F>24.211 is <.00001).

ANOVA tests on the abundance of major taxonomic groups indicated that arthopods showed a significant decrease from June through Nov./Dec. (P of F>19.7 is <0.0001) while the mollusca showed significant increases in abundance during the same period (P of F>2.74 = 0.073: Table 7.10). ANOVA analysis of the Infaunal Trophic Index values for the three quarterly METRO/Baseline sampling periods showed no significant differences. However, ANOVA analysis of Shannon-Wiener and Gleason's diversities did show a

Table 7.9. Number of taxa and abundance for each sampling period. Each represents a mean of 2 replicates except for stations H-640, OT-1 and OT-2 where 5 replicates were taken.

| SPP/IND | A600E JUNE | A600E SEPT | A600E NOV | A720 JUNE | A720 SEPT | A720 NOV | B600E JUNE | B600E SEPT | B600E NOV | B660 JUNE | B660 SEPT | B660 NOV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All taxa | 36.5/119.5 | 31/109.5 | 27/69 | 50.5/465.5 | 44/436.5 | 47/649 | 62/352.5 | 35/190 | 36.5/205.5 | 44.5/195.5 | 30/177 | 34.5/125.5 |
| Polychaeta | 13/18.5 | 12/16 | 13.5/20 | 18/37 | 18.5/51.5 | 21.5/81 | 25/63 | 14.5/27.5 | 15/36.5 | 12.5/28.5 | 11.5/25.5 | 14.5/22.5 |
| Arthropoda | 14.5/64.5 | 9.5/28.5 | 4/12 | 20/223 | 14/185 | 11/101 | 23/114 | 10/42 | 10/39 | 17.5/71.5 | 6.5/30 | 8/28 |
| Mollusca | 5/26 | 7/65.5 | 6.5/32 | 9/196.5 | 10.5/198.5 | 12.5/464 | 10.5/168 | 7.5/115 | 8/124.5 | 10/85 | 9/115.5 | 8.5/66.5 |
| Echinodermata | 2/7 | 1.5/2 | 2.5/4.5 | 0/0 | .5/1 | 0/0 | 2/2.5 | 1.5/3.5 | 1.5/1.5 | 2/7 | 2/5 | 1.5/3 |
| Miscellaneous | 2/3.5 | 1/1 | .5/.5 | 3.5/9 | .5/.5 | 2/3 | 1/5 | 1.5/2 | 2/4 | 2.5/3.5 | 1/1 | 2/5.5 |
| | C600E | | | C640 | | | D660 | | | E600E | | |
| All taxa | 40/176.5 | 37/236.5 | 31/238 | 46/198.5 | 25/110.5 | 34/68.5 | 40.5/179 | 35/188.5 | 30.5/155.5 | 76/411.5 | 51.5/3 3.5 | 46/310.5 |
| Polychaeta | 13/23 | 16/32 | 17/55.5 | 15/33.5 | 9/20 | 16/29.5 | 15/39 | 17.5/32 | 16/34 | 39.5/133 | 25/66 | 24/59.5 |
| Arthropoda | 14/62.5 | 12/28.5 | 6/24.5 | 20/100 | 7.5/17 | 8/16 | 15.5/53 | 11/20 | 4/15 | 19.5/109.5 | 12.5/58 | 9/21.5 |
| Mollusca | 8/78.5 | 6.5/170 | 5.5/152.5 | 6.5/46.5 | 7/73 | 7/63 | 7.5/80 | 8/131 | 7/101.5 | 11.5/153.5 | 9.5/247 | 9.5/234.5 |
| Echinodermata | 2.5/5 | 2/55 | 1.5/2.5 | 2.5/8 | 1/2 | 1.5/55 | 1/4 | 1.5/2.5 | 1.5/2 | 1/1.5 | 2.5/4 | 2/2.5 |
| Miscellaneous | 2.5/8.5 | .5/.5 | 1.0/3 | 2/105 | .5/1 | 1.5/2.5 | 1.5/3 | 2/3 | 2/3 | 4.5/14 | 2/3 | 1.5/2 |
| | E750 | | | F600E | | | F780 | | | G600E | | |
| All taxa | 70.5/320.5 | 51.5/294.5 | 44/387.5 | 100/565 | 98.5/401 | 108.5/410 | 62/291.5 | 55.5/336.5 | 59/414 | 73.5/324 | 59/197.5 | 65.5/237.5 |
| Polychaeta | 33/100 | 27.5/54 | 24/36.5 | 51/200 | 50.5/157.5 | 56.5/180.5 | 25/73.5 | 24/103 | 31.5/174.5 | 40/190.5 | 31/112 | 39.5/139.5 |
| Arthropoda | 20.5/115 | 13/56.5 | 10/47.5 | 27.5/121.5 | 27.5/64.5 | 24/73.5 | 20/68 | 15/76 | 11.5/38 | 16/58.5 | 11.5/22 | 9.5/17 |
| Mollusca | 12.5/94 | 9/179.5 | 8/284 | 12/137.5 | 11/85 | 12.5/80 | 13.5/143 | 12.5/152 | 11.5/190 | 10/57.5 | 11/51.5 | 11/72 |
| Echinodermata | 1.5/1.5 | 1.5/2 | .5/.5 | 3.5/19.5 | 2.5/15 | 4/22.5 | .5/.5 | 2.5/3.5 | 3/3.5 | 2.5/5.5 | 2/3 | 2/3.5 |
| Miscellaneous | 3/1.0 | 1/2.5 | 1.5/1.5 | 6/865 | 7/69 | 6.5/55.5 | 3/6.5 | 2.5/2 | 1.5/8 | 5/12 | 3.5/9 | 3/5.5 |
| | G780 | | | H600E | | | H640 | | | I600E | | |
| All taxa | 39/108 | 39/273 | 39/240 | 40.5/100.5 | 31.5/158 | 34.5/95 | 45.8/151 | 33.4/147.8 | 28/106 | 84/306 | 47/152 | 58.5/261.5 |
| Polychaeta | 18.5/46.5 | 18.5/53 | 16/44.5 | 15/34 | 15/38 | 18/46.5 | 17/43 | 15.6/37 | 12.2/37.6 | 37.5/127.5 | 26.5/67 | 36/141.5 |
| Arthropoda | 11.5/22 | 11/23 | 9/18 | 14/41 | 9.5/37.5 | 7/8.5 | 18.8/72.6 | 8/24 | 7.2/19.8 | 27/93.5 | 8/13 | 12/27 |
| Mollusca | 7/34.5 | 7/190.5 | 10.5/220.5 | 6.5/16.5 | 4.5/77 | 6/33 | 6.6/27.4 | 7.4/82.8 | 6.2/45 | 13/68.5 | 8/67 | 7/88 |
| Echinodermata | 1/2.5 | 2/5 | 1.5/3.5 | 1/1 | 1.5/3 | 1.5/3.5 | 2/4.6 | 1.6/3 | .8/1.8 | 2/2.5 | 2.5/3 | 1.5/1.5 |
| Miscellaneous | 1/2.5 | .5/.5 | 2/3.5 | 2/5 | 1/3 | 2/3.5 | 1.4/3.4 | .8/1 | 1.6/2.6 | 2.5/9 | 2/2.5 | 2/4.5 |
| | I690 | | | J600E | | | J690 | | | J.6500E | | |
| All taxa | 64/216.5 | 53/212.5 | 40/190 | 53/190.5 | 39/145 | 32/134.5 | 53/167.5 | 46/239.5 | 47/194.5 | 36/106 | 33/139.5 | |
| Polychaeta | 25.5/52 | 26/60 | 20.5/64 | 26.5/83 | 21.5/41 | 21/54 | 24/58 | 22.5/55 | 22.5/63 | 16/40 | 17.5/27.5 | |
| Arthropoda | 23.5/96.5 | 14/50 | 9/28.5 | 16.5/58.5 | 6.5/11 | 5.5/10.5 | 18/71.5 | 14.5/61.5 | 13/32.5 | 10/17.5 | 8.5/23 | |
| Mollusca | 10.5/54.5 | 9/92.5 | 7.5/91 | 7.5/40 | 7.5/87.5 | 4.8/69 | 6.5/31 | 6/115.5 | 7.5/94 | 7.5/51 | 5.5/87 | |
| Echinodermata | 1.5/3 | 2/3 | 1/1 | 2/2.5 | 2.5/4.5 | .5/.5 | 1.5/3 | 2.5/3.5 | 2/2.5 | 1/4 | 1/1.5 | |
| Miscellandous | 3/10.5 | 2/7 | 2/4.5 | 4.5/16 | 1/1 | .5/.5 | 3/4 | 2.5/4 | 1.5/2.5 | 1.5/2.5 | .5/.5 | |
| | OT-1 | | | OT-2 | | | | | | | | |
| All taxa | 34.2/117.8 | 27.8/119.2 | 30.6/126.6 | 39.2/225.8 | 35.6/250 | 36.8/333.2 | | | | | | |
| Polychaeta | 12.8/30 | 12.4/19.5 | 12.6/27.4 | 16.6/29.2 | 17.6/45.4 | 20/55 | | | | | | |
| Arthropoda | 13.2/49.8 | 8.2/18 | 7.6/17.8 | 11.4/21.2 | 8.8/20.2 | 8.2/19 | | | | | | |
| Mollusca | 5.2/28.4 | 5.8/98.4 | 7.2/75.6 | 7.6/167.8 | 7.2/184.4 | 6.2/251.2 | | | | | | |
| Echinodermata | .8/1 | 1/3.2 | 24/3.6 | 1.8/2.8 | 1.6/2.4 | 2.0/2.6 | | | | | | |
| Miscellaneous | .8/2.6 | .4/.4 | 1.2/2.2 | 1.8/4.8 | .4/1.4 | 1.2/2.4 | | | | | | |

Table 7.10. ANOVA analysis of the number of species and abundance of arthropoda, and the abundance of mollusca during three METRO/Baseline sampling periods.

| Sampling period | Mean | Variance | Range |
|---|---|---|---|
| ARTHROPODA: NUMBER OF SPECIES | | | |
| June/July | 18.119 | 21.681 | 11.4 - 27.5 |
| Sept./Oct. | 11.296 | 19.715 | 6.5 - 27.5 |
| Nov./Dec. | 9.182 | 16.433 | 4.0 - 24.0 |
| F calc: 24.211 | F critical $\alpha(2).05 = 3.93$ | | |
| (P of F >24.211 is <0.00001) | | | |
| ARTHROPODA: ABUNDANCE | | | |
| June/July | 80.67 | 1867.67 | 21.2 - 223 |
| Sept./Oct. | 33.51 | 367.39 | 13 - 76 |
| Nov./Dec. | 28.98 | 467.10 | 8.5 - 101 |
| F calc: 19.74 | F critical $\alpha(2).05 = 3.93$ | | |
| (P of F >19.74 is <0.00001) | | | |
| MOLLUSCA: ABUNDANCE | | | |
| June/July | 81.00 | 2927.16 | 16.5 - 196.5 |
| Sept./Oct. | 119.55 | 2992.07 | 51.0 - 247.0 |
| Nov./Dec. | 132.67 | 10837.92 | 32.0 - 464.0 |
| (P of F >2.74 is 0.0726) | | | |

significant difference (Table 7.11). Gleasons arthropod diversity gave a calculated F = 23.3., F (critical) = (2), .05 = 3.93 and Shannon-Wiener mollusca and arthropoda diversities gave F values of 9.31 and 12.33 respectively. The critical value of F is the same as above (Table 7.10).

Dominant taxa at all stations during each of the sampling periods were examined in order to detect changes in the numerical importance of key species (Table 7.12). This table summarizes the numbers of samples that each of the species were most abundant in total taxa or major taxa groups. Several dominant trends can be seen from this data. In all cases the most dominant taxa were either Axinopsida serricata or Macoma carlottensis (both pelecypoda). These two species patterns of dominance were split nearly equally during the June sampling period but Axinopsida serricata dominated most of the samples during September and December samplings. Within major taxa groups the dominant annelida were Ampharete acutifrons, Cossura spp., Mediomastus californiensis, Spiophanes berkeleyorum, Tauberis gracilis, Pectinaria californiensis, and several species of Nephtys. The dominant arthropods were the water column copepod Calanus, the cumaceans Eudorella pacifica Eudorellopsis integra, the ostracod Euphilomedes producta, and the amphipods Bathymedon, Harpiniopsis fulgens, Paraphoxus and Heterophoxus oculatus. In addition to the two mollusca discussed above Chaetoderma spp., Bittium spp. and Nucula tenuis were the most abundant taxa present at least once during the survey.

The data set taken for the METRO/TPPS survey, consisting of samples at depths greater than 185 m near the West Point sewage effluent discharge pipes, are summarized in Table 7.13. Samples were taken in September/October 1981 and again in March and July 1982. The total number of taxa was greatest during September/October 1981 than in the March and July 1982 sampling periods

Table 7.11. ANOVA analysis of Gleason's diversity for the anthropoda and Shannon-Wiener's diversity for the arthropoda and the mollusca, showing sign differences.

SHANNON-WIENER'S DIVERSITY

ARTHROPODA

| Parameter | June/July | Sept/Oct | Nov/Dec | Fcalc | Fcrit$\alpha$(2).05 |
|---|---|---|---|---|---|
| $\bar{x}$ | 0.98 | 0.84 | 0.76 | 12.33 | 3.93 |
| S.D. | 0.08 | 0.15 | 0.19 | | |
| N | 21 | 22 | 22 | | |

MOLLUSCA

| | | | | | |
|---|---|---|---|---|---|
| $\bar{x}$ | 0.64 | 0.47 | 0.46 | 9.31 | 3.93 |
| S.D. | 0.14 | 0.16 | 0.16 | | |
| N | 21 | 22 | 22 | | |

GLEASON'S DIVERSITY

ARTHROPODA

| Parameter | June/July | Sept/Oct | Nov/Dec | Fcalc | Fcrit$\alpha$(2).05 |
|---|---|---|---|---|---|
| $\bar{x}$ | 4.03 | 2.98 | 2.41 | 23.31 | 3.93 |
| S.D. | 0.73 | 0.98 | 0.61 | | |
| N | 21 | 22 | 22 | | |

Table 7.12. Dominant taxa at all stations sampled during the three quarterly Metro/Baseline sampling periods. Dominance (DOM) refers to the numerically dominant taxa in the sample. Codominant (COD) refers to the number of times that taxa shares dominance with another taxa.

| | June/July | | Sept/Oct | | Nov/Dec | |
|---|---|---|---|---|---|---|
| | DOM | COD | DOM | COD | DOM | COD |
| OVERALL DOMINANT TAXA | | | | | | |
| Axinopsida serricata | 15 | 1 | 47 | 1 | 45 | 1 |
| Macoma carlottensis | 14 | 1 | 4 | 1 | 3 | |
| Calanus sp. | 12 | | | | | |
| Eudorellopsis integra | 3 | 1 | | | | |
| Tauberia gracilis | 1 | 1 | | | | |
| Mediomastus californiensis | 2 | | 1 | | 2 | |
| Spiophanes berkeleyorum | 1 | | | | | |
| Ampharete acutifrons | 1 | | 1 | | | |
| Eudorella pacifica | 1 | | | | | |
| Euphilomedes producta | 1 | | 1 | | 1 | |
| Bathymedon spp. | 1 | | | | | |
| Nucula tenuis | | | | | 1 | |
| POLYCHAETA | | | | | | |
| Ampharete acutifrons | 15 | 2 | 30 | 4 | 30 | 2 |
| Cossura sp. | 10 | 1 | 6 | 5 | | |
| Mediomastus californiensis | 10 | 3 | 7 | 2 | 7 | |
| Spiophanes berkeleyorum | 8 | 3 | 2 | 2 | 14 | 3 |
| Tauberia gracilis | 6 | 1 | 8 | 1 | 1 | |
| Pectinaria californiensis | 4 | 2 | 6 | 1 | 4 | 3 |
| Nephtys spp. | 2 | 1 | 1 | 1 | 1 | |
| ARTHROPODA | | | | | | |
| Calanus sp. | 24 | 2 | | | | |
| Eudorella pacifica | 10 | 3 | 17 | 3 | 13 | 5 |
| Euphilomedes producta | 8 | | 21 | 2 | 22 | 4 |
| Eudorellopsis integra | 8 | 2 | 5 | 2 | 9 | 5 |
| Bathymedon spp. | 2 | | | | 1 | 1 |
| Harpiniopsis fulgens | 2 | 2 | 4 | | 7 | 2 |
| Paraphoxus oculatus | 1 | 1 | 2 | | 9 | 2 |
| Heterophoxus oculatus | | | 6 | 1 | 6 | 4 |
| MOLLUSCA | | | | | | |
| Axinopsida serricata | 24 | 3 | 48 | 1 | 47 | |
| Macoma carlottensis | 22 | 2 | 5 | 1 | 5 | |
| Chaetoderma spp. | 3 | 1 | | | | |
| Bittium spp. | 1 | | | | | |
| Nucula tenuis | | | | | 1 | |

Table 7.13. Mean number of taxa and mean abundance for three METRO/TPPS sampling periods ($\bar{x}$ of four reps except where indicated by an asterisk which were single samples).

| Sampling period | Taxa | II - 750 # Species | II - 750 Abun. | III - 750 # Species | III - 750 Abun. | V - 750 # Species | V - 750 Abun. | VII - 750 # Species | VII - 750 Abun. | VIII - 750 # Species | VIII - 750 Abun. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept/Oct 1981 | Total | 39.7 | 431 | *43 | 518 | *33 | 327 | *44 | 359 | *55 | 549 |
| | Polychaeta | 15.7 | 38.7 | 15 | 82 | 13 | 52 | 16 | 71 | 28 | 132 |
| | Arthropoda | 12.3 | 71 | 18 | 113 | 9 | 107 | 15 | 116 | 11 | 84 |
| | Mollusca | 10 | 299 | 9 | 322 | 8 | 164 | 10 | 169 | 14 | 329 |
| | Echino | .33 | .33 | -0- | -0- | 1 | 2 | 1 | 1 | -0- | -0- |
| | Misc. | 1.3 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 4 |
| March 1982 | Total | 33.3 | 243.5 | 31.3 | 325.8 | 41.0 | 275.0 | 33.8 | 157 | 29.8 | 113.0 |
| | Polychaeta | 12.8 | 28.3 | 13.0 | 39.0 | 16.8 | 43.3 | 12.0 | 34.3 | 12.8 | 21.0 |
| | Arthropoda | 11.0 | 43.0 | 9.5 | 57.5 | 13.3 | 57.5 | 9.8 | 46.3 | 9.3 | 40.5 |
| | Mollusca | 8.8 | 171.8 | 8.5 | 228.8 | 8.5 | 171.3 | 8.8 | 71.5 | 5.5 | 48.5 |
| | Echino | .3 | .3 | .25 | .50 | 1 | 1.3 | 2.0 | 3.3 | 2.0 | 2.8 |
| | Misc. | .50 | .50 | -0- | -0- | 1.3 | 1.8 | 2.3 | 2.8 | .3 | .3 |
| July 1982 | Total | 48.3 | 750 | 54.3 | 583.5 | 44.0 | 427 | 46.5 | 269.3 | 37.3 | 221.0 |
| | Polychaeta | 14.0 | 33.0 | 17.3 | 40.5 | 17.5 | 42.3 | 19.3 | 50.3 | 12.5 | 22 |
| | Arthropoda | 20.5 | 292.3 | 20.8 | 202.3 | 13.3 | 103.3 | 12.5 | 80.0 | 12.8 | 89.0 |
| | Mollusca | 11.0 | 391.0 | 12.0 | 327.8 | 10.0 | 252.5 | 11.3 | 132.8 | 27.0 | 102.0 |
| | Echino | .8 | .8 | 1.8 | 10.0 | 1.8 | 2.3 | 2.0 | 4.5 | 1.3 | 5.3 |
| | Misc. | 2.0 | 33.0 | 2.5 | 3.0 | 1.5 | 1.8 | 1.8 | 1.8 | 2.0 | 2.8 |

Stations II, III, V, VII, and VIII - 750 were not sampled in Sept/Oct 1981. Data from the following stations was substituted for the missing data after anova analysis indicated no significant difference between the 600' station and the 880' station on the appropriate transect.

| | | |
|---|---|---|
| V - 880 | for | V - 750 |
| VII - 800 | for | VII - 750 |
| VIII - 800 | for | VIII - 750 |

but the differences in the number of taxa were not significant (F = 2.6; Fc = 4.32) Table 7.14 at the .05 level. The abundance of organisms at these same stations were also not significantly different (F = 3.19). The number of species and individuals was lower during the March period of sampling than in either of the other two periods. Arthropoda and polychaeta abundance were the only major taxa groups that showed significantly different values during the three sampling periods (F = 4.56 and F = 5.46, respectively) (Table 7.14).

Comparison of samples taken during the Baseline and METRO/TPPS surveys showed that there were no significant differences in the mean number of taxa at a station (F = 0.26) (Table 7.15), but that there were significantly greater numbers of individuals collected from the West Point than the south Sound areas (F = 32.05). These differences in total abundance were indicated in all three major taxonomic groups (annelida, arthropoda, and mollusca). Mollusca accounted for the majority of the significant differences between the West Point area and the south Sound followed by arthropoda and polychaeta (F = 38.67, 13.86, and 4.05, respectively) (Table 7.15).

Long Term Comparison

Definite changes have occurred in the structure of the benthic infaunal community at the Nichols/Baseline Station H-640 during the past 13 years. There are significantly more invertebrate taxa living in the sediments at the present time than during the 1969-1970 sampling periods (Table 7.15). A sign test shows that the direction of this change is highly significant during all comparable sampling periods. Individual comparisons between each pair of sampling periods shows that the June/July and November/December samplings are significantly different and the September/October and the February/March periods are not.

The majority of species responsible for this greater number are in the

Table 7.14. ANOVA analysis of METRO/TPPS data for the three sampling periods.

| | | Sept/Oct | Mar | July | Fcalc | Fcrit (2).05 |
|---|---|---|---|---|---|---|
| TOTAL | | | | | | |
| Taxa | $\bar{x}$ | 52.6 | 33.8 | 46.0 | 2.60 | 4.32 |
| | S.D. | 19.6 | 4.3 | 6.2 | | |
| Abundance | $\bar{x}$ | 436.5 | 223.0 | 450.2 | 3.19 | 4.32 |
| | S.D. | 176.2 | 86.9 | 220.1 | | |
| POLYCHAETA | | | | | | |
| Taxa | $\bar{x}$ | 17.6 | 13.6 | 16 | 1.28 | 5.26 |
| | S.D. | 5.9 | 1.9 | 2.9 | | |
| Abundance | $\bar{x}$ | 75.2 | 33.0 | 37.6 | 5.46 | 5.26 |
| | S.D. | 35.8 | 8.8 | 10.6 | | |
| ARTHROPODA | | | | | | |
| Taxa | $\bar{x}$ | 13.0 | 10.6 | 16.2 | 3.48 | 5.26 |
| | S.D. | 3.5 | 1.5 | 4.4 | | |
| Abundance | $\bar{x}$ | 98.2 | 49.2 | 153.4 | 4.56 | 5.26 |
| | S.D. | 19.7 | 8.2 | 92.1 | | |
| MOLLUSCA | | | | | | |
| Abundance | $\bar{x}$ | 256.6 | 138.6 | 241.4 | 2.22 | 5.26 |
| | S.D. | 83.0 | 75.3 | 123.7 | | |

Table 7.15. ANOVA analysis between north sound and south sound for two seasonal periods. October and July - TPPS, September and June - Baseline.

| | TPPS | Baseline | Fcalc | Fcrit α(2).05 | Significance |
|---|---|---|---|---|---|
| TOTAL | | | | | |
| Taxa | | | | | |
| $\bar{x}$ | 51.09 | 48.74 | 0.26 | 5.29 | N.S. |
| S.D. | 17.58 | 17.63 | | | |
| Abundance | | | | | |
| $\bar{x}$ | 439.54 | 234.60 | 32.05 | 5.29 | Highly significant |
| S.D. | 181.43 | 110.29 | | | |
| POLYCHAETA | | | | | |
| Abundance | | | | | |
| $\bar{x}$ | 90.86 | 60.49 | 4.05 | 5.29 | N.S. |
| S.D. | 77.42 | 44.47 | | | |
| ARTHROPODA | | | | | |
| Abundance | | | | | |
| $\bar{x}$ | 110.99 | 60.26 | 13.86 | 5.29 | Highly significant |
| S.D. | 64.12 | 44.68 | | | |
| MOLLUSCA | | | | | |
| Abundance | | | | | |
| $\bar{x}$ | 221.68 | 101.50 | 38.67 | 5.29 | Highly significant |
| S.D. | 98.14 | 57.77 | | | |

polychaeta and mullusca taxa groups. Significantly greater numbers of polychaeta species were present in three of the four sampling periods, while molluscan species were more prevalent during all four of the sampling periods. Arthropoda taxa were more abundant during three of the four sampling periods but this pattern was only significant during the June/July period. In the majority of circumstances the numbers of echinoderm and other phyla were not significantly different (Table 7.16).

Sign tests show that there is a statistically significant trend towards more individuals in the present Baseline samples than in Nichols 1969-1970 samplings at the same stations. Mollusca represented the majority of increases in abundance while polychaeta represented another group of species showing significant trends in both directions (Table 7.17). Mollusca were significantly more abundant during all sampling periods while polychaeta were more abundant during June/July, less abundant during September/October, and not significantly different in the remainder of Baseline samplings. Arthropoda were not significantly different in abundance between the two sampling periods when taxa which live in the water column were removed from the data. There were no general trends in the abundance of all echinoderms or other phyla between the two sampling periods. The low abundance of these two groups contributed very little to the total abundance of organisms at this station. Two large echinoderms (Brisaster latifrons and Molpadia intermedia) were important to the biomass of the stations and their patterns of abundance were examined in more detail.

Polychaeta responsible for the differences in abundance of this major taxa group were divisible into two groups. Pectinaria spp. and Glycera capitata were more abundant during the 1969-1970 surveys while Ampharete spp., Cossura sp., Mediomastus spp., Tauberia gracilis, Spiophanes spp., and Laonice

Table 7.16. Table of means and F values comparing the total taxa and the number of taxa in each major taxonomic group for the Nichol's 1969-1970 survey and the Baseline subtidal 1982-1983 survey.
*Indicates significance at an alpha level of 0.05.
**Indicates significance at an alpha level of 0.10.

| Parameter | | Nichol's Mean | Baseline Mean | F | P of F> |
|---|---|---|---|---|---|
| TOTAL TAXA | | | | | |
| June-July to July | + | 23.4 | 45.8 | 40.46 | .0002* |
| Sept.-Oct. to Sept. | + | 29.2 | 33.4 | 1.29 | .2893 |
| Nov.-Dec. to Nov. | + | 23.2 | 28.4 | 3.30 | .1069** |
| Feb.-Mar. to Feb. | + | 21.0 | 26.0 | 1.01 | .3533 |
| POLYCHEATE TAXA | | | | | |
| June-July to July | + | 10.8 | 17.0 | 10.56 | .0117* |
| Sept.-Oct. to Sept. | + | 11.2 | 15.6 | 7.74 | .0238* |
| Nov.-Dec. to Nov. | + | 9.2 | 12.2 | 6.52 | .0340* |
| Feb.-Mar. to Feb. | + | 8.7 | 12.2 | 2.15 | .1933 |
| MOLLUSCA TAXA | | | | | |
| June-July to July | + | 1.8 | 6.6 | 25.60 | .0010* |
| Sept.-Oct. to Sept. | + | 5.2 | 7.4 | 4.03 | .0795** |
| Nov.-Dec. to Nov. | + | 4.4 | 6.2 | 2.95 | .1245 |
| Feb.-Mar. to Feb. | + | 3.3 | 5.2 | 4.14 | .0881** |
| ARTHROPOD TAXA | | | | | |
| June-July to July | + | 8.8 | 18.8 | 11.39 | .0097* |
| Sept.-Oct. to Sept. | + | 8.0 | 10.6 | 1.59 | .2433 |
| Nov.-Dec. to Nov. | 0 | 8.0 | 7.0 | .48 | .5097 |
| Feb.-Mar. to Feb. | + | 5.7 | 7.4 | .58 | .4737 |
| ECHINODERM TAXA | | | | | |
| June-July to July | + | 1.2 | 2.0 | 4.57 | .0650** |
| Sept.-Oct. to Sept. | 0 | 1.4 | 1.6 | .33 | .5796 |
| Nov.-Dec. to Nov. | 0 | 1.2 | 1.6 | .80 | .3972 |
| Feb.-Mar. to Feb. | 0 | 1.3 | .60 | 3.24 | .1219 |
| OTHER PHYLA TAXA | | | | | |
| June-July to July | + | .8 | 1.4 | 3.60 | .0943 |
| Sept.-Oct. to Sept. | 0 | .8 | .8 | .00 | - |
| Nov.-Dec. to Nov. | 0 | .4 | .8 | .80 | .3972 |
| Feb.-Mar. to Feb. | 0 | .7 | .6 | .01 | .7850 |

Table 7.17. Table of means and F values comparing the total abundance and the abundance in each major taxonomic group for the Nichol's 1969-1970 survey and the Baseline subtidal 1982-1983 survey.
*Indicates significance at an alpha level of 0.05.
**Indicates significance at an alpha level of 0.10.

| Parameter | Nichol's Mean | Baseline Mean | F | P of F> |
|---|---|---|---|---|
| TOTAL ABUNDANCE | | | | |
| June-July to July + | 58.6 | 151.0 | 30.32 | .0006* |
| Sept.-Oct. to Sept. + | 127.4 | 147.8 | .75 | .4127 |
| Nov.-Dec. to Nov. + | 81.2 | 104.6 | 2.04 | .1911 |
| Feb.-Mar. to Feb. + | 50.3 | 89.0 | 1.51 | .2654 |
| POLYCHAETE ABUNDANCE | | | | |
| June-July to July + | 14.6 | 43.0 | 20.60 | .0019* |
| Sept.-Oct. to Sept. - | 67.4 | 37.0 | 14.25 | .0054* |
| Nov.-Dec. to Nov. - | 45.0 | 37.6 | .84 | .3868 |
| Feb.-Mar. to Feb. - | 23.0 | 38.6 | 1.64 | .2478 |
| MOLLUSC ABUNDANCE | | | | |
| June-July to July + | 4.6 | 27.4 | 40.87 | .0002* |
| Sept.-Oct. to Sept. + | 22.2 | 82.8 | 52.55 | .0001* |
| Nov.-Dec. to Nov. + | 10.4 | 43.6 | 36.35 | .0003* |
| Feb.-Mar. to Feb. + | 3.3 | 30.4 | 3.60 | .1067** |
| ARTHROPOD ABUNDANCE | | | | |
| June-July to July + | 36.8 | 72.6 | 2.79 | .1353 |
| Sept.-Oct. to Sept. - | 31.0 | 24.0 | .73 | .4186 |
| Nov.-Dec. to Nov. - | 22.6 | 19.0 | .15 | .7126 |
| Feb.-Mar. to Feb. 0 | 16.7 | 17.0 | .00 | .5603 |
| ECHINODERM ABUNDANCE | | | | |
| June-July to July + | 1.8 | 4.6 | 8.71 | .0184* |
| Sept.-Oct. to Dept. - | 5.6 | 3.0 | 2.07 | .1878 |
| Nov.-Dec. to Nov. 0 | 2.6 | 2.6 | .00 | - |
| Feb.-Mar. to Feb. - | 5.7 | 1.4 | 3.95 | .0941** |
| OTHER PHYLA ABUNDANCE | | | | |
| June-July to July + | .8 | 3.4 | 22.53 | .0015* |
| Sept.-Oct. to Sept. 0 | 1.2 | 1.0 | .09 | .7687 |
| Nov.-Dec. to Nov. + | .6 | 1.8 | 1.31 | .2856 |
| Feb.-Mar. to Feb. 0 | 1.6 | 1.7 | .00 | .4057 |

cirrata were more abundant during the present survey. Four of thirty-two comparisons were consistent with this trend and significantly different from the other survey (Table 7.18). Pectinaria spp. showed a strong seasonal cycling during the 1969-1970 survey with September/October and November/December being the periods of greatest abundance. This strong seasonal trend was not obvious during the present survey either with Pectinaria spp. or with the other taxa.

Significant differences in the abundance of mollusca between both sampling periods consistently showed that there were more individuals present during the 1982-1983 survey than during the 1969-1970 survey. The abundace of nine mulluscan taxa were examined and Axinopsida serricata was shown to be responsible for the majority of the total differences (Table 7.19). Axinopsida serricata also showed strong seasonal cyclings in abundance with the September/October period showing peak abundance. This pattern coincided with the 1969-1970 patterns in abundance of Pectinaria spp. thus numerically compensating for the lower abundances of Pectinaria spp. during the present surveys.

Although the total abundance of echinoderms were not significantly different between the two surveys the species composition showed a decided difference between the two. Brisaster latifrons was significantly more abundant during the 1969-1970 survey while Molpadia intermedia was significantly more abundant during the present survey (Table 7.20). It is interesting to note that these two echinoderm species (irregular sea urchin and sea cucumber) while both present in south central Puget Sound generally tended to not occur in the same sample.

Significant differences in Shannon-Wiener (7 of 12) and Gleasons (4 of 12) diversities within major taxa groups and the Infaunal Trophic Index (1 of

Table 7.18. Table of means and F values for the polychete taxa responsible for the significant differences between the Nichol's 1969-1970 survey and the Baseline subtidal 1982-1983 survey.
*Indicates significance at an alpha level of 0.05.
**Indicates significance at an alpha level of 0.10.

| Parameter | | Nichol's Mean | Baseline Mean | F | P of F> |
|---|---|---|---|---|---|
| JULY 1970 to JUNE-JULY 1982 | | | | | |
| Ampharete sp. | + | .40 | 8.20 | 32.02 | .0005* |
| Cossura sp. | + | 0 | 6.4 | 38.64 | .0003* |
| Mediomastus sp. | + | .20 | 3.2 | 15.52 | .0043* |
| Pectinaria sp. | - | 3.20 | 1.8 | 2.88 | .1208 |
| Tauberia gracilis | + | .60 | 7.4 | 6.98 | .0296* |
| Spiophanes sp. | + | 0 | 3.0 | 18.00 | .0028* |
| Glycera capitata | - | 1.4 | 0 | 7.54 | .0252* |
| SEPT. 1970 TO SEPT.-OCT. 1982 | | | | | |
| Ampharete sp. | + | 3.0 | 7.2 | 7.54 | .0252* |
| Cossura sp. | + | .40 | 4.2 | 16.04 | .0039* |
| Mediomastus sp. | + | 0 | 3.8 | 19.51 | .0022* |
| Pectinaria sp. | - | 41.60 | 1.8 | 13.34 | .0065* |
| Tauberia gracilis | + | .20 | 4.0 | 4.46 | .0678** |
| Spiophanes sp. | + | .60 | 3.2 | 7.51 | .0252* |
| Glycera capitata | - | 1.8 | 0 | 23.14 | .0013* |
| Laonice cirrata | + | .20 | 1.6 | 9.80 | .0140* |
| NOV. 1970 TO NOV.-DEC. 1982 | | | | | |
| Ampharete sp. | + | 2.0 | 5.6 | 4.87 | .0583** |
| Cossura sp. | + | 0 | 4.6 | 16.79 | .0034* |
| Mediomastus sp. | + | .40 | 7.8 | 13.36 | .0065* |
| Tauberia gracilis | + | 0 | 3.4 | 7.41 | .0262* |
| Spiophanes sp. | + | .20 | 7.2 | 24.75 | .0011* |
| Laonice cirrata | 0 | .20 | .8 | 2.00 | .1950 |
| Pectinaria sp. | - | 32.40 | .8 | 37.40 | .0003* |
| Glycera capitata | - | 1.80 | .8 | 1.28 | .2903 |
| FEB. 1970 TO FEB.-MAR. 1983 | | | | | |
| Ampharete sp. | + | 0 | 5.0 | 4.85 | .0699** |
| Cossura sp. | + | 0 | 1.6 | 4.00 | .0924** |
| Mediomastus sp. | + | 0 | 6.8 | 5.99 | .0499* |
| Tauberia gracilis | + | 0 | 1.6 | 5.54 | .0568** |
| Spiophanes sp. | + | 0 | 11.2 | 5.96 | .0504* |
| Laonice cirrata | + | .70 | 1.6 | 2.53 | .1625 |
| Pectinaria sp. | - | 12.0 | 2.0 | 20.83 | .0038* |
| Glycera capitata | - | 2.7 | .4 | 30.96 | .0014* |

Table 7.19. Table of means and F values for the mollusc taxa responsible for the significant differences between the Nichol's 1969-1970 survey and the Baseline subtidal 1982-1983 survey.
*Indicates significance at an alpha level of 0.05.
**Indicates significance at an alpha level of 0.10.

| Parameter | | Nichol's Mean | Baseline Mean | F F | P of F> P of F> |
|---|---|---|---|---|---|
| JUNE-JULY 1982 TO JULY 1970 | | | | | |
| Axinopsida serricata | + | .80 | 5.40 | 26.45 | .0009* |
| Macoma carlottensis | + | 3.40 | 6.20 | 1.43 | .2667 |
| Chaetoderma sp. | + | 0 | 9.4 | 33.22 | .0004* |
| Yoldia scissurata | + | 0 | 1.2 | 4.24 | .0736** |
| Bittium sp. | + | 0 | 1.0 | 2.50 | .1525 |
| Aglaja sp. | + | 0 | 1.4 | 3.50 | .0983** |
| SEPT.-OCT. 1982 TO SEPT. 1970 | | | | | |
| Axinopsida serricata | + | 5.8 | 61.4 | 123.7 | .0000* |
| Macoma carlottensis | - | 12.4 | 7.4 | 2.25 | .1722 |
| Chaetoderma sp. | + | .20 | 7.0 | 28.19 | .0007* |
| Bittium sp. | 0 | .60 | 1.4 | 1.52 | .2521 |
| Odostomia sp. | + | .20 | 1.6 | 2.80 | .1328 |
| Cylichna sp. | + | 0 | 1.2 | 6.00 | .0400* |
| NOV.-DEC. 1982 TO NOV. 1970 | | | | | |
| Axinopsida serricata | + | 1.6 | 30.0 | 140.0 | .0000* |
| Macoma carlottensis | - | 6.0 | 4.2 | 1.67 | .2323 |
| Chaetoderma sp. | + | .20 | 5.4 | 10.40 | .0122* |
| Bittium sp. | + | 1.0 | 2.4 | 1.18 | .3089 |
| Cylichna sp. | + | 0 | 1.2 | 4.24 | .0736** |
| FEB.-MAR. 1983 TO FEB. 1970 | | | | | |
| Axinopsida serricata | + | 0 | 17.6 | 3.57 | .1079** |
| Macoma carlottensis | + | .33 | 3.8 | 2.85 | .1424 |
| Chaetoderma sp. | + | .33 | 5.0 | 5.03 | .0660** |
| Bittium sp. | + | .67 | 2.2 | 1.96 | .2106 |
| Cylichna sp. | 0 | 0 | .8 | 2.57 | .1600 |

Table 7.20. Table of means and F values for the abundance of Brisaster latifrons and Molpadia intermedia comparing the Nichol's 1969-1970 and the Baseline subtidal 1982-1983 survey.
*Indicates significance at an alpha level of 0.05.
**Indicates significance at an alpha level of 0.10.

| Parameter | | Nichol's Mean | Baseline Mean | F | P of F> |
|---|---|---|---|---|---|
| BRISASTER ABUNDANCE | | | | | |
| June-July to July | - | 2.2 | 1.2 | 2.63 | .1434 |
| Sept.-Oct. to Sept. | - | 5.2 | .2 | 12.02 | .0085* |
| Nov.-Dec. to Nov. | - | 2.4 | .4 | 12.50 | .0077* |
| Feb.-Mar. to Feb. | - | 5.3 | 0 | 6.58 | .0427* |
| MOLPADIA ABUNDANCE | | | | | |
| June-July to July | + | 0 | 3.6 | 28.17 | .0007* |
| Sept.-Oct. to Sept. | + | 0 | 2.4 | 16.00 | .0039* |
| Nov.-Dec. to Nov. | + | 0 | 1.4 | 7.54 | .0252* |
| Feb.-Mar. to Feb. | + | 0 | 1.4 | 2.40 | .1726 |

12) were primarily greater during the present survey (Table 7.21). Molluscan diversities were the only two cases that showed decreases in diversities for the present period that were significant.

The completion of analysis of the February/March baseline sampling enables us to compare one year of baseline with the year of Nichol's data. Dr. Nichol's data indicated a monthly change in abundance related to the recruitment of polychetes in August and November. This recruitment did not occur during baseline sampling or the same periods but occurs earlier and at lower abundance per species during June/July. Unlike the 1969-1970 Nichol's sampling there was a heavy recruitment of the mollusca Axinopsida serricata in September/October 1982. These greater abundances are carried through all four baseline sampling periods. While there were more taxa of arthropods collected in the baseline survey they did not significantly increase the baseline arthropod abundance. The echinoderms showed a curious trend in that Molpadia intermedia was absent during Dr. Nichol's survey but is present in significant numbers in the baseline survey. Brisaster latifrons was the most abundant echinoderm collected by Nichols and while present in the baseline survey Molpadia intermedia was more abundant. This raises an important question in that the increased abundance of Molpadia intermedia, an apodous holothuroid which feeds on surface and subsurface deposited material may mean that organic enrichment has occurred at this station. The increased abundance of detrital and surface deposit feeding polychetes and molluscs also tend to support this. As indicated in the quarterly reports there are significantly more individuals collected during the baseline than in Dr. Nichol's study. This trend is consistent for all sampling periods but whether these are natural changes which occur occasionally over long time periods or are long term trends potentially due to organic enrichment cannot be distinguished with the present

data set. Distinguishing between these two ideas is possible if data is examined over many years. This data is potentially available through Dr. Nichols for a region in the northern Puget Sound and should be persued to help answer this question.

7.4.3 Mollusca Patterns

The numerically dominant taxa at stations deeper than 185 m in both the north and central portions of East Passage in Puget Sound were generally species of mollusca. This observation is similar to that made by Lie (1968) at his station 2 (depth 172-216 m) between February 1963 and August 1964, but contrast with Nichols' observations of the numerical dominances of the polychaeta (Pectinaria californiensis) during his studies in 1970 in the Baseline study area (Nichols, 1972). Lie's dominant molluscan taxa were the same as those observed during the Baseline survey but these same speices were not very common at all during Nichols' study. The variation in dominant taxa showed seasonal trends (discussed earlier) in the Baseline study as well as in the studies by Lie and Nichols but these variations were not enough to normally alter the species that was the most abundant at a station.

Forty-one species of mollusca were found at depths greater than 185 m during the METRO/Baseline and the METRO/TPPS study (Table 7.22). Macoma carlottensis and Axinopsida serricata were the most numerically abundant mollusca species at the majority of stations in both areas throughout the entire period of sampling (Table 7.23, Figure 7.18). Station II-880 in September/October 1981 off West Point was dominated by Acila catrensis and station C600E in the November/December 1982 Baseline samples was dominated by Nucula tenuis. All other stations were dominated by the two species previously discussed. There was significantly greater abundance of Macoma carlottensis in the West Point area than in the south central Puget Sound area

Table 7.21. Table of means and F values for the Shannon-Wiener and Gleason diversity values for each major taxonomic group comparing the Nichol's 1969-1970 survey and the Baseline subtidal 1982-1983 survey. Means and F values also given for the Infaunal Trophic Index for comparable sampling periods during the same surveys.
*Indicates significance at an alpha level of 0.05.
**Indicates significance at an alpha level of 0.10.

| Parameter | | Nichol's Mean | Baseline Mean | F | P of F> |
|---|---|---|---|---|---|
| SHANNON-WIENER DIVERSITY | | | | | |
| POLYCHAETA | | | | | |
| June-July to July | + | .97 | 1.09 | 4.94 | .0570** |
| Sept.-Oct. to Sept. | + | .57 | 1.09 | 17.28 | .0032* |
| Nov.-Dec. to Nov. | + | .50 | .92 | 113.4 | .0000* |
| Feb.-Mar. to Feb. | + | .70 | .90 | 6.35 | .0453* |
| MOLLUSCA | | | | | |
| June-July to July | + | .20 | .68 | 18.19 | .0027* |
| Sept.-Oct. to Sept. | - | .51 | .42 | 3.40 | .1023** |
| Nov.-Dec. to Nov. | - | .50 | .45 | .35 | .5699 |
| Feb.-Mar. to Feb. | + | .50 | .54 | .23 | .6508 |
| ARTHROPODA | | | | | |
| June-July to July | + | .77 | 1.06 | 17.76 | .0029* |
| Sept.-Oct. to Sept. | - | .86 | .81 | .31 | .5931 |
| No.v-Dec. to Nov. | - | .81 | .69 | 5.41 | .0484 |
| Feb.-Mar. to Feb. | - | .76 | .73 | .04 | .8261 |
| GLEASONS DIVERSITY | | | | | |
| POLYCHAETA | | | | | |
| June-July to July | + | 3.66 | 4.28 | 2.17 | .1790 |
| Sept.-Oct. to Sept. | + | 2.43 | 4.05 | 18.21 | .0023* |
| Nov.-Dec. to Nov. | + | 2.16 | 3.12 | 17.48 | .0031* |
| Feb.-Mar. to Feb. | + | 2.45 | 3.12 | 1.79 | .2294 |
| MOLLUSCA | | | | | |
| June-July to July | + | .56 | 1.69 | 12.02 | .0085* |
| Sept.-Oct. to Sept. | + | 1.40 | 1.44 | .03 | .8268 |
| Nov.-Dec. to Nov. | - | 1.62 | 1.36 | .74 | .4143 |
| Feb.-Mar. to Mar. | - | 1.92 | 1.36 | 3.81 | .0989 |
| ARTHROPODA | | | | | |
| June-July to July | + | 2.21 | 4.21 | 13.60 | .0061* |
| Sept.-Oct. to Sept. | - | 2.76 | 2.35 | .68 | .4335 |
| Nov.-Dec. to Nov. | - | 2.31 | 2.19 | .14 | .7204 |
| Feb.-Mar. to Feb. | + | 2.17 | 2.26 | .03 | .1194 |
| INFAUNAL TROPHIC INDEX | | | | | |
| June-July to July | - | 72.3 | 70.6 | .27 | .6156 |
| Sept.-Oct. to Sept. | + | 65.4 | 68.3 | 7.29 | .0271* |
| Nov.-Dec. to Nov. | + | 68.3 | 71.0 | 1.09 | .3272 |
| Feb.-Mar. to Feb. | + | 70.6 | 71.4 | .13 | .7307 |

Table 7.22. Forty-one species of mollusca were collected at depths greater than 185 m in the north and south central Puget Sound.

1. Macoma carlottensis*
2. Axinopsida serricata*
3. Nemocardiam centifilosum*
4. Adontorhina cyclia
5. Nuculana minuta*
6. Hiatella arctica
7. Yoldia thraciaeformis*
8. Yoldia scissurata*
9. Nucula tenuis*
10. Megacrenella columbiana*
11. Crenella decussata*
12. Macoma elimata
13. Cyclocardia ventricosa
14. Parvilucina tenuisculpta
15. Lucinoma acutilineata
16. Compsomyax subdiaphana
17. Acila castrensis*
18. Panopea generosa
19. Modiolus sp.
20. Macoma obliqua
21. Bittium sp.*
22. Odostomia (O.) sp.
23. Mangelia sp.
24. Polinices pallida
25. Cylichna attonsa
26. Aglaga sp.
27. Gastropteron pacificum
28. Limacina pacificum
29. Gastropoda UI
30. Chaetoderma sp.*
31. Pandora bilirata
32. Lyonsia arenosa
33. Haminoea sp.
34. Mitrella gouldi
35. Turbonilla sp.
36. Clinocardium
37. Cephalaspidea
38. Nuculana penderi
39. Netastoma japonica
40. Trichotropis cancellata
41. Fusitriton oregonensis

* These species were used in the data analysis of prominent mollusca for all cruises.

Table 7.23. The abundance of the seven most dominant molluscan taxa collected during the Metro/TPPS and Metro/Baseline surveys.

| | I | | | II | | III | | | | V | | | | VII | | | | VIII | | | | IX | | X | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 660 | 880 | 750 | 750 | 600 | 750 | 750 | 750 | 600 | 880 | 750 | 750 | 600 | 800 | 750 | 750 | 600 | 800 | 750 | 750 | 600 | 680 | 600 | 620 |
| | OCT | OCT | OCT | MAR | JUL | OCT | OCT | MAR | JUL | OCT | OCT | MAR | JUL | OCT | OCT | MAR | JUL | OCT | OCT | MAR | JUL | OCT | OCT | OCT | OCT |
| Axinopsida serricata | 43 | 116 | 55 | 27 | 295 | 148 | 253 | 51 | 53 | 104 | 101 | 37 | 54 | 183 | 85 | 22 | 54 | 106 | 238 | 19 | 39 | 47 | 45 | 20 | 48 |
| Macoma carlottensis | 2 | 0 | 122 | 125 | 64 | 6 | 5 | 153 | 236 | 1 | 7 | 113 | 170 | 0 | 6 | 38 | 52 | 0 | 3 | 18 | 38 | 0 | 6 | 1 | 0 |
| Nucula tenuis | 0 | 2 | 7 | 6 | 3 | 3 | 5 | 10 | 8 | 0 | 1 | 4 | 5 | 4 | 7 | 2 | 4 | 4 | 4 | 1 | 2 | 4 | 7 | 0 | 0 |
| Acila castrensis | 65 | 45 | 77 | 5 | 9 | 42 | 37 | 2 | 3 | 43 | 33 | 2 | 0 | 62 | 55 | 1 | 0 | 116 | 53 | 0 | 0 | 45 | 109 | 46 | 119 |
| Nuculana minuta | 0 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 7 | 8 | 0 | 0 | 0 | 0 | 1 | 0 |
| Bittium sp. | 77 | 12 | 20 | 3 | 1 | 14 | 12 | 9 | 17 | 18 | 5 | 12 | 10 | 35 | 4 | 3 | 6 | 3 | 7 | 4 | 7 | 6 | 8 | 14 | 2 |
| Chaetoderma sp. | 9 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 1 | 4 | 0 | 2 | 2 | 9 | 0 | 4 | 4 | 3 | 0 | 2 | 1 | 1 |

| | A600E | | | A720 | | | B600E | | | B660 | | | C600E | | | C640 | | | D660 | | | E600E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV |
| Axinopsida serricata | 8 | 50 | 16 | 16 | 64 | 114 | 41 | 80 | 80 | 32 | 83 | 35 | 29 | 135 | 117 | 11 | 47 | 42 | 61 | 103 | 76 | 77 | 202 | 194 |
| Macoma carlottensis | 11 | 7 | 10 | 166 | 111 | 317 | 46 | 23 | 34 | 36 | 16 | 18 | 40 | 27 | 30 | 18 | 11 | 11 | 11 | 10 | 17 | 31 | 28 | 27 |
| Nucula tenuis | 1 | 0 | 1 | 4 | 11 | 7 | 4 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 2 |
| Acila castrensis | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuculana minuta | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Bittium sp. | 1 | 2 | 1 | 1 | 3 | 7 | 8 | 2 | 3 | 1 | 3 | 1 | 1 | 0 | 1 | 3 | 1 | 1 | 2 | 1 | 4 | 5 | 2 | 0 |
| Chaetoderma sp. | 5 | 4 | 0 | 1 | 1 | 1 | 11 | 5 | 3 | 8 | 7 | 3 | 5 | 2 | 1 | 11 | 8 | 5 | 1 | 5 | 2 | 3 | 2 | 4 |

| | E750 | | | F600E | | | F780 | | | G600E | | | G780 | | | H600E | | | H640 | | | I600E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV |
| Axinopsida serricata | 28 | 99 | 168 | 1 | 0 | 1 | 44 | 64 | 66 | 13 | 13 | 32 | 12 | 161 | 137 | 4 | 54 | 23 | 5 | 61 | 30 | 13 | 39 | 55 |
| Macoma carlottensis | 32 | 68 | 100 | 5 | 2 | 8 | 58 | 57 | 59 | 19 | 16 | 16 | 15 | 21 | 14 | 3 | 12 | 2 | 6 | 7 | 4 | 17 | 9 | 16 |
| Nucula tenuis | 1 | 1 | 1 | 0 | 1 | 0 | 2 | 3 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Acila castrensis | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuculana minuta | 0 | 1 | 0 | 52 | 12 | 26 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bittium sp. | 7 | 1 | 8 | 0 | 0 | 0 | 3 | 3 | 1 | 3 | 1 | 2 | 1 | 3 | 4 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 2 |
| Chaetoderma sp. | 7 | 0 | 3 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 7 | 4 | 8 | 5 | 7 | 7 | 5 | 1 | 1 | 1 |

| | I690 | | | J600E | | | J690 | | | J.5600E | | | OT-1 | | | OT-2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV | JUN | SEP | NOV |
| Axinopsida serricata | 11 | 68 | 61 | 7 | 61 | 52 | 5 | 73 | 71 | - | 31 | 68 | 13 | 79 | 56 | 137 | 161 | 223 |
| Macoma carlottensis | 25 | 11 | 22 | 21 | 6 | 10 | 21 | 34 | 10 | - | 10 | 14 | 7 | 13 | 10 | 22 | 16 | 21 |
| Nucula tenuis | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | - | 1 | 0 | 0 | 1 | 0 | 1 | 5 | 0 |
| Acila castrensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | - | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Nuculana minuta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bittium sp. | 1 | 3 | 0 | 2 | 1 | 3 | 1 | 3 | 2 | - | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| Chaetoderma sp. | 3 | 2 | 3 | 5 | 6 | 4 | 1 | 3 | 8 | - | 4 | 1 | 6 | 2 | 5 | 3 | 1 | 2 |

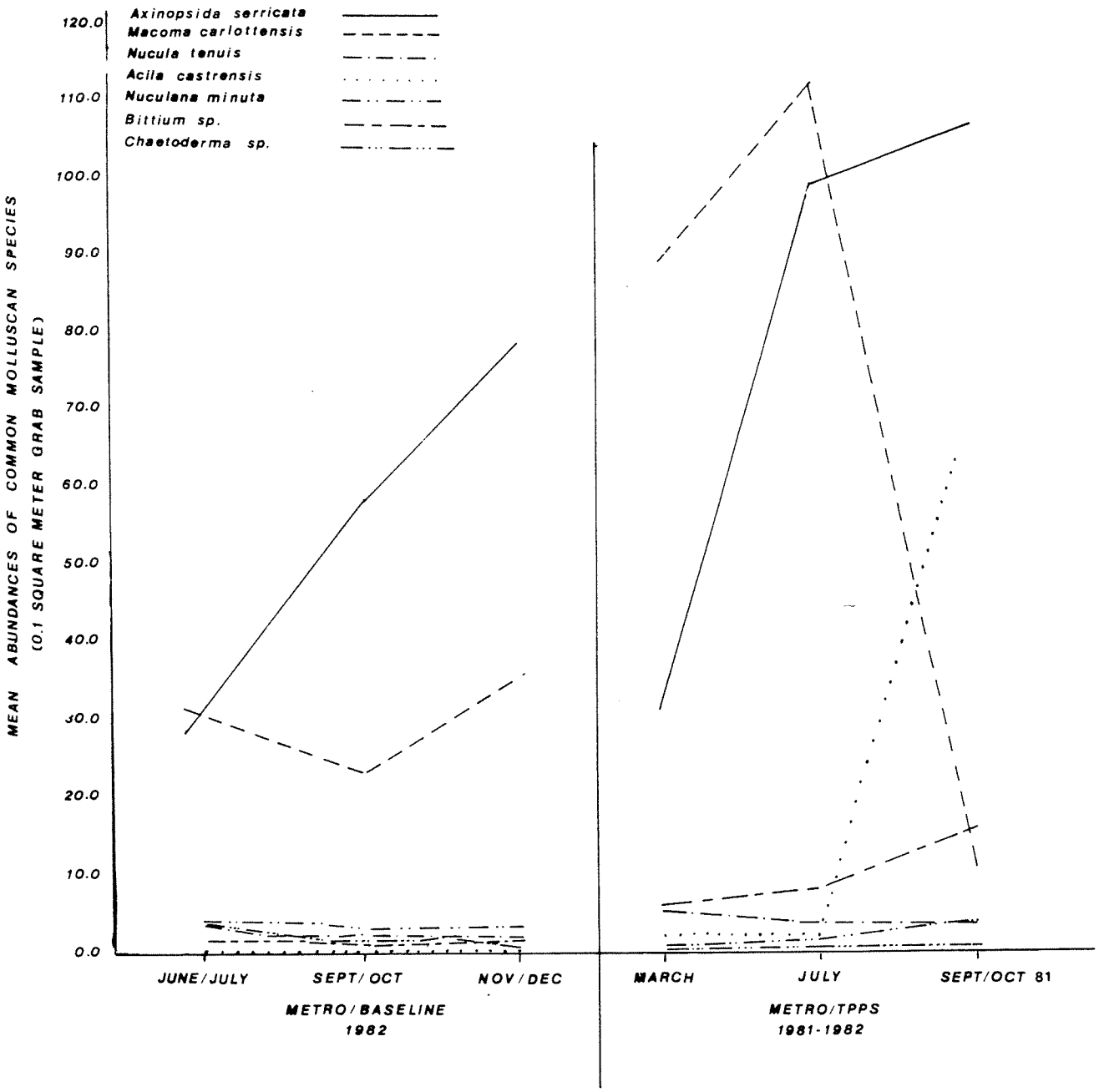



Fig.7.18. Plot of the seasonal changes in the abundance of the seven most common mollusca in the two sampling areas.

during all sampling periods (Table 7.24, F = 5.25). ANOVA done on seasonal/regional basis not regional basis only.

The amount of molluscan dissimilarity between stations sampled off West Point is low (<0.4) during each of the sampling periods (Figures 7.19-7.21). Arbitrarily selecting the dissimilarity value of 0.25 as a cut-off point for establishing groupings of stations, results in two or three site groups in each of sampling periods for September/October 1981 and March 1982 and three site groups for July 1982. In all but two cases the replicate samples at a station are clustered closely together. Molluscan dissimilarity measurements for the south central Puget Sound study are also low (<0.45). A dissimilarity value of 0.3 was used as an arbitrary cut-off point for grouping stations into comparable sites for this area. This resulted in seven site groups during June/July 1982 and six site groups during the September/October and November/December 1982 sample periods (Figures 7.22-7.24). Again the general pattern was that the replicate samples for each station were closely associated and in almost all cases were contained within the same site group.

Two comparable sampling periods between the West Point and south central Puget Sound areas were also clustered together (Figures 7.25 - 7.26). The ranges of dissimilarity index values between areas were somewhat larger than for either area considered separately (<0.5). Establishment of dissimilarity index values of 0.275 as a cut-off level for establishing groups of stations provided seven site groups for the September/October comparisons and eight site groups for the June/July comparisons of areas. During the September/October comparison one replicate sample from Station F600E clustered with all METRO/TPPS samples from West Point (Figure 7.25). During the June/July comparison the differences between the Baseline and the West Point area was not as obvious (Figure 7.26). In this case one replicate measurement

Table 7.24. ANOVA test for METRO/TPPS and Baseline *Macoma carlottensis* abundance.

| | July | | Sept/Oct | | March | Nov/Dec |
|---|---|---|---|---|---|---|
| | TPPS | Baseline | TPPS | Baseline | TPPS | Baseline |
| $\bar{x}$ | 158.4 | 25.8 | 11.7 | 21.4 | 89.1 | 30.9 |
| S.D. | 111.7 | 32.9 | 36.0 | 24.5 | 59.1 | 65.9 |
| Sum | 3168.0 | 1313 | 198.0 | 1133.0 | 1782.0 | 1640.0 |
| n | 20 | 51 | 17 | 53 | 20 | 53 |
| df | 1,69 → 70 | | 1,68 → 69 | | 1,71 → 72 | |
| F | 59.9 | | 1.6 | | 12.0 | |
| $F_{crit}$ | 5.25 | | 5.25 | | 5.25 | |
| | Highly significant | | Not significant | | Highly significant | |

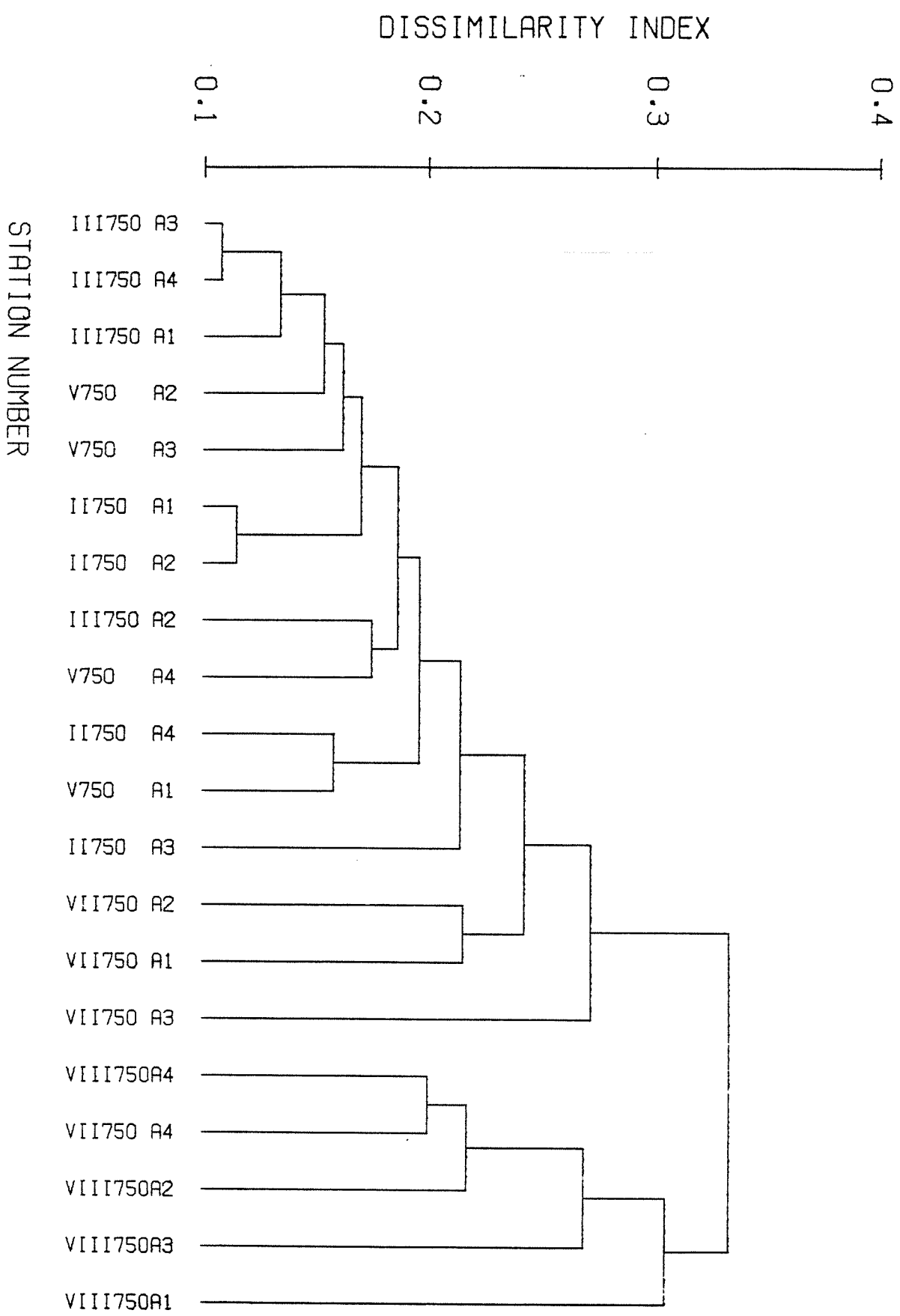



Fig. 7.19. Mollusca station cluster for the METRO/TPPS March sampling period.

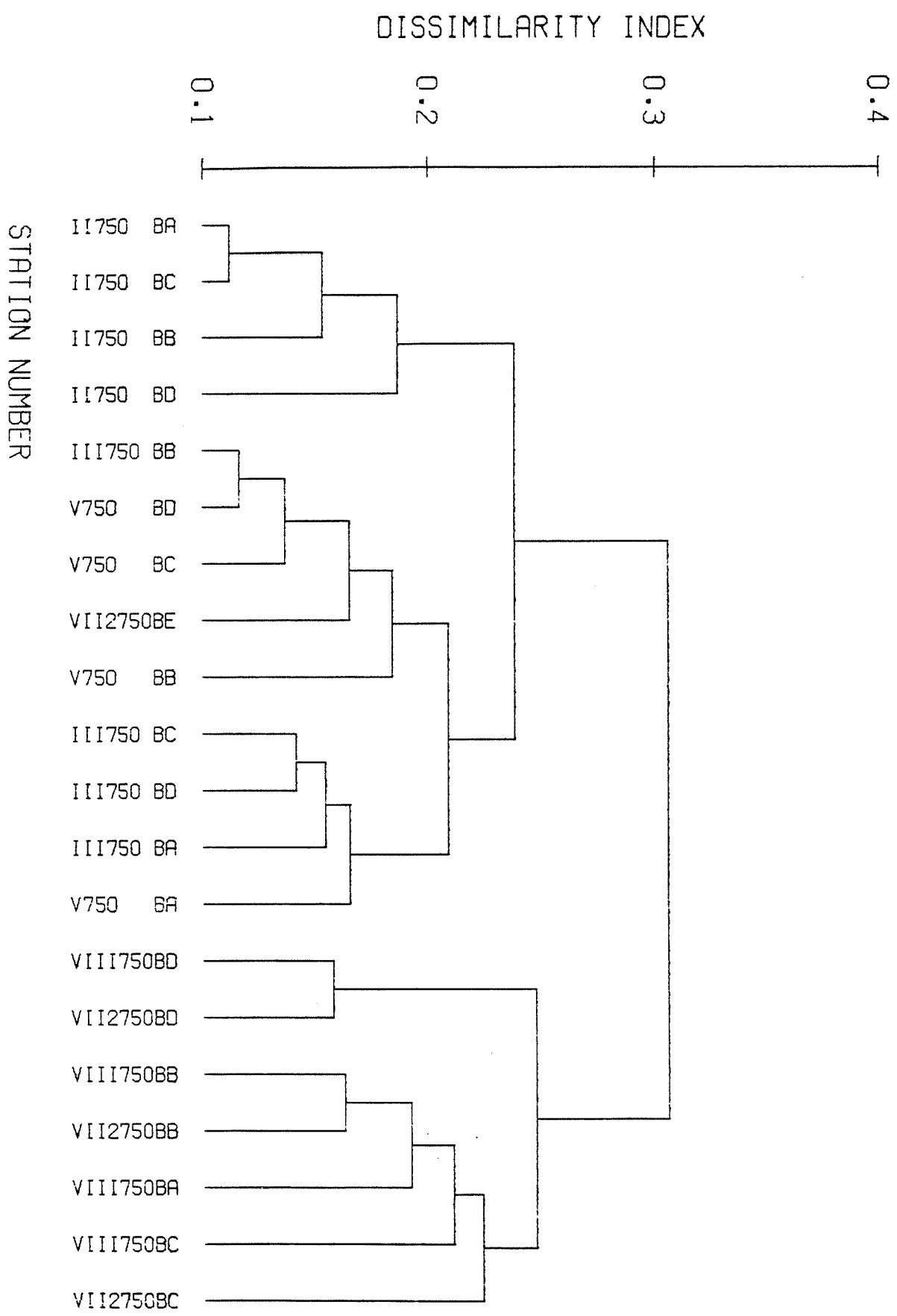



Fig. 7.20. Mollusca station cluster for the METRO/TPPS July sampling period.

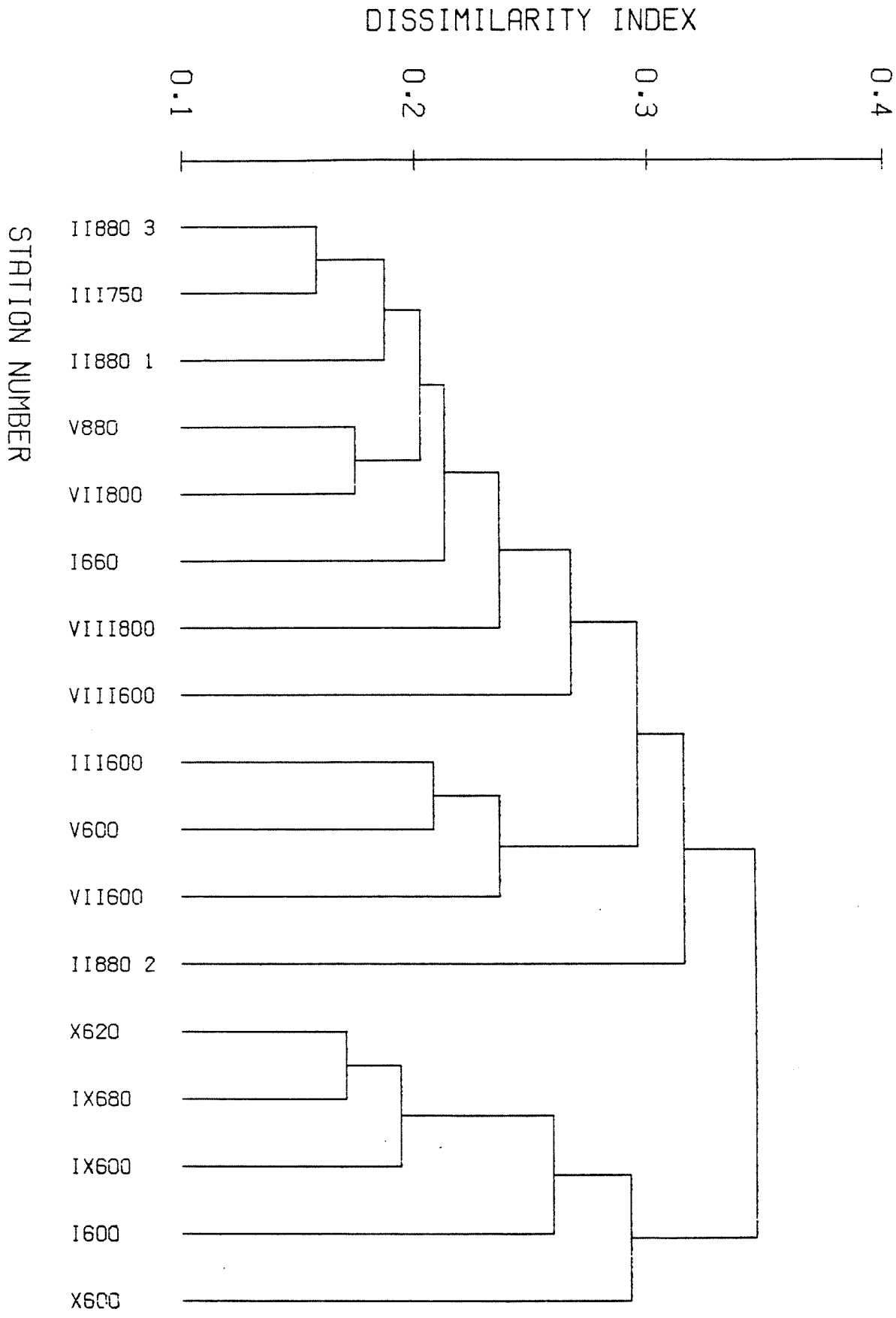



Fig. 7.21. Mollusca station cluster for the METRO/TPPS September/ October sampling period.

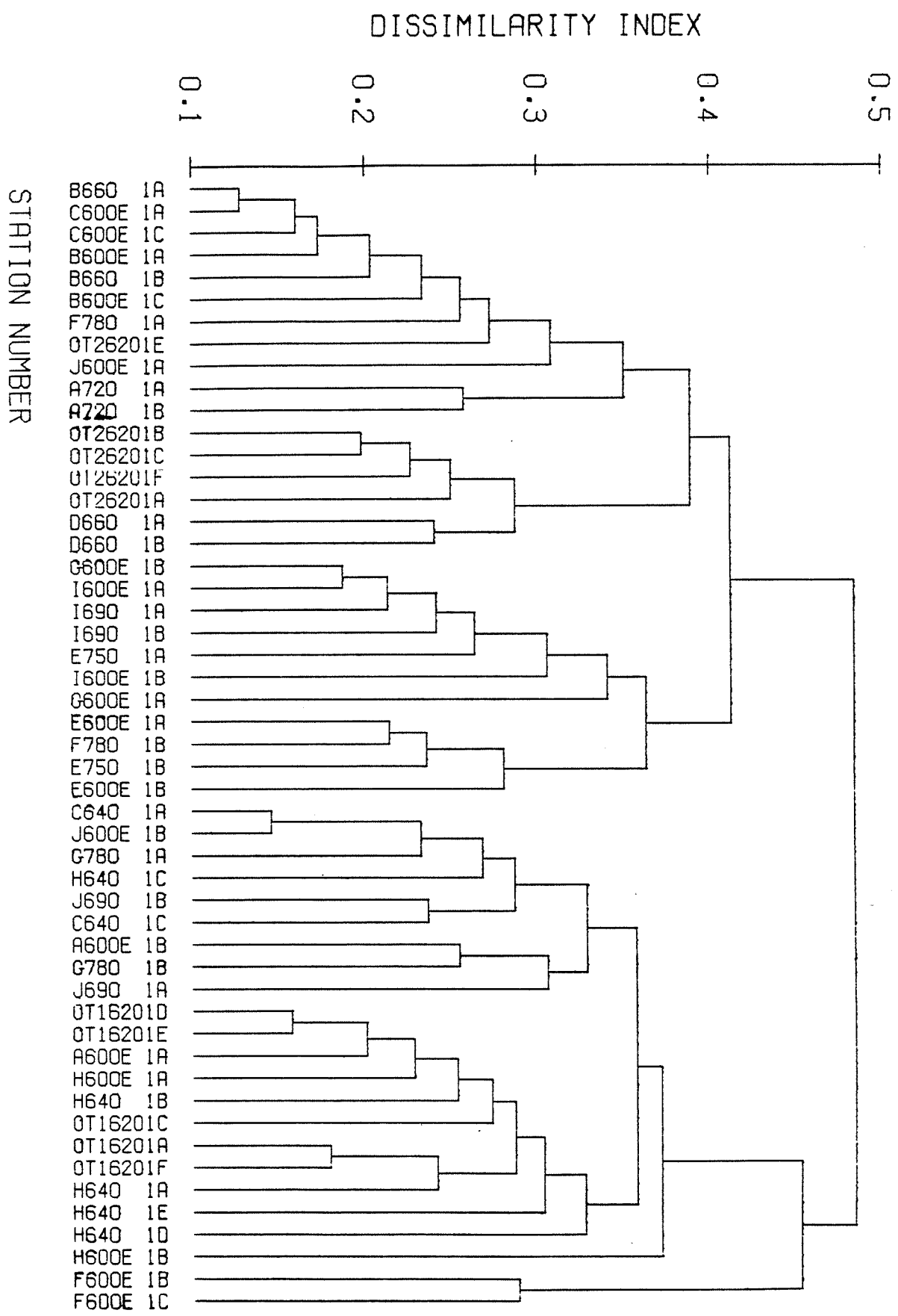



Fig. 7.22. Mollusca station cluster for the METRO/Baseline June/July sampling period.

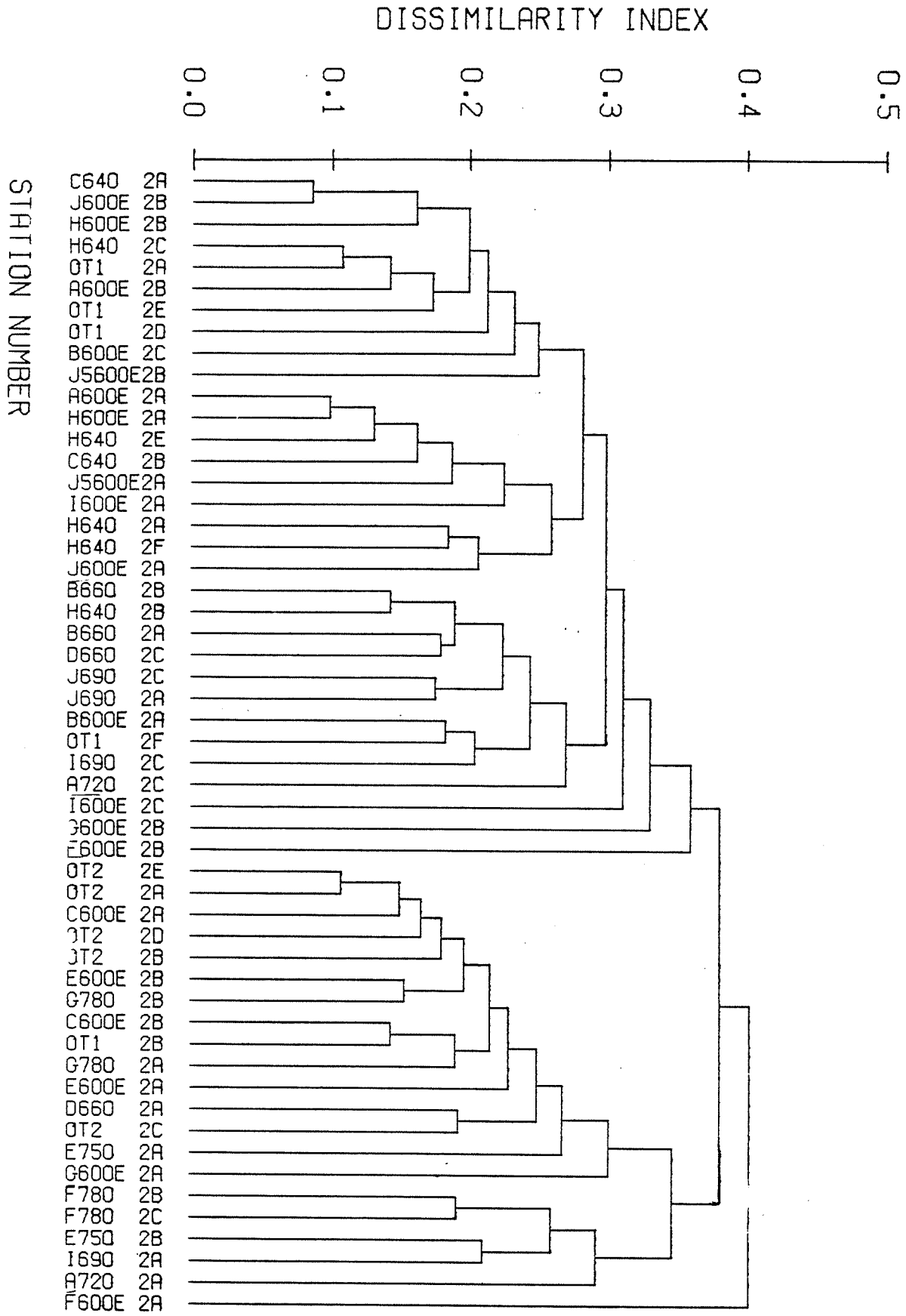



Fig. 7.23. Mollusca station cluster for the METRO/Baseline September/October sampling period.

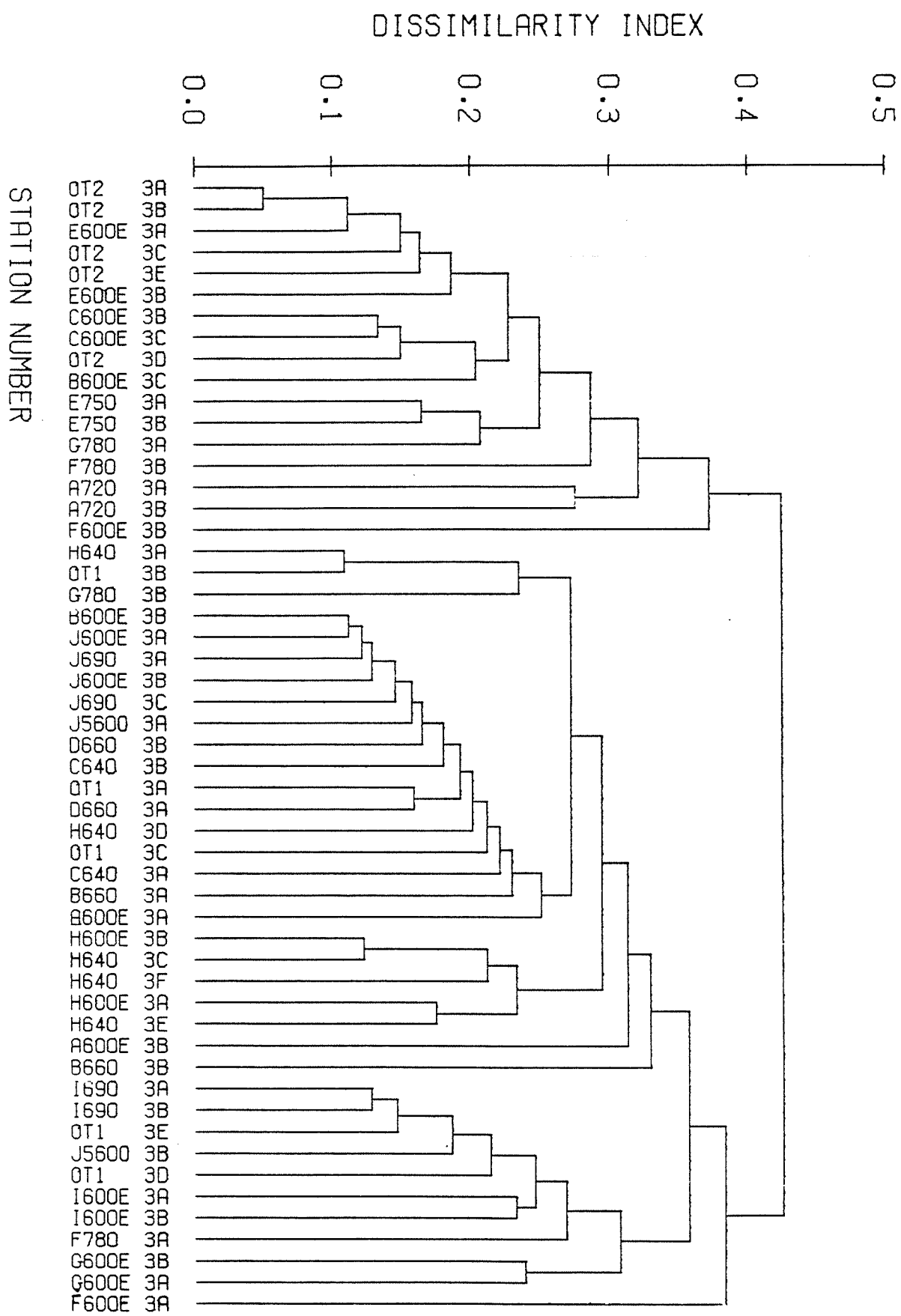



Fig. 7.24. Mollusca station cluster for the METRO/Baseline November/December sampling period.

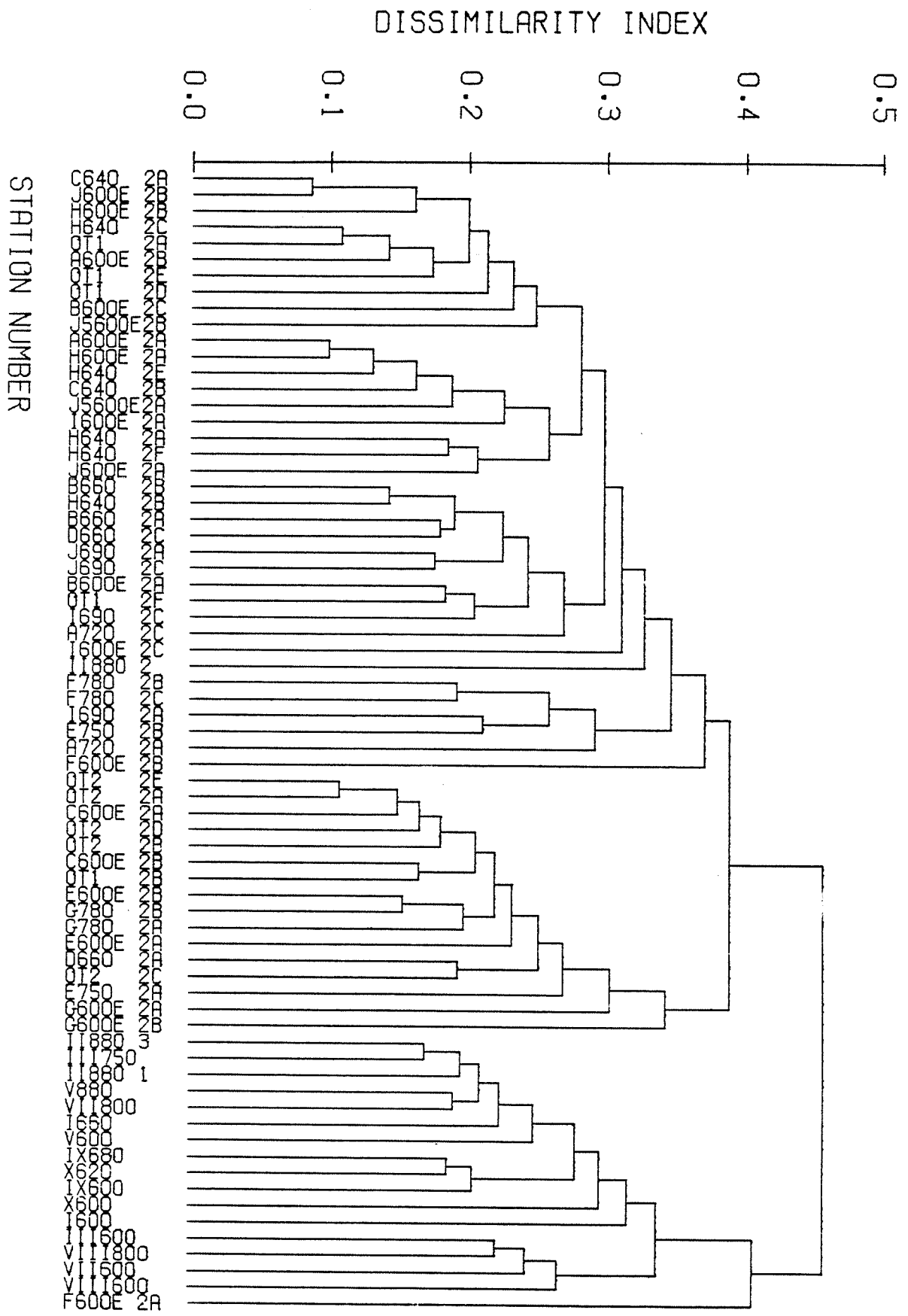



Fig. 7.25. Mollusca station cluster for the METRO/TPPS and Baseline September/October sampling period.

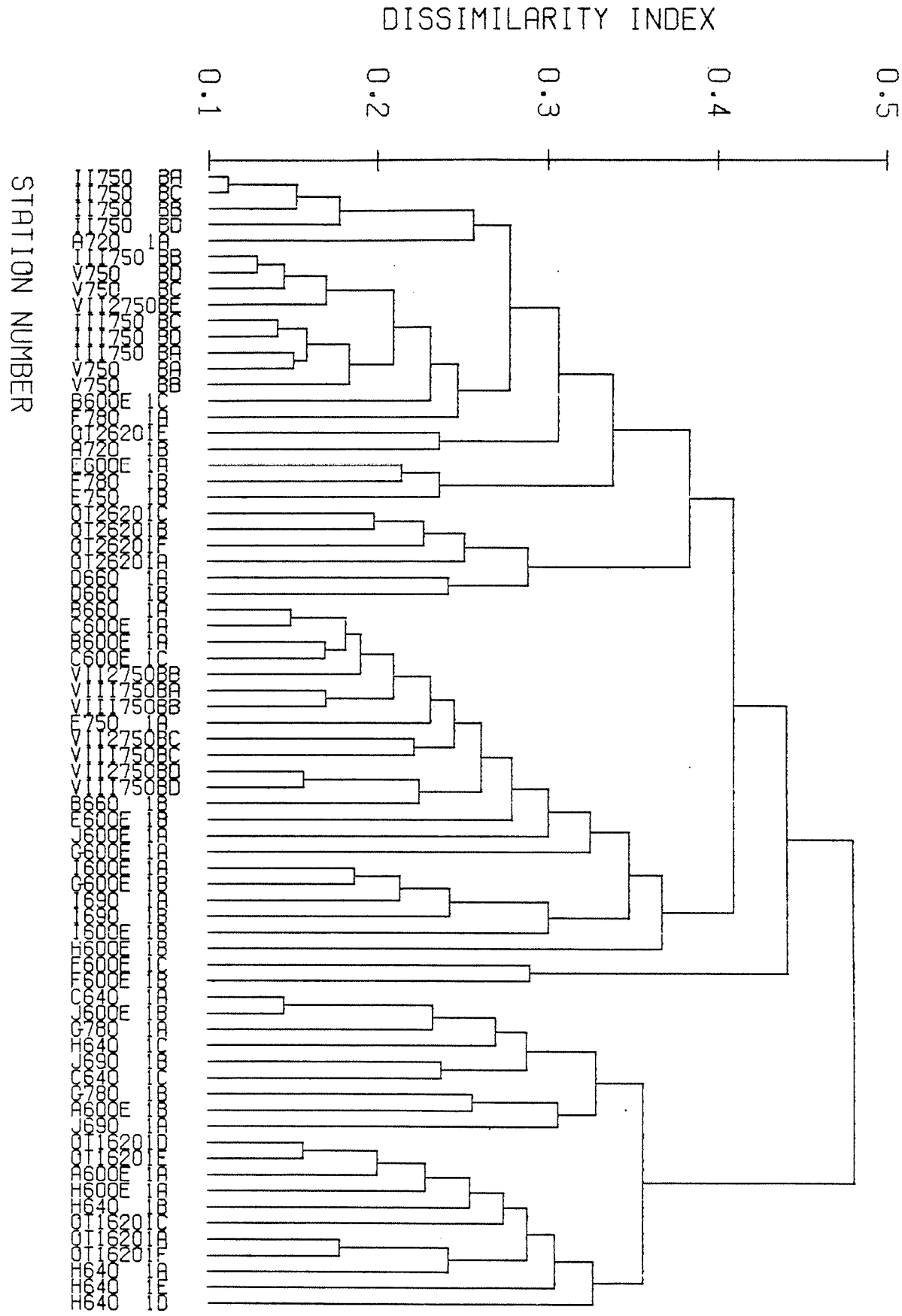



Fig. 7.26. Mollusca station cluster for METRO/TPPS and Baseline June/July sampling period.

from station A720 clustered with all TPPS samples north of West Point and one sample south of West Point. The remaining replicates from that station located off Magnolia Bluff at the mouth of Elliott Bay clustered with a series of stations generally from the northern end of the Baseline sampling area (north of Three Tree Point). The mollusca site groups for the METRO/Baseline study are presented on Figures 7.27-7.29, the September/October and November/December site groupings are very similar in distribution throughout the south sound area while the June/July site groups have a different distribution.

Twelve species of mollusca were found either abundantly or at the majority of sampling locations throughout the different quarterly periods. These species were examined in more detail in order to determine which were dominating the different site groups or most influencing the categories of grouping between the two areas or within the subgroupings within the METRO/Baseline study or METRO/TPPS study area. The dominant species in the first site group West Point stations contained quantities of Axinopsida serricata, Yoldia scissurata, Nucula tenuis, Acila castrensis, and Bittium spp. during the September/October 1981 sampling period. The second site group contained fewer individuals of Axinopsida serricata and Acila castrensis but more individuals of the gastropod genus Bittium. The third site group was dominated by Acila castrensis and Bittium spp. and had still fewer individuals of Axinopsida serricata than either of the other two site groups. During the March 1982 sampling period Macoma carlottensis became more abundant than Axinopsida serricata and a different species of Yoldia thraciaeformis, and fewer Bittium than in the October site groups. Yoldia, Yoldia thraciaeformis was the only species represented within this subgroup that was most abundant at all METRO/TPPS stations. The last site group of this sampling period had

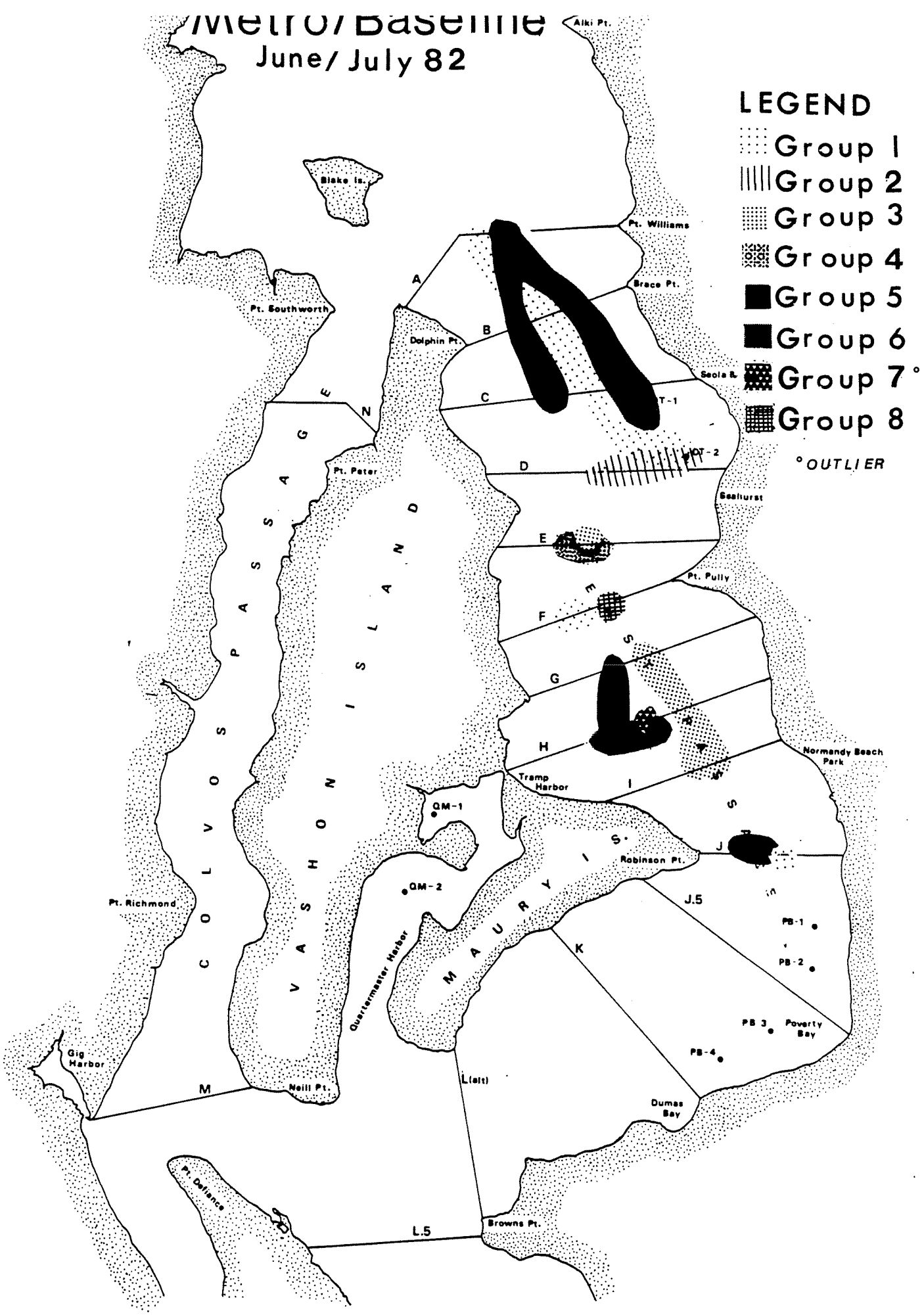



Fig. 7.27. Mollusca site groups. METRO/Baseline June/July 1982 sampling period.

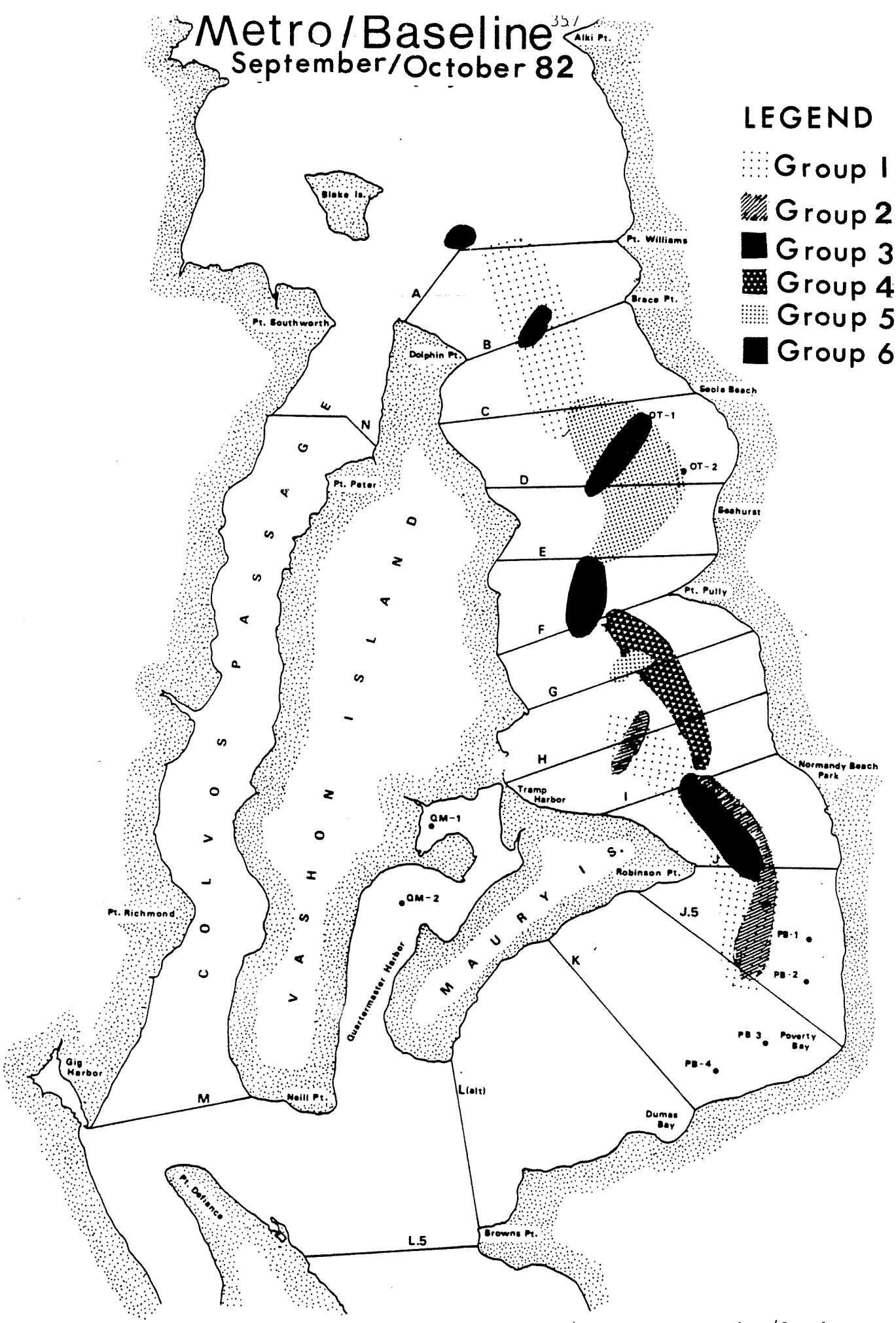



Fig. 7.28. Mollusca site groups. METRO/Baseline September/October 1982 sampling period.

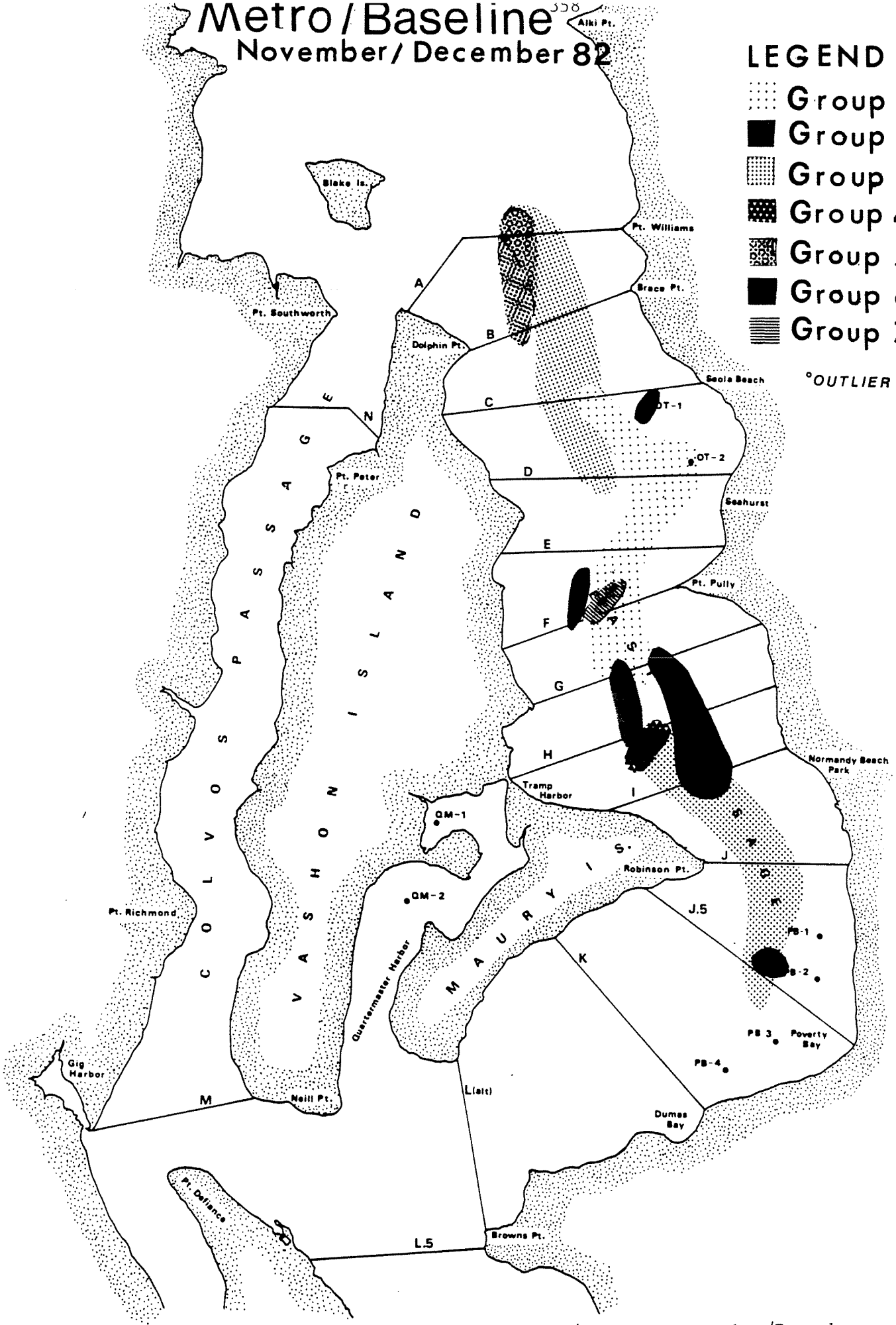



Fig. 7.29. Mollusca site groups. METRO/Baseline November/December 1982 sampling period.

no species that were very abundant in comparison to the species distributions in the other site groups. The final sampling (July) period for the METRO/TPPS area contained three groupings of stations. The first site group was dominated by Macoma carlottensis, Yoldia thraciaeformis, and Megacrenella columbiana. The second site group had Macoma carlottensis, Axinopsida serricata, Bittium, and Chaetoderma in abundance relative to the other sites. Megacrenella columbiana and Chaetoderma were most abundant relative to other sites in the final site grouping (Table 7.25).

The Renton Baseline site groups had seven groups of stations with an outlier station during June, six site groups during September, and six site groups plus an outlier station in December 1982. The species that were most important in these groupings of stations were examined by determining the quartiles of the mean values of the abundances of each of the primary twelve molluscan species (Table 7.25). Macoma carlottensis, Nucula tenuis, Yoldia scissurata, Bittium spp., and Chaetoderma spp. were the species that were most abundant in site group one in comparison to all other station groupings during the June survey. Axinopsida serricata and Acila castrensis were most important in site group two. Yoldia thraceiaformis and Acila castrensis, Bittium spp., and Chaetoderma spp., were most abundant in site group one. Site groups 5 and 6 were occupied by Chaetoderma spp. with Yoldia thraceiaformis also present in site group five. Yoldia thraceiaformis and Bittium spp. were abundantly represented in group seven. Nemocardium centifilosum, Nuculana minuta, Megacrenella columbiana, and Crenella decussatta were present in site group eight. All of these site groups occurred during the June survey. The remaining site groups at each of the sampling periods were represented by different groupings of these same species.

Table 7.25. Quartiles of data means of subgroups.
* = First quartile (most abundant)
+ = Second quartile
- = Third quartile
o = Fourth quartile (least abundant)

| | 1982 METRO Baseline | | | | | | | | | | | | | | | | 1981-2 METRO TPPS | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jun/Jul | | | | | | | | Sep/Oct | | | | | | Nov/Dec | | | | | | | | Sep/Oct 81 | | | | Mar 82 | | | | Jul 82 | | | | |
| Organism | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 |
| Macoma carlottensis | * | o | - | + | o | o | o | o | o | o | - | o | - | + | * | o | o | o | o | - | o | | o | o | o | o | + | - | o | o | * | - | * | o | o |
| Axinopsida serricata | - | + | o | - | o | o | o | o | - | - | + | o | * | - | * | - | - | o | o | - | o | | * | + | + | o | o | o | o | o | - | - | - | - | o |
| Nemocardium centifilosum | o | o | - | + | o | o | o | * | o | o | o | - | o | - | - | o | o | o | o | - | * | | o | o | - | o | o | o | o | o | o | o | o | o | o |
| Yoldia thraciaformis | - | - | * | o | + | o | * | o | - | - | - | o | - | o | o | - | o | o | o | o | o | | o | o | o | - | * | + | * | o | * | - | + | o | o |
| Yoldia scissurata | + | - | - | * | - | o | o | o | o | - | - | - | o | + | o | - | o | o | - | - | o | | * | - | - | o | o | o | o | o | o | o | c | o | o |
| Nucula tenuis | + | o | - | o | o | o | o | o | o | o | + | * | + | * | + | o | o | o | - | o | o | | * | + | - | - | o | o | o | o | - | o | o | - | o |
| Megacrenella columbiana | o | o | o | - | o | o | o | * | o | o | o | * | o | o | o | o | o | o | o | o | - | | o | o | o | o | o | o | o | o | * | o | o | o | * |
| Crenella decussata | o | o | o | - | o | o | o | * | o | o | o | + | o | o | o | o | o | o | o | o | * | | o | o | o | o | o | o | o | o | o | o | o | o | o |
| Acila castrensis | - | + | o | * | o | o | o | o | - | o | o | o | - | o | - | o | - | o | o | * | o | | + | * | + | * | o | o | o | o | o | o | o | o | o |
| Bittium sp. | + | o | + | * | - | o | * | o | o | - | - | o | o | + | - | - | - | - | o | - | o | | * | - | * | * | - | - | o | o | o | o | * | o | - |
| Chaetoderma sp. | * | - | - | * | + | * | - | o | + | * | * | o | o | o | - | + | + | + | - | - | o | | o | o | o | - | o | o | o | - | o | + | o | * | o |
| Nucula acuminata | | | | | | | | | | | | | | | | | | | | | | | o | o | o | o | o | o | o | o | o | o | o | o | o |
| Nuculana minuta | o | o | o | o | o | o | o | * | o | o | o | o | o | * | o | o | o | o | o | o | * | | | | | | | | | | | | | | |

### 7.4.4 Polychaeta Patterns

The METRO/TPPS and Baseline polychaeta abundance information for stations deeper than 600 feet was analyzed using a cluster analysis program, to reveal groupings of species and stations. In most clusters the polychaeta dissimilarity values did not separate stations or species into distinctly different groups. In the TPPS stations clusters the dissimilarity values for March 1982 ranged from 0.3 to 0.7 as did the values for July 1982 and September/October 1981 (Figures 7.30-7.32). With the exception of station II-750, replicate samples did not consistently cluster together.

Polychaeta abundance patterns for the 1982 METRO/Baseline station clusters also showed high levels of dissimilarity ranging from 0.25 to 0.8 during the June/July and September/October samplings, and between 0.25 and 0.6 during the November/December sampling periods. Two separate site groups are identifiable during June/July and September/October and three during the November/December sampling period (Figures 7.33-7.35). Although these site groups are not especially different they do have the majority of replicate samples from each station clustered within one of the two or three site groups. In the June/July sampling period certain stations on the E, F, G, I, and J transects, and a single station on the A transect, clustered separately from all other transects and stations (Figure 7.33). This same trend continues during the September/October sampling period with the addition of stations C-640 and OT-2. The trends of station groups seen during the June/July and September/October periods do not continue into November/December, though several sites on the A, F, G, and I transects still cluster separately.

Comparison of the polychaeta abundance data from the two geographical study areas, the West Point TPPS stations and the southern Baseline stations,

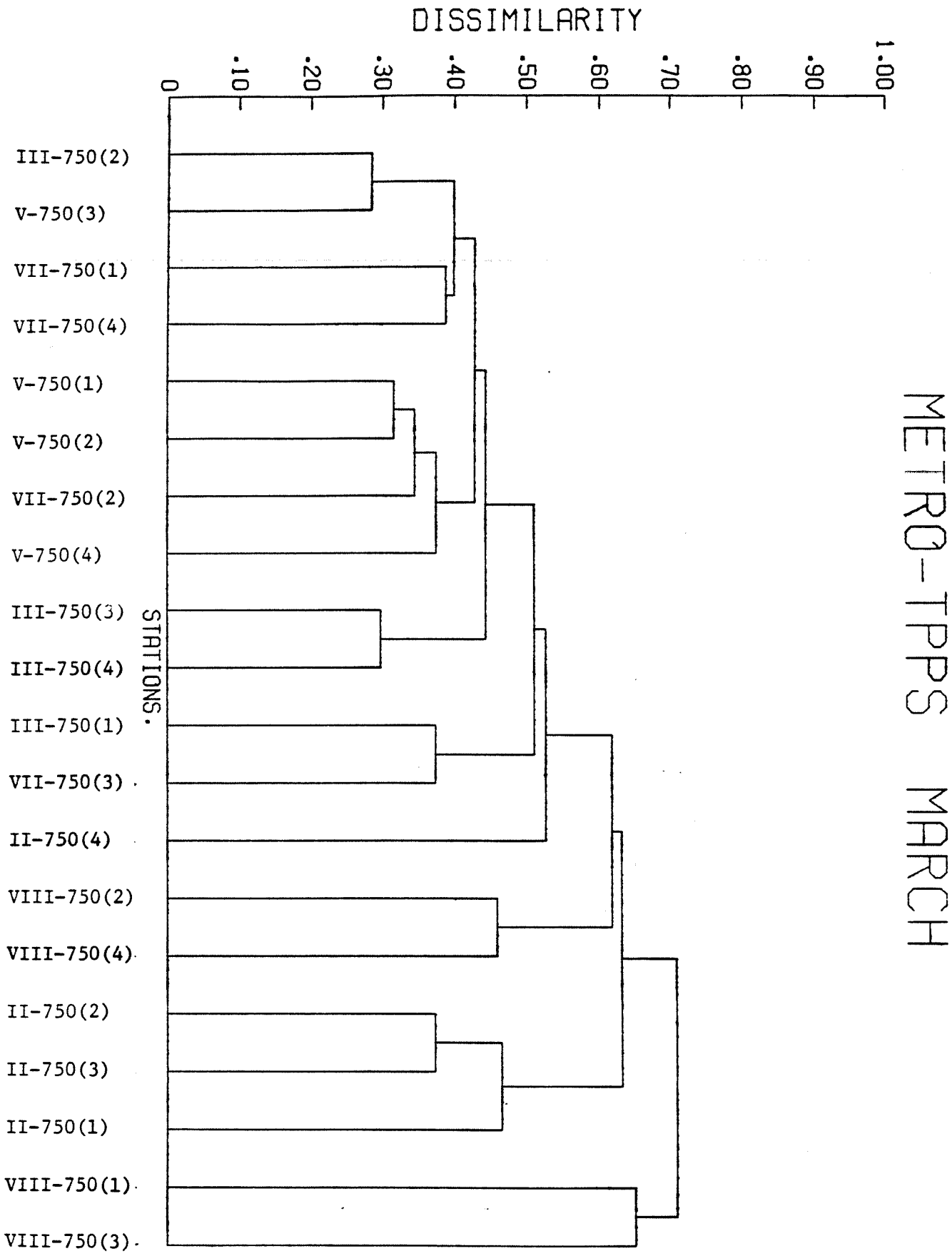



Fig. 7.30. Polychaeta station clusters for the METRO/TPPS March sampling period.

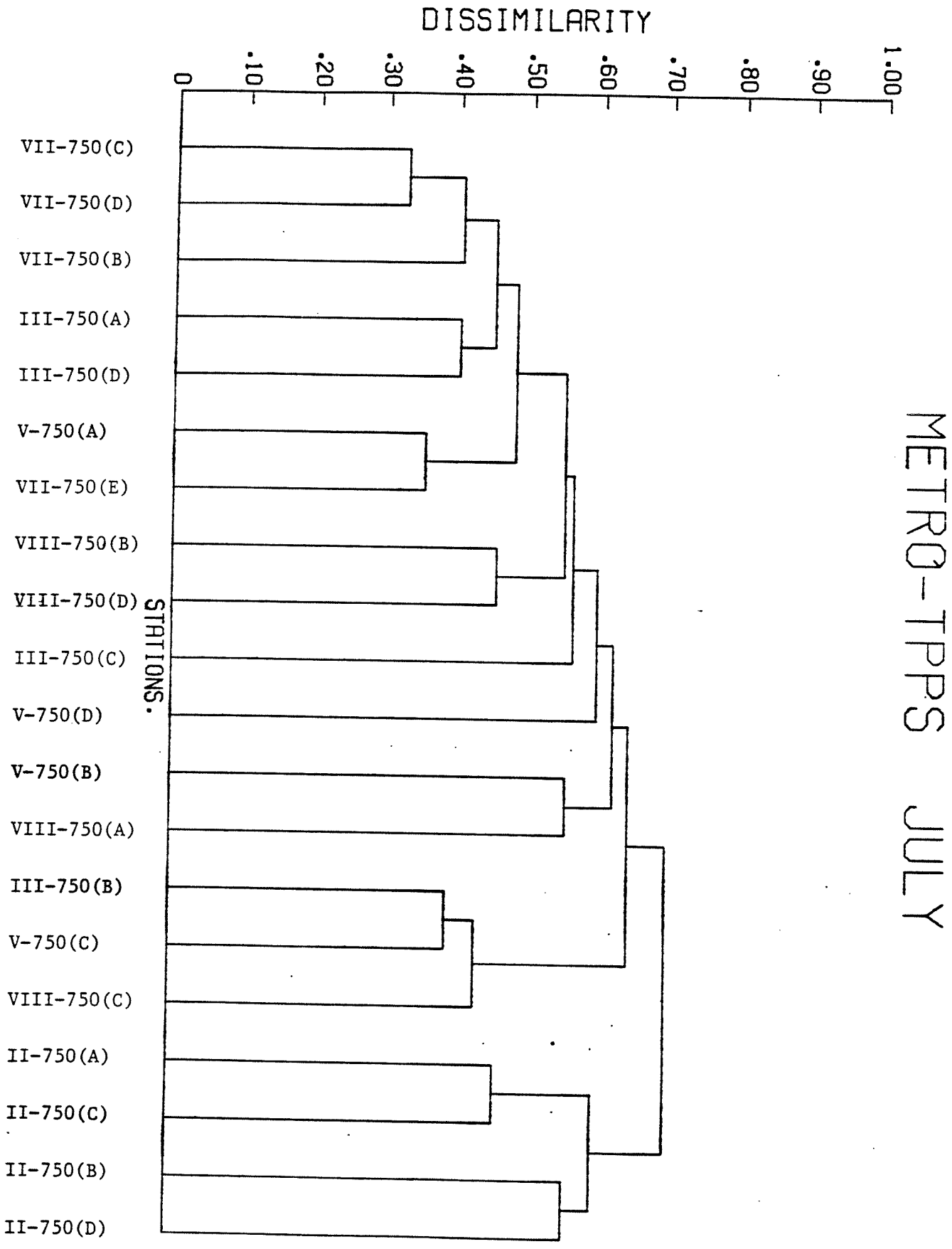



Fig. 7.31. Polychaeta station clusters for the METRO/TPPS July sampling period.

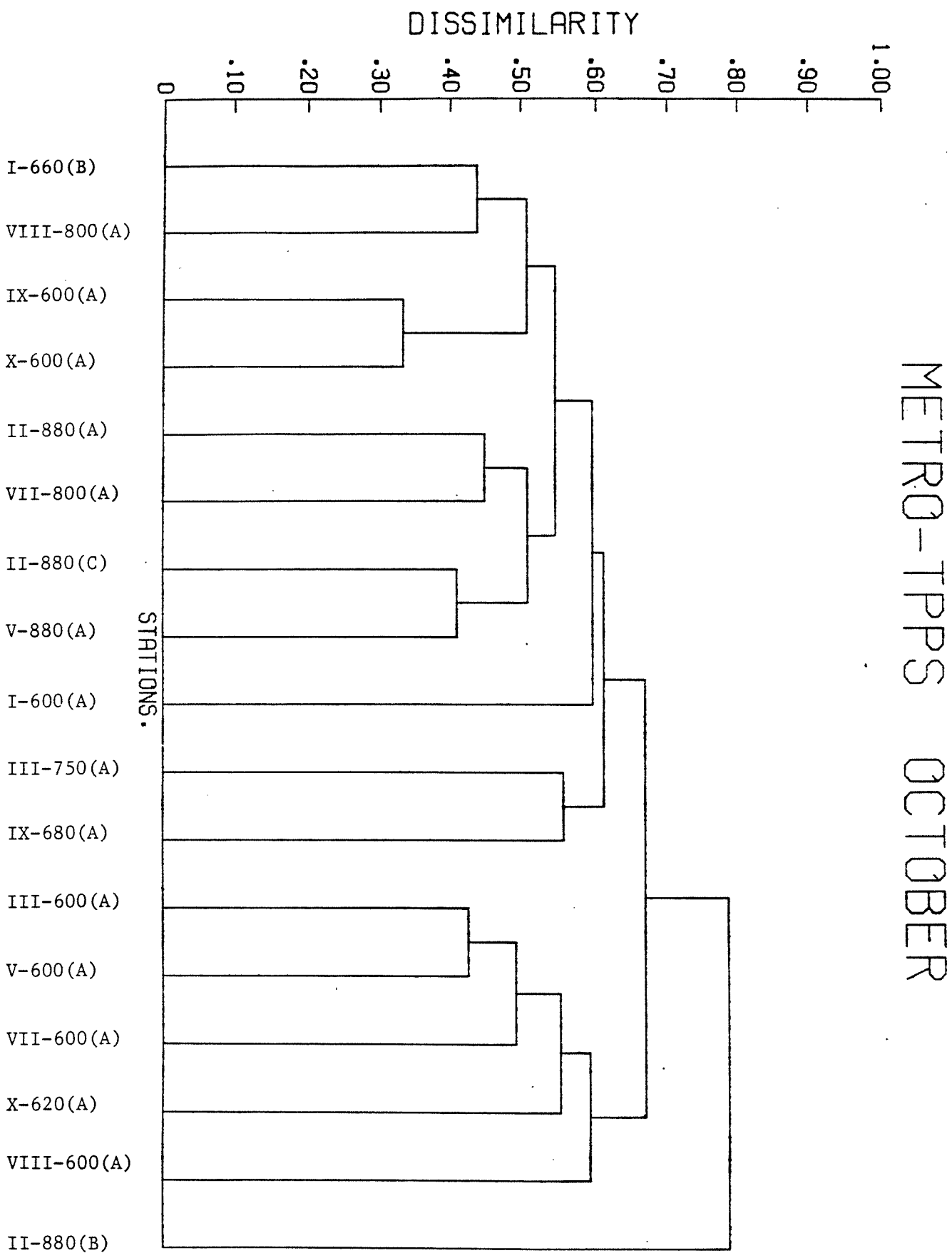



Fig. 7.32. Polychaeta station clusters for the METRO/TPPS September/October sampling period.

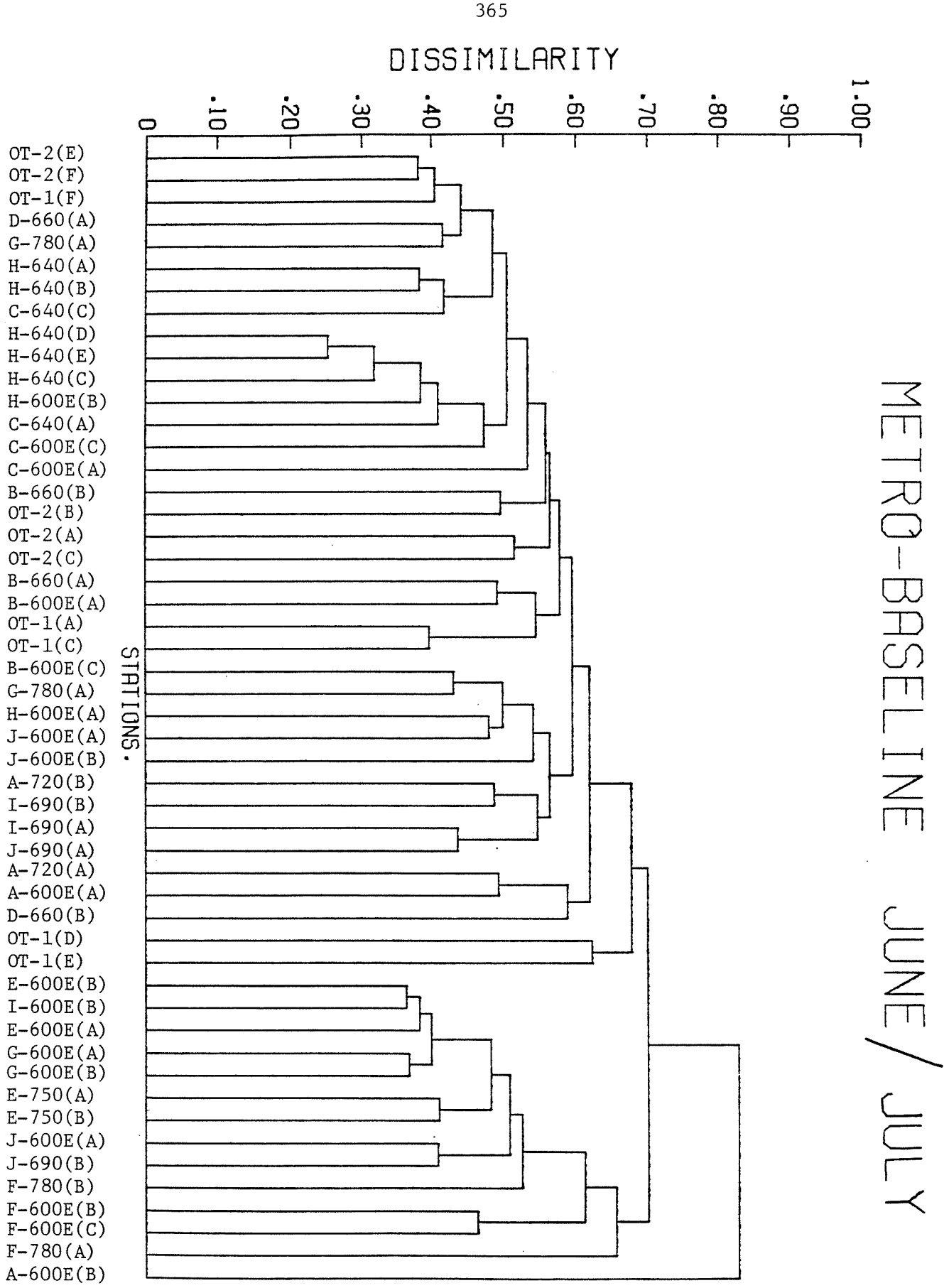



Fig. 7.33. Polychaeta station cluster for the METRO/Baseline June/July sampling period.

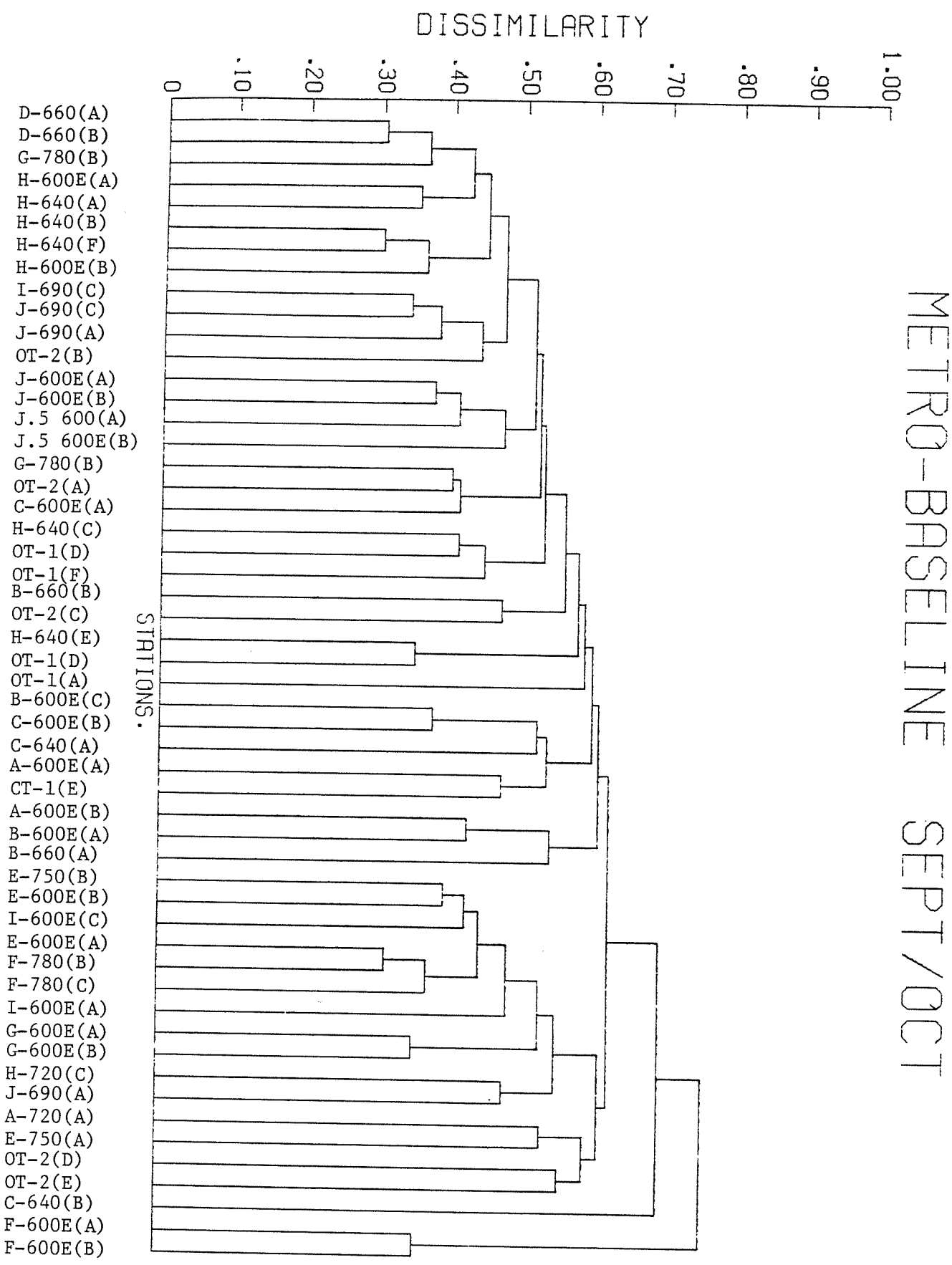



Fig. 7.34. Polychaeta station cluster for the METRO/Baseline Sept/Oct sampling period.

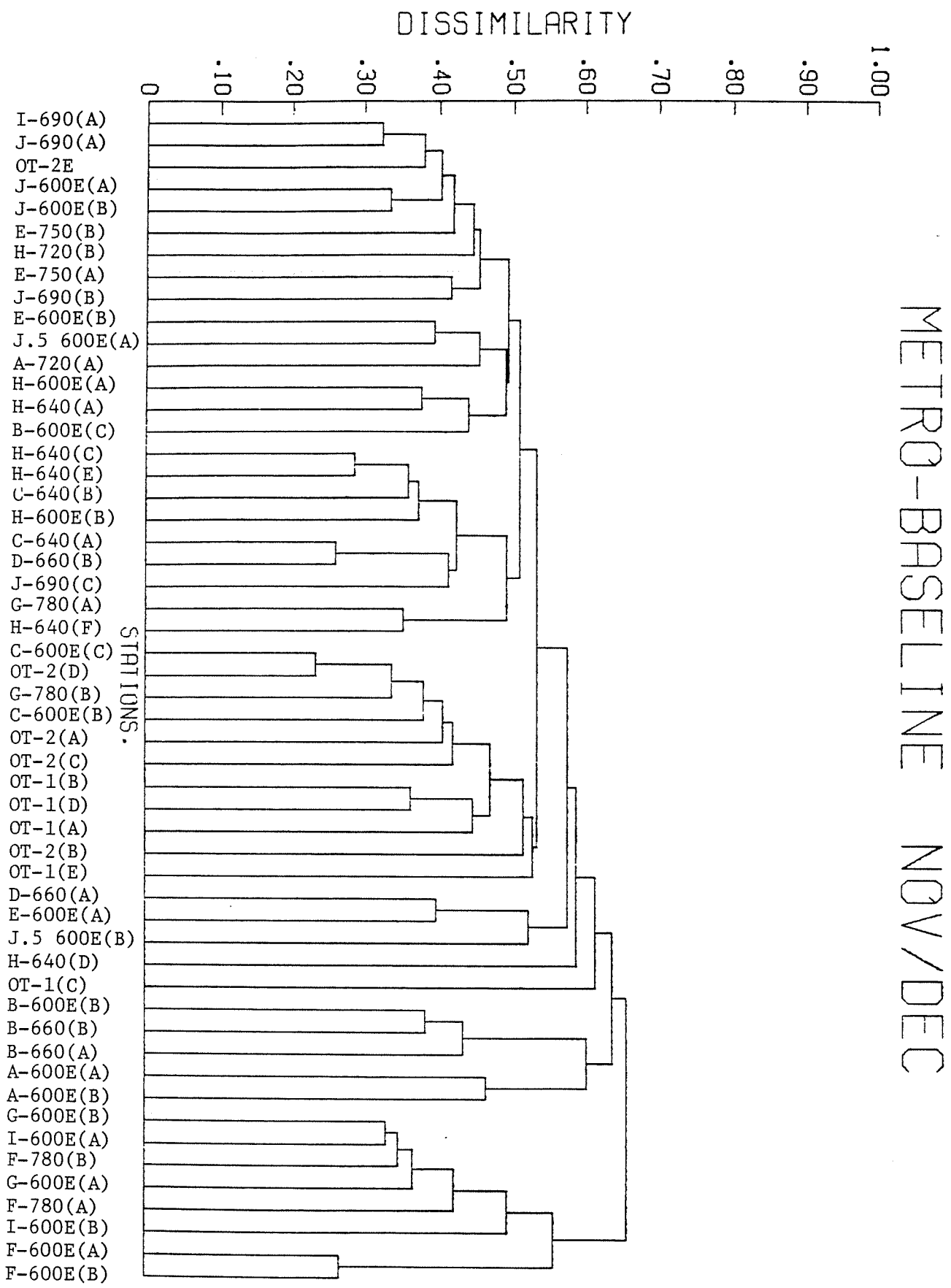



Fig. 7.35. Polychaeta station cluster for the METRO/Baseline Nov/Dec sampling period.

resulted in two dendograms which exhibited very different distribution patterns (Figures 7.36-7.37). The September/October comparison revealed that there was not a major distinction between the stations off West Point and the stations in the south central Puget Sound area (Figure 7.36). The distribution of the stations showed almost a flat profile of dissimilarity values ranging from 0.3 to 0.6. The June/July comparison seemed to show a better separation of stations, with the majority of the TPPS stations grouping at a dissimilarity value of 0.6 or greater.

The same data sets were then used to cluster species to detect which polychaets commonly occurred together. Seasonal comparisons were made, as well as comparisons between the two surveys. All species that occurred in more than one sample were included in this analysis. One cosmopolitan group of 24 species is found in both of the major areas of this study (Table 7.26). In all of the dendograms, the main cluster includes these taxa, and other species not encountered in all samples (Figures 7.38-7.45). The secondary clusters in the June/July, September/October comparisons shared 5-8 species which indicates that these secondary clusters are not common between both areas or sampling periods.

Sixteen of these cosmopolitan species were examined seasonally and compared between the two areas within Puget Sound. The primary difference between the two areas were the high abundance of Ampharete acutifrons in the West Point area throughout all seasons but primarily during the October sampling. Nephtys ferruginea also showed greater abundance in the West Point area while Spiophanes berkeleyorum and Mediomastus californiensis were in greater abundance in the south central Puget Sound area. The remaining species did not show greatly different trends between the two different areas (Figure 7.46).

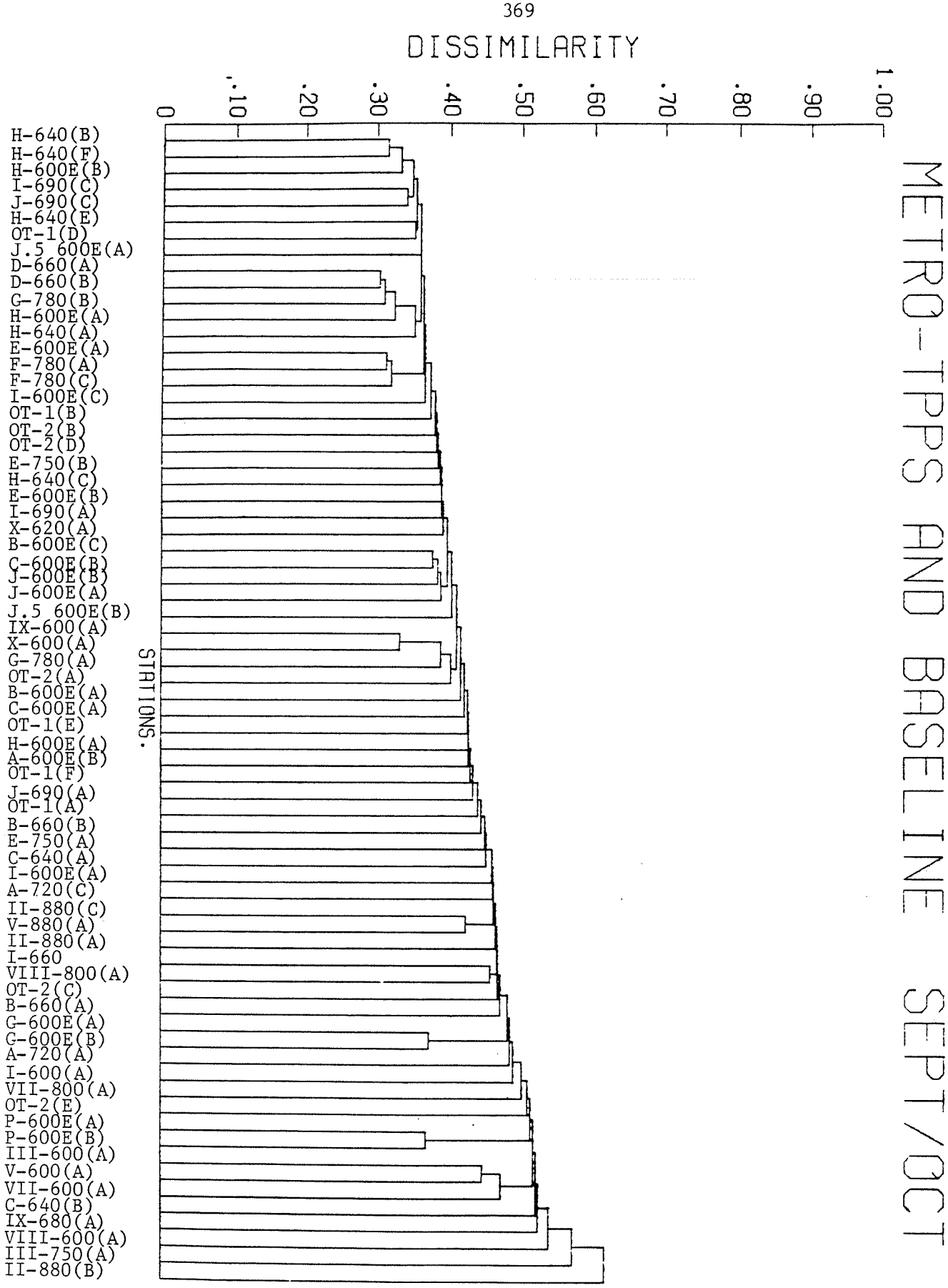



Fig. 7.36. Polychaeta station clusters for the METRO/TPPS and Baseline Sept/Oct sampling period.

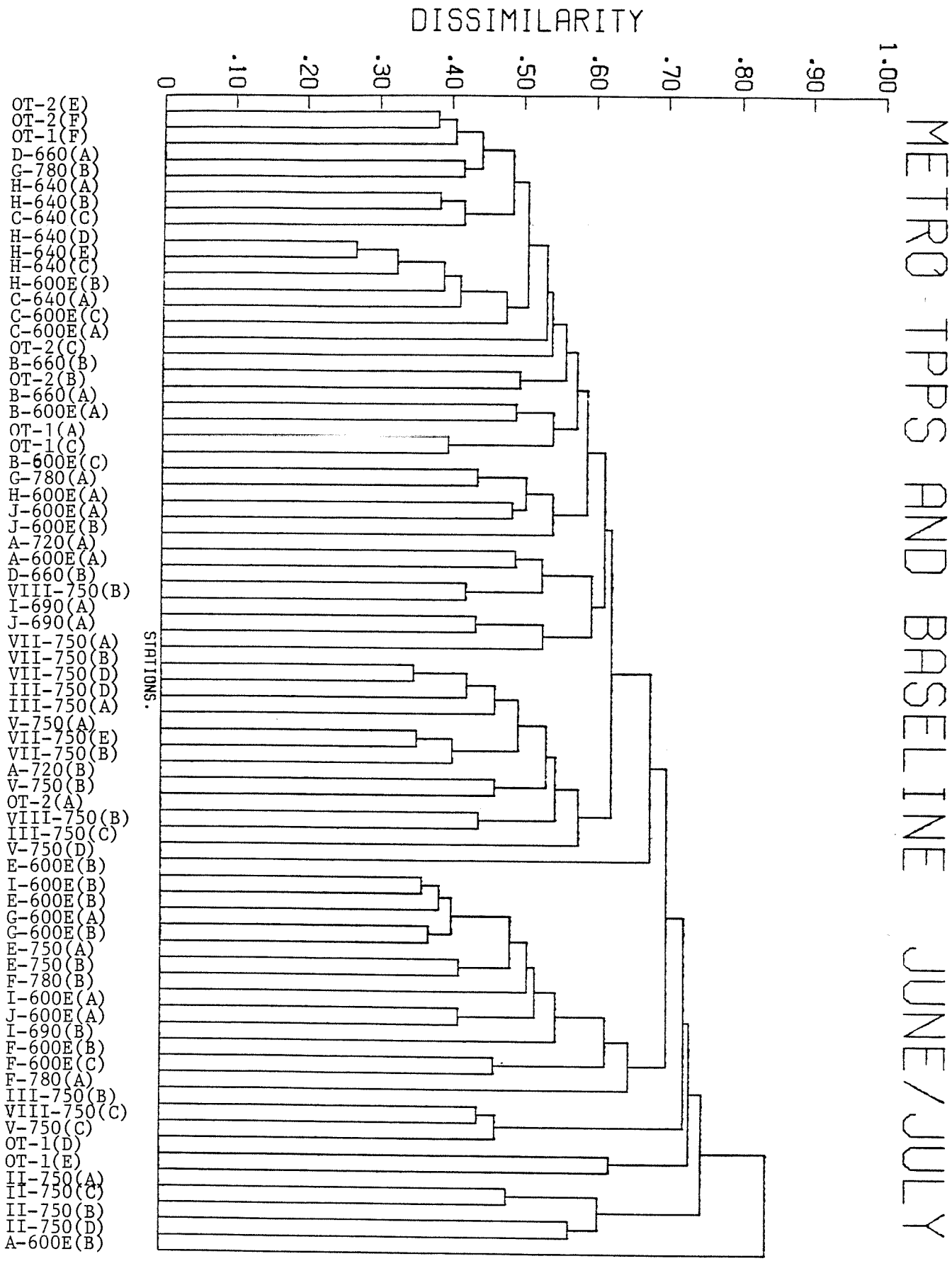



Fig. 7.37. Polychaeta station clusters for the METRO/TPPS Baseline June/July sampling period.

Table 7.26. Group of 24 species of polychaetes found in both the METRO TPPS and METRO Baseline study areas (+ indicates seasonal and area comparisons were made of these species).

| | |
|---|---|
| + | Ampharete acutifrons (includes Ampharete sp.) |
| + | Barantolla americana |
| | Brada sachalina |
| | Chaetozone setosa |
| + | Cossura sp. 1 |
| | Glycera capitata |
| | Goniada brunnea |
| | Gyptis brevipalpa |
| | Harmothoinae (includes Gattyana treadwelli, Harmothoe lunulata, Harmothoinae) |
| | Heteromastus filobranchus |
| | Laonice cirrata |
| | Lumbrineris sp., Group I (includes L. luti) |
| + | Mediomastus californiensis |
| | Nephtys cornuta franciscana |
| + | Nephtys ferruginea |
| | Onuphis iridescens |
| + | Paraprionospio pinnata |
| + | Pectinaria californiensis (includes Pectinaria sp.) |
| | Prionospio cirrifera |
| | Prionospio steenstrupi |
| + | Spiophanes berkeleyorum (includes Spiophanes sp.) |
| + | Tauberia gracilis |
| | Terebellides stroemi |
| | Travisia pupa |

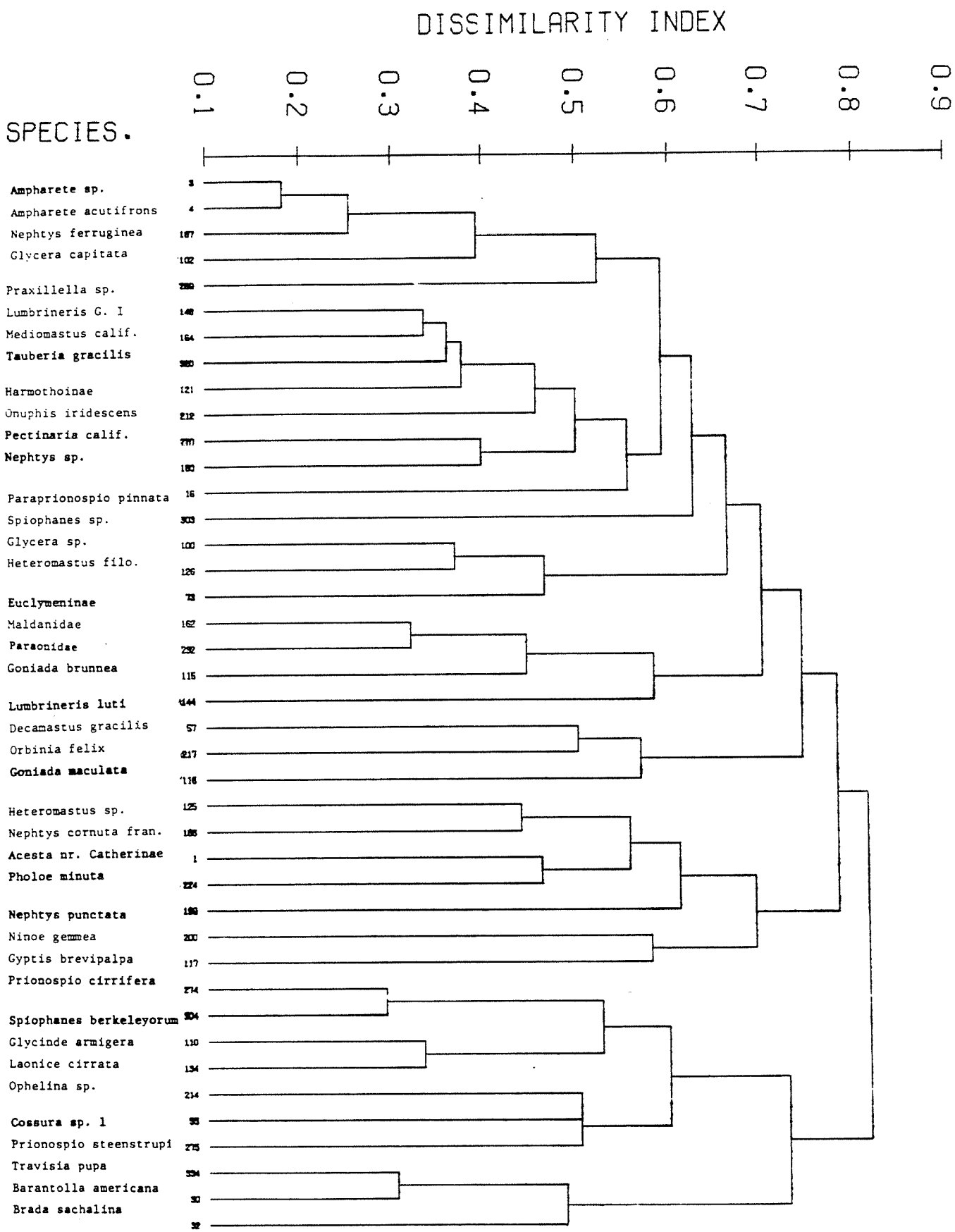



Fig. 7.38. Polychaeta species cluster for the METRO/TPPS March sampling period.

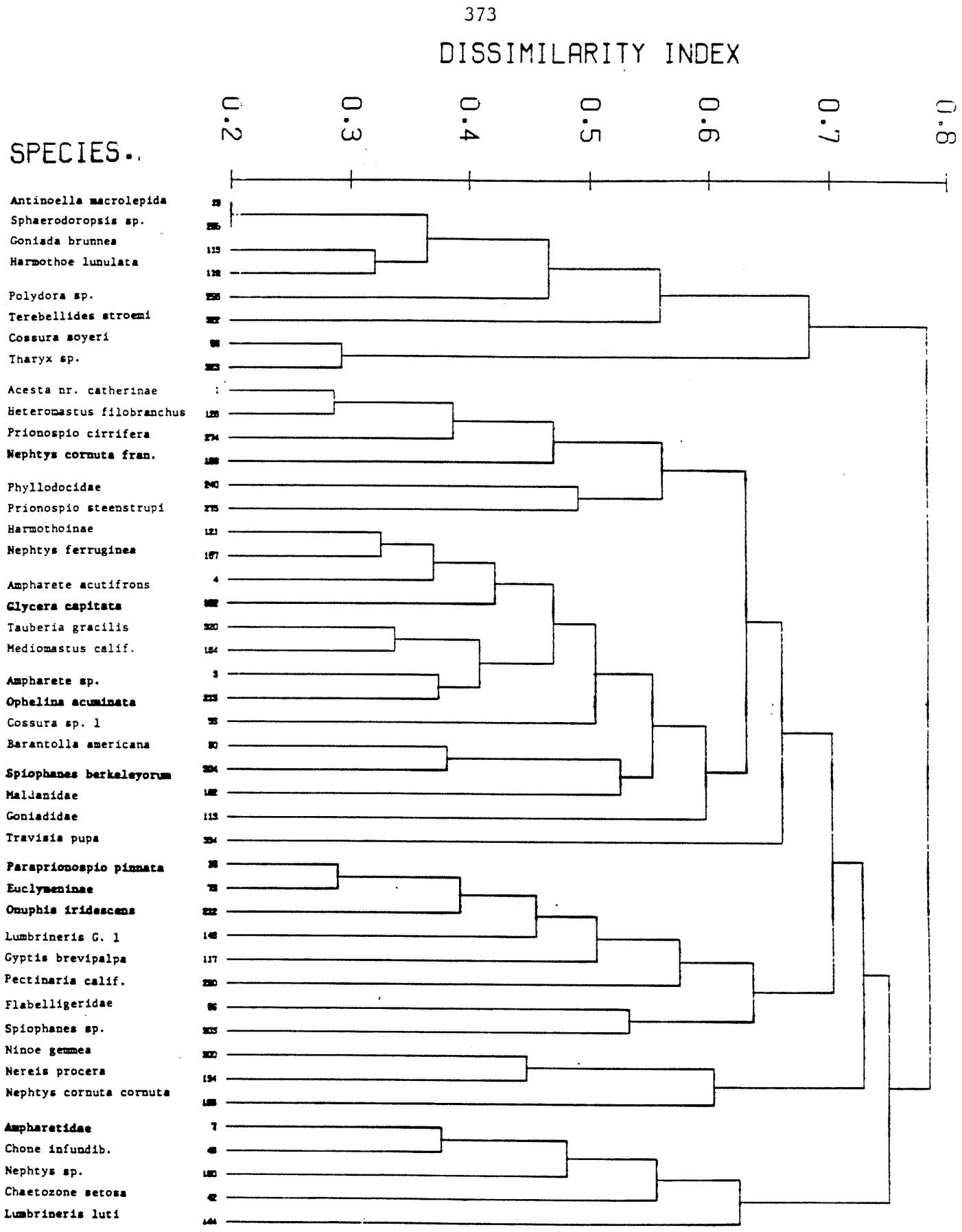



Fig. 7.39. Polychaeta species cluster for the METRO/TPPS July sampling period.

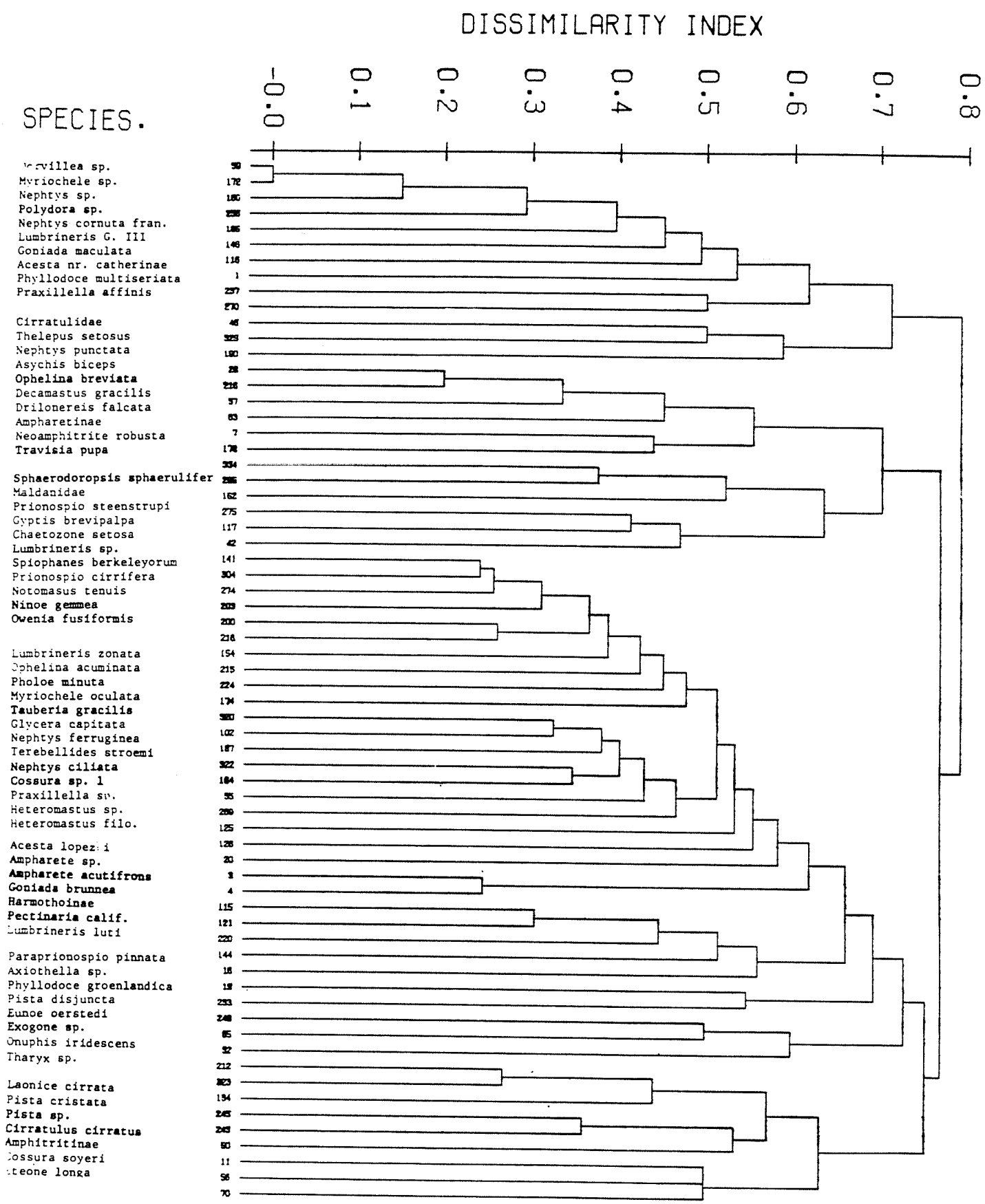



Fig. 7.40. Polychaeta species cluster for the METRO/TPPS September/ October sampling period.

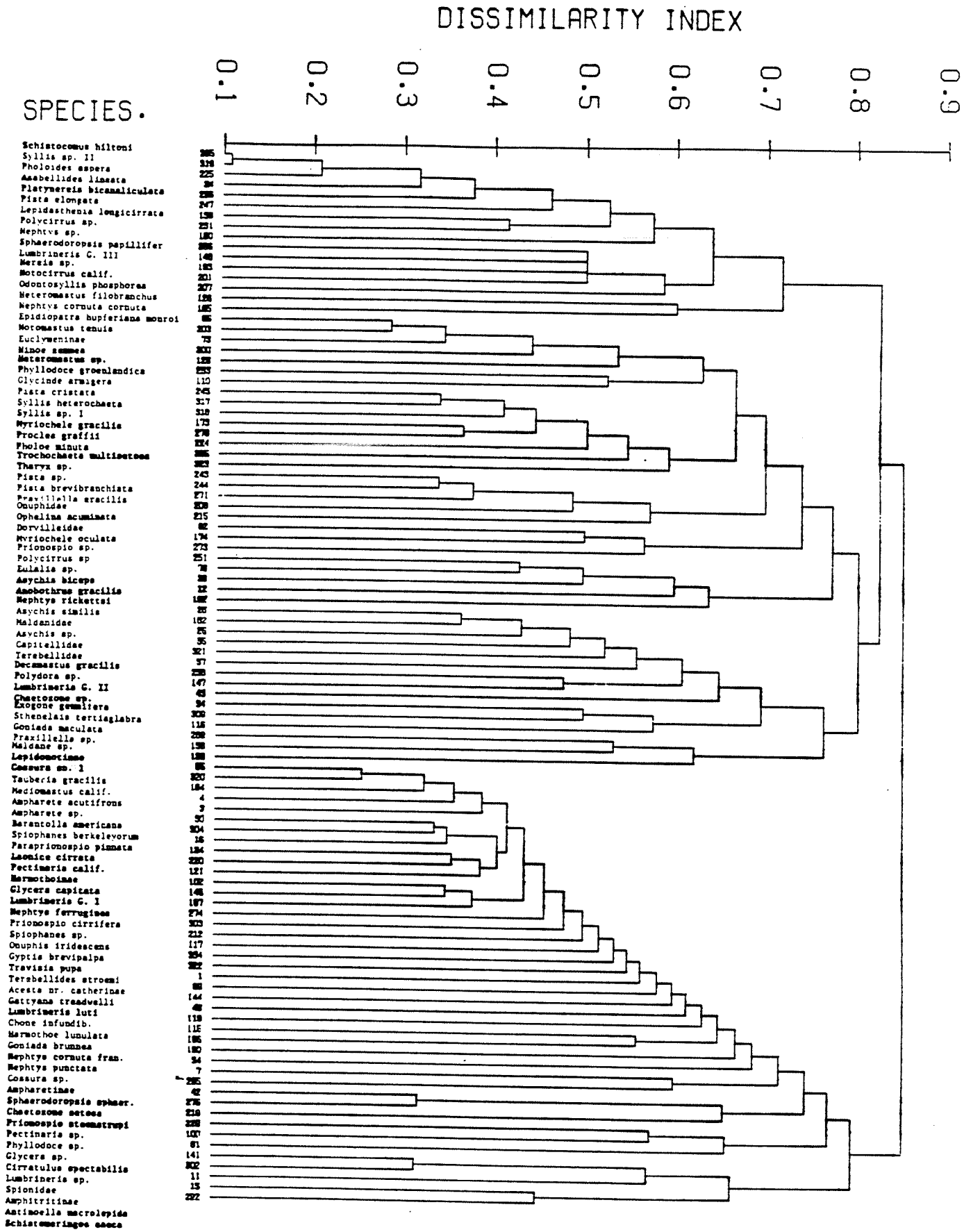



Fig. 7.41. Polychaeta species cluster for the METRO/Baseline June/July sampling period.

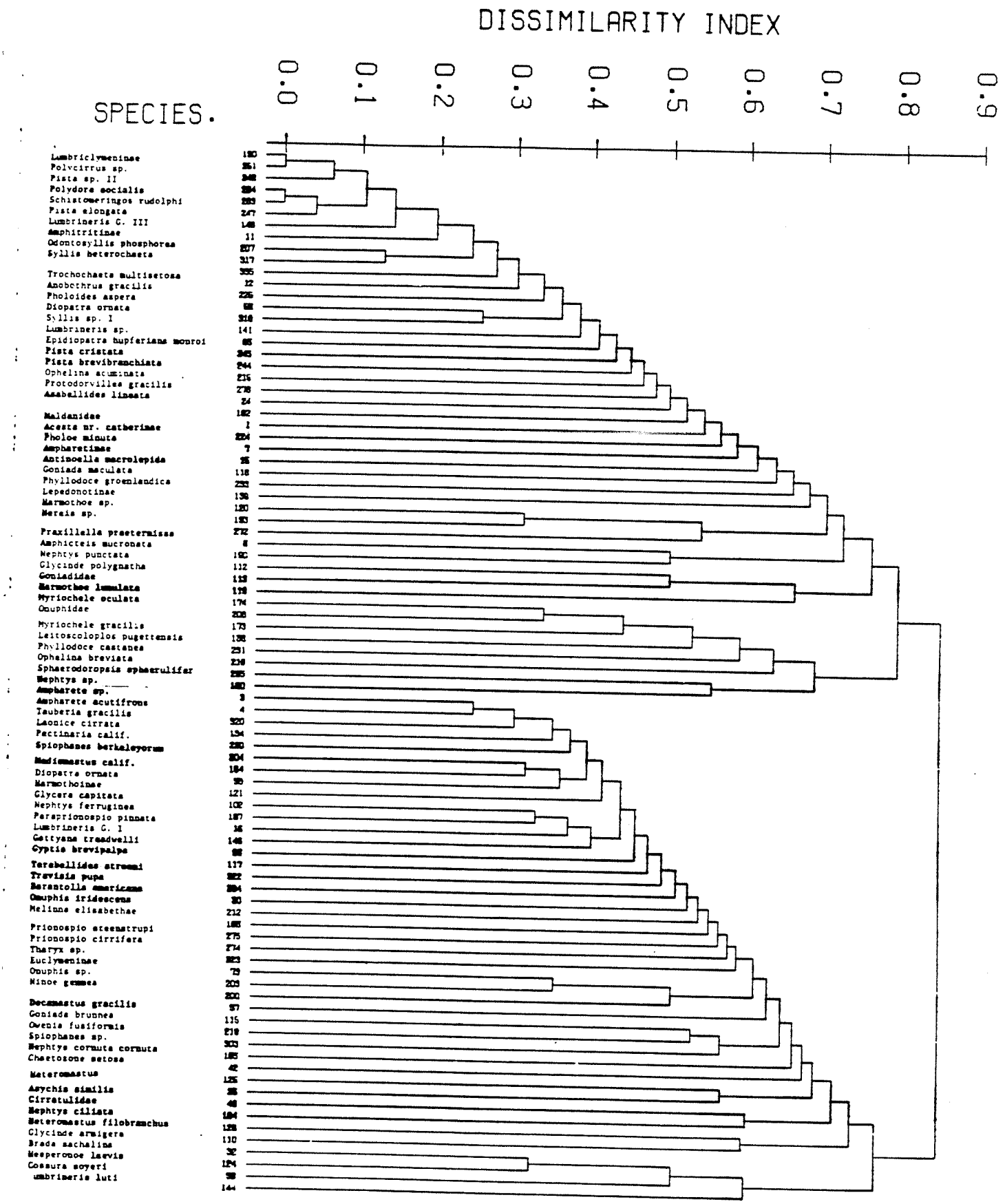



Fig. 7.42. Polychaeta species cluster for the METRO/Baseline September/October sampling period.

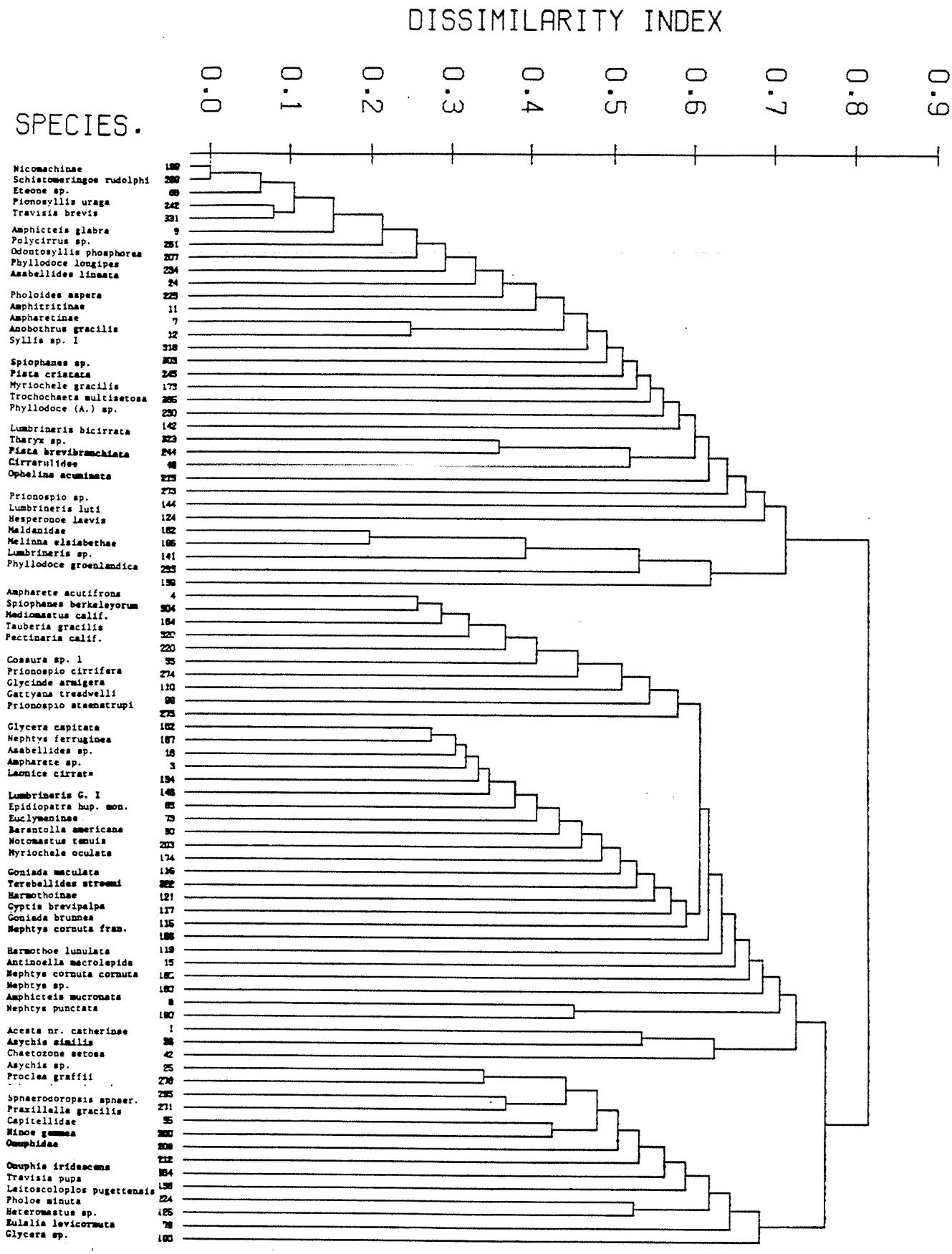



Fig. 7.43. Polychaeta species cluster for the METRO/Baseline November/December sampling period.

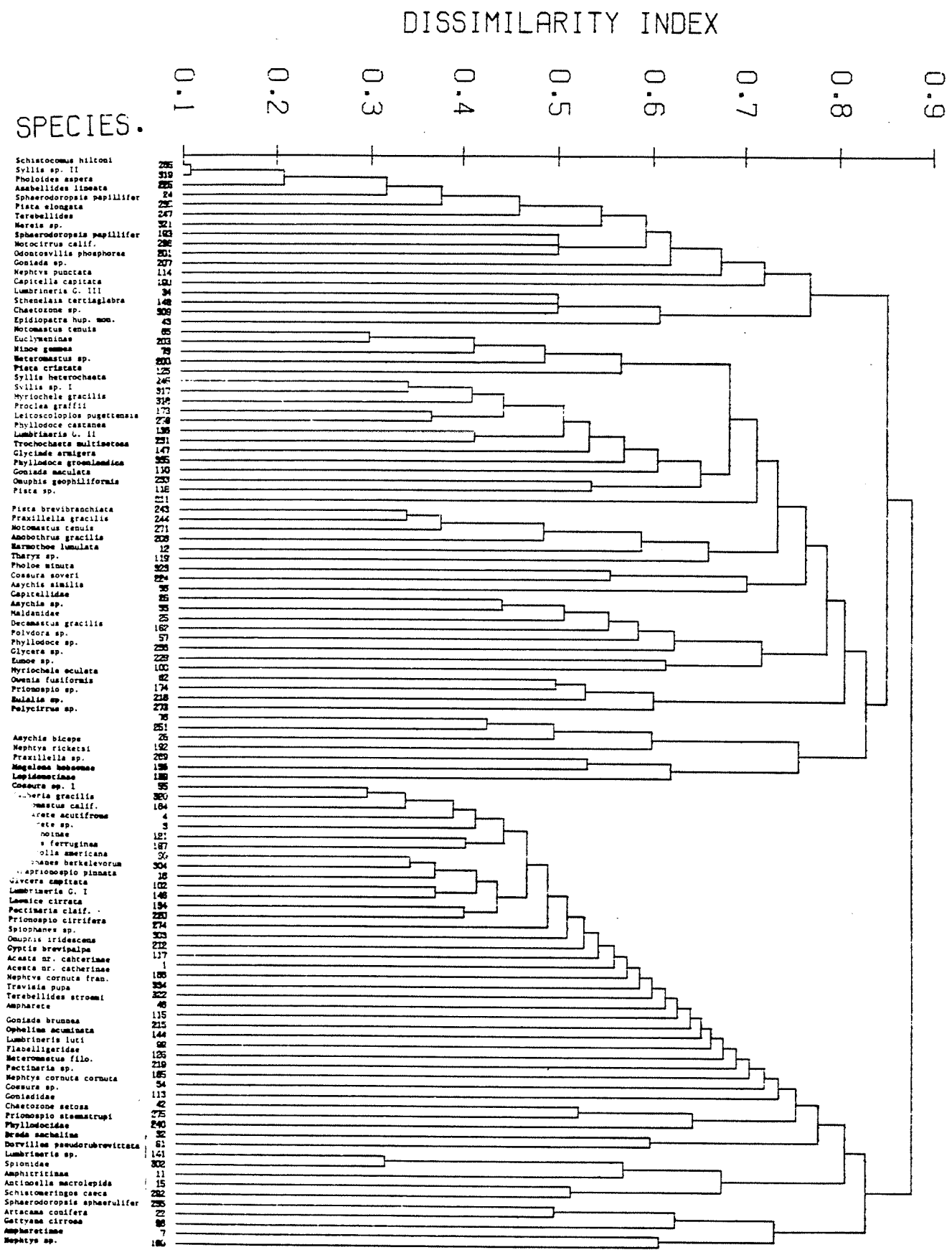



Fig. 7.44. Polychaeta species cluster for the METRO/TPPS and Baseline June/July sampling period.

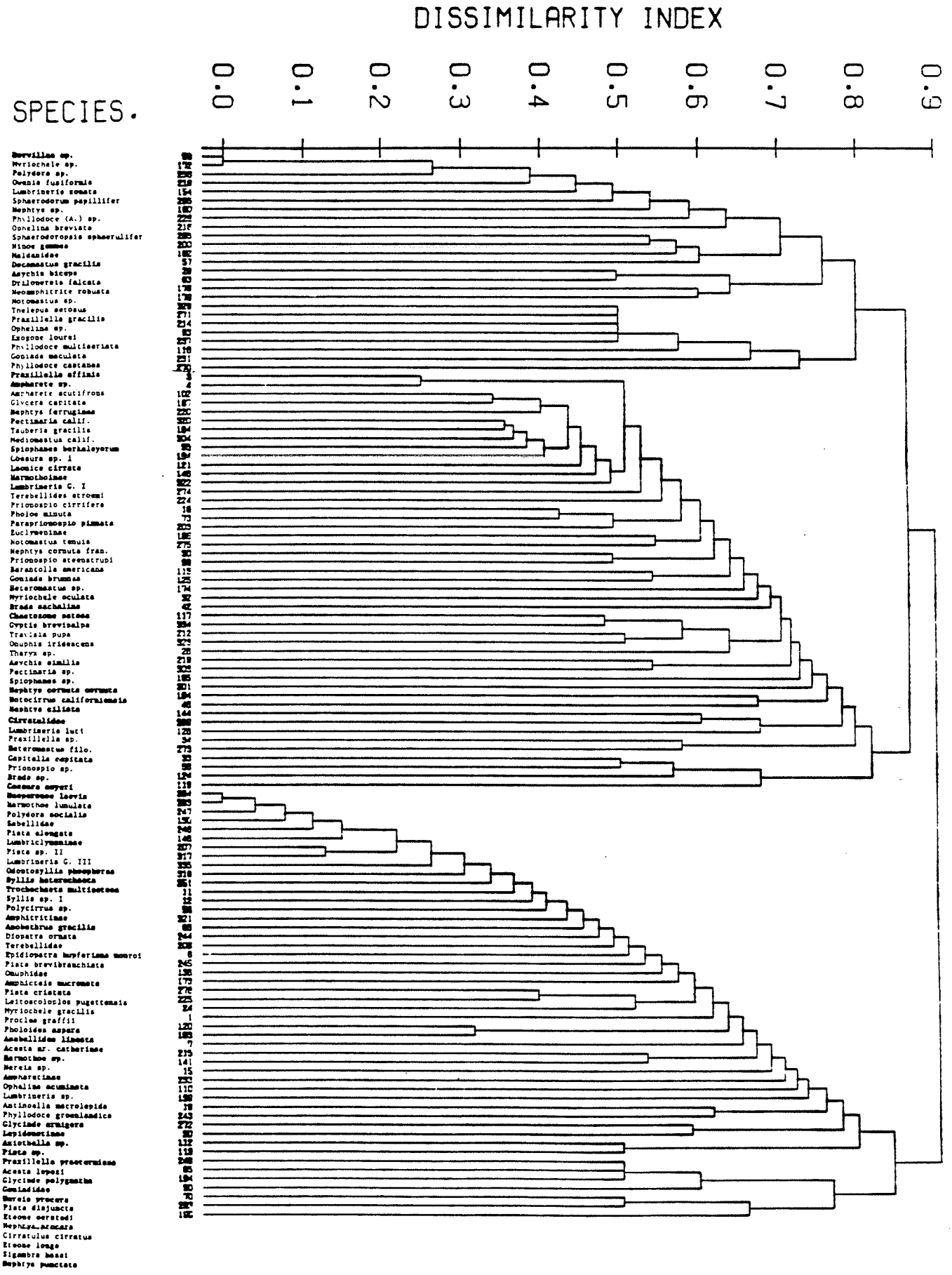



Fig. 7.45. Polychaeta species cluster for the METRO/TPPS and Baseline September/October sampling period.

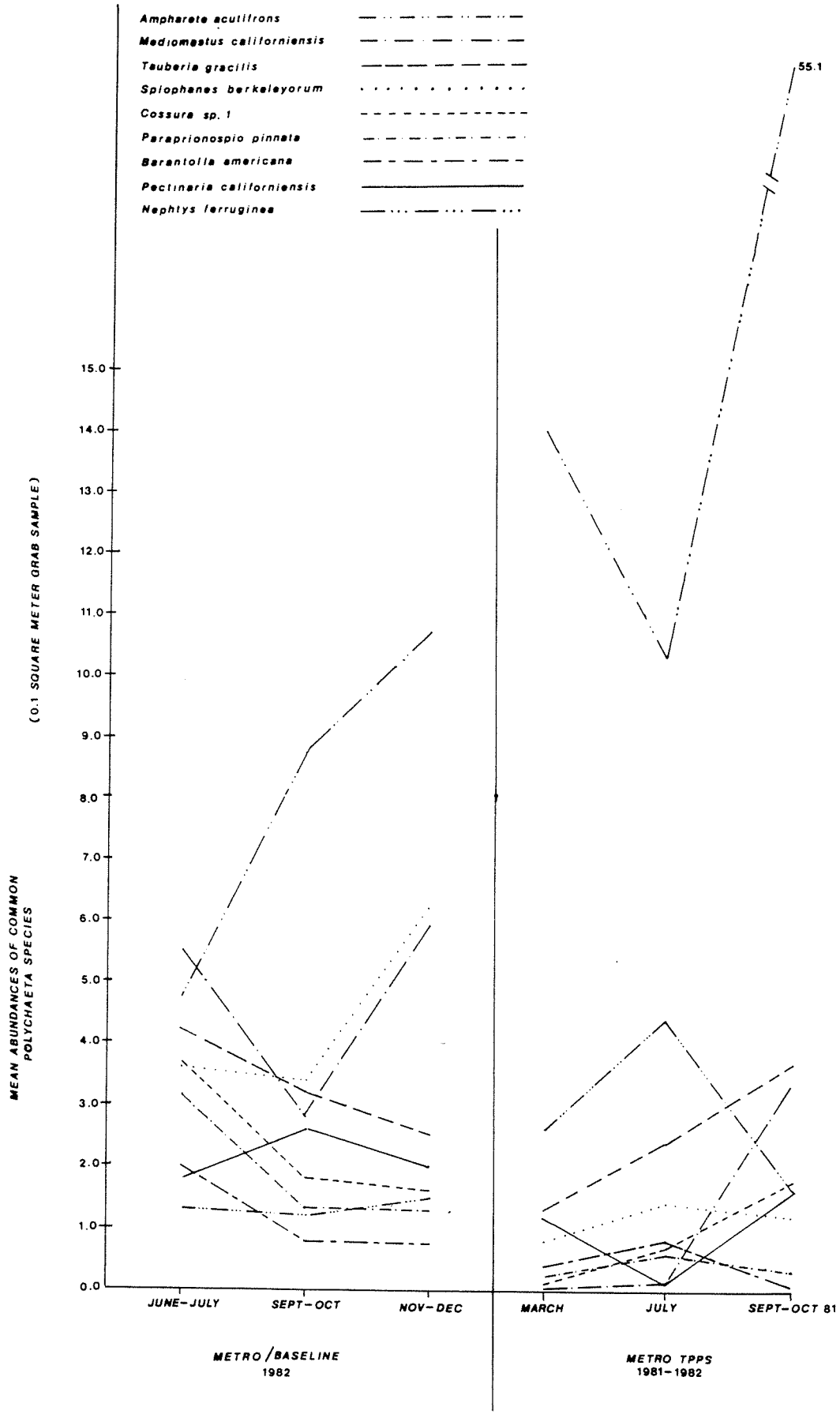



Fig. 7.46. Seasonal abundance of the nine most common polychaeta found in the two sampling areas.

The METRO/Baseline polychaeta communities at stations deeper than 600 feet were summarized by station depth to ascertain if differences in these biological communities could be attributed to depth. There were no trends evident in this analysis. The last comparison of polychaeta information was the examination of the ranges and mean values of the following parameters: number of species, abundance, Shannon-Wiener's Diversity, Gleason's Diversity, and the Infaunal Trophic Index (Table 7.27). The METRO/Baseline stations F-600, G-600, and F-780, which are off Point Pully, were separated from all other stations in these tables because biological characteristics for these stations were significantly different that all others. ANOVA examination of the differences between these two groups resulted in very high F values (Table 7.28). The greater degree of water movement off this Point Pully may result in the greater complexity of sediments that would allow for more species and individuals to inhabit this area, as well as increase the diversity values. The higher Infaunal Trophic Index values at these stations indicate a greater dependency of this community on suspension feeding than at comparable depths in other areas of the south central Puget Sound.

7.4.5 Arthropoda Patterns

Species and station clustering was performed on the arthropoda abundance data for each of the METRO/TPPS and METRO/Baseline sampling periods. The objectives were to determine the distribution of similar stations and the groupings of species that commmonly occur together. The procedure of clustering and the grouping strategies have been discussed in previous sections.

The analysis of the TPPS July 1982 data indicated that there were two distinct groups of stations (Figure 7.47). This grouping separated all replicate samples at stations II-750 and III-750 from the remainder of the

Table 7.27. Parameters describing the Polychaeta communities at both study sites.

| METRO/TPPS, 1981-2 | Mar n=20 | Jul n=20 | Sep/Oct n=17 |
|---|---|---|---|
| Number of species | | | |
| Range | 6-20 | 12-24 | 13-39 |
| Mean | 13.5 | 16.1 | 22.2 |
| Abundance | | | |
| Range | 14-52 | 19-63 | 23-365 |
| Mean | 33.2 | 37.6 | 106.5 |
| Gleason | | | |
| Range | 3.14-4.19 | 3.74-4.68 | 2.67-7.53 |
| Mean | 3.59 | 4.2 | 4.64 |
| Shannon-Wiener | | | |
| Range | 0.83-1.04 | 1.01-1.15 | 0.53-1.43 |
| Mean | 0.98 | 1.06 | 0.95 |
| Infaunal Trophic Index | | | |
| Range | 41.6-73.0 | 42.6-64.9 | 51.3-68.5 |
| Mean | 57.1 | 54.7 | 60.7 |
| METRO/Baseline, 1982 (excluding F-600E, G-600E, and F-780) | Jun/Jul n=51 | Sep/Oct n=53 | Nov/Dec n=53 |
| Number of species | | | |
| Range | 9-42 | 8-29 | 10-41 |
| Mean | 19.9 | 17.5 | 18.1 |
| S.D. | 8.4 | 5.5 | 6.0 |
| Abundance | | | |
| Range | 11-148 | 16-69 | 17-201 |
| Mean | 50.2 | 39.0 | 48.2 |
| S.D. | 33.2 | 16.2 | 30.3 |
| Gleason | | | |
| Range | 2.71-8.31 | 2.26-6.80 | 2.91-7.54 |
| Mean | 4.87 | 4.53 | 4.49 |
| S.D. | 1.42 | 1.07 | 1.05 |
| Shannon-Wiener | | | |
| Range | 0.79-1.43 | 0.78-1.35 | 0.87-1.35 |
| Mean | 1.14 | 1.12 | 1.09 |
| S.D. | 0.15 | 0.13 | 0.13 |
| Infaunal Trophic Index | | | |
| Range | 52.4-76.1 | 57.5-75.1 | 50.2-77.7 |
| Mean | 65.8 | 66.5 | 67.1 |
| S.D. | 5.3 | 3.1 | 5.3 |

Table 7.27 (continued).

| METRO/Baseline, 1982 (only stations F-600, F-780, G-600) | Jun | Sept | Nov |
|---|---|---|---|
| Number of species | | | |
| Range | 23-58 | 21-52 | 30-57 |
| Mean | 38.7 | 35.2 | 42.5 |
| S.D. | 12.9 | 12.7 | 11.6 |
| Abundance | | | |
| Range | 73-266 | 83-177 | 110-239 |
| Mean | 154.7 | 127.5 | 164.8 |
| S.D. | 82.1 | 34.3 | 45.6 |
| Gleason | | | |
| Range | 5.13-10.21 | 4.53-9.85 | 5.84-10.74 |
| Mean | 7.51 | 7.00 | 8.16 |
| S.D. | 1.86 | 2.24 | 2.13 |
| Shannon-Wiener | | | |
| Range | 1.09-1.54 | 1.18-1.56 | 1.21-1.55 |
| Mean | 1.34 | 1.32 | 1.36 |
| S.D. | 0.15 | 0.16 | 0.14 |
| Infaunal Trophic Index | | | |
| Range | 63.8-79.7 | 63.3-85.6 | 71.1-76.4 |
| Mean | 70.3 | 71.3 | 73.4 |
| S.D. | 5.2 | 8.1 | 1.9 |

Table 7.28. ANOVA analysis of Polychaeta communities during all sampling periods of the METRO/Baseline study.

| | Polychaeta communities ANOVA F values All stations vs. F600, G600, F780 METRO/Baseline, 1982 | | |
|---|---|---|---|
| | Jun/Jul | Sep/Oct | Nov/Dec |
| Number of species | 23.09 | 38.30 | 70.29 |
| Abundance | 34.48 | 118.66 | 70.13 |
| Gleason | 17.12 | 21.22 | 50.21 |
| Shannon-Wiener | 8.78 | 11.59 | 23.77 |
| Infaunal Trophic Index | 3.91 | 7.98 | 8.18 |

$F_{crit-0.05,1,49(51)} = 5.34$ $F_{crit-0.10,1,49(51)} = 4.03$

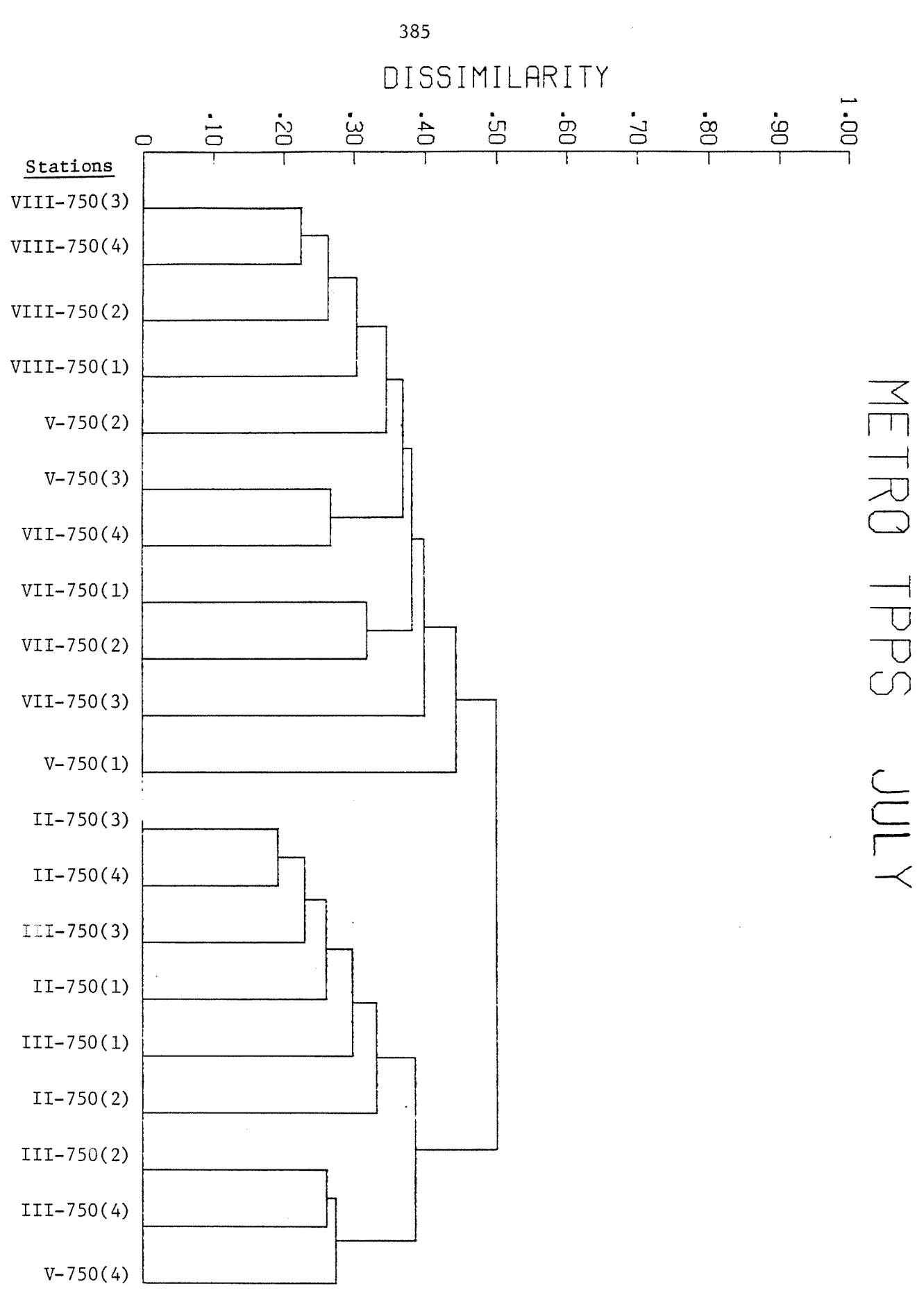



Figure 7.47. Arthropoda station cluster for the METRO/TPPS July sampling period.

samples off West Point at a 0.5 level of dissimilarity (Figure 7.47). The data indicate that there was a larger abundance of the copepod Calanus at these two stations than at the other three and greater abundance of Euphilomedes producta, which may account for the cluster diagram. The TPPS March 1982 grouping of stations separated three of the four replicate samples at station II-750 from the remaining samples at a dissimilarity value of 0.5 (Figure 7.48). A number of factors may be accounting for this cluster. The abundance of Euphilomedes producta and Heterophoxus oculatus are much less at II-750 than at the other stations and the abundance of Eudorella pacifica is greater than at the other stations.

The site groupings for the September/October 1981 data, performed on a different set of stations, showed two primary clusters of stations with a dissimilarity value of 0.6 (Figure 7.49). This grouping separated stations that were at depths of 185-210 m from those at depths greater than 230 m except for four cases, two of which were on transect I, and two on transect X.

The Baseline stations in south central Puget Sound grouped in less distinct patterns. During the June/July sampling period (Figure 7.50) the majority of the stations on transects B, C, D, and stations H-640 and OT-1 had lower dissimilarity values than did the stations on transects A, E-G, I, and J. During this sampling period the most different areas were stations OT-2, E600E, F600E, F780, G600E, G780, H600E, and I600E. These stations are very similar to the groupings of stations that were most different in the mollusca and polychaeta station groupings. The September/October and November/December dendograms (Figures 7.51-7.52) showed that some of these stations, particularly F600E and G600E, were again strongly dissimilar to all others.

The June/July comparison of the METRO/Baseline and METRO/TPPS samples showed three major groupings of stations (Figure 7.53). All METRO/TPPS

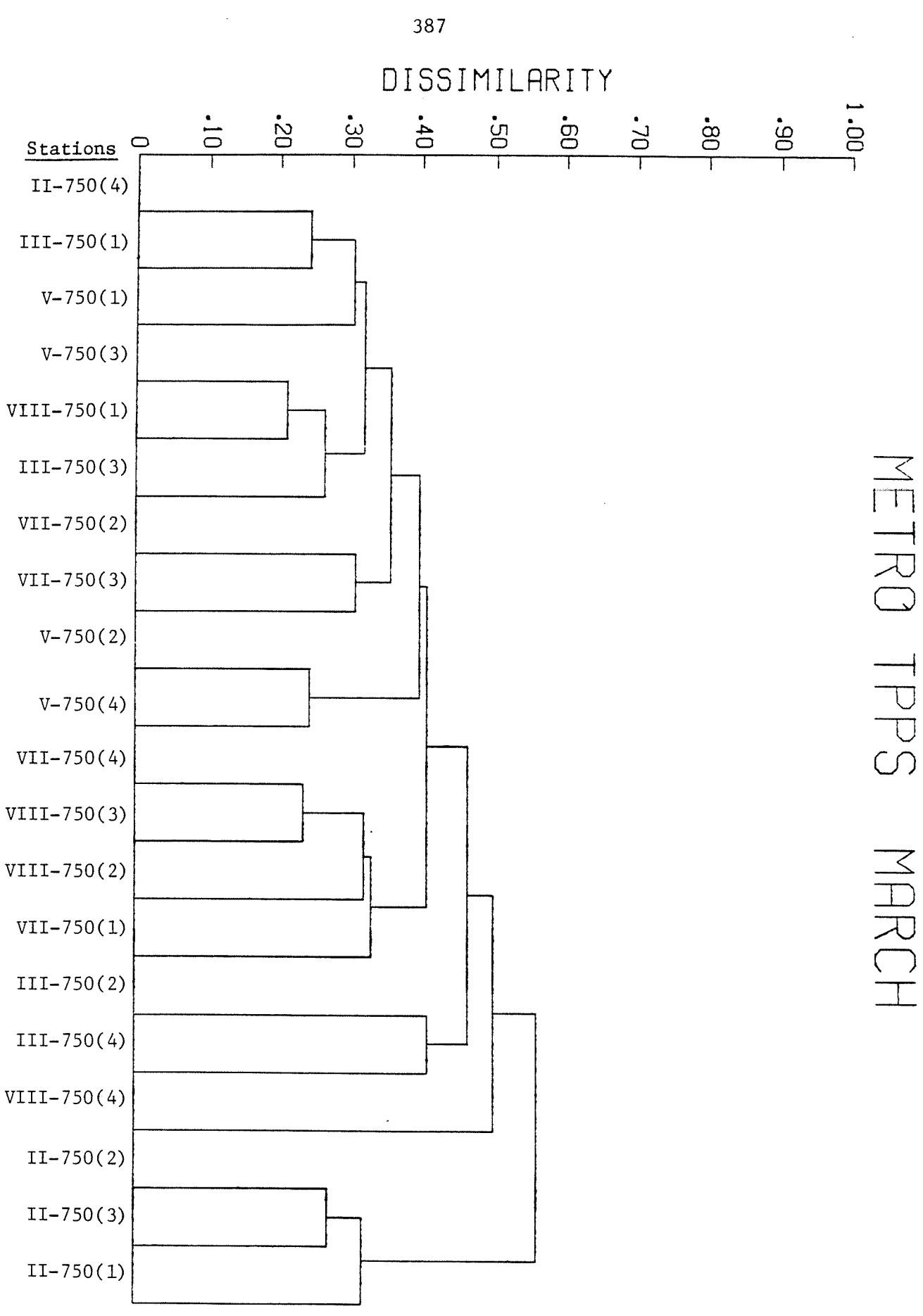



Fig. 7.48. Arthropoda station cluster for the METRO/TPPS March sampling period.

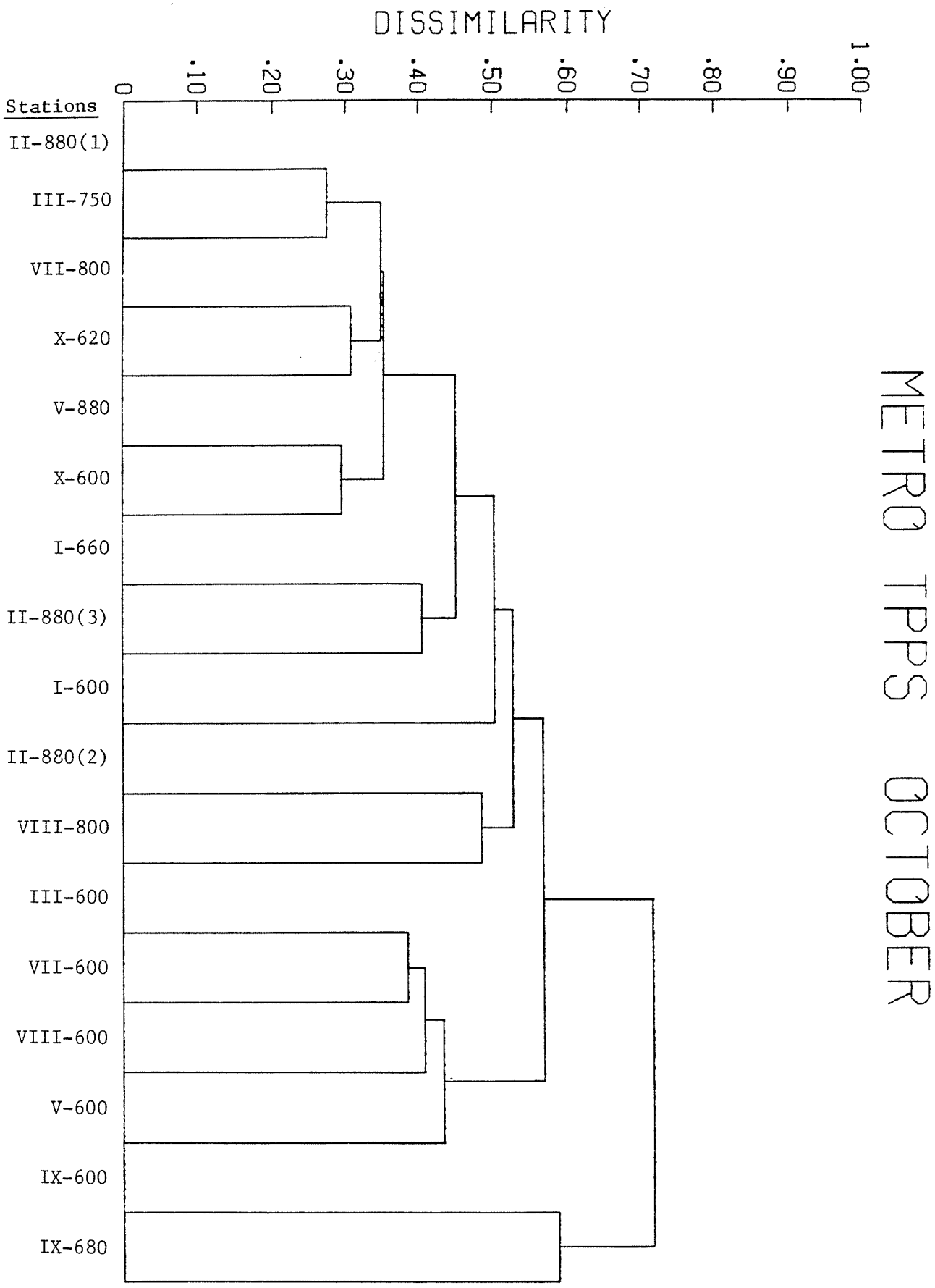



Figure 7.49. Arthropoda station cluster for the METRO/TPPS Sept./Oct. sampling period.

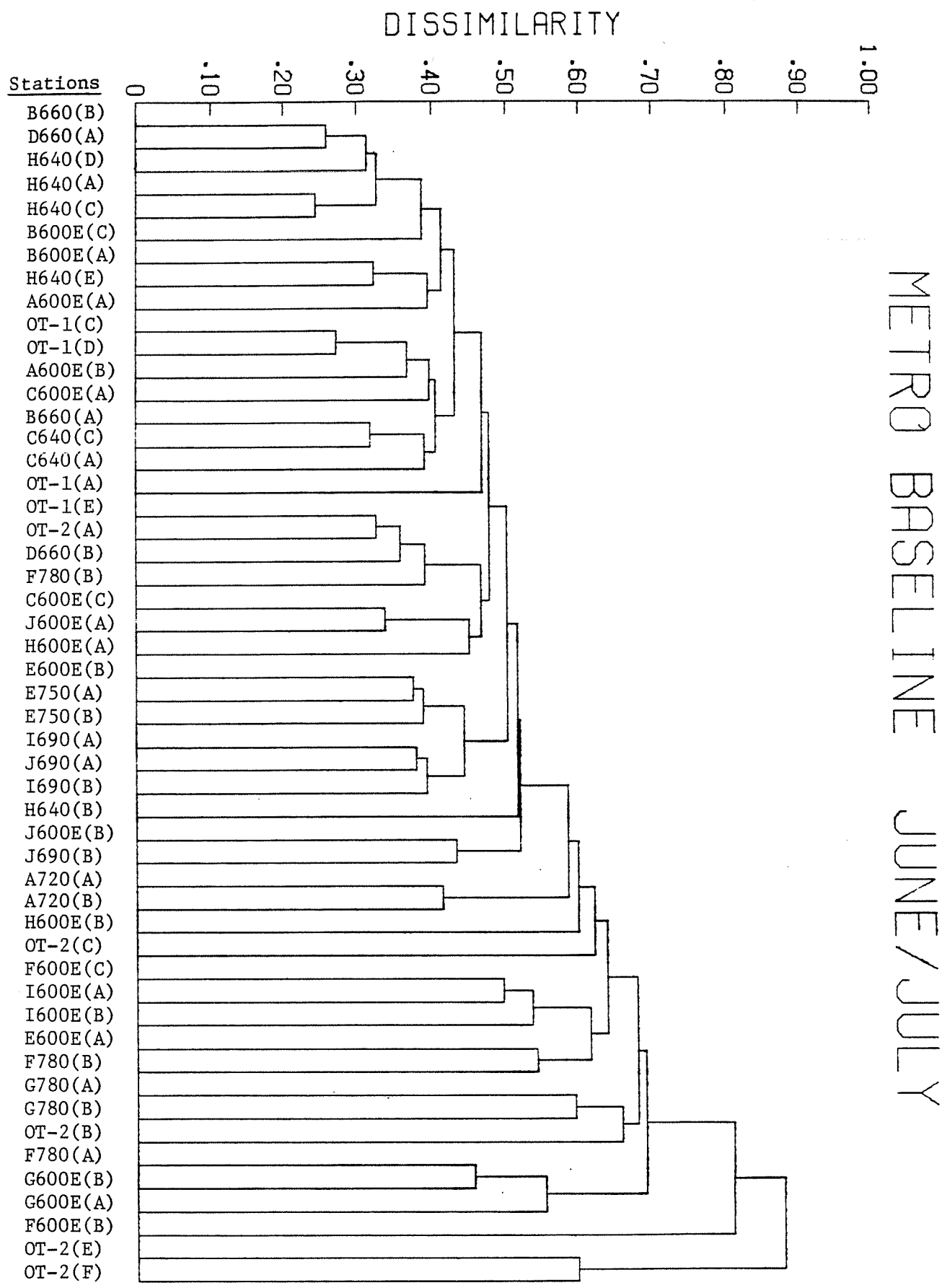



Fig. 7.50. Arthropoda station cluster for the METRO/Baseline June/July sampling period.

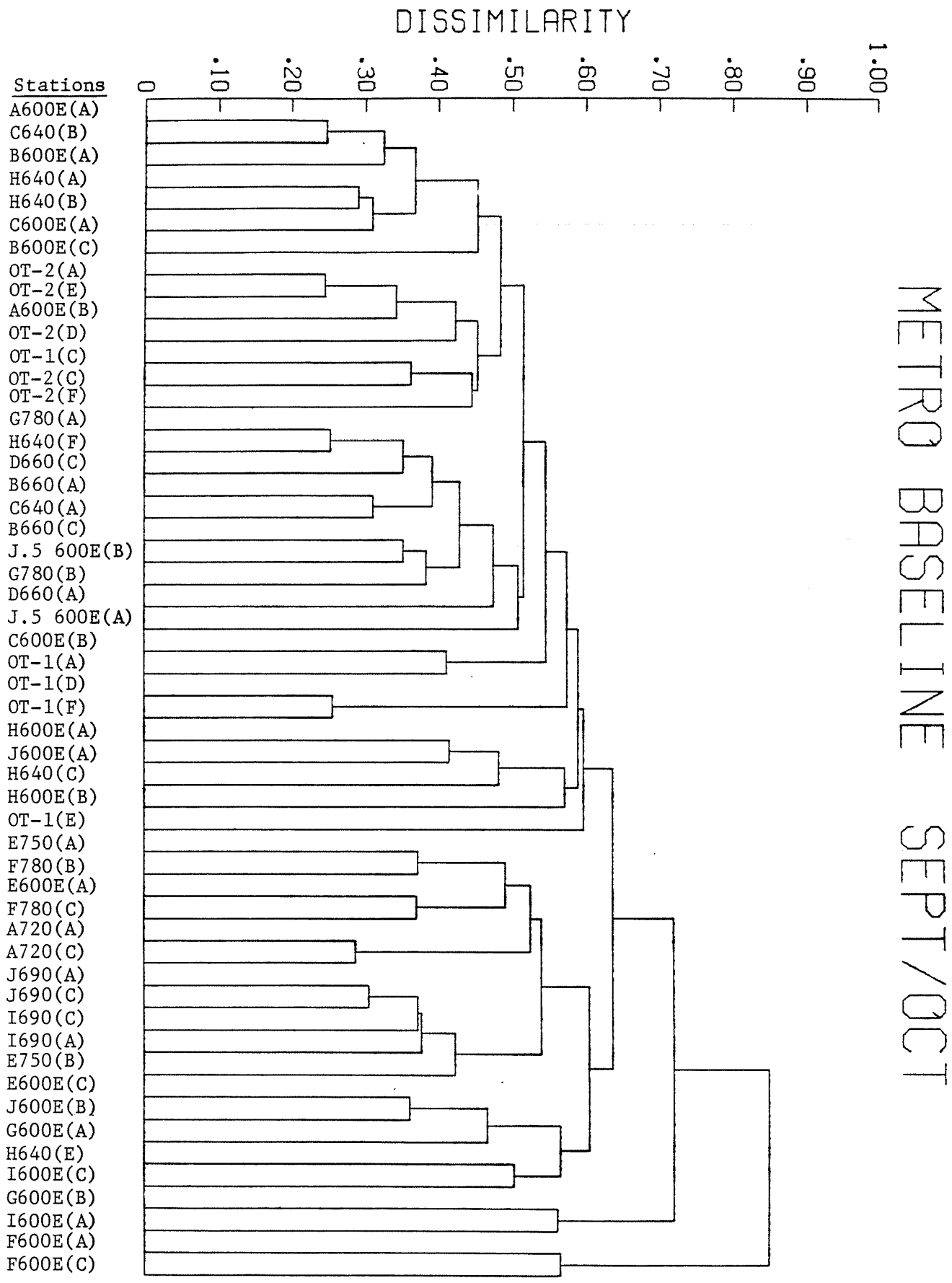



Fig. 7.51. Arthropoda cluster for the METRO/Baseline Sep/Oct sampling period.

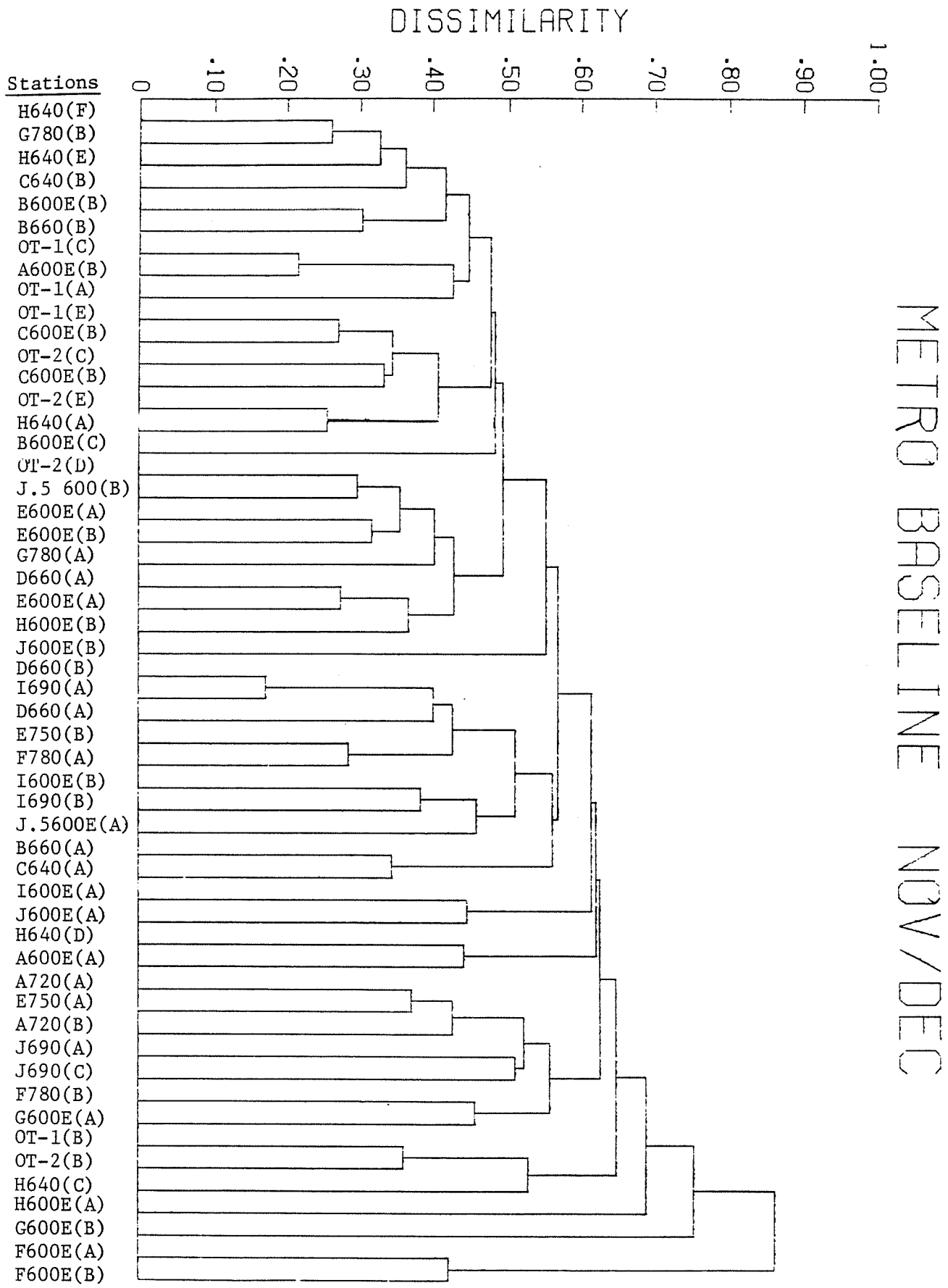



Fig. 7.52. Arthropoda station cluster for the METRO/Baseline Nov/Dec sampling period.

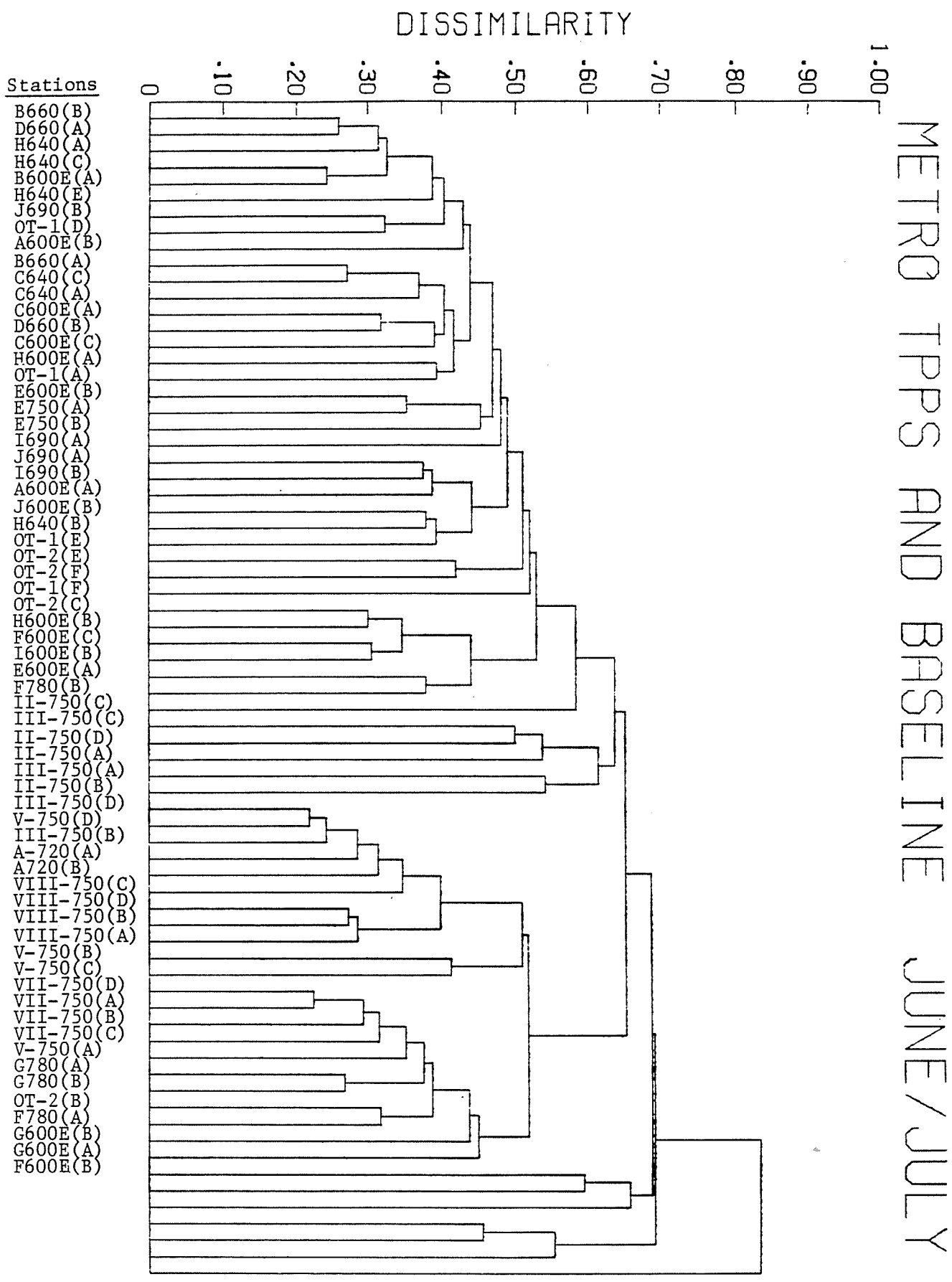



Fig. 7.53. Arthropoda station cluster for the METRO/TPPS and Baseline June/July sampling period

stations and the baseline station A720, clustered at a dissimilarity of 0.5. The baseline stations G780, F780, G600E, F600E and OT-2, clustered with a 0.7 level of dissimilarity, separate from the remaining baseline stations.

The comparison of the September/October sampling periods also showed a major separation between areas off West Point and those in south central Puget Sound (Figure 7.54). The cluster of TPPS stations again included the most northern Baseline station, A-720. The Baseline outlier group found in the June/July data was not as apparent in the September/October data, though F600E, G600E and I600E clustered separately.

Examination of the arthropoda species clusters showed a ubiquitous group of taxa common to all the sampling periods in both the METRO/Baseline and METRO/TPPS surveys (Figures 7.55-7.62). These five species consistently occurred in the same cluster in all dendograms: Eudorella pacifica, Heterophoxus oculatus, Harpiniopsis fulgens, Euphilomedes producta, and Paraphoxus oculatus. In the METRO/TPPS study this grouping of species also included Diastylis pellucida and Protomedeia articulatea, while in the Baseline study Bathymedon spp., Ampelisca macrocephala, and Eudorellopsis integra were included in the ubiquitous group of species.

Examination of the abundance of nine of the common species revealed that in all instances Euphilomedes producta and Eudorella pacifica were more abundant at the TPPS stations than at the Baseline stations (Figures 7.63). It also showed that the majority of species commonly encountered were not major numerical components of either of the two areas. It should be noted that in the TPPS and Baseline comparisons the arthropods Calanus and Cyphocar challengeri were excluded from the analysis because they are considered to be members of the water column fauna, not the benthos.

During all sampling periods of the Baseline survey, the ranges and means

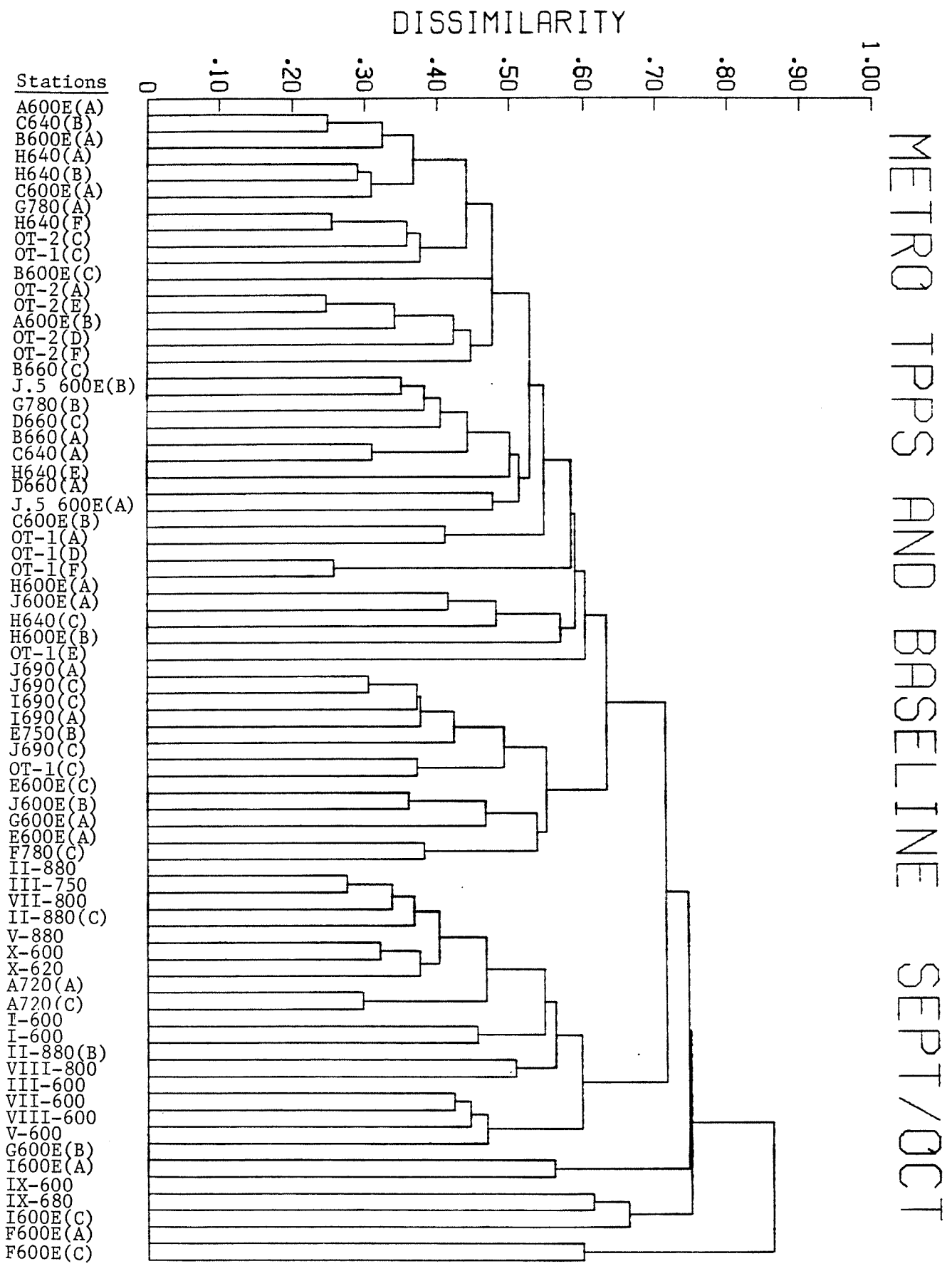



Fig. 7.54. Arthropoda station cluster for the METRO/TPPS and Baseline Sep/Oct sampling period.

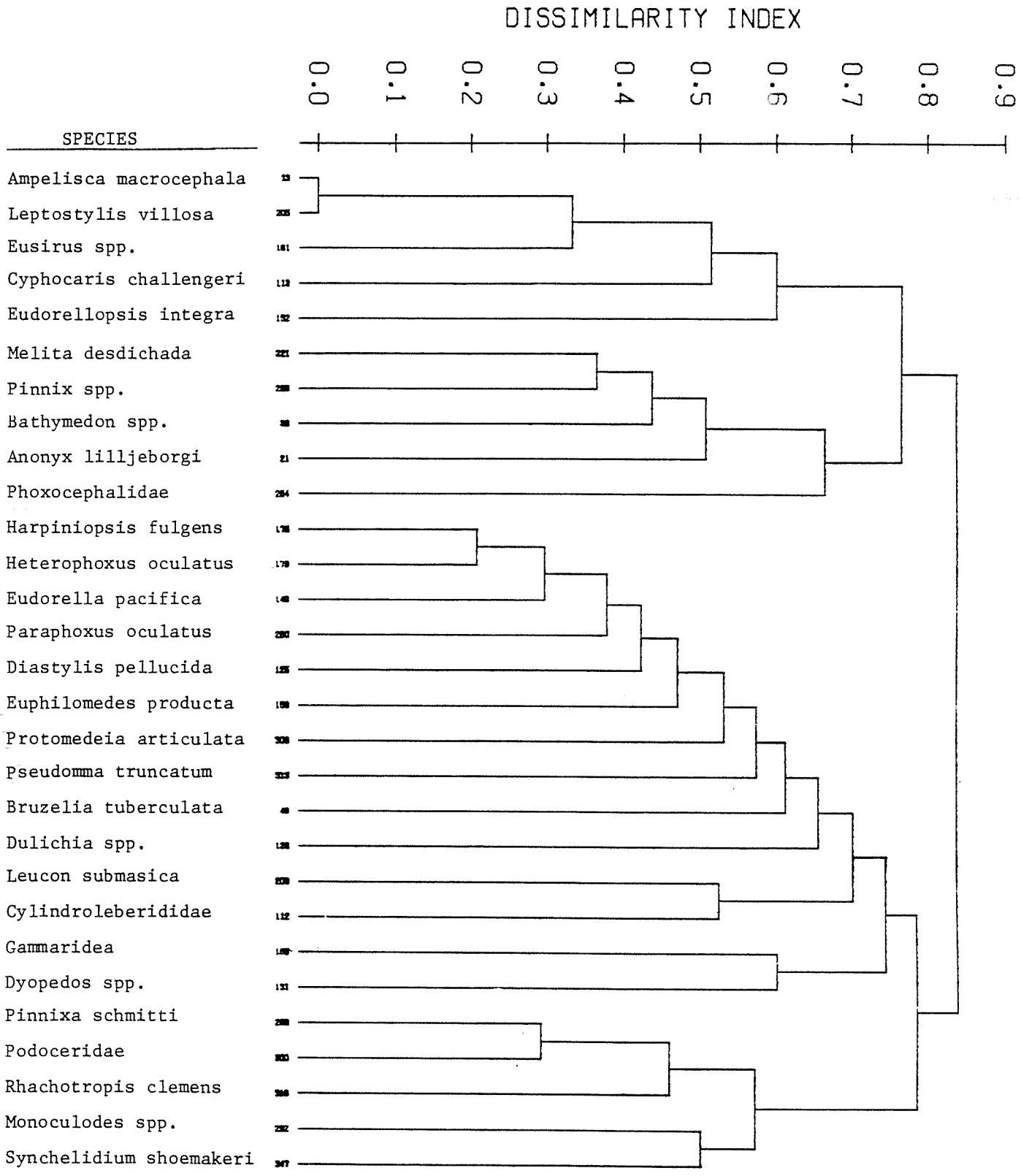



Fig. 7.55. Arthropoda species cluster for the METRO/TPPS March sampling period.

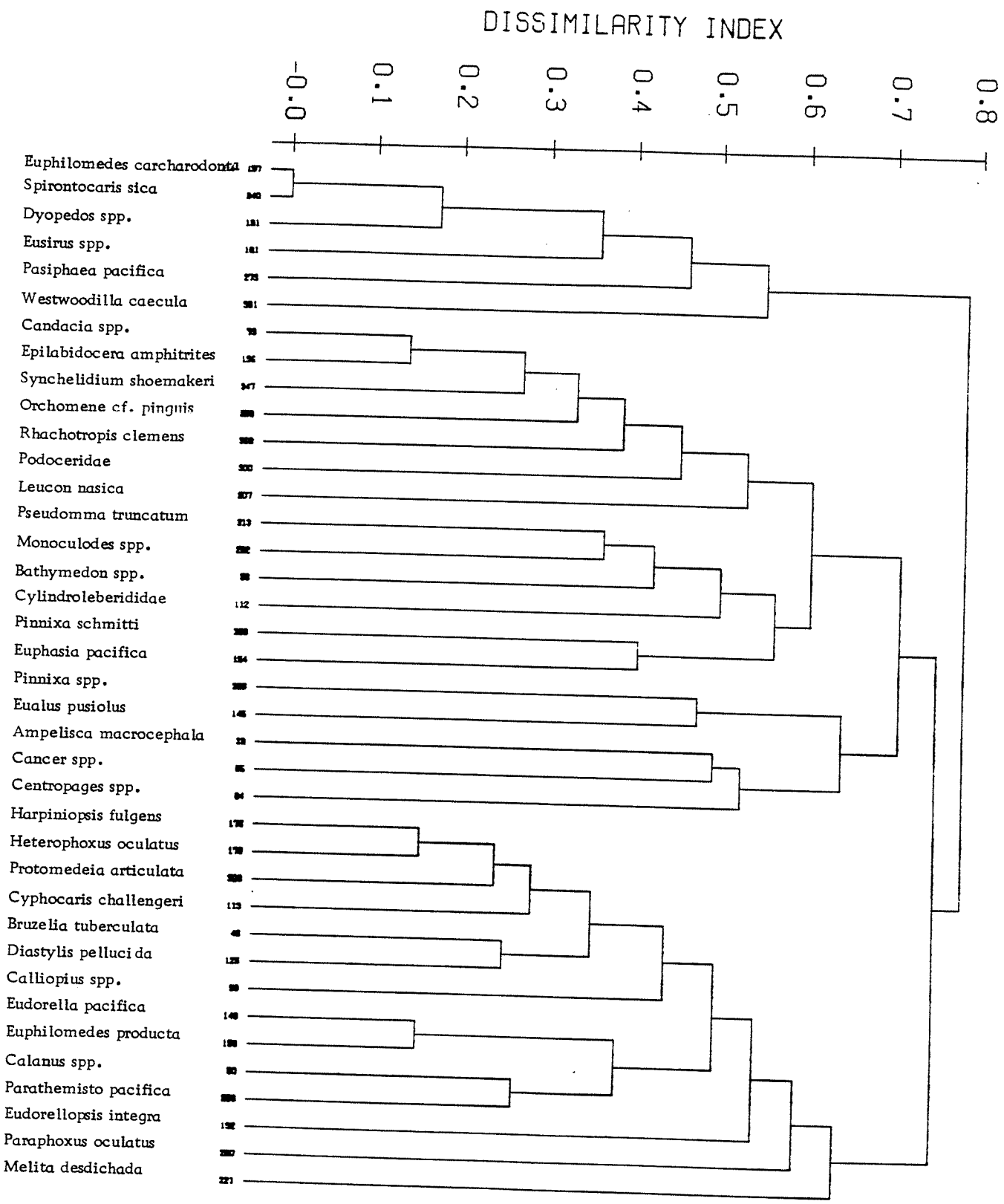



Fig. 7.56. Arthropoda species cluster for the METRO/TPPS July sampling period.

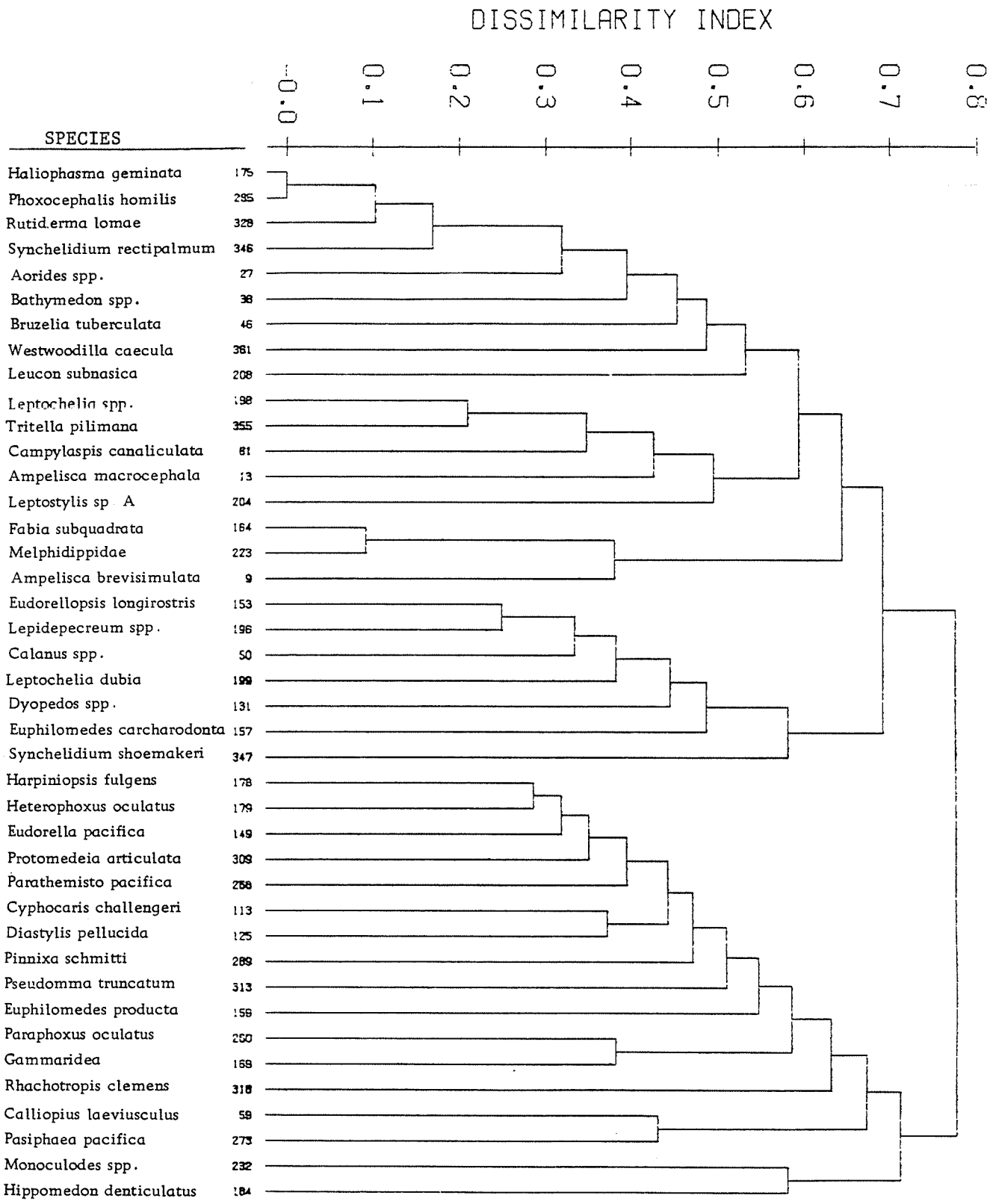



Fig. 7.57. Arthropoda species cluster for the METRO/TPPS Sept/Oct sampling period.

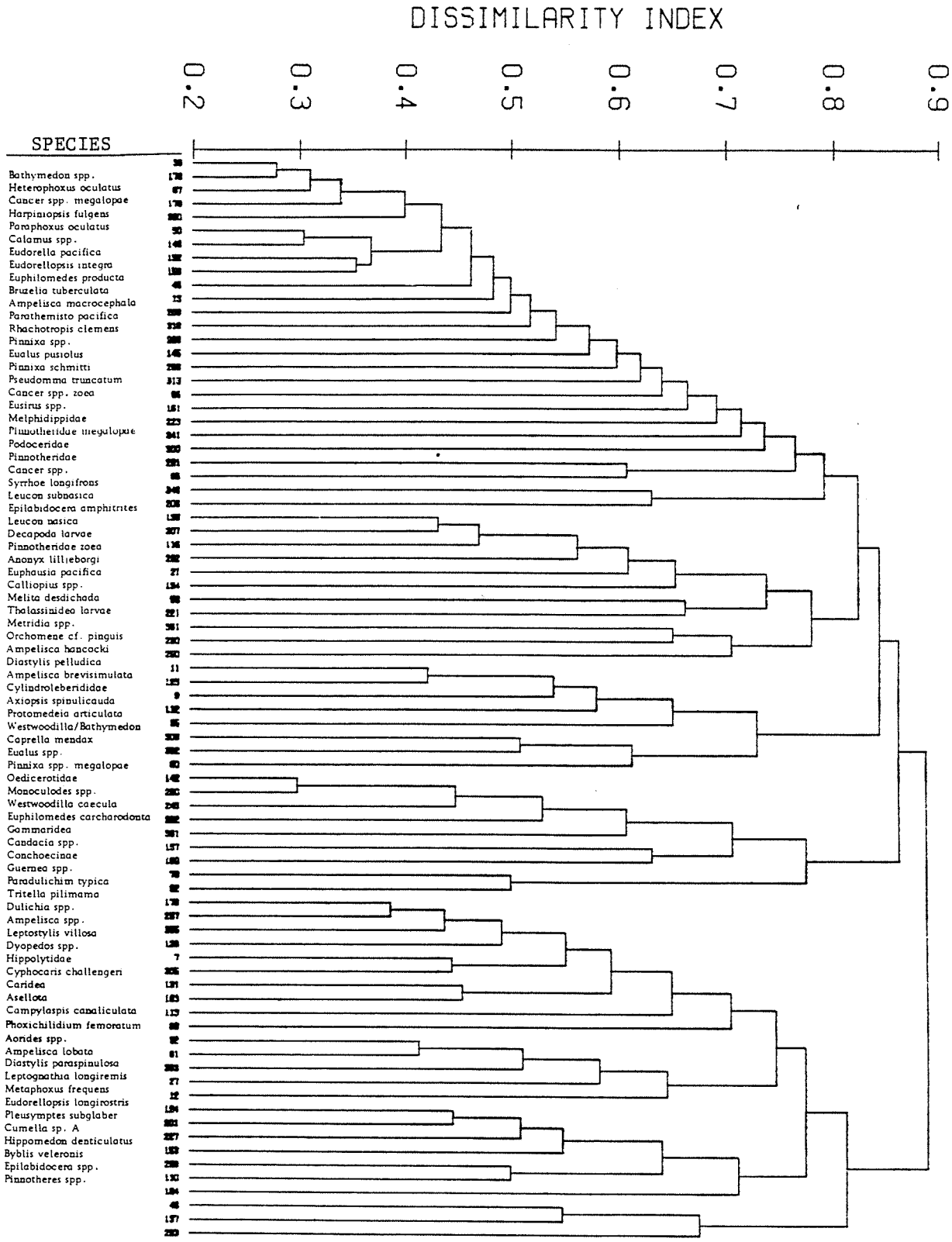



Fig. 7.58. Arthropoda species cluster for the METRO/Baseline June/July sampling period.

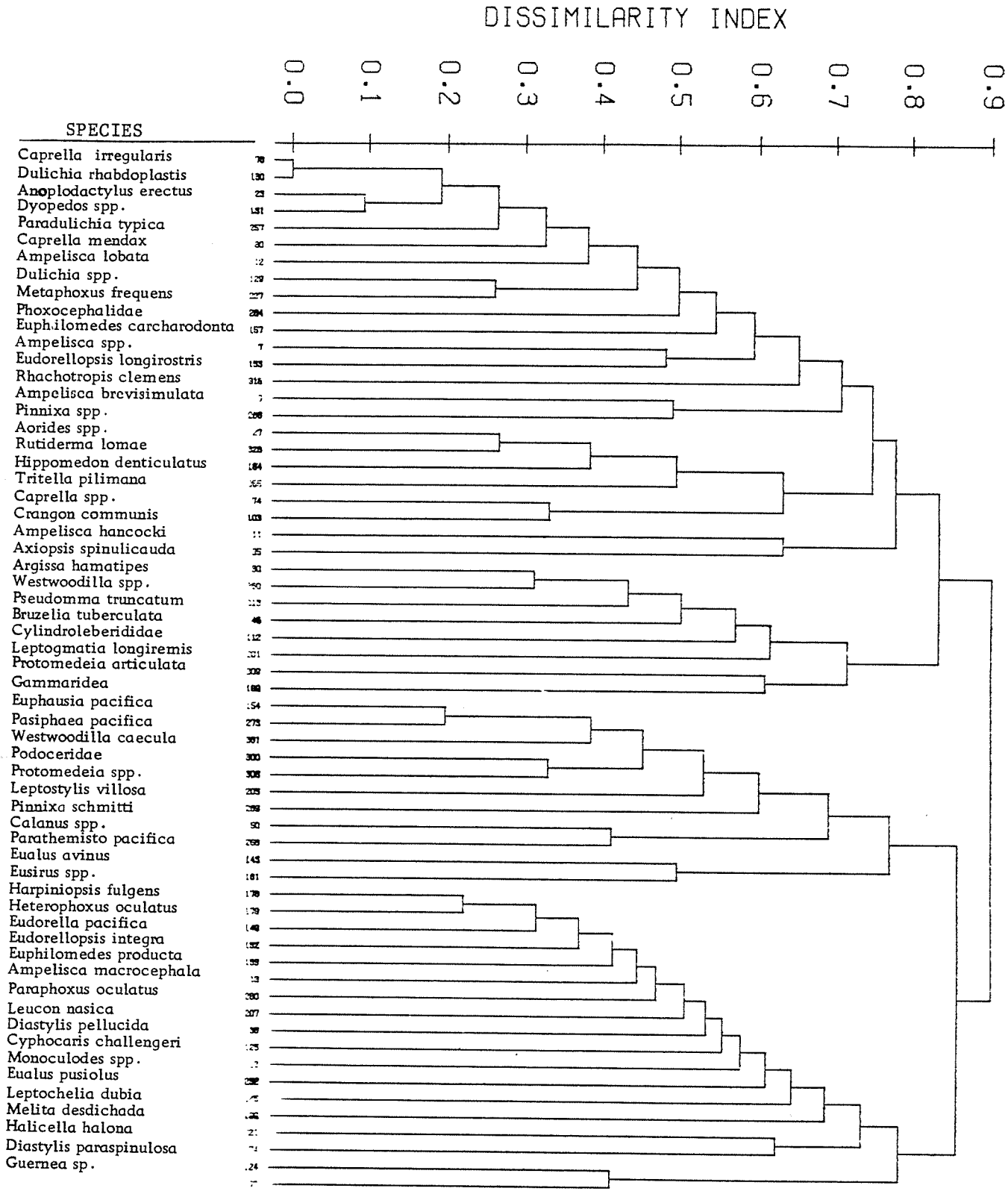



Fig. 7.59. Arthropoda species cluster for the METRO/Baseline Sept/Oct sampling period.

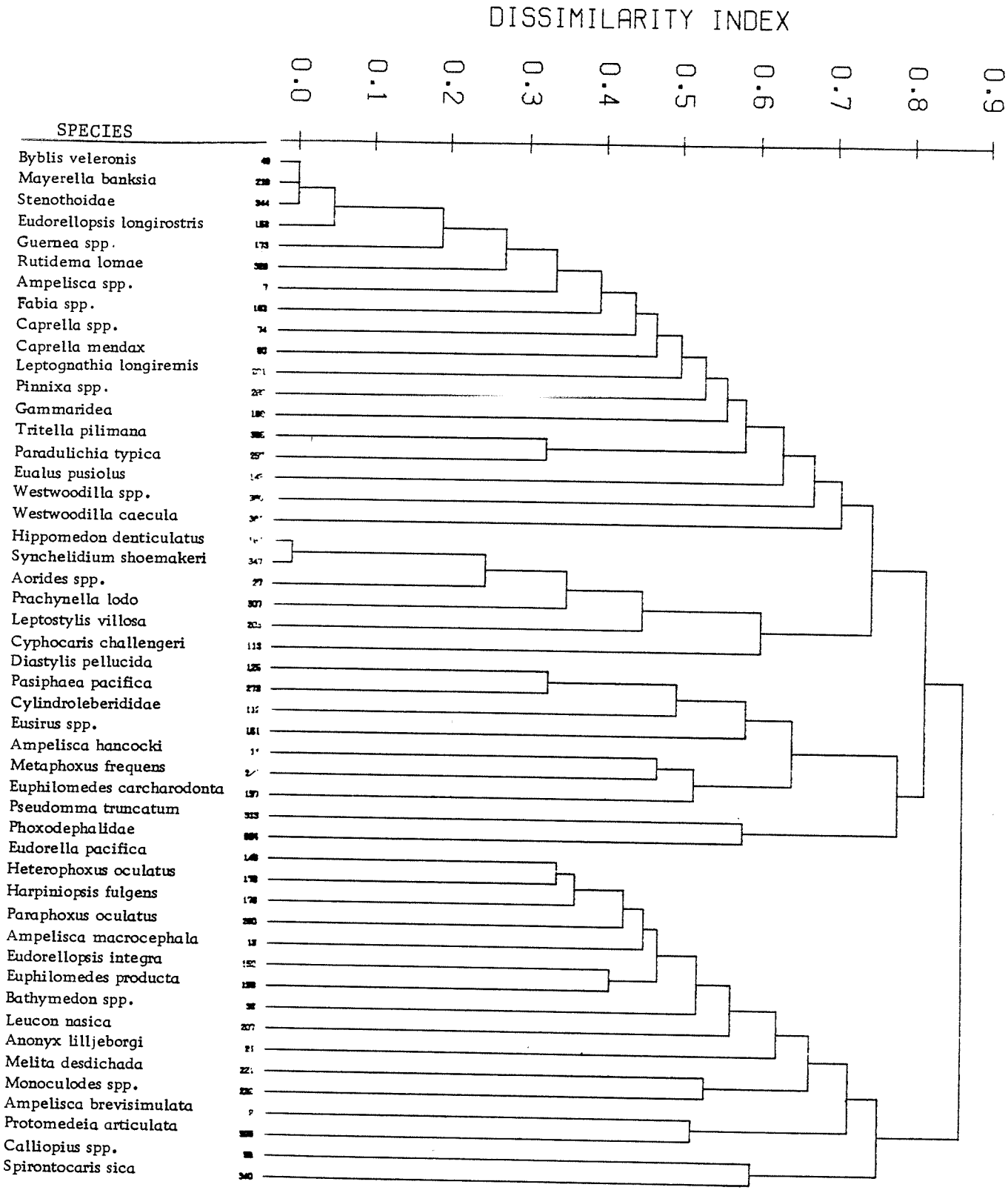



Fig. 7.60. Arthropoda species cluster for the METRO/Baseline Nov/Dec sampling period.

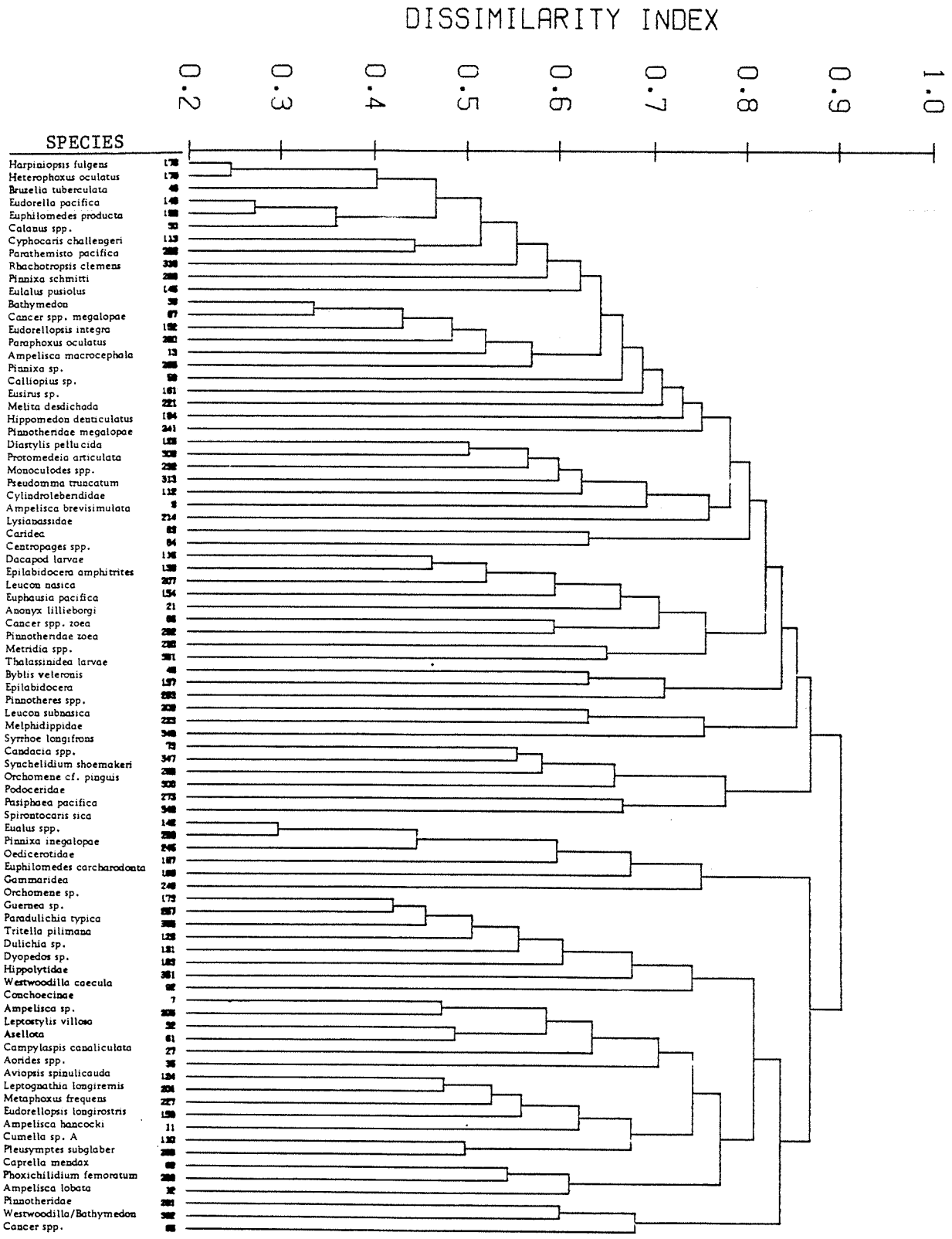



Fig. 7.61. Arthropoda species cluster for the METRO/TPPS and Baseline June/July sampling period.

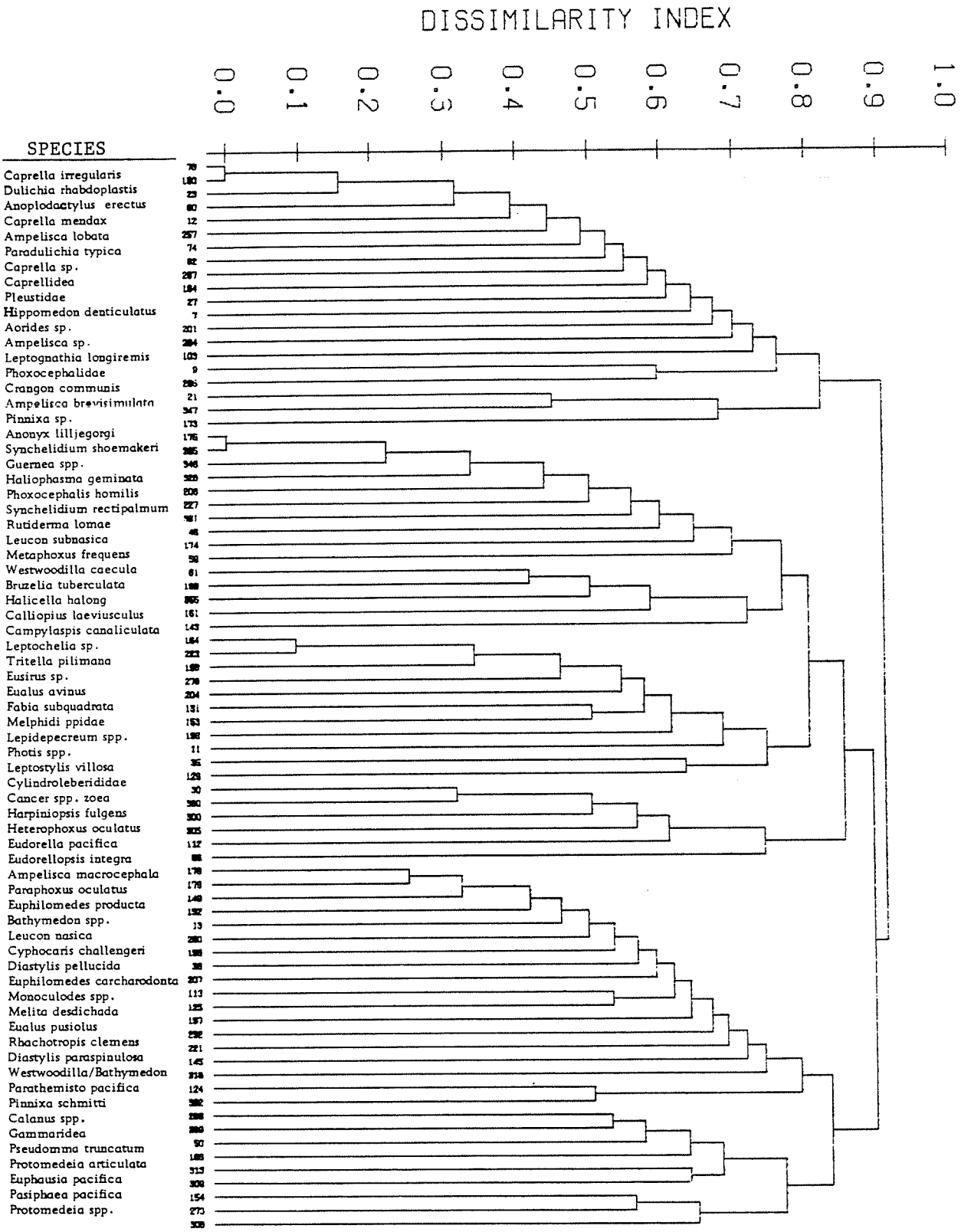



Fig. 7.62. Arthropoda species cluster for the METRO/TPPS and Baseline Sept/Oct sampling period.

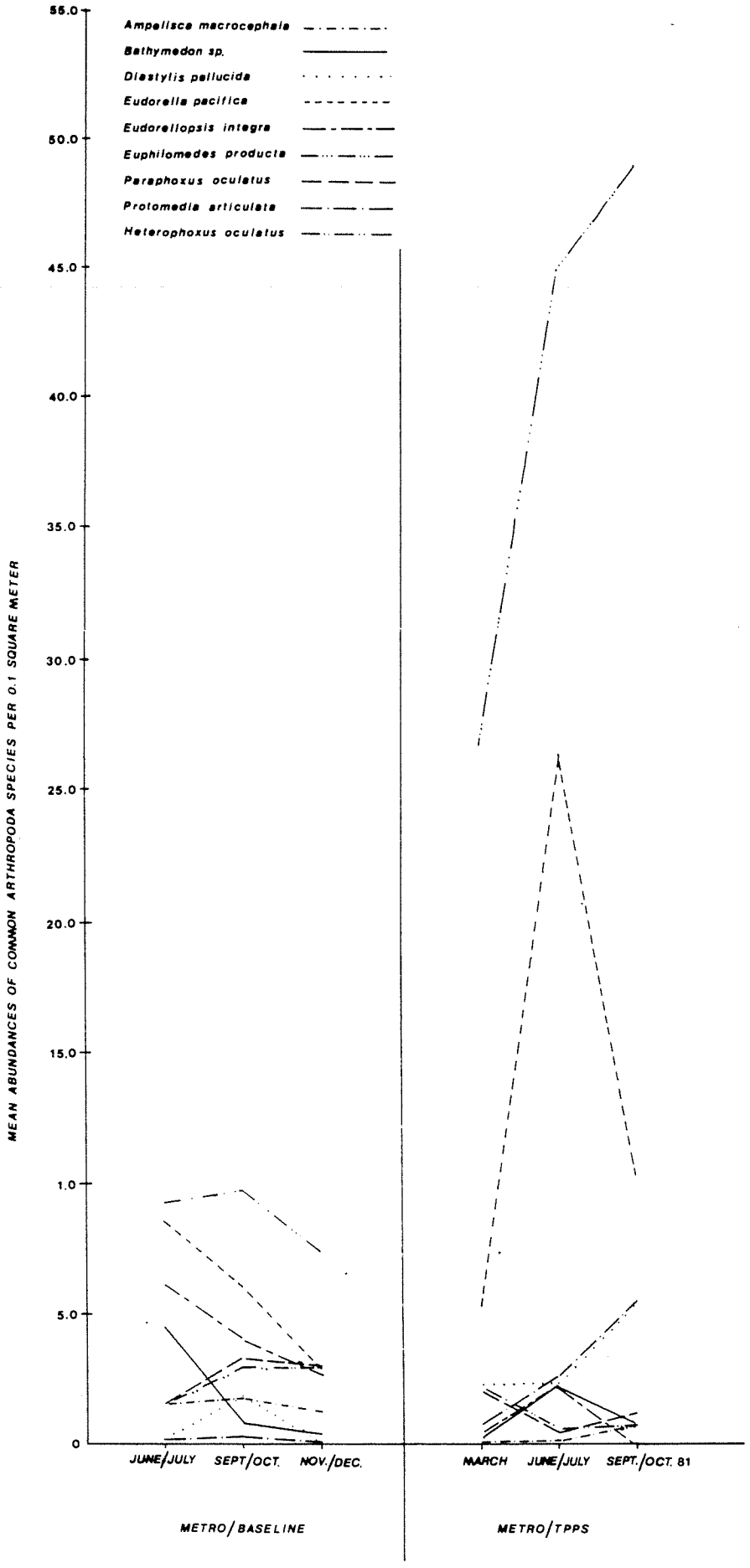



Fig. 7. 63. Seasonal abundance patterns for the nine most common arthropoda in the two study areas.

of the following values were tabulated: number of species, abundance, Gleason's Diversity, Shannon-Wiener's Diversity, Infaunal Trophic Index, none of which were significantly different from season to season. Station F600E was so consistently set apart in the dendograms that an ANOVA examination was done to determine if its biological characteristics differed significantly from all other Baseline stations. The analysis showed that there was a significant difference in all values except for the arthropoda abundance for the June/July and September/October sampling periods (Table 7.29 a & b).

7.4.6 Chemistry

Chemical and physical data were clustered on 93 stations within south central Puget Sound. These data formed a dendogram with eight major groups of stations (Figure 7.64). Basic statistics were obtained on each of these groupings of stations including means, standard deviations, coefficients of variation, standard errors, coefficients of skewness, and coefficients of kurtosis (Table 7.30). These groupings were then placed in a hierarchy so that ranks could be assigned to each group based upon the concentrations of carbon and water in the sediments. Carbon and percent water rankings reflected the rankings of other major chemical measurements and showed trends in the physical measurements of sediment grain sizes. The rankings gave the stations with the lowest carbon and water content the lowest rank and proceeded through the grouping so that the relative position within the rankings reflected a gradient in these parameters.

Each group was then assigned a color pattern which reflected the amount of organic material in the sediments, ranging from black for a high organic content to a light stippling for a low organic content. This was then plotted on a chart of the sampling area. In general, the concentration of organics, percentage water in the sediments, and the percentage of silt and clay

Table 7.29A. Biological parameters of the arthropod communities sampled during the three METRO/Baseline surveys, excluding station F-600E.

| | Jun/Jul (n=49) | Sep/Oct (n=51) | Nov/Dec (n=51) |
|---|---|---|---|
| No. of taxa | | | |
| $\bar{x} \pm$ S.D. | 16.92 ± 5.41 | 10.12 ± 3.18 | 8.35 ± 3.01 |
| Range | 2-29 | 4-18 | 4-15 |
| Abundance | | | |
| $\bar{x} \pm$ S.D. | 72.67 ± 45.87 | 36.55 ± 37.26 | 25.45 ± 20.55 |
| Range | 12-226 | 7-229 | 8-128 |
| Gleasons-D | | | |
| $\bar{x} \pm$ S.D. | 3.88 ± 0.86 | 2.74 ± 0.62 | 2.39 ± 0.72 |
| Range | 2.01-6.76 | 1.35-4.10 | 1.11-4.04 |
| Shan.-Wien.-D | | | |
| $\bar{x} \pm$ S.D. | 0.97 ± 0.11 | 0.81 ± 0.15 | 0.75 ± 0.16 |
| Range | 0.75-1.37 | 0.46-1.06 | 0.44-1.08 |

Table 7.29B. ANOVA examination of the arthropod communities from the METRO/Baseline sampling program. The values compare these biological parameters for station F-600E against all other baseline stations (two replicates).

| | Jun/Jul (n=49) | Sep/Oct (n=51) | Nov/Dec (n=51) |
|---|---|---|---|
| Number of spp. | 21, 34 | 29, 26 | 23, 25 |
| F value | $7.08_{(1,47)}$* | $58.17_{(1,49)}$* | $52.97_{(1,49)}$* |
| Abundance | 129, 114 | 74, 55 | 41, 106 |
| F value | $2.22_{(1,47)}$ | $1.10_{(1,49)}$ | $9.75_{(1,49)}$* |
| Gleason | 4.12, 6.97 | 6.51, 6.24 | 5.92, 5.15 |
| F value | $7.44_{(1,19)}$* | $106.17_{(1,20)}$* | $46.19_{(1,20)}$* |
| Shannon-Wiener | 0.99, 1.27 | 1.26, 1.27 | 1.25, 0.96 |
| F value | $5.65_{(1,19)}$* | $27.53_{(1,20)}$* | $7.41_{(1,20)}$* |
| Infaunal Trophic Index | 79.7, 70.0 | 75.5, 85.6 | 72.8, 76.4 |
| F value | $6.4_{(1,19)}$* | $36.25_{(1,20)}$* | $3.93_{(1,20)}$** |

*Significant, $\alpha = 0.05$ $F_{(0.05,1,45)} = 4.06$ $F_{(0.05,1,50)} = 4.03$

**Significant, $\alpha = 0.10$ $F_{(0.05,1,19)} = 4.38$ $F_{(0.05,1,20)} = 4.35$

$F_{(0.10,1,20)} = 2.97$

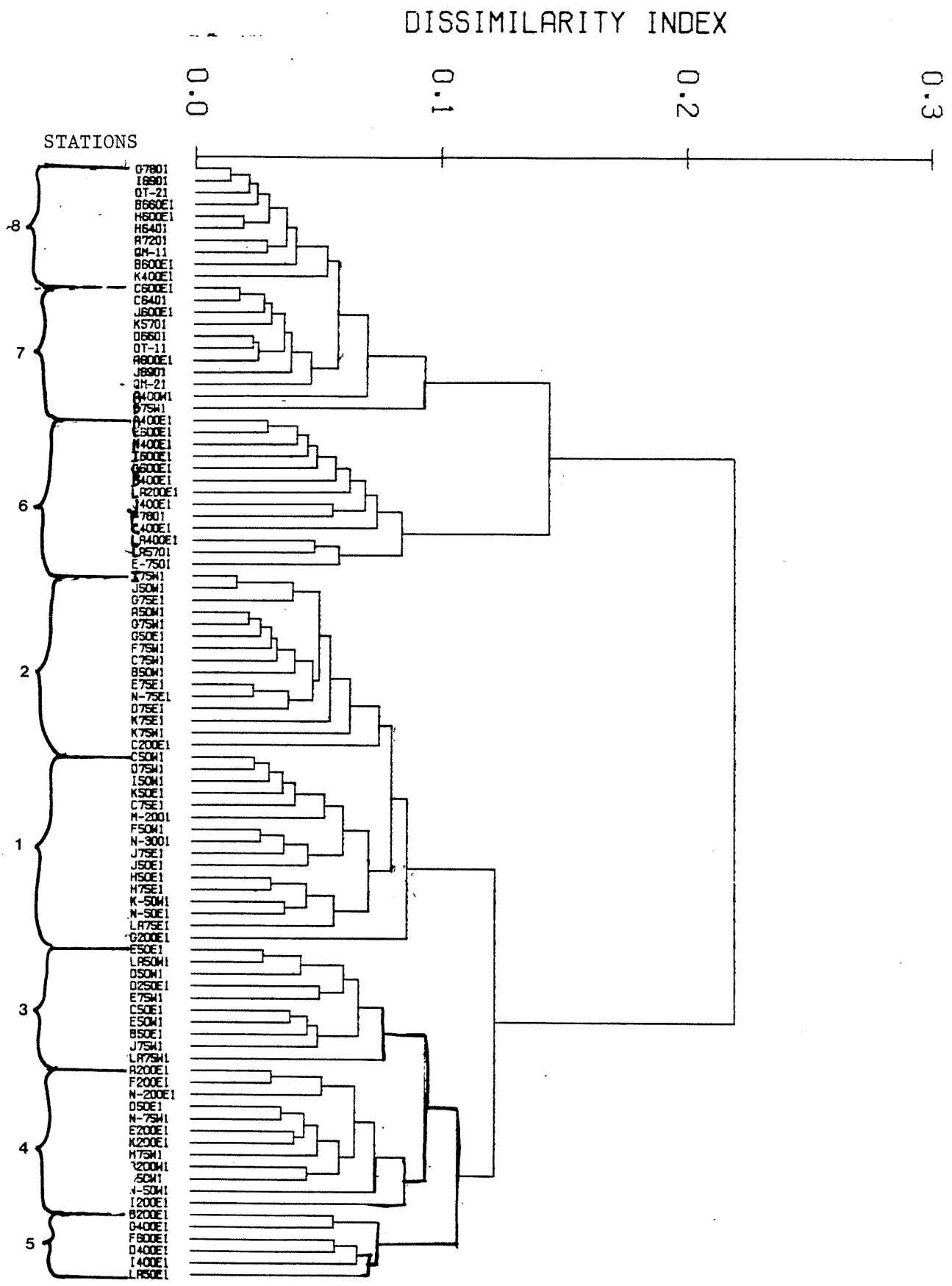



Fig. 7.64. Dendogram with eight major groupings of stations ranked from lowest to highest levels of organics. 1982 METRO/Baseline. June/July, 93 stations.

| | C-50W; M200; N300; J-50E; H75E; K50W D-75W; F 50W; J-75E; H-50E; N50E I-50W K-50E C-75E GROUP 1 | | | | | | I 75W, D 75E, K 75E, J-50W K-50W, C -200E, G-75E, A-50W G-75W, G-50E F-75W, C -75W B-50W, E -75E, N-75E GROUP 2 | | | | | | E50E D50W, E-75W, C100E LA50W; D250E; E50W; B50E J75W, LA75W GROUP 3 | | | | | | H200E I 200E H200E | D50E N75W E200E | K200E H175W A200W | G50W N50W I 200E | | | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Std. Error | Coef. Var. | Coef. Skew. | Coef. Kurt. | Mean | Std. Dev. | Std. Error | Coef. Var. | Coef. Skew. | Coef. Kurt. | Mean | Std. Dev. | Std. Error | Coef. Var. | Coef. Skew. | Coef. Kurt. | GROUP 4 | Mean | Std. Dev | Std. Error | Coef. Var. | Coef. Skew. | Coef. Kurt. | |
| Carbon | 1.08 | 0.38 | 0.89 | 30.77 | 0.21 | -1.24 | 1.20 | 0.43 | 0.11 | 35.88 | 0.51 | -0.48 | 1.97 | 1.31 | 0.44 | 76.66 | 1.42 | 0.94 | | 3.12 | 1.49 | 0.43 | 47.55 | 0.33 | -1.60 | |
| Nit | 0.31 | 0.14 | 0.37 | 37.20 | 0.45 | -0.97 | 0.42 | 0.22 | 0.06 | 50.99 | 1.12 | 0.49 | 0.53 | 0.51 | 0.12 | 72.54 | 1.94 | 2.92 | | 0.69 | 0.32 | 0.93 | 46.47 | 1.83 | 2.43 | |
| C/N | 2.90 | 1.12 | 0.30 | 38.59 | -0.55 | 0.17 | 2.83 | 1.67 | 0.43 | 58.95 | -0.11 | -1.14 | 3.54 | 1.72 | 0.45 | 48.73 | 0.08 | -0.51 | | 3.88 | 2.44 | 0.70 | 62.81 | 0.38 | 0.08 | |
| BOD | 261.36 | 48.21 | 12.89 | 18.45 | 0.80 | -0.15 | 205.53 | 43.03 | 11.11 | 20.93 | -0.67 | -0.22 | 455.50 | 124.58 | 39.37 | 29.34 | -0.67 | -0.40 | | 429.25 | 119.01 | 34.35 | 27.72 | 2.52 | 5.36 | |
| VS | 1.16 | 0.36 | 0.95 | 30.63 | 1.10 | 0.83 | 1.53 | 1.52 | 0.39 | 99.26 | 3.33 | 9.44 | 1.15 | 0.27 | 0.08 | 23.22 | 0.99 | 0.89 | | 1.76 | 0.64 | 0.19 | 36.58 | 1.05 | -0.30 | |
| BOD/VS | 234.82 | 49.95 | 13.35 | 21.27 | 0.22 | -1.02 | 148.51 | 43.04 | 11.11 | 25.54 | -1.94 | 4.80 | 400.08 | 95.38 | 30.16 | 23.84 | -0.79 | 0.40 | | 263.53 | 62.26 | 17.98 | 23.63 | -0.50 | -0.13 | |
| % Gravel | 1.37 | 2.04 | 0.55 | 148.35 | 2.34 | 4.93 | 0.84 | 1.29 | 0.33 | 154.50 | 1.85 | 1.59 | 2.34 | 6.40 | 2.03 | 273.54 | 2.65 | 5.05 | | 2.80 | 5.65 | 1.63 | 202.22 | 2.67 | 5.75 | |
| % C Sand | 11.99 | 6.83 | 1.83 | 56.96 | 0.41 | -1.15 | 5.62 | 3.83 | 0.99 | 68.07 | 1.69 | 2.09 | 6.59 | 7.33 | 2.32 | 111.34 | 1.69 | 1.78 | | 9.07 | 7.13 | 2.06 | 78.66 | 0.77 | -0.24 | |
| % F Sand | 84.02 | 7.83 | 2.09 | 9.32 | -0.37 | -1.34 | 89.85 | 4.99 | 1.29 | 5.56 | -0.77 | -0.44 | 76.88 | 29.21 | 9.24 | 37.99 | -1.96 | 2.48 | | 80.05 | 13.73 | 3.97 | 17.16 | -1.70 | 2.70 | |
| % Silt | 0.89 | 0.46 | 0.12 | 52.17 | 0.42 | -0.52 | 1.50 | 0.95 | 0.25 | 63.43 | 0.90 | -0.03 | 11.55 | 29.12 | 9.21 | 252.04 | 2.64 | 5.04 | | 3.82 | 1.78 | 0.52 | 46.51 | -0.26 | -1.06 | |
| % Clay | 1.77 | 0.61 | 0.16 | 34.31 | 1.87 | 3.03 | 2.14 | 0.81 | 0.21 | 37.68 | 1.05 | 0.16 | 2.54 | 1.24 | 0.34 | 47.96 | 1.14 | 0.26 | | 4.21 | 1.66 | 0.48 | 39.28 | 0.34 | -1.17 | |
| % Water | 21.51 | 1.32 | 0.35 | 6.14 | 0.62 | -0.89 | 21.94 | 3.05 | 0.79 | 13.91 | -1.66 | 2.28 | 21.36 | 8.00 | 2.53 | 37.46 | -1.61 | 1.84 | | 26.46 | 3.06 | 0.88 | 11.56 | 0.33 | 0.40 | |
| D/wt. | 0.75 | 0.02 | 0.05 | 2.24 | 0.22 | -0.78 | 0.74 | 0.01 | 0.004 | 1.82 | 0.31 | -0.96 | 5.60 | 1.19 | 2.27 | 289.42 | 2.67 | 5.11 | | 0.72 | 0.03 | 0.01 | 3.52 | 0.35 | -0.84 | |
| | B200E; G400E F 600E; I400E LA50E; D400E GROUP 5 | ↓ | ↓ | ↓ | ↓ | ↓ | A400E; E600E; C400E H400E; I600E C400E G600E; B400E LA400E LA50E E750E GROUP 6 | | | | | | C-600E; C640 DM-2 J-500; K590 A400W D660; OT-1 875W A-600E; J690 GROUP 7 | | | | | | G780; I640 OT-2; B-660E H-600E; H640 A720; GM-1 GROUP 8 | B400E X400E | | | | | | 407 |
| | Mean | | | | | | | | | | | | | | | | | | | | | | | | | |
| Carbon | 4.61 | 1.09 | 0.45 | 23.70 | -0.89 | -0.48 | 10.18 | 3.92 | 1.09 | 38.50 | -0.27 | 0.11 | 17.76 | 7.41 | 2.24 | 41.73 | -0.39 | -1.02 | | 23.24 | 4.07 | 1.29 | 17.50 | -0.52 | -1.03 | |
| Nit | 0.77 | 0.21 | 0.08 | 26.79 | 0.02 | -1.82 | 1.60 | 0.56 | 0.16 | 35.29 | 1.34 | 0.48 | 3.27 | 2.03 | 0.61 | 62.18 | 1.63 | 2.38 | | 3.52 | 2.15 | 0.68 | 61.13 | 2.19 | 3.66 | |
| C/N | 4.43 | 3.43 | 1.40 | 77.48 | -0.47 | -1.55 | 6.40 | 3.42 | 0.95 | 53.37 | -0.26 | -0.49 | 5.36 | 2.75 | 0.83 | 51.23 | -1.01 | -0.19 | | 7.80 | 2.68 | 0.85 | 34.41 | -0.50 | -0.41 | |
| BOD | 545.67 | 38.85 | 15.86 | 7.12 | 0.51 | -1.06 | 913.77 | 135.84 | 34.68 | 14.86 | 1.25 | 1.67 | 1948.27 | 531.58 | 160.28 | 27.28 | -1.52 | 0.77 | | 2605.50 | 416.32 | 131.65 | 15.98 | -0.85 | 1.41 | |
| VS | 2.73 | 0.45 | 0.18 | 16.53 | 0.60 | -0.78 | 5.23 | 1.36 | 0.38 | 25.99 | 0.73 | -0.43 | 7.71 | 3.07 | 0.93 | 39.84 | -0.86 | -0.34 | | 8.80 | 1.15 | 0.36 | 13.08 | -0.77 | -0.62 | |
| BOD/VS | 205.73 | 42.78 | 17.47 | 20.79 | 0.33 | -0.36 | 172.86 | 38.59 | 10.90 | 22.31 | -0.57 | -0.22 | 284.81 | 99.25 | 29.92 | 34.85 | 1.44 | 0.78 | | 301.32 | 41.92 | 15.15 | 15.90 | 0.70 | -0.76 | |
| %Gravel | 7.55 | 6.90 | 2.82 | 91.44 | 0.97 | -0.26 | 4.24 | 4.88 | 1.35 | 115.02 | 0.99 | 0.39 | 11.76 | 25.62 | 11.46 | 217.88 | 1.50 | 0.25 | | 0.09 | 0.11 | 0.05 | 132.65 | 0.83 | -0.96 | |
| % C Sand | 18.65 | 6.50 | 2.65 | 34.82 | 0.13 | -1.09 | 6.88 | 5.49 | 1.52 | 79.78 | 0.45 | -0.99 | 2.28 | 6.35 | 1.92 | 278.91 | 2.83 | 6.04 | | 0.61 | 0.88 | 0.28 | 144.95 | 1.99 | 2.79 | |
| %F Sand | 54.71 | 6.99 | 2.85 | 12.78 | 0.22 | -1.24 | 38.84 | 14.16 | 3.93 | 36.45 | 0.06 | -0.72 | 13.64 | 15.63 | 4.71 | 114.60 | 2.62 | 5.33 | | 11.00 | 7.41 | 2.34 | 67.40 | 0.89 | -0.53 | |
| % Silt | 10.00 | 3.64 | 1.49 | 36.43 | 0.27 | -1.12 | 28.86 | 14.62 | 4.06 | 50.67 | 0.97 | 0.17 | 41.38 | 18.91 | 5.70 | 39.92 | -1.29 | 0.74 | | 5154.01 | 1803.23 | 570.39 | 33.47 | 2.67 | 5.11 | |
| % Clay | 9.04 | 3.29 | 1.34 | 36.36 | 0.20 | -1.40 | 21.02 | 6.50 | 1.80 | 30.91 | 0.38 | -1.6 | 31.34 | 14.24 | 4.29 | 45.43 | -0.75 | -0.36 | | 31.49 | 8.80 | 2.78 | 23.48 | 0.20 | -1.58 | |
| % Water | 29.99 | 3.79 | 1.55 | 12.62 | 0.69 | -0.40 | 50.18 | 6.05 | 1.68 | 12.06 | -0.49 | -0.41 | 60.67 | 14.75 | 4.45 | 24.32 | -1.96 | 2.76 | | 65.58 | 2.34 | 0.74 | 3.57 | -0.09 | -1.32 | |
| Dry/wet Ratio | 0.69 | 0.06 | 0.02 | 8.71 | 0.09 | -1.24 | 0.49 | 0.05 | 0.01 | 9.85 | -0.54 | -0.90 | 0.38 | 0.12 | 0.04 | 31.10 | 1.61 | 1.40 | | 0.33 | 0.03 | 0.01 | 10.11 | 0.79 | -0.99 | |

Table 7.30. Ranking of eight groups of stations. Showing basic statistics of these groups including means, standard deviations, coefficients of variation, standard error coefficients of skewness, coefficients of kurtosis.

increased with depth, while the quantities of sands and gravels decreased (Figure 7.65). In addition to this trend, it was found that certain stations within each depth strata showed higher than expected concentrations of volatile solids (90% exceeds the maximum range for confidence intervals for each depth). These stations were J50E, L50E, QM1, QM2, C75E, H75E, J75E, L75E, B200E, C200E, L200E, K400E, L400E, A600E, C600E, H600E, J600E, OT1, C640, H640, I690, B75W, G50W, N50W. Stations J.5400E, J.5520E, J.5 600, L.5 200E, L.5 550, and L.5 400W were also in excess of these confidence limits during the September/October 1982 samples. Preliminary contours of stations showing these trends were drawn on a chart and they revealed that there were four parts of the study area that showed greater than expected levels of organics for these depths (Figure 7.66). We have provisionally indicated that these stations are potentially of a greater depositional nature. This increased deposition may be due to either greater quantities of organic inputs within each subregion or may be naturally more depositional due to physical attributes of the stations (e.g. less than normal bottom slopes or lower overall current velocities are potential causes for the depositions.

The addition of more stations during the second and third cruise of this study required that we determine whether the amount of seasonal variability was sufficient to move a station from one group to another. In addition to these new stations, we also seasonally examined the concentrations of chemicals and the physical attributes at 28 stations. ANOVA examination between all of the June/July samples and the repeated measurements made during September/October and November/December cruises indicated that the distribution of seasonally replicated stations within groups formed from the first survey analysis were not significantly different from groupings of the same stations during the second and third periods of sampling (Table 7.31).

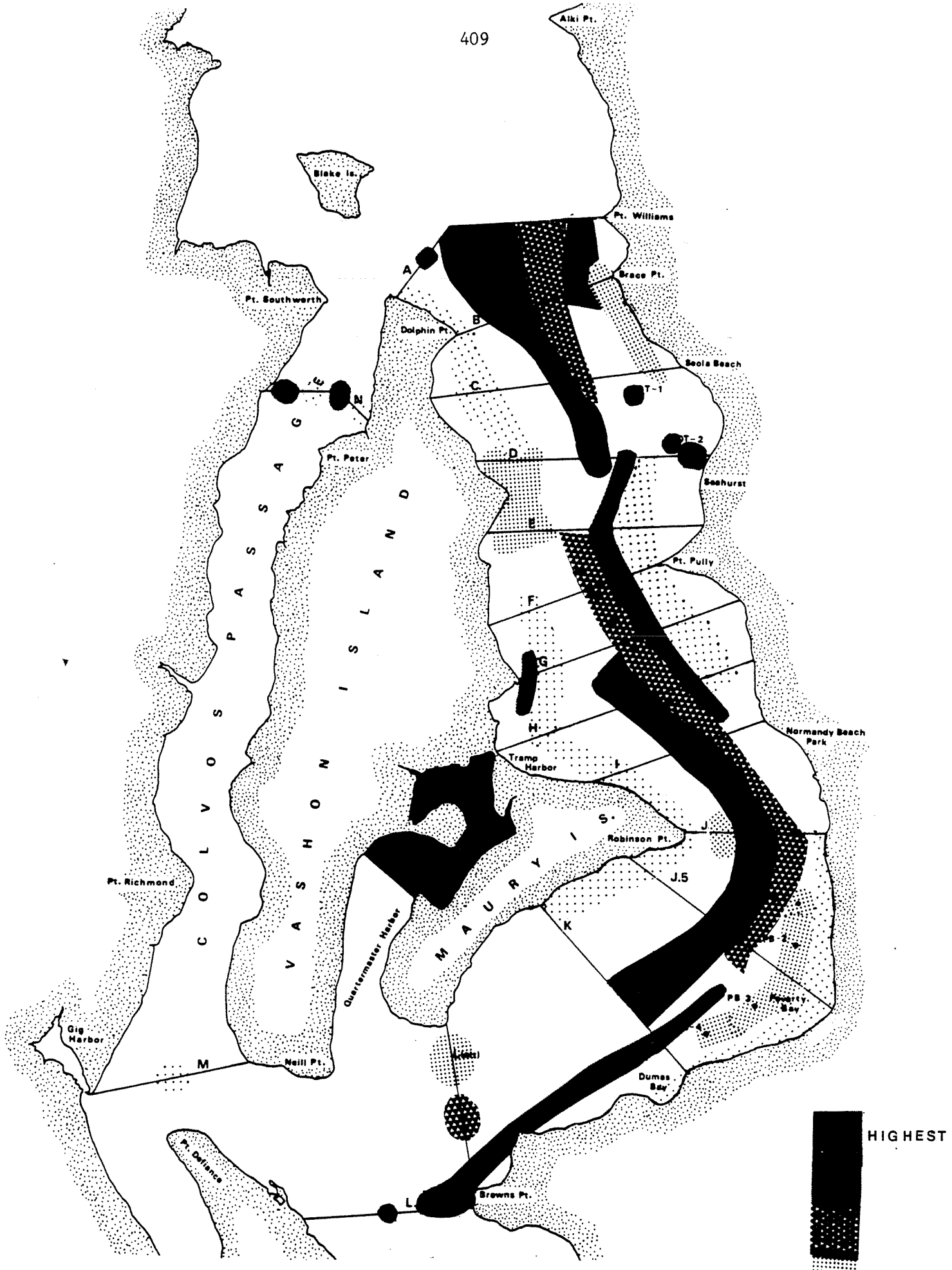



Fig. 7.65. Gradient of increasing darkness reflect increase quantities of carbon, biological oxygen demand and decrease in water content in the sediment.

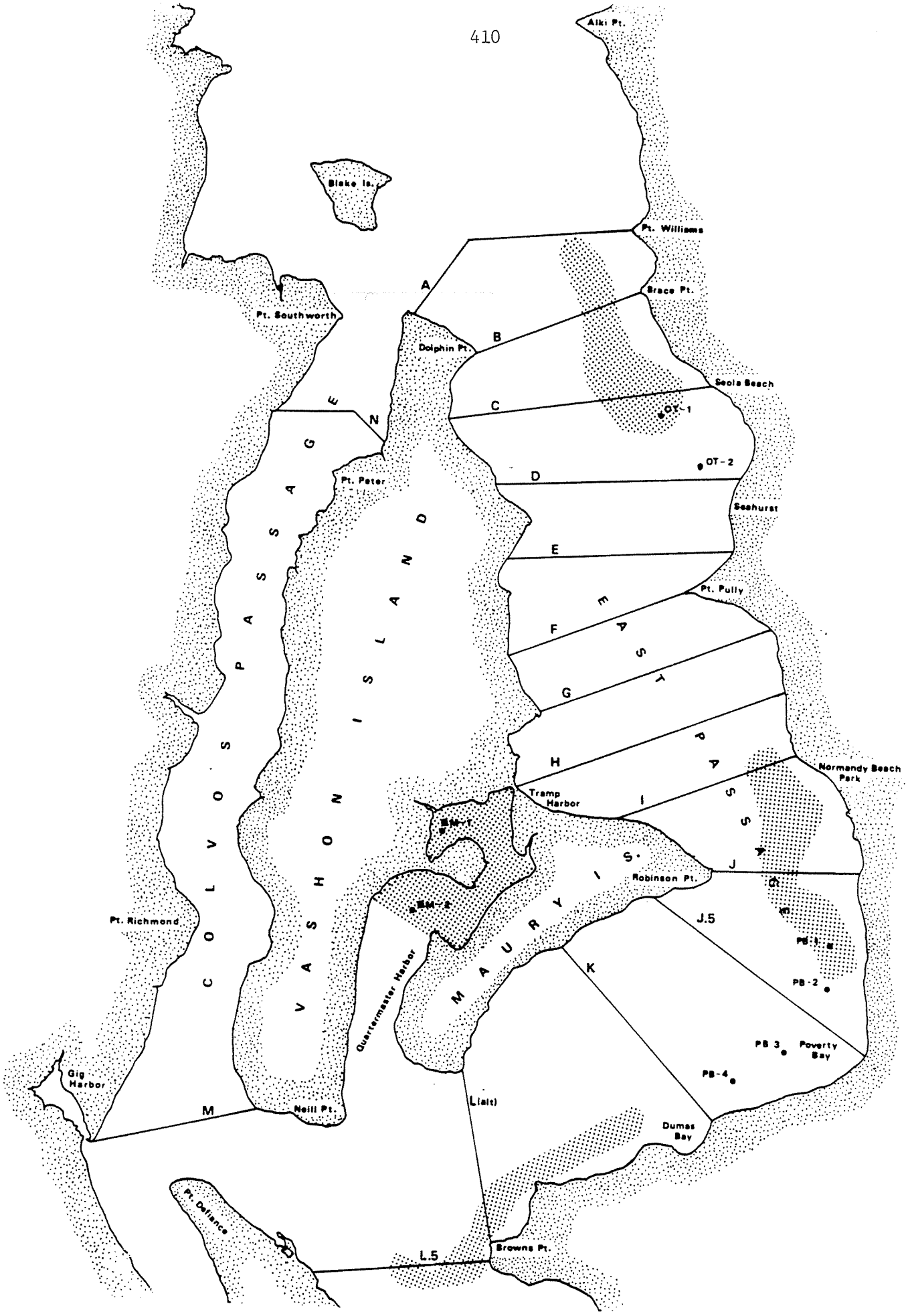



Fig. 7.66. Areas that showed greater than expected levels of organics for these depths.

Table 7.31. ANOVA table for carbon, % water, volatile solids, % silt, 1982 METRO/Baseline, all seasons combined. (Asterisk indicates significant difference. Group 3 is not included because no stations were replicated during cruises 2 and 3. Refer to Table 1).

| Comparison | Parameter | 1 | 2[a] | 4 | 5[a] | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| | df: | | | | | | | |
| | Treat | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Error | 22 | 15 | 12 | 8 | 21 | 23 | 22 |
| | Total | 23 | 16 | 13 | 9 | 22 | 24 | 23 |
| | $F_{crit}$ $\alpha(2)=0.05$ | 5.79 | 6.12 | 6.41 | 7.21 | 5.83 | 5.75 | 5.79 |
| Carbon | F | 0.08 | 18.25* | 3.22 | 4.66 | 0.03 | 0.08 | 3.68 |
| % Water | F | 0.03 | 0.22 | 0.40 | 11.42* | 0.35 | 0.30 | 0.04 |
| Volatile | F | 2.62 | 0.14 | 0.93 | 20.12* | 1.22 | 0.51 | 1.63 |
| % Silt | F | 0.01 | 0.03 | 2.33 | 10.93* | 0.35 | 0.84 | 0.58 |

[a]Groups 2 and 5 which showed a significant difference included only 2 or 1 stations. Refer to Table 1.

This indicates that the degree of seasonal variation in chemical measurements at a station are not large enough to force that station into a different group of stations. It allows the data collected from the new stations, sampled during the second and third cruises to be added to Figure 7.65, thereby increasing the spatial coverage of the original cluster analysis.

Comparisons of the north central and south central Sound revealed some distinctive differences in these areas. Each of the cluster analyses performed on data collected from the two different areas within the same month showed that the areas were displaying very different chemical patterns. The initial METRO/Baseline cruise was compared to METRO/TPPS cruise 3B. Both were sampled in June/July 1982 at depths in excess of 185m and were clustered into four separate groups (Figure 7.67). Four of the five METRO/TPPS stations (III750, V750, II750, VII750) were grouped into a category that had the lowest levels of organic carbon. Groups 2, 3, and 4 were entirely Baseline samples, except for one METRO/TPPS sample (VIII750). These latter groups had greater quantities of organic carbon. Groups 1 and 2 had similar quantities of organic carbon and volatile solids, but very different concentrations of BOD demanding material and the relative concentrations of grain size. In contrast to the expected, group 1 had the highest percentage of clay fractions of all of the station groupings and the lowest organic carbon and nitrogen concentrations. It also had a relatively high biological quality value for the ratio of BOD/Volatile solids (Table 7.32).

The comparisons of the September/October METRO/TPPS and Baseline sampling periods revealed very different groupings of data through the cluster analysis. This cluster of stations resulted in six site groups, three for METRO/TPPS and three for the Baseline chemistry data (Figure 7.68). Again, the METRO/TPPS groupings had lower values of organics in the sediments, higher

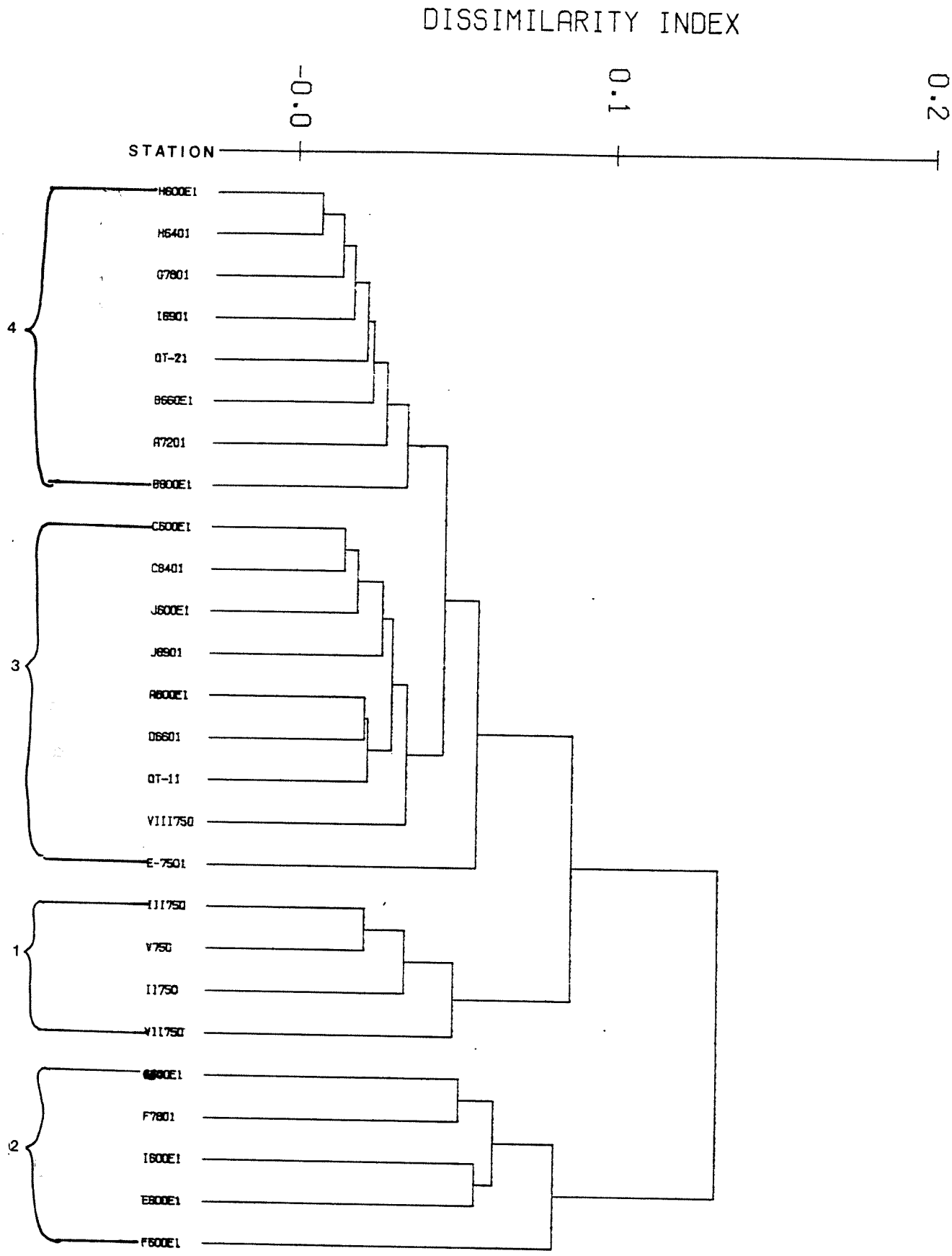



Fig. 7.67. METRO/Baseline June/July compared to METRO/TPPS July. Four major groupings are evident.

Table 7.32. Mean values of chemistry parameters comparing 1982 METRO/Baseline June/July and 1982 METRO/TPPS July. Four groupings were formed from cluster analysis.

| | Group 1 | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|
| Carbon | 5.000 | 7.794 | 20.525 | 24.350 |
| BOD | 1508.650 | 832.200 | 2142.637 | 2731.875 |
| VS | 5.707 | 4.578 | 9.133 | 9.263 |
| BOD/VS | 263.275 | 184.622 | 239.753 | 296.740 |
| % Gravel | 0 | 8.361 | 0.021 | 0.030 |
| % C Sand | 0.025 | 10.013 | 0.259 | 0.300 |
| % F Sand | 0.600 | 42.581 | 6.831 | 9.035 |
| % Silt | 3.325 | 18.807 | 54.992 | 51.388 |
| % Clay | 95.100 | 19.947 | 37.217 | 39.266 |
| % Water | 63.375 | 45.573 | 67.144 | 66.059 |
| Dry/wet ratio | 0.368 | 0.524 | 0.323 | 0.319 |
| | III 750 | G600E | C600E D660 | H600E A-720 |
| | V 750 | F780 | C640 OT-1 | H640 B-600 |
| | II 750 | I600E | J600E A600E | G780 |
| | VII 750 | E600E | J690 VIII 750 | I690 |
| | | F600E | | OT-2 |
| | | | | B-660 |

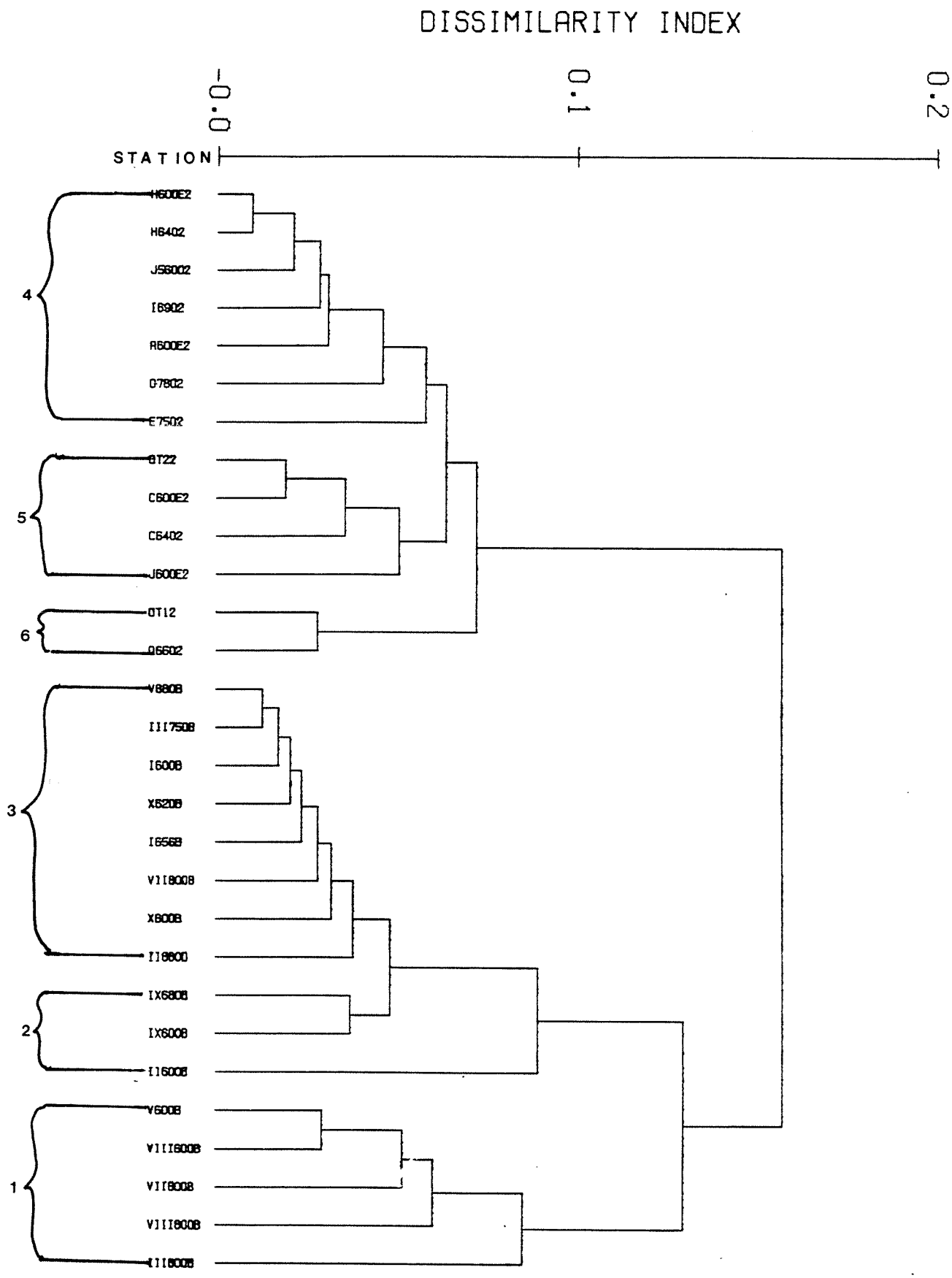



Fig. 7.68. 1982 METRO/Baseline September/October sampling period compared to 1981 METRO/TPPS September/October. Six major groupings of stations are evident.

percentages of clay size fractions, and higher biological qualities of the sediments than in any of the groupings of the Baseline series. In this series, the amount of water present in the METRO/TPPS samples is relatively low when compared to the amounts of water in samples at comparable depths in the south Sound area and, also, for samples collected in the same area during the sampling period which is discussed above (Table 7.33).

The final comparison of sediment chemistry in the two areas was an overall clustering of all METRO/TPPS and Baseline station information which pertains to the comparisons discussed above. This cluster of stations resulted in seven site groups (Figure 7.69). In all but two cases, METRO/TPPS samples were separately grouped from Baseline stations. The only cases where this was not true were at Baseline station H600E, during the September/October samplings and METRO/TPPS station VIII750, also during the September/October sampling cruises. The major split of the dendogram was the isolation of the two areas of Puget Sound (Figure 7.69). The major differences between the two areas were greater biological quality values and larger quantities of the clay size fractions of the sediments (Table 7.34). The larger biological quality values of all METRO/TPPS site groupings were significantly different than those in the Baseline areas, even though the total quantities of volatile solid materials (a gross measurement of the potential quantities of useable organics) in the sediments were low by comparison.

## 7.5 Summary and Conclusions

The primary objectives of the Baseline survey during the first year were to establish background descriptions of the physical, chemical, and biological attributes of East Passage with a special emphasis on the Seahurst area.

Table 7.33. Mean value of chemistry parameters comparing 1982 METRO/ Baseline Sep/Oct with 1981 METRO/TPPS Sep/Oct.

| | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 |
|---|---|---|---|---|---|---|
| BOD | 719.144 | 1272.960 | 1805.838 | 1883.429 | 1894.00 | 2716.00 |
| VS | 1.316 | 3.863 | 3.728 | 9.099 | 9.408 | 9.385 |
| BOD/VS | 591.100 | 659.100 | 497.125 | 207.266 | 200.655 | 289.330 |
| % Gravel | 0 | 0 | 0 | 0.001 | 0.214 | 0.003 |
| % C Sand | 0 | 0 | 0 | 0.641 | 10.369 | 15.884 |
| % F Sand | 5.120 | 8.700 | 1.000 | 19.188 | 33.474 | 25.295 |
| % Silt | 16.660 | 4.967 | 0.700 | 42.079 | 29.441 | 33.084 |
| % Clay | 78.000 | 86.267 | 97.850 | 37.537 | 27.356 | 25.262 |
| % Water | 35.694 | 45.243 | 55.408 | 68.489 | 77.000 | 69.446 |
| Dry/wet ratio | 0.643 | 0.548 | 0.446 | 0.318 | 0.299 | 0.256 |
| | V 600B | IX 680B | V 880B | H 600E(2) | OT-2(2) | OT-1(2) |
| | VIII 600B | IX 600B | III 750B | H 640(2) | C-600E(2) | D660(2) |
| | VII 600B | II 600B | I 600B | J 5600(2) | C-640(2) | |
| | VIII 800B | | X 620B | I 690(2) | J-600E(2) | |
| | III 600B | | I 656B | A 600E(2) | | |
| | | | VII 600B | G 780(2) | | |
| | | | X 600B | E 750(2) | | |
| | | | II 880B | | | |

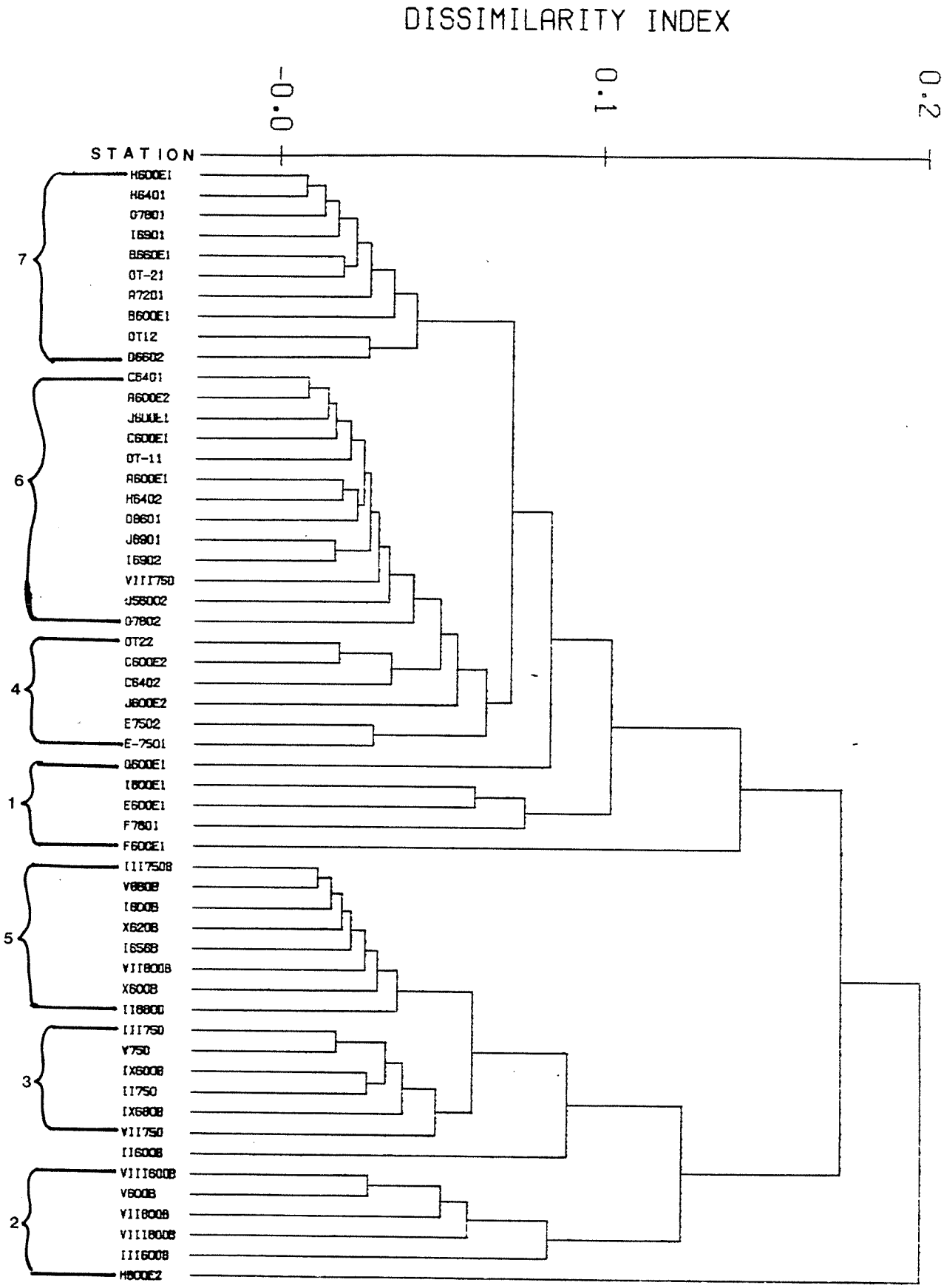



Fig. 7.69. Dendogram comparing 1982 METRO/Baseline June/July and September/October to 1981-2 METRO/TPPS July and September/October. Dendogram shows a major split between these two groups.

Table 7.34. Mean values of chemistry parameters comparing 1982 METRO/Baseline Jun/Jul and Sep/Oct sampling period with 1982 METRO/TPPS July and Sep/Oct sampling period.

| | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 |
|---|---|---|---|---|---|---|---|
| BOD | 832.200 | 924.453 | 1527.833 | 1696.167 | 1805.838 | 2080.238 | 2728.70 |
| VS | 4.578 | 2.762 | 5.655 | 8.713 | 3.728 | 9.240 | 9.287 |
| BOD/VS | 184.622 | 525.132 | 270.617 | 194.405 | 497.125 | 228.726 | 295.258 |
| % Gravel | 8.361 | 0 | 0 | 0.156 | 0 | 0.013 | 0.025 |
| % C Sand | 10.013 | 0.080 | 0.017 | 7.107 | 0 | 0.412 | 3.417 |
| % F Sand | 42.581 | 5.564 | 0.400 | 33.326 | 1.000 | 11.383 | 12.287 |
| % Silt | 18.807 | 22.078 | 2.217 | 31.904 | 0.700 | 50.250 | 47.727 |
| % Clay | 19.947 | 72.061 | 97.400 | 28.011 | 97.850 | 37.257 | 36.465 |
| % Water | 45.573 | 41.466 | 61.392 | 71.341 | 55.408 | 67.978 | 66.736 |
| Wet/dry ratio | 0.524 | 0.587 | 0.387 | 0.334 | 0.446 | 0.315 | 0.306 |
| | F780(1) | VIII 600B | III 750 | OT-2(2) | III 750B | G780(2) | H600E(1) |
| | G600E(1) | V 600B | V 750 | C600E(2) | V 880B | C640(1) | H640(1) |
| | E600E(1) | VII 600B | IX 600B | C640(2) | I 600B | J600E(1) | G780(1) |
| | I600E(1) | VIII 800B | II 750 | J600E(2) | X 620B | OT-1(1) | I690(1) |
| | F600E(1) | III 600B | IX 680B | E750(2) | I 656B | H640(2) | B660(1) |
| | | H 600E(2) | VII 750 | E750(1) | VII 800B | D660(1) | OT-2(1) |
| | | | | | X 600B | VIII 750 | A720(1) |
| | | | | | II 880B | A 600E(2) | B600E(1) |
| | | | | | | C600E(1) | OT-1(2) |
| | | | | | | A600E(1) | D660(2) |
| | | | | | | J690(1) | |
| | | | | | | I690(2) | |
| | | | | | | J560(2) | |

Emphasis was placed on the biological communities at water depths in excess of 185m and on the physical and chemical properties of the sediments at each of the proposed sampling depths. The following points summarize the progress thus far.

1. Physical and chemical data indicated that quantities of organics increase and the grain size decreases with an increase in depth.
2. This pattern is somewhat modified in four areas so that greater quantities of organics are present than would be expected for these depths in south central Puget Sound.
3. Some cycling exists in the physical and chemical constituents of the sediments which is related to seasonal patterns. This cycling is not sufficient to move a station from one site grouping to another based on computer clustering and ANOVA between stations which are sampled at different seasons.
4. Significant differences exist in the make-up of sediment chemistry and physical parameters between stations taken near West Point for the METRO/TPPS program and the Baseline program. The quantities of clay size particles and biological quality of the sediment organics is greater while percent water content is less in the West Point area than in the south central Puget Sound area.
5. Seasonal cyclings are identified in the abundance and number of species in major taxa groups in both the south central Puget Sound and in the West Point area. Polychaeta and arthropoda groups are more abundant during the autumn months and mollusca during the summer periods in the south central Puget Sound area. Polychaeta are more abundant in the autumn periods off West Point.
6. Improvement in the precision of estimation of the inherent

variability of species richness, abundance, Shannon-Wiener's and Gleason's Diversity and the Infaunal Trophic Index can be accomplished by repetitive samplings. The amount of improvement between additional samples rapidly approaches an asymptotic point, where increased replication supplies little useful new data. In the worst cases of variability, which are noted in the West Point and Baseline surveys, replicate samples provide most of the potential improvement in the estimation of inherent variation. In the best cases, between 1 and 2 samples at a station provided most of the potential improvement in the estimation of inherent variability.

7. Mollusca are the most abundant species at depths greater than 185m in both the south central Puget Sound and West Point areas.
8. Macoma carlottensis is generally the most abundant species near West Point, while Axinopsida serricata is generally the most abundant in the south central Puget Sound area.
9. Euphilomedes producta and Eudorella pacifica are more abundant in the West Point region than in the south central Puget Sound area.
10. The polychaeta Ampharete acutifrons is more abundant in the West Point area than in the Baseline area.
11. Long-term trends in comparable data indicate a major change from Pectinaria californiensis dominance during 1969 to Axinopsida serricata and Macoma carlottensis dominances during the present survey.
12. The regions in the vicinity of Three-Tree Point in south central Puget Sound differ greatly from all other areas between Point Williams and Point Defiance. Significantly more species and individuals, as well as higher diversities and Infaunal Trophic

Index values, exist at these stations than at any other stations from a comparable depth.

13. These trends in the data near Three Tree Point are also seen in the major taxa groups arthropoda, mollusca, and polychaeta.
14. There are indications of the presence of more species and individuals at present than during the period of 1969-70.
15. Greater numbers of surface and subsurface deposite feeders are present at this time potentially indicating enhanced deposition of organic materials.
16. We cannot access whether these greater abundances and species are showing long term trends or whether they occur occasionally at long time periods.
17. We suggest that critical examinations of Dr. Nichols long term data in north Puget Sound may help discover which alternative is more correct.

The preceding points are the prelminary results of the Subtidal Baseline survey for the first year of the project. Many other specifics are found in the main body of the report. During Phase II of the study, the range of sampling depths will be increased and integrated with previous data to provide improved understanding of both the area and the interaction with higher trophic levels with a change in the structure of benthic communities. The increased sampling range and the program integration will generate a thorough assessment of the potential effects of secondary effluent in the Seahurst area and provide a better sampling design for detecting changes in the monitoring phase.

# 8.0 COMMERCIAL/RECREATIONAL FISHERIES

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## 8.1 Introduction

Changes in water quality due to waste water effluent have previously been reported (Russo et al. 1977; Grigg 1979; Topping 1976; McIntyre and Johnston 1974; Eppley et al. 1972; Chen and Orlob 1972; Carlisle 1969; Turner 1965) to result in changes in aquatic organism community structure. Commercial and recreational fish assemblages can be useful as an index to monitor environmental quality.

The purpose of this study is to provide predischarge information on fish assemblages at four locations near the proposed Seahurst outfall site. Specific objectives include determination of seasonal and between site differences in fish spatial and temporal distribution. This information will be a useful aid in the location of the outfall depth which would result in the lowest impact on the fish assemblage and as baseline data for monitoring changes in the fish assemblage structure after the proposed outfall becomes operational.

## 8.2 Sampling Rationale and a Description of Study Area and Stations

Study areas were selected on the basis of the proposed outfall location, of known or perceived oceanographic conditions, and of historical data indicating similar fish species assemblages at the sites.

Offshore and shoreline seine sampling sites were located at Seahurst Park, Point Pully, Tramp Harbor and Aquarium (Figure 8.1). Seahurst Park is

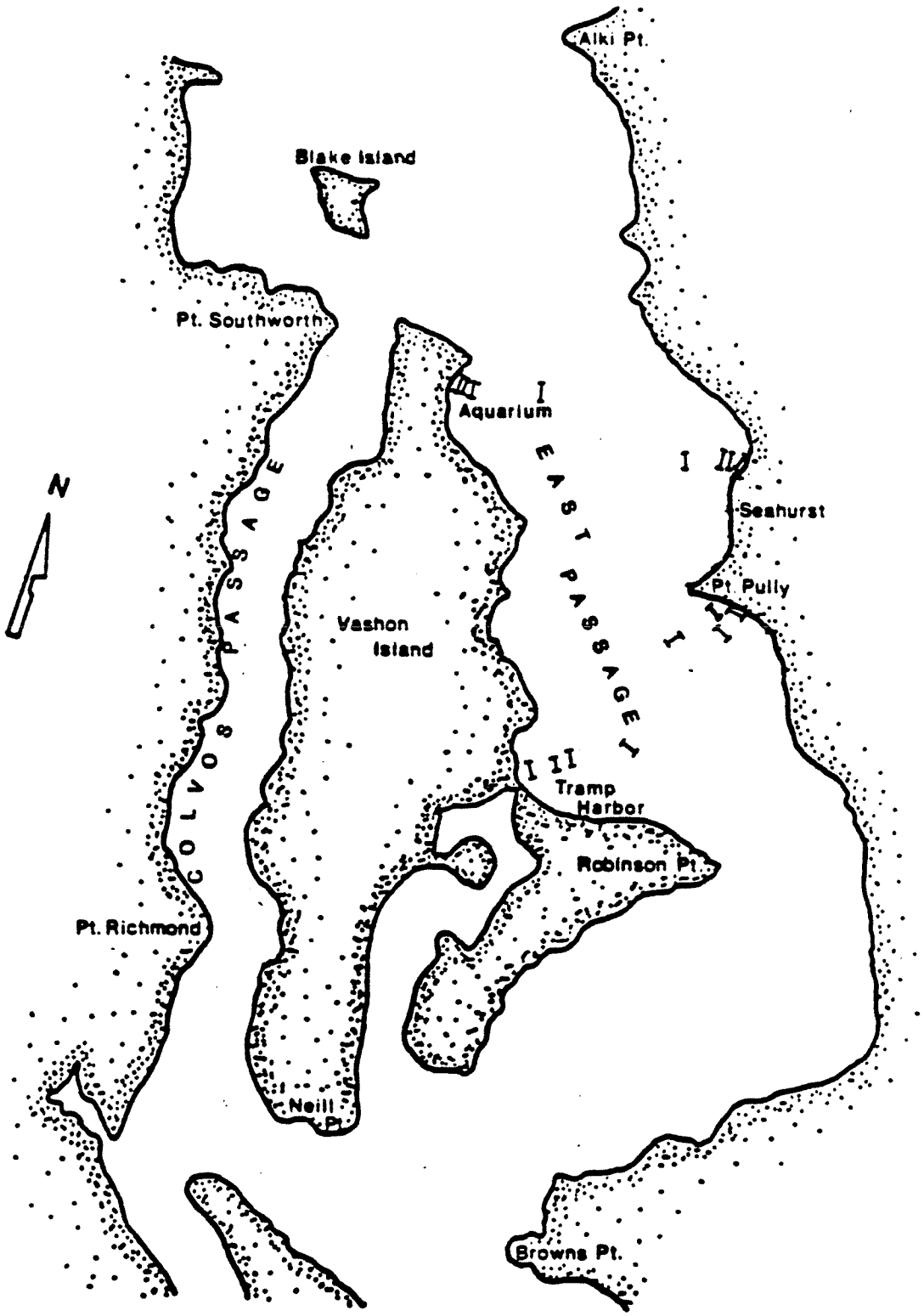



Figure 8.1. Fisheries offshore trawling stations (▬); shoreline beach seining sites are adjacent to the inshore trawl path. Trawling stations, at each site, are at depths of 15, 50, 100, and 200 meters.

the proposed outfall site, Point Pully is a site where good historical data exists on species assemblages and disease incidence, Tramp Harbor is a site considered potentially impacted based on oceanographic studies, and Aquarium was considered a potentially non-impacted site and the only site north of Seahurst Park. These sites also are compatible with sites being used by other researchers on the Seahurst Baseline Study. In addition, the artificial reef (a sunken barge) off Seahurst was selected for diving observations. The south stream in Seahurst Park, based on historical data and its possible location in the path of the proposed sewage tunnel, was also studied.

The choice of sampling depths and sampling frequency was based on previous studies in Puget Sound similar in objective to this study (Miller et al. 1977; Moulton 1977; Wingert and Miller 1979; Miller et al. 1980). These previous studies indicate that in general Puget Sound fish assemblages differ in the following depth zones: < 10 m (shoreline), 10-30 m, 30-70 m, and > 70 m. In addition to sampling these four depth zones, we also added a 200-m depth sample based on suggestions that the outfall might be located at that depth. Sampling frequency was also based on the same previous studies that indicated that two or more years of seasonal (quarterly) sampling was necessary to account for various ecological life history characteristics (spawning, feeding, growth, migrations, disease) which are occurring and which must be understood to properly analyze the data statistically.

It is anticipated, based on previous studies (Moulton 1977; Wingert and Miller 1979; Miller et al. 1980), that abundance changes of about 50% will have to occur to be statistically meaningful -- i.e., changes due to causes other than normal environmental and biological variation. It is also known that the understanding obtained from this study of the ecological life history characteristics of the fishes will be necessary for properly interpreting

(statistically) the pre- and post- discharge monitoring data on fish diseases, which have proven to be one of the more convincing environmental monitoring methods available due to an apparently more direct causal relationship of fish disease and pollution.

## 8.3 Materials and Methods

### 8.3.1 Water Quality

Water quality was monitored at each depth and sample location during quarterly fish sampling. Surface temperature was measured with a hand held thermometer and subsurface temperatures were taken with a bathythermograph. Subsurface water samples for dissolved oxygen and salinity measurements were taken with a VanDorn bottle. Dissolved oxygen content was determined by the Winkler method (APHA 1976). Manganese sulfate and alkaline iodide-azide solution were added immediately and samples were held on ice for transport to the laboratory. Winkler titrations were completed within two weeks.

### 8.3.2 Stream Fishes

Electrofishing in the Seahurst County Park south stream was conducted on 9 April, 2 September and 11 December 1982. In April, 275 m of stream were surveyed from the footbridge to the culvert. In September, an additional 50 m of stream above the culvert to the upper parking lot, and from the footbridge to the mouth of the stream, were sampled. The December fish survey sampled the 325-m stream section from the footbridge to the upper parking lot. In all surveys the stream was divided by pools and riffles. At each sampling station, length measurements and location of capture were recorded, and fish were subsequently released to the same stream location after complete recovery from electroshocking.

### 8.3.3 Artificial Reef Fishes

An artificial reef (a sunken barge) is located off Seahurst Park in approximately 13 m of water. Dives were made seasonally in the spring (1 July 1982), summer (9 September 1982), autumn (5 December 1982) and winter (25 February 1983). The entire reef was surveyed for fish abundance; observations were recorded underwater on a slate.

### 8.3.4 Nearshore Fishes

Field sampling for nearshore fishes was also conducted seasonally (quarterly) with two types of beach seines, floating and sinking, in all four study areas. Specific sampling dates are reported in Appendix 8A. The floating seine sampled fishes in the surface water while the sinking seine sampled demersal fishes of the shoreline zone. In most cases, the sinking seine was set first, as close to low tide as possible (usually within 0.5 hours of low tide). Two 37 m nets were used for sampling. Each net had 18 m wings and a 0.6 x 2.4 x 2.3 m bag lined with 6 mm mesh. The sinking net was set 30 m from shore with a small rowboat and retrieved at a rate of 10 m/minute. Lines attached to the bridles at each wing end were initially retrieved from a distance on the beach of 40 m apart. When 10 m of line remained to be retrieved, the net opening was closed to 12 m and retrieval completed. Seven floats were then attached to the seine and this floating net was then set 60 m from shore and retrieval was in the same manner as the sinking set. Replicate sinking and floating sets were taken on adjacent sections of the shoreline at each study location.

Contents of each haul were placed in plastic bags, held on ice for transport to the laboratory where the bags of fish were immediately frozen and remained frozen until processed (one to four months).

In the laboratory, fish were thawed and separated by species. Total

length (mm) was measured on each fish and a total group weight was taken for each species. Length to the end of the second dorsal fin was also taken on ratfish. Fish were examined for the presence of external disease.

8.3.5 Offshore Fishes

Offshore demersal fishes were sampled seasonally with a 7.6-m otter trawl (6 mm bag mesh) fished from the R. V. Kittiwake. Sampling dates are included in Appendix 8A. Two replicate 5 minute tows were conducted at 15, 50, 100, and 200 m. Contents of each haul were bagged and held on ice for transport to the laboratory. Bags of fish were immediately frozen and held for one to four months until processed.

The procedure for processing fish and recording information was the same as outlined for shoreline fishes.

8.3.6 Midwater Fishes

Midwater fishes were sampled by hydroacoustics and midwater nets on 29 October 1982.

Hydroacoustic equipment consisted of a high frequency, scientific quality echosounding system (SIMRAD EK120). The transducer was mounted in a towed body for stability purposes. A high fidelity TEAC AM tape recorder was used to store acoustic data. Data was monitored in real time on chart paper (echograms) and an oscilloscope.

The R. V. Kittiwake was outfitted with two midwater trawls (2-m RMT and 2-m Isaacs-Kidd). The predicted efficiency of these nets for capturing the schooling fishes (e.g., herring) that were expected in the Seahurst area during daylight was low, but efficiency was expected to increase after dark. Net sampling effort was viewed strictly as a feasibility effort to evaluate the practicability of assessing the midwater fish assemblages in the Seahurst area which might be impacted by the Seahurst discharge system. Emphasis in

this initial effort was primarily on the hydroacoustic survey.

The survey design was to run nine transects perpendicular to the shoreline between Brace and Pully Points (Figure 8.2). Transects began shallow at 10 m and ended at about 170 m depth; these transects were run twice during daylight hours and once during darkness between 1300 and 2000 hrs.

The procedure for midwater trawling was that in the event that acoustic targets (fish) were monitored on the survey, the midwater trawl would be deployed to a depth greater than the targets and retrieved in a stepwise fashion through the expected target depth and fishing range. Since acoustics provided the quantitative data on fish density, the primary information required from the net catch for stock assessment was the composition and relative abundance of species.

### 8.3.7 Data Analyses

"Catch Summary," a program developed for the Fisheries Research Institute, was utilized for haul analyses. Information obtained from this computer program included: average abundance, number of fishes and biomass per sampling site, depth and season.

## 8.4 Results

### 8.4.1 Water Quality

Water quality results for temperature, dissolved oxygen and salinity were summarized by station and season for shoreline and offshore sampling trips (Table 8.1).

Water temperature ranged from 9.1 to 19.0 C and changes in water temperature were observed with season and depth. Autumn temperatures were the lowest and summer temperatures were characteristically the highest.

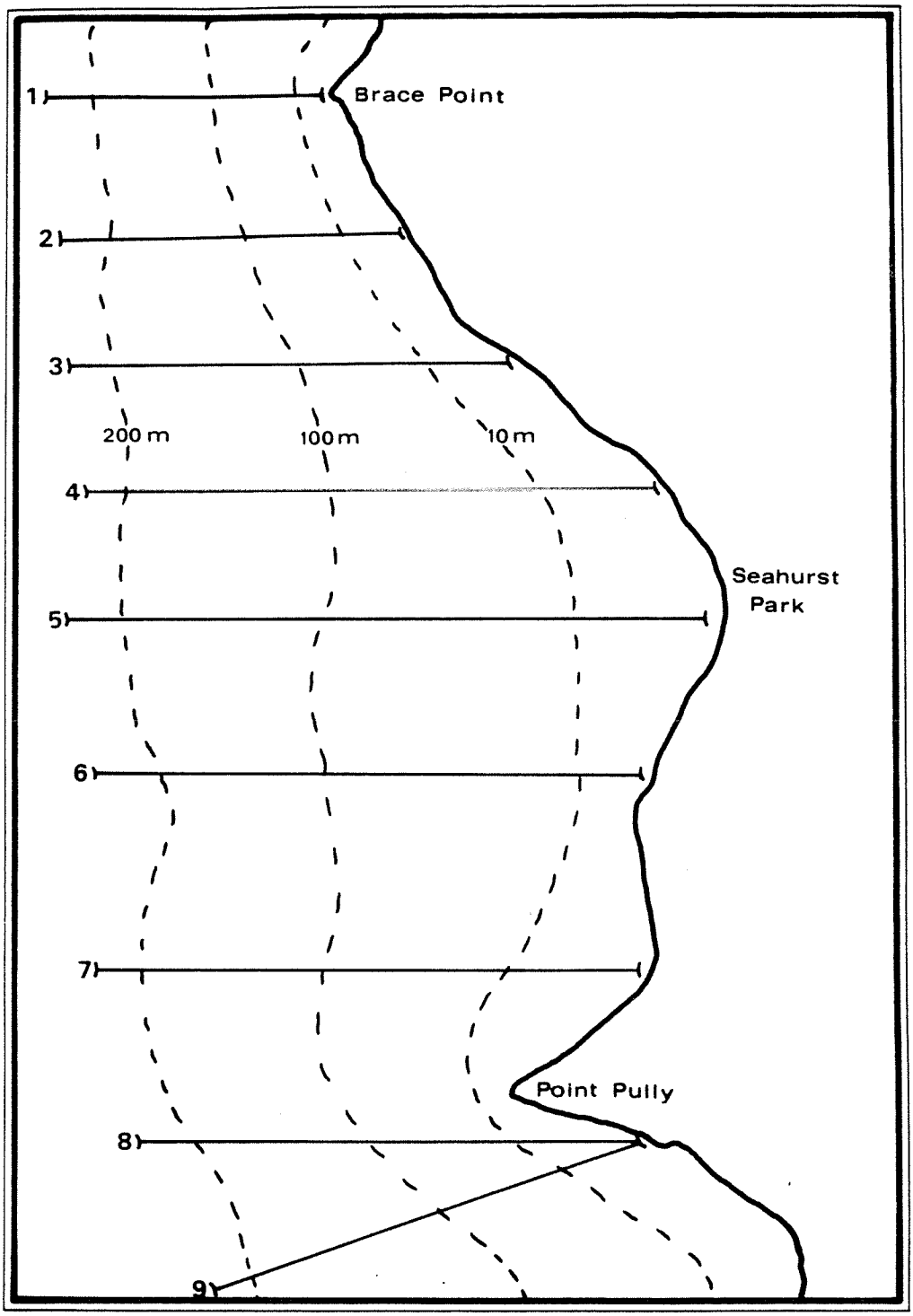



Figure 8.2. Exploratory acoustic transects in Seahurst study area.

Table 8.1. Temperature, dissolved oxygen, and salinity summary for shoreline and offshore stations.

| | Seahurst | | | Pt. Pulley | | | Tramp Harbor | | | Aquarium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| Temperature (°C) | | | | | | | | | | | | |
| Shoreline | 18.5 | 14.8 | | 15.9 | 17.1 | 10.2 | 19.0 | 17.4 | 10.0 | 18.0 | | 11.1 |
| Offshore | | | | | | | | | | | | |
| Surface | 12.4 | 12.5 | 9.6 | 12.6 | 12.8 | 9.5 | 12.0 | 13.0 | 9.5 | 11.2 | 11.5 | 9.8 |
| 15 m | 11.2 | | 8.7 | 10.8 | 11.3 | 9.0 | 10.9 | 12.8 | 9.5 | 10.3 | 11.3 | 9.5 |
| 50 m | 9.9 | 10.5 | 9.1 | 9.9 | 10.5 | 9.4 | 9.8 | 10.7 | 9.5 | 9.9 | 11.0 | 9.5 |
| 100 m | 9.7 | 10.2 | 9.1 | 9.4 | 10.0 | 9.5 | 9.9 | 10.0 | 9.5 | 10.2 | 10.0 | 9.4 |
| 200 m | 9.4 | 10.0 | 9.8 | | 10.0 | 9.6 | | 9.8 | 9.8 | | 9.8 | 9.5 |
| Dissolved Oxygen (mg/L) | | | | | | | | | | | | |
| Shoreline | 10.7 | 10.3 | 7.0 | 11.2 | 10.1 | 7.9 | 10.7 | 10.3 | 8.1 | 8.9 | 11.4 | 7.9 |
| Offshore | | | | | | | | | | | | |
| 15 m | | | 7.4 | | | 8.1 | | | 7.4 | | | 6.9 |
| 50 m | | | 7.4 | | | 7.5 | | | 7.0 | | | 7.1 |
| 100 m | | | 7.4 | | | 6.3 | | | 6.6 | | | 7.9 |
| 200 m | | | 6.0 | | | 6.2 | | | 6.6 | | | 6.9 |
| Salinity (ppt) | | | | | | | | | | | | |
| Shoreline | 28.4 | 29.7 | 31.1 | 27.9 | 29.3 | 30.1 | 28.5 | 29.8 | 30.7 | 28.6 | 26.8 | 30.6 |
| Offshore | | | | | | | | | | | | |
| 15 m | 28.2 | | 30.4 | 28.0 | | 30.4 | 28.3 | | 30.2 | 28.5 | | 29.8 |
| 50 m | 28.4 | | 31.2 | 28.6 | | 30.6 | 28.5 | | 30.9 | 28.7 | | 30.6 |
| 100 m | 28.9 | 30.0 | 31.0 | 29.0 | | 30.6 | 28.8 | | 30.7 | 28.5 | | 30.5 |
| 200 m | 29.0 | 29.9 | 31.3 | | | 31.0 | | | 30.9 | | | 30.7 |

Temperature decreased with increasing depth. Shoreline temperatures varied the most over seasons while temperatures at 200 m were the least affected by seasonal changes.

Dissolved oxygen determinations were consistantly made during shoreline fishing trips. Highest dissolved oxygen was reported in spring (10.3 mg/l) and lowest in autumn (7.7 mg/l) samples. Dissolved oxygen levels tended to decrease with increasing depths during autumn.

Salinity varied with season and depth, but not between locations. The highest salinities were recorded in the autumn 200 m samples (30.8 ppt). In general, salinity ranged from 26.8 to 31.3 ppt.

8.4.2 Stream Fishes

A total of 84 coastal cutthroat trout (Salmo clarki clarki) and 52 sculpins (Cottidae) were caught in the 1982 Seahurst stream surveys (Table 8.2). Cutthroat trout were most abundant in summer and autumn catches. The highest incidental catch of sculpins was in the autumn.

8.4.3 Artificial Reef Fishes

The seasonal diving survey on the artificial reef at Seahurst indicated that striped seaperch and pile perch were the two most abundant species and that their abundance showed some seasonal fluctuation with spring accounting for the least number of both species (Table 8.3). Copper rockfish and painted greenling were also fairly abundant but did not show clear cut seasonal changes.

The overall abundance of fishes increased noticeably from spring-summer to fall-winter.

There was no evidence of external disease or abnormalities on the fish associated with the artificial reef.

Table 8.2. Numbers of fish in 1982 Seahurst County Park stream survey.

| | Spring | Summer | Autumn |
|---|---|---|---|
| Cutthroat trout | 15 | 37 | 32 |
| Sculpin | 0 | 10 | 42 |

Table 8.3. Number of fish seen on seasonal dive surveys at the Seahurst artificial reef.

| Species | Spring | Summer | Autumn | Winter | Total |
|---|---|---|---|---|---|
| Striped seaperch. | 13 | 39 | 350 | 650 | 1,052 |
| Juveniles | 10 | 65 | 200 | 192 | 467 |
| Pile perch | 24 | 57 | 111 | 50 | 242 |
| Juveniles | | 67 | 40 | 1 | 108 |
| Brown rockfish | 3 | 1 | 1 | | 5 |
| Copper rockfish | 12 | 32 | 27 | 49 | 120 |
| Juveniles | 12 | 7 | 24 | 19 | 62 |
| Quillback rockfish | 6 | 3 | 2 | | 11 |
| Juveniles | 5 | | 7 | | 12 |
| Cabezon | 2 | | 4 | 1 | 7 |
| Juveniles | | | 1 | 2 | 3 |
| Painted greenling | 5 | 9 | 17 | 11 | 42 |
| Juveniles | 1 | | | | 1 |
| Buffalo sculpin | 1 | | | | 1 |
| Red Irish lord | | 1 | 3 | | 4 |
| Sailfin sculpin | | 1 | | | 1 |
| UID cottid | 1 | | | | 1 |
| C-O sole | 1 | | 2 | | 3 |
| Juveniles | | | 3 | | 3 |
| English sole | 1 | | | | 1 |
| Lemon sole | | | 1 | | 1 |
| Rock sole | 5 | 7 | 3 | | 15 |
| Total | 102 | 289 | 796 | 975 | 2,162 |

### 8.4.4 Shoreline Fishes

A combined total of 86 species of fish were collected during spring, summer, and autumn of 1982 from Seahurst, Pt. Pully, Tramp Harbor and Aquarium (Table 8.4). Twenty-four of these species occurred in both the shoreline (beach seine) and the offshore (trawl) samples. A total of 28 species appeared solely in the shoreline catches, while 34 species were found exclusively in offshore catches.

The greatest number of species per sample occurred in the shoreline collection (Table 8.5). The total number ranged from a high of 30 species in the summer collections at Aquarium to a low of 14 species in the summer at Tramp Harbor. Over all seasons, the average number of species per haul was also lowest at Tramp Harbor (16 species per haul) and highest at Aquarium (22 species per haul) (Figure 8.3). Seahurst had the largest average number of fish per haul (1595) and Pt. Pully the smallest (729) (Figure 8.3).

For shoreline collections, the average number of fish per haul tended to increase from spring to autumn but the average biomass per haul showed considerable fluctuation (Table 8.6). The greatest average number of fish (2741) were sampled at Seahurst in autumn and the greatest biomass (over 68 kg) at Pt. Pully in the spring. In general, Seahurst and Pt. Pully had the largest catches by weight.

### 8.4.5 Offshore Fishes

The total number of species in the offshore samples was greatest in the 50 m stations and lowest in the 200 m stations (Table 8.5). The highest number of species (22) was found in the 50 m autumn collection at Aquarium. From spring to autumn, species diversity increased at all offshore stations. The average number of species per haul and average number of fish per haul followed the same general bathymetric pattern at all locations (Figures 8.4 -

Table 8.4. Species occurring in beach seine and trawl catches.

| | Common name | Scientific name | Occurrence Shoreline | Occurrence Offshore |
|---|---|---|---|---|
| 1 | Sand sole | Psettichthys melanostictus | x | x |
| 2 | Curlfin sole | Pleuronichthys decurrens | | x |
| 3 | C-O sole | Pleuronichthys coenosus | x | x |
| 4 | Starry flounder | Platichthys stellatus | x | |
| 5 | English sole | Parophrys vetulus | x | x |
| 6 | Dover sole | Microstomus pacificus | x | x |
| 7 | Slender sole | Lyopsetta exilis | x | x |
| 8 | Rock sole | Lepidopsetta bilineata | x | x |
| 9 | Butter sole | Isopsetta isolepis | | x |
| 10 | Flathead sole | Hippoglossoides elassodon | | x |
| 11 | Rex sole | Glyptocephalus zachinus | | x |
| 12 | Speckled sanddab | Citharichthys stigmaeus | | x |
| 13 | Pacific sanddab | Citharichthys sordidus | x | x |
| 14 | Pacific sand lance | Ammodytes hexapterus | x | |
| 15 | Saddleback gunnel | Pholis ornata | x | |
| 16 | Crescent gunnel | Pholis laeta | x | |
| 17 | Penpoint gunnel | Apodichthys flavidus | x | |
| 18 | Whitebarred prickleback | Poroclinus rothrocki | | x |
| 19 | Bluebarred prickleback | Plectobranchus evides | | x |
| 20 | Snake prickleback | Lumpenus sagitta | x | |
| 21 | Northern ronquil | Ronquilis jordani | | x |
| 22 | Pile perch | Rhacochilus vacca | x | x |
| 23 | Striped seaperch | Embiotoca lateralis | x | x |
| 24 | Shiner perch | Cymatogaster aggregata | x | x |
| 25 | Showy snailfish | Liparis pulchellus | | x |
| 26 | Slipskin snailfish | Liparis fucensis | | x |
| 27 | Blacktail snailfish | Careproctus melanurus | | x |
| 28 | Bluespotted poacher | Xeneretmus triacanthus | | x |
| 29 | Blacktip poacher | Xeneretmus latifrons | | x |
| 30 | Pygmy poacher | Odontophyxis trispinosa | | x |
| 31 | Sturgeon poacher | Argonus acipenserinus | x | x |
| 32 | Bigeye poacher | Asterotheca pentacanthus | | x |
| 33 | Northern spearnose poacher | Agonopsis emmelane | x | |
| 34 | Soft sculpin | Gilbertidia sigalutes | | x |
| 35 | Tadpole sculpin | Psychrolutes paradoxus | x | |
| 36 | Sculpins | Cottidae | | x |
| 37 | Roughback sculpin | Chitonotus pugetensis | x | x |

Table 8.4 (cont'd)

| | Common name | Scientific name | Occurrence Shoreline | Occurrence Offshore |
|---|---|---|---|---|
| 38 | Ribbed sculpin | Triglops pingeli | x | x |
| 39 | Manacled sculpin | Synchirus gilli | x | |
| 40 | Cabezon | Scorpaenichthys marmoratus | x | |
| 41 | Slim sculpin | Radulinus asprellus | | x |
| 42 | Spinyhead sculpin | Dasycottus setiger | | x |
| 43 | Tidepool sculpin | Oligocottus maculosus | x | |
| 44 | Sailfin sculpin | Nautichthys oculofasciatus | x | x |
| 45 | Great sculpin | Myoxocephalus polyacanthocephalus | x | |
| 46 | Blackfin sculpin | Malacocottus kincaidi | | x |
| 47 | Pacific staghorn sculpin | Leptocottus armatus | x | |
| 48 | Spotfin sculpin | Icelinus tenuis | | x |
| 49 | Threadfin sculpin | Icelinus filamentosus | | x |
| 50 | Buffalo sculpin | Enophrys bison | x | |
| 51 | Prickly sculpin | Cottus asper | x | |
| 52 | Sharpnose sculpin | Clinocottus acuticeps | x | |
| 53 | Silverspotted sculpin | Blepsias cirrhosus | x | x |
| 54 | Padded sculpin | Artedius fenestralis | x | |
| 55 | Sablefish | Anoplopoma fimbria | | x |
| 56 | Painted greenling | Oxylebius pictus | x | |
| 57 | Lingcod | Ophidon elongatus | x | |
| 58 | Whitespotted greenling | Hexagrammos stelleri | x | |
| 59 | Kelp greenling | Hexagrammos decagrammus | x | |
| 60 | Redstriped rockfish | Sebastes proriger | | x |
| 61 | Quillback rockfish | Sebastes maliger | x | x |
| 62 | Yellowtail rockfish | Sebastes flavidus | | x |
| 63 | Greenstriped rockfish | Sebastes elongatus | | x |
| 64 | Splitnose rockfish | Sebastes diploproa | | x |
| 65 | Copper rockfish | Sebastes caurinus | x | x |
| 66 | Brown rockfish | Sebastes auriculatus | x | x |
| 67 | Bay pipefish | Syngnathus leptorhynchus | x | |
| 68 | Tubesnout | Aulorhynchus flavidus | x | x |
| 69 | Threespine stickleback | Gasterosteus aculeatus | x | |
| 70 | Pallid eelpout | Lycodes mandibularis | | x |
| 71 | Blackbelly eelpout | Lycodopsis pacifica | | x |
| 72 | Bigfin eelpout | Aprodon cortezianus | | x |
| 73 | Black eelpout | Lycodes diapterus | | x |
| 74 | Pacific hake | Merluccius productus | | x |
| 75 | Walleye pollock | Theragra chalcogramma | x | x |
| 76 | Pacific tomcod | Microgadus proximus | x | x |
| 77 | Pacific cod | Gadus macrocephalus | x | |

Table 8.4 (cont'd)

| | Common name | Scientific name | Occurrence Shoreline | Occurrence Offshore |
|---|---|---|---|---|
| 78 | Red brotula | Brosmophycis marginata | | x |
| 79 | Plainfin midshipman | Porichthys notatus | x | x |
| 80 | Surf smelt | Hypomesus pretiosus | x | |
| 81 | Chinook salmon | Oncorhynchus tshawytscha | x | |
| 82 | Chum salmon | Oncorhynchus keta | x | |
| 83 | Pink salmon | Oncorhynchus gorbuscha | x | |
| 84 | Pacific herring | Clupea harengus pallasi | x | x |
| 85 | Ratfish | Hydrolagus colliei | x | x |
| 86 | Spiny dogfish | Squalus acanthias | x | x |

Table 8.5. Total number of species occurring at each station by depth and season.

| | Shoreline | Offshore | | | |
|---|---|---|---|---|---|
| | < 10 m | 15 m | 50 m | 100 m | 200 m |
| Seahurst | | | | | |
| Spring | 22 | 9 | 16 | 9 | 3 |
| Summer | 26 | 11 | 14 | 11 | 8 |
| Autumn | 26 | -- | 19 | 19 | 9 |
| Pt. Pulley | | | | | |
| Spring | 21 | 8 | 14 | 6 | 5 |
| Summer | 18 | 14 | 13 | 15 | 6 |
| Autumn | 26 | 14 | 20 | 14 | 8 |
| Tramp Harbor | | | | | |
| Spring | 21 | 9 | 9 | 4 | 2 |
| Summer | 14 | 6 | 12 | 10 | 14 |
| Autumn | 20 | 6 | 19 | 19 | 6 |
| Aquarium | | | | | |
| Spring | 21 | 7 | 13 | 5 | 8 |
| Summer | 30 | 14 | 12 | 20 | 6 |
| Autumn | 24 | 13 | 22 | 14 | 7 |

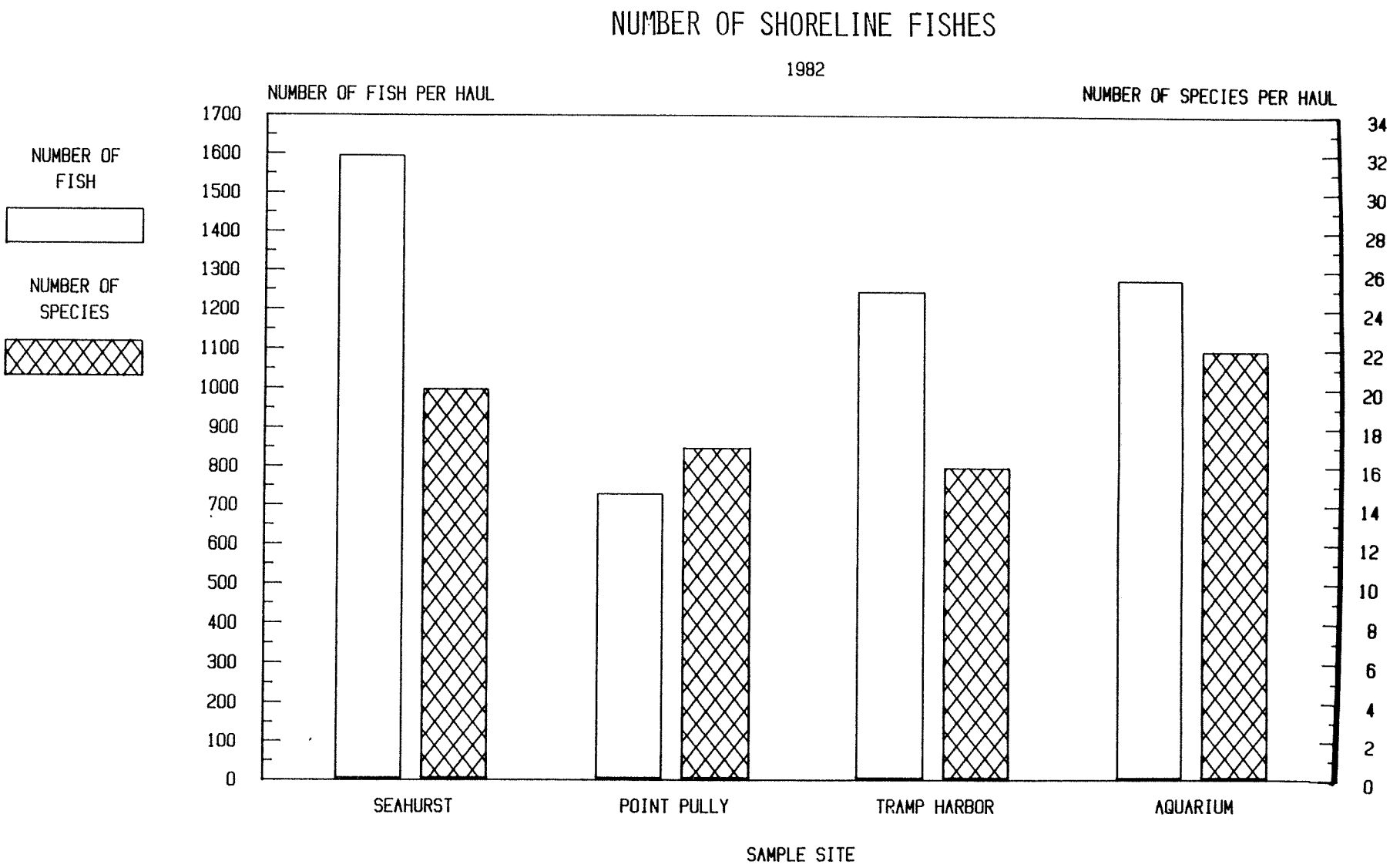



Figure 8.3. Average number of fish and average number of species per haul.

Table 8.6. Average catch per haul in shoreline catches by area and season.

| | Shoreline <10 m | |
|---|---|---|
| | Wet weight (g) | Number of fish |
| Seahurst | | |
| Spring | 42,228 | 383 |
| Summer | 22,677 | 1,662 |
| Autumn | 48,280 | 2,741 |
| Pt. Pulley | | |
| Spring | 68,013 | 772 |
| Summer | 12,339 | 312 |
| Autumn | 26,802 | 1,103 |
| Tramp Harbor | | |
| Spring | 6,183 | 332 |
| Summer | 7,515 | 2,269 |
| Autumn | 14,169 | 1,137 |
| Aquarium | | |
| Spring | 5,269 | 429 |
| Summer | 22,827 | 1,401 |
| Autumn | 22,578 | 2,004 |

8.7), i.e., highest catch and species diversity at the 50 m depth, and the lowest catch and species diversity at the 200 m depth.

### 8.4.6 Species Assemblages

#### 8.4.6.1 Shoreline Fishes

Six species (English sole, crescent gunnel, striped seaperch, shiner perch, staghorn sculpin, and whitespotted greenling) occurred at all the shoreline sites throughout the sampling seasons (Table 8.7). Another four species (rock sole, C-O sole, pile perch, and tidepool sculpin) occurred in all but one of the collections.

Shiner perch, striped seaperch, English sole and rock sole were the most abundant species and the most important by biomass in the shoreline samples (Tables 8.7-8.8). Other species, such as the Pacific sandlance, tidepool sculpin, tubesnout, pollock, and juvenile rock fish, were occasionally present in large numbers. C-O sole, pile perch, staghorn sculpin, and cabezon were sometimes important by weight.

Shiner perch were most abundant in the autumn (except in Tramp Harbor) and least abundant in spring. Striped seaperch appeared to be most abundant in the shoreline area during the spring and summer, except at Pt. Pully where there was little variation. Flatfish (English sole, rock sole, and C-O sole) were much more abundant at Pt. Pully (and to a lesser extent at Seahurst) than at Tramp Harbor or Aquarium. Tubesnout were abundant in autumn samples from all areas except at Pt. Pully.

#### 8.4.6.2 Offshore Fishes

All offshore (trawl) areas exhibited a general trend of increasing average catch per haul (CPH) in both numbers and biomass from spring to autumn (Table 8.9). Autumn catches combined over all depths were at least twice as large as spring catches. The highest average CPH by weight (25 to 30 kg)

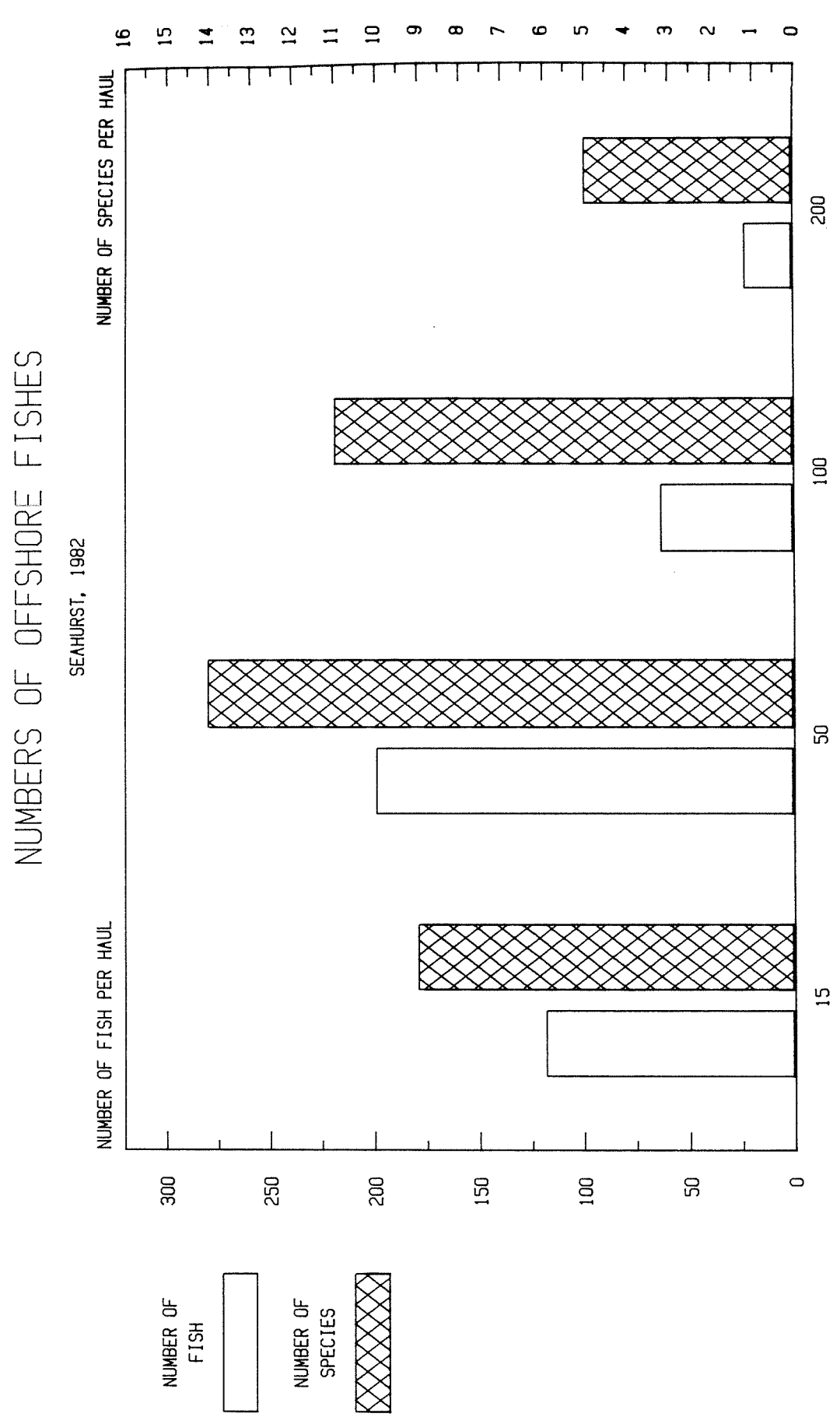



Figure 8.4. Average number of fish and average number of species per haul

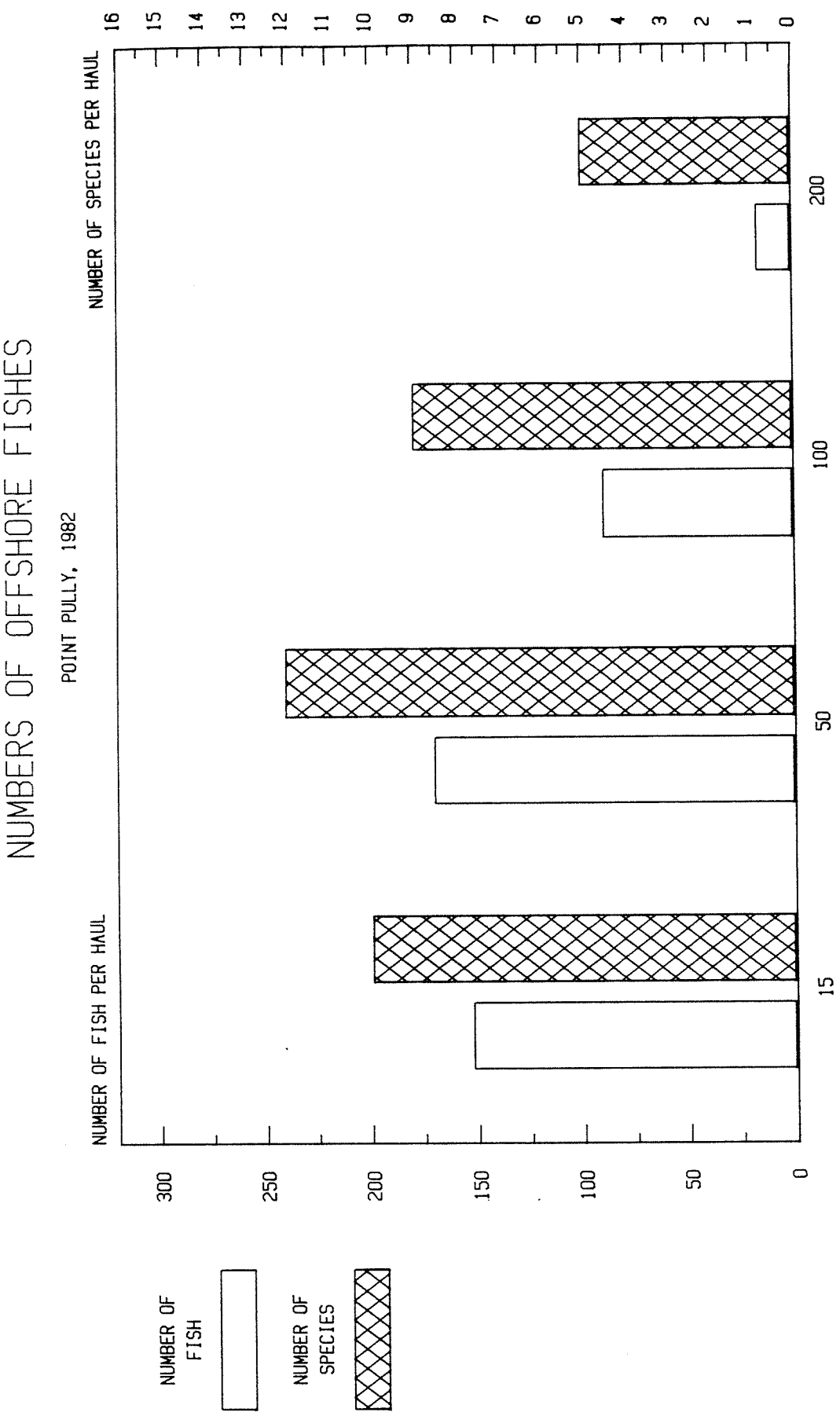



Figure 8.5. Average number of fish and average number of species per haul

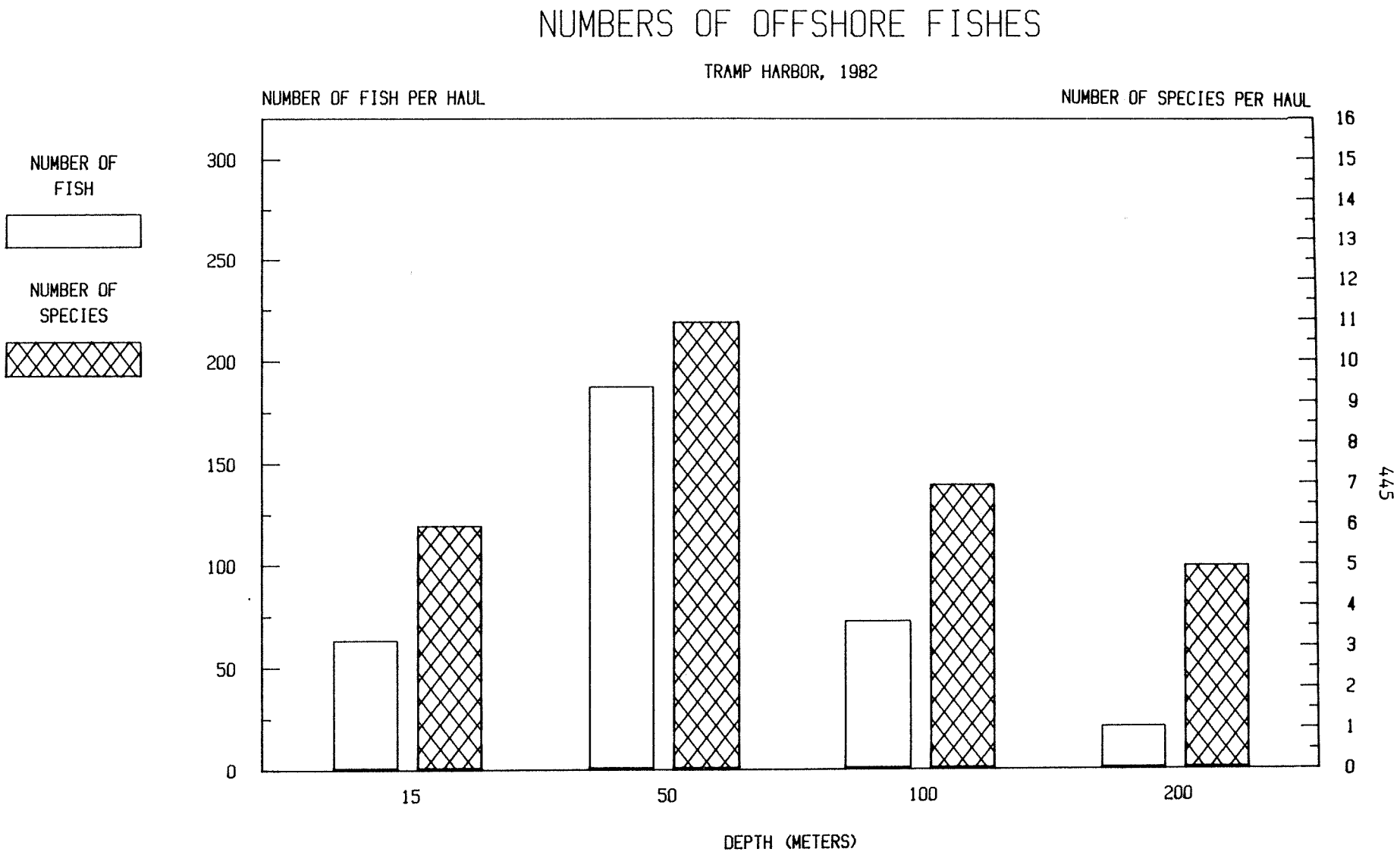



Figure 8.6 Average number of fish and average number of species per haul.

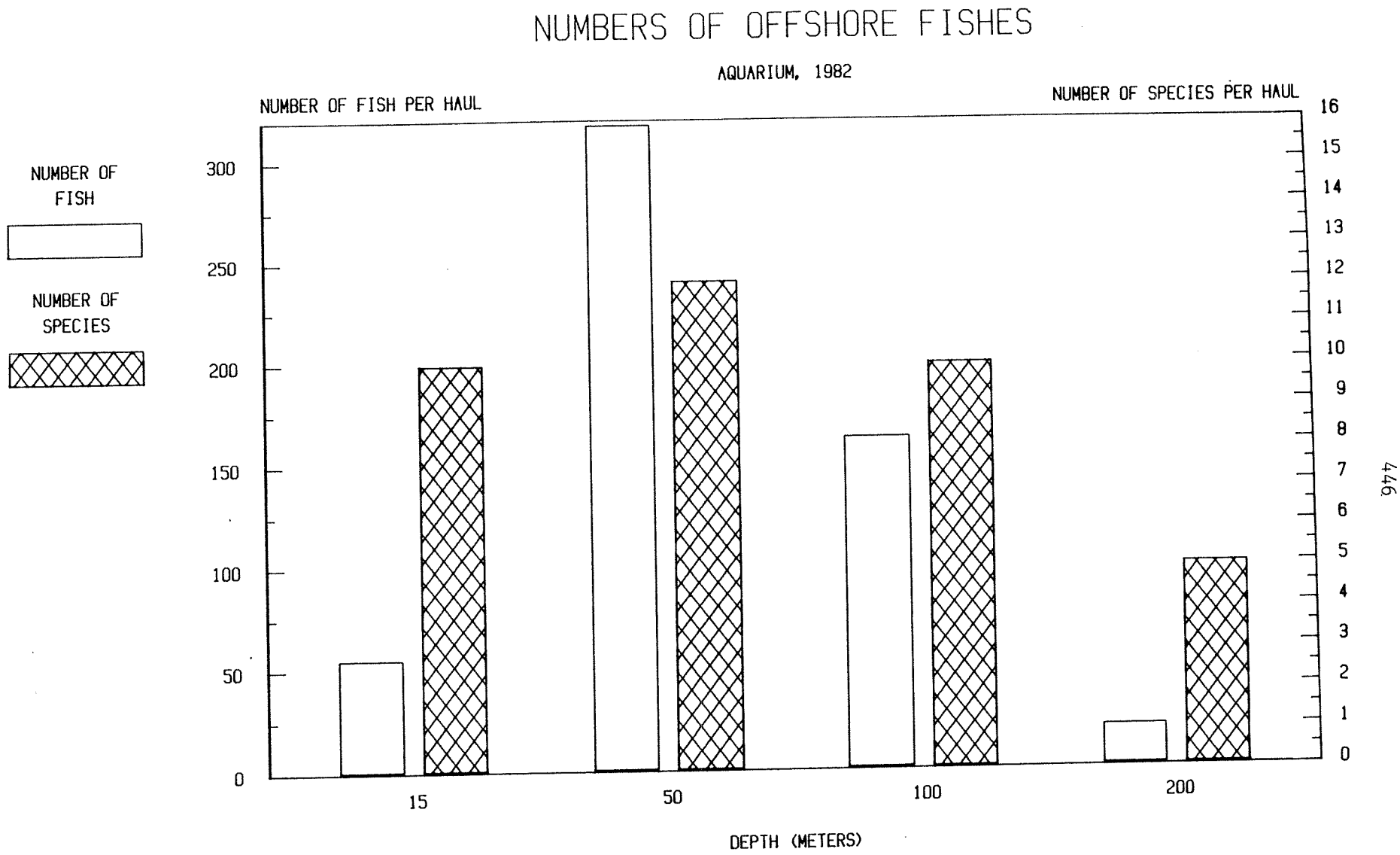



Figure 8.7. Average number of fish and average number of species per haul

Table 8.7. Average catch per haul in numbers for frequently occurring species in shoreline catches by area and season.

| | Seahurst | | | Point Pully | | | Tramp Harbor | | | Aquarium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 18.0 | 1.5 | 51.5 | 106.5 | 46.0 | 131.5 | 22.5 | 1.5 | 26.0 | 18.0 | 35.5 | 68.0 |
| Rock sole | 96.5 | 22.5 | 25.5 | 94.0 | 48.5 | 115.5 | 13.5 | | 19.5 | 10.0 | 24.5 | 23.0 |
| C-O sole | 28.5 | 3.5 | 17.0 | 61.0 | 16.5 | 20.0 | 5.5 | | 3.5 | 7.0 | 8.0 | 8.5 |
| Starry flounder | | | | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | | 1.0 | 1.0 | 3.5 |
| Pacific sand lance | | 4.0 | | | | | | | | 231.0 | | |
| Crescent gunnel | 1.5 | 2.0 | 3.0 | 0.5 | 9.0 | 1.5 | 12.0 | 22.0 | 3.0 | 35.0 | 14.0 | 17.0 |
| Saddleback gunnel | 0.5 | 3.0 | 0.5 | | | 2.0 | | | 14.0 | 9.0 | | 5.5 |
| Penpoint gunnel | 7.5 | 5.0 | | 4.0 | 9.5 | | 8.5 | 10.5 | | 18.0 | 18.0 | 0.5 |
| Pile perch | 9.0 | 20.5 | 14.0 | 33.5 | 2.5 | 5.5 | 1.5 | | 3.0 | 7.0 | 16.5 | 11.0 |
| Striped seaperch | 127.5 | 558.5 | 25.0 | 55.0 | 44.5 | 54.5 | 180.0 | 88.0 | 15.5 | 1.0 | 242.5 | 92.0 |
| Shiner perch | 65.5 | 935.0 | 2368.5 | 373.0 | 58.0 | 682.5 | 22.0 | 1337.5 | 604.0 | 19.0 | 861.0 | 1266.0 |
| Tidepool sculpin | 6.5 | 1.0 | 2.0 | 2.0 | | 0.5 | 28.0 | 200.5 | 127.0 | 18.0 | 0.5 | 0.5 |
| Staghorn sculpin | 9.0 | 8.0 | 23.0 | 5.0 | 17.0 | 14.0 | 17.5 | 34.5 | 15.5 | 15.0 | 9.0 | 13.5 |
| Buffalo sculpin | 0.5 | 2.5 | 2.5 | | | | 1.0 | | 2.5 | | 1.0 | 1.5 |
| Padded sculpin | | 16.5 | 8.5 | | 20.0 | | | 33.0 | | | 67.0 | |
| Cabezon | 1.0 | 0.5 | | 1.0 | 0.5 | | | | | | | |
| Whitespot greenling | 0.5 | 0.5 | 3.0 | 2.0 | 1.0 | 1.5 | 2.0 | 0.5 | 0.5 | 1.0 | 0.5 | 2.5 |
| Rockfish juvenile | | 23.5 | 3.0 | | 19.5 | 1.5 | | 19.0 | 0.5 | | 43.5 | 94.5 |
| Tubesnout | 1.0 | 12.0 | 106.5 | | | 0.5 | 3.0 | 4.0 | 230.0 | 18.0 | 2.0 | 124.0 |
| Walleye pollock | | 7.5 | 17.5 | | | 37.0 | 0.5 | | 6.5 | | | 191.0 |
| Pacific tomcod | | 18.0 | 35.0 | | | 1.0 | | 0.5 | 31.0 | | 36.0 | 11.0 |
| Chum salmon | | 0.5 | | | | | 1.5 | | | 8.0 | | |
| Avg. Total | 382.5 | 1662.0 | 2741.0 | 771.5 | 311.5 | 1103.0 | 331.5 | 2269 | 1136.5 | 429.0 | 1401.0 | 2003.5 |

Table 8.8. Average catch per haul in biomass (g) for frequently occurring species in shoreline catches by area and season.

| Species | Seahurst | | | Point Pully | | | Tramp Harbor | | | Aquarium | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 1576.4 | 7.3 | 6495.0 | 15803.5 | 1460.8 | 7751.1 | 123.0 | 6.0 | 3411.5 | 306.4 | 506.8 | 3777.9 |
| Rock sole | 8931.1 | 1723.8 | 4107.2 | 11300.0 | 2980.0 | 6505.4 | 950.0 | | 2978.1 | 1461.7 | 3939.0 | 2814.8 |
| C-O sole | 5150.5 | 710.4 | 3625.9 | 11863.5 | 3126.8 | 2596.9 | 134.1 | | 200.0 | 511.3 | 218.4 | 610.1 |
| Starry flounder | | | | 170.7 | 2.7 | 330.2 | 202.6 | 2.9 | | 410.0 | 3.3 | 11.0 |
| Pacific sand lance | | 6.57 | | | | | | | | 101.0 | | |
| Crescent gunnel | 16.1 | 20.8 | 10.4 | 6.6 | 86.0 | 3.5 | 115.7 | 78.7 | 6.7 | 94.1 | 46.7 | 32.4 |
| Saddleback gunnel | 2.4 | 31.2 | 3.4 | | | 5.5 | | | 35.0 | 73.5 | | 14.8 |
| Penpoint gunnel | 233.8 | 291.4 | | 186.1 | 330.0 | | 146.6 | 52.2 | | 132.4 | 397.4 | 2.3 |
| Pile perch | 303.9 | 207.2 | 3274.4 | 4970.8 | 153.3 | 52.1 | 29.1 | | 31.5 | 356.9 | 1026.1 | 113.7 |
| Striped seaperch | 22055.5 | 13756.9 | 6504.4 | 8544.2 | 1971.0 | 1666.2 | 3150.3 | 642.5 | 257.2 | 3.6 | 10665.4 | 1859.5 |
| Shiner perch | 1046.5 | 4310.6 | 18925.0 | 2755.6 | 474.5 | 4641.5 | 325.5 | 5525.8 | 4437.5 | 476.8 | 4407.7 | 9447.5 |
| Tidepool sculpin | 7.8 | 2.2 | 6.9 | 1.2 | | 1.0 | 21.3 | 178.6 | 201.6 | 11.4 | 0.2 | 0.5 |
| Staghorn sculpin | 462.7 | 810.6 | 1315.7 | 356.5 | 862.7 | 1301.6 | 897.2 | 838.0 | 800.0 | 1251.0 | 859.1 | 793.3 |
| Buffalo sculpin | 13.6 | 205.7 | 134.5 | | | | 0.4 | | 6.8 | | 54.2 | 86.6 |
| Padded sculpin | | 68.9 | 74.5 | | 78.0 | | | 113.7 | | | 248.2 | |
| Cabezon | 2244.0 | 138.0 | | 2351.8 | 0.9 | | | | | | | |
| Whitespot greenling | 1.1 | 8.6 | 1001.4 | 293.3 | 8.8 | 128.4 | 11.2 | 1.9 | 22.8 | 3.3 | 11.3 | 188.5 |
| Rockfish juvenile | | 20.1 | 18.8 | | 18.4 | 3.1 | | 19.5 | 2.5 | | 40.8 | 423.0 |
| Tubesnout | 2.2 | 39.6 | 307.9 | | | 1.2 | 1.8 | 2.4 | 600.6 | 132.4 | 2.9 | 265.2 |
| Walleye pollock | | 40.2 | 130.8 | | | 203.5 | 0.7 | | 39.6 | | | 1206.0 |
| Pacific tomcod | | 79.1 | 702.2 | | | 73.3 | | 4.1 | 137.0 | | 194.2 | 114.0 |
| Chum salmon | | 5.5 | | | | | 12.0 | | | 57.8 | | |
| Avg. Total | 42228.0 | 22677.3 | 48279.8 | 68012.7 | 12338.7 | 26801.9 | 6182.8 | 7514.5 | 14168.8 | 5268.7 | 22827.1 | 22577.6 |

Table 8.9. Average catch per haul by numbers and weight (g) in offshore catches by area, depth, and season.

| | | Offshore | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 15 m | | 50 m | | 100 m | | 200 m | |
| Station | Season | Wet weight (g) | Number of fish | Wet weight (g) | Number of fish | Wet weight (g) | Number of fish | Wet weight (g) | Number of fish |
| Seahurst | Spring | 8044 | 102 | 4901 | 82 | 10214 | 49 | 211 | 9 |
| | Summer | 12878 | 135 | 10095 | 167 | 3627 | 25 | 4592 | 37 |
| | Autumn | -- | -- | 27641 | 353 | 15040 | 119 | 10571 | 24 |
| Pt. Pully | Spring | 6962 | 89 | 5420 | 64 | 4043 | 19 | 1858 | 11 |
| | Summer | 10895 | 130 | 7264 | 44 | 6917 | 191 | 3284 | 14 |
| | Autumn | 6901 | 240 | 28906 | 403 | 5908 | 60 | 5668 | 23 |
| Tramp Harbor | Spring | 7671 | 107 | 8554 | 77 | 5200 | 20 | 2078 | 8 |
| | Summer | 3062 | 40 | 4934 | 72 | 7172 | 94 | 4079 | 37 |
| | Autumn | 2772 | 42 | 28928 | 417 | 10407 | 111 | 6025 | 19 |
| Aquarium | Spring | 7910 | 49 | 5786 | 86 | 4661 | 31 | 2001 | 14 |
| | Summer | 7467 | 65 | 8531 | 320 | 14031 | 294 | 5905 | 31 |
| | Autumn | 7047 | 52 | 20563 | 548 | 11367 | 167 | 2385 | 16 |

occurred at the 50 m stations during the autumn collection in all areas. In spring samples, catches were greatest in the shallow (15 m) stations. In the deeper stations (100 m and 200 m), the average CPH was much greater in the summer and autumn.

In addition to changes in overall abundance, considerable changes in species assemblages were observed with station depth and season both by abundance (Tables 8.10-8.13) and biomass (Tables 8.14-8.17).

In the 15 m stations, rock sole and English sole dominated the trawl catches by both abundance and biomass. Roughback sculpin, shiner perch, pile perch, Pacific sanddab, ratfish and juvenile rockfish were occasionally important by abundance at some of the sites.

Flatfish (slender sole, English sole, Dover sole, rock sole and Pacific sanddab) were the most abundant species at the 50 m stations. English and rock sole showed a substantial increase in abundance at 50 m in the autumn samples, which accounted for most of the increase in CPH at all four sites during the autumn sampling. Pollock and tomcod were abundant in summer and/or autumn in each area but not in spring.

At the 100 m sites, ratfish dominated the catches at all stations by number and biomass. Pollock were important by number in the summer and fall. Dover sole, slender sole, and English sole were minor but consistent components of the catch at 100 m, while rock sole were almost entirely absent. Blackbelly eelpout were occasionally abundant at Tramp Harbor and Aquarium but not at Seahurst or Pt. Pully.

The 200 m stations had the lowest overall abundance of fish. Slender sole, ratfish, pollock, and Dover sole were the most important species. English sole were practically absent.

Table 8.10. Average catch per haul by numbers for common species in offshore catches by depth and season at Seahurst.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 19.0 | 44.0 | NO | 13.7 | 19.0 | 181.0 | 7.5 | 2.5 | 21.5 | | 0.5 | |
| Dover sole | 2.0 | | SAMPLING | 16.3 | 10.5 | 5.0 | 7.0 | 1.5 | 7.5 | | 2.0 | 1.5 |
| Slender sole | 1.0 | 0.5 | | 25.3 | 3.5 | 12.0 | | 3.5 | 7.5 | 5.0 | 17.5 | 4.5 |
| Rock sole | 63.5 | 60.5 | | 1.0 | 4.0 | 70.0 | | | 5.5 | | | |
| Flathead sole | | | | | | | | | | | | |
| Rex sole | | | | 3.0 | 4.5 | 3.5 | 2.5 | | | 3.0 | 3.0 | 0.5 |
| Pacific sanddab | 4.5 | 7.5 | | 2.3 | 7.5 | 13.0 | | | 1.0 | | | |
| Pile perch | | | | | 0.5 | 2.5 | | | 0.5 | | | |
| Striped seaperch | | 0.5 | | | | | | | | | | |
| Shiner perch | | 6.0 | | 0.3 | | 26.5 | | | 1.0 | | | |
| Roughback sculpin | 2.0 | 3.0 | | 7.3 | 1.5 | 8.5 | | | | | | |
| Quillback rockfish | | 3.5 | | 1.7 | 5.5 | 1.5 | | 3.5 | 5.5 | | | 0.5 |
| Copper rockfish | | | | 0.3 | | 3.0 | | | | | | |
| Rockfish juveniles | | | | | | 0.5 | | | | | | |
| Blackbelly eelpout | | | | 4.3 | | | 1.5 | | 1.0 | | | 1.5 |
| Walleye pollock | | 0.5 | | | 50.5 | 6.5 | | 1.0 | 26.5 | | 9.5 | 0.5 |
| Pacific tomcod | | | | | 48.0 | 12.5 | | 2.5 | 2.0 | | | |
| Plainfin midshipman | 6.0 | 5.0 | | 3.7 | 10.5 | 4.0 | | | 9.0 | | | |
| Ratfish | 0.5 | | | 0.3 | 1.0 | 0.5 | 26.5 | 7.5 | 20.5 | 1.0 | 4.0 | 12.5 |
| Avg. Total | 102.0 | 134.5 | | 82.3 | 167.0 | 353.0 | 48.5 | 25.0 | 118.5 | 9.0 | 37.0 | 23.5 |

Table 8.11. Average catch per haul by numbers for common species in offshore catches by depth and season at Pt. Pully.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 16.5 | 21.5 | 34.5 | 8.5 | 11.0 | 145.0 | 1.5 | 4.0 | 10.3 | | | 1.0 |
| Dover sole | 4.5 | | | 3.0 | 5.0 | 16.5 | 1.0 | 8.0 | 4.7 | 0.8 | 2.5 | 3.0 |
| Slender sole | 0.5 | 0.5 | | 11.0 | 2.5 | 9.0 | 0.5 | 3.5 | 4.0 | 3.8 | 4.0 | 5.0 |
| Rock sole | 55.5 | 71.0 | 88.0 | 7.5 | 10.5 | 47.0 | | 0.5 | | | | |
| Flathead sole | | | | | | | | | | | | |
| Rex sole | | | | 3.5 | 1.5 | 0.5 | | 2.0 | 4.3 | | | |
| Pacific sanddab | 5.0 | 12.0 | 6.0 | 9.0 | 7.5 | 10.0 | | 0.5 | | | | |
| Pile perch | | 2.0 | 20.0 | | | 13.0 | | | | | | |
| Striped seaperch | | 2.0 | 8.0 | | | 64.5 | | | | | | |
| Shiner perch | | 1.5 | 50.0 | | | 8.0 | | | 3.3 | | | |
| Roughback sculpin | 4.5 | 3.5 | 19.5 | 10.5 | 1.0 | 24.0 | 0.5 | | | 0.5 | | |
| Quillback rockfish | | 2.5 | | | | 3.5 | | 2.0 | 0.7 | | | |
| Copper rockfish | | 1.5 | 1.0 | 6.5 | 0.5 | 2.0 | | | | | | |
| Rockfish juveniles | | | 5.5 | | | 5.5 | | | | | | |
| Blackbelly eelpout | | | | 0.5 | | | | 0.5 | | 1.0 | | 0.5 |
| Walleye pollock | | 0.5 | | | 0.5 | 24.5 | | 127.5 | 11.4 | | 3.5 | 2.0 |
| Pacific tomcod | | | | | 0.5 | 23.0 | | 5.5 | 1.0 | | | |
| Plainfin midshipman | | | | 0.5 | 1.5 | 1.5 | 0.5 | | 1.0 | | | 1.0 |
| Ratfish | 1.5 | 0.5 | 0.5 | 1.0 | | 0.5 | 14.5 | 30.0 | 14.3 | 4.3 | 3.0 | 10.0 |
| Avg. Total | 89.0 | 130.0 | 240.0 | 64.0 | 43.5 | 403.0 | 18.5 | 190.5 | 59.5 | 11.0 | 14.0 | 23.0 |

Table 8.12. Average catch per haul by numbers for common species in offshore catches by depth and season at Tramp Harbor.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 27.5 | 17.3 | 6.5 | 37.5 | 11.5 | 176.5 | | | 6.7 | | 0.3 | 1.0 |
| Dover sole | | | | 8.5 | 15.5 | 67.0 | 2.5 | 3.0 | 11.3 | | 2.7 | |
| Slender sole | | | | 4.0 | 10.5 | 18.5 | 1.0 | 8.5 | 16.3 | 2.0 | 12.3 | 7.5 |
| Rock sole | 32.0 | 14.3 | 21.0 | | 0.5 | 14.0 | | | | | | |
| Flathead sole | | | | 0.5 | | 1.5 | | | | | | |
| Rex sole | | | | 15.0 | 4.0 | 17.5 | | 0.5 | 6.3 | | 1.0 | |
| Pacific sanddab | 0.5 | 4.3 | 0.5 | 2.5 | 0.5 | 0.5 | | | | | | |
| Pile perch | | | | | | 24.0 | | | | | | |
| Striped seaperch | | | | | | | | | | | | |
| Shiner perch | | | | | | 1.5 | | | 0.7 | | | |
| Roughback sculpin | 24.5 | 1.7 | 13.0 | | 1.0 | 3.5 | | | | | | |
| Quillback rockfish | | | | | | | | 1.5 | | | | |
| Copper rockfish | 4.5 | 0.7 | | 0.5 | | | 0.5 | | 1.0 | | | |
| Rockfish juveniles | | | | | | 1.5 | | | 0.7 | | | |
| Blackbelly eelpout | | | | 6.0 | 3.0 | 0.5 | | 23.0 | 5.0 | | 1.7 | |
| Walleye pollock | | | | | 14.0 | 35.0 | | 14.0 | 14.3 | | 4.7 | 2.5 |
| Pacific tomcod | | 0.3 | | | 9.5 | 50.5 | | | 1.3 | | | |
| Plainfin midshipman | 1.0 | | | 1.0 | 2.0 | 0.5 | | | 12.3 | | 0.3 | |
| Ratfish | 0.5 | 1.0 | 0.5 | | | | 15.5 | 40.5 | 25.7 | 5.5 | 11.7 | 7.0 |
| Avg. Total | 107.0 | 40.0 | 42.0 | 76.5 | 72.0 | 416.0 | 19.5 | 93.5 | 111.3 | 7.5 | 37.0 | 19.0 |

Table 8.13. Average catch per haul by numbers for common species in offshore catches by depth and season at Aquarium.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 12.0 | 9.0 | 5.0 | 14.0 | 20.0 | 92.5 | 0.5 | 17.0 | 1.0 | | | |
| Dover sole | | | | 18.0 | 5.0 | 17.5 | | 6.5 | 32.5 | 1.0 | | |
| Slender sole | | | | 9.5 | 2.5 | 9.5 | 8.5 | 33.5 | 22.5 | 8.0 | 9.5 | 9.0 |
| Rock sole | 21.0 | 22.0 | 10.0 | | 1.5 | 35.5 | | 0.5 | 0.5 | | | |
| Flathead sole | | | | | | | | 0.5 | | 1.0 | 0.5 | 0.5 |
| Rex sole | 0.5 | | | 19.5 | 4.5 | 10.0 | | 8.0 | 3.5 | | | 0.5 |
| Pacific sanddab | | 8.0 | 1.0 | 9.5 | 2.0 | 5.5 | | 2.0 | 0.5 | | | |
| Pile perch | | 2.5 | 1.0 | | | 1.5 | | | | | | |
| Striped seaperch | | | 0.5 | | | 1.0 | | | | | | |
| Shiner perch | | 8.5 | | | 1.0 | 2.0 | | 3.0 | | | | |
| Roughback sculpin | 4.0 | 1.0 | 7.5 | | | 1.0 | | | | | | |
| Quillback rockfish | | 0.5 | | 0.5 | 6.0 | 7.0 | | 1.0 | 1.0 | | | |
| Copper rockfish | 2.5 | 4.5 | 1.5 | | | | | | | | | |
| Rockfish juveniles | | | 14.0 | | | 0.5 | | | 0.5 | | | |
| Blackbelly eelpout | | | | 7.0 | | 2.5 | 6.0 | 18.0 | 14.0 | 0.5 | | |
| Walleye pollock | | | | | 269.5 | 322.5 | | 123.0 | 18.5 | | 13.0 | 2.5 |
| Pacific tomcod | | | | 0.5 | 4.0 | 20.0 | | 16.5 | 0.5 | | | |
| Plainfin midshipman | | 1.0 | | 1.5 | 3.0 | 9.5 | | 2.0 | 9.5 | | | |
| Ratfish | 7.0 | 2.5 | 5.5 | 3.0 | 0.5 | 3.0 | 15.0 | 53.5 | 51.5 | 3.0 | 6.5 | 2.5 |
| Avg. Total | 49.0 | 64.5 | 51.5 | 86.0 | 319.5 | 547.5 | 30.5 | 293.5 | 167.0 | 14.0 | 31.0 | 16.0 |

Table 8.14. Average catch per haul by weight (g) for common species in offshore catches by depth and season at Seahurst.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 3378.2 | 4777.5 | NO | 1966.0 | 3570.6 | 19131.0 | 1202.0 | 600.0 | 2540.0 | | 425.0 | |
| Dover sole | 114.6 | | SAMPLING | 705.4 | 1346.9 | 359.9 | 1532.5 | 193.7 | 1390.0 | | 562.5 | 1445.0 |
| Slender sole | 103.3 | 67.4 | | 771.4 | 127.7 | 511.5 | 111.4 | 180.4 | 411.0 | 177.5 | 933.9 | 209.3 |
| Rock sole | 3558.5 | 4592.5 | | 67.8 | 235.2 | 2306.3 | | | 555.0 | | | |
| Flathead sole | | | | | | | | | | | | |
| Rex sole | | | | 154.3 | 269.8 | 143.3 | 87.4 | | | 16.3 | 47.5 | 6.35 |
| Pacific sanddab | 173.9 | 66.3 | | 249.1 | 1230.4 | 2101.7 | | | 180.0 | | | |
| Pile perch | | | | | 44.6 | 86.0 | | | 55.3 | | | |
| Striped seaperch | | 252.5 | | | | | | | | | | |
| Shiner perch | | 82.4 | | 9.1 | | 256.4 | | | 25.0 | | | |
| Roughback sculpin | 10.1 | 16.8 | | 63.4 | 13.9 | 194.5 | | | | | | |
| Quillback rockfish | | 1335.0 | | 121.0 | 1481.7 | 855.8 | | 276.6 | 2563.0 | | | 455.0 |
| Copper rockfish | | | | 162.4 | | 770.5 | | | | | | |
| Rockfish juveniles | | | | | | 3.25 | | | | | | |
| Blackbelly eelpout | | | | 89.1 | | | 54.5 | | 14.5 | | | 31.55 |
| Walleye pollock | | 0.8 | | | 233.8 | 30.2 | | 4.2 | 652.5 | | 206.1 | 262.5 |
| Pacific tomcod | | | | | 213.8 | 77.4 | | 56.1 | 199.0 | | | |
| Plainfin midshipman | 425.8 | 335.4 | | 384.5 | 852.3 | 284.4 | | | 692.0 | | | |
| Ratfish | 237.0 | | | 123.8 | 472.8 | 347.5 | 6571.8 | 2195.7 | 4680.0 | 16.9 | 2415.0 | 7745.0 |
| Avg. Total | 8044.3 | 12878.0 | | 4901.3 | 10094.8 | 27641.2 | 10214.1 | 3627.2 | 15040.3 | 210.7 | 4591.8 | 10571.0 |

Table 8.15. Average catch per haul by weight (g) for common species in offshore catches by depth and season at Pt. Pully.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 3244.8 | 5002.5 | 1295.0 | 1502.2 | 3897.5 | 16880.0 | 200.0 | 719.7 | 1136.0 | | | 185.0 |
| Dover sole | 208.8 | | | 417.5 | 527.6 | 977.5 | 177.6 | 1389.4 | 394.4 | 216.0 | 1019.1 | 632.5 |
| Slender sole | 57.2 | 18.9 | | 289.0 | 87.9 | 729.7 | 25.8 | 179.7 | 220.0 | 176.1 | 41.3 | 350.0 |
| Rock sole | 2543.6 | 3580.2 | 3390.4 | 826.6 | 1212.5 | 4358.1 | | 50.8 | | | | |
| Flathead sole | | | | | | | | | | | | |
| Rex sole | | | | 111.8 | 178.5 | 10.6 | | 118.4 | 281.0 | | | |
| Pacific sanddab | 162.7 | 764.0 | 168.7 | 1655.0 | 1203.1 | 1464.2 | | 90.8 | | | | |
| Pile perch | | 196.0 | 190.0 | | | 179.8 | | | | | | |
| Striped seaperch | | 74.9 | 165.5 | | | 1262.4 | | | | | | |
| Shiner perch | | 13.4 | 254.3 | | | 82.7 | | | 116.3 | | | |
| Roughback sculpin | 19.8 | 58.6 | 149.3 | 105.2 | 19.2 | 394.6 | 2.23 | | | 3.0 | | |
| Quillback rockfish | | 659.8 | | | | 1127.8 | | 596.5 | 116.7 | | | |
| Copper rockfish | | 246.3 | 455.0 | 160.8 | 13.4 | 103.9 | | | | | | |
| Rockfish juveniles | | | 48.6 | | | 34.1 | | | | | | |
| Blackbelly eelpout | | | | 5.6 | | | | 14.1 | | 37.1 | | 2.15 |
| Walleye pollock | | 2.2 | | | 0.9 | 158.2 | | 638.5 | 465.9 | | 18.2 | 472.2 |
| Pacific tomcod | | | | | 2.1 | 224.3 | | 34.9 | 105.6 | | | |
| Plainfin midshipman | | | | 49.6 | 111.8 | 171.8 | 27.6 | | 76.0 | | | 172.8 |
| Ratfish | 618.6 | 232.5 | 255.0 | 255.0 | | 185.0 | 3609.7 | 2074.2 | 1883.7 | 1412.9 | 2202.5 | 3845.4 |
| Avg. Total | 6962.4 | 10895.0 | 6900.5 | 5420.2 | 7263.8 | 28906.2 | 4043.0 | 6917.3 | 5908.1 | 1857.5 | 3284.1 | 5667.5 |

Table 8.16. Average catch per haul by weight (g) for common species in offshore catches by depth and season at Tramp Harbor.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 4226.7 | 1271.5 | 1685.0 | 6008.9 | 2210.8 | 18620.0 | | | 1161.3 | | 66.1 | 252.5 |
| Dover sole | | | | 737.2 | 1473.9 | 4420.0 | 538.1 | 483.8 | 1784.3 | | 546.8 | |
| Slender sole | | | | 92.6 | 625.7 | 1263.9 | 68.1 | 386.0 | 617.7 | 72.5 | 465.4 | 422.5 |
| Rock sole | 1653.1 | 1001.3 | 693.5 | | 45.6 | 1125.5 | | | | | | |
| Flathead sole | | | | 8.5 | | 57.5 | | | | | | |
| Rex sole | | | | 891.7 | 160.4 | 2113.0 | | 30.9 | 511.3 | | 65.9 | |
| Pacific sanddab | 14.4 | 124.4 | 8.6 | 596.1 | 53.3 | 114.0 | | | | | | |
| Pile perch | | | | | | 321.8 | | | | | | |
| Striped seaperch | | | | | | | | | | | | |
| Shiner perch | | | | | | 33.7 | | | 18.8 | | | |
| Roughback sculpin | 89.7 | 6.8 | 42.4 | | 5.0 | 54.3 | | | | | | |
| Quillback rockfish | | | | | | | | 940.7 | | | | |
| Copper rockfish | 1083.6 | 229.2 | | 5.1 | | | 132.5 | | 433.8 | | | |
| Rockfish juveniles | | | | | | 9.8 | | | 8.4 | | | |
| Blackbelly eelpout | | | | 147.3 | 51.8 | 1.5 | | 894.9 | 99.3 | | 14.0 | |
| Walleye pollock | | | | | 51.0 | 190.0 | | 81.7 | 216.9 | | 19.7 | 753.2 |
| Pacific tomcod | | 0.6 | | | 63.2 | 369.2 | | | 6.5 | | | |
| Plainfin midshipman | 69.8 | | | 52.3 | 183.9 | 37.1 | | | 664.0 | | 25.9 | |
| Ratfish | 233.8 | 425.1 | 210.0 | | | | 4461.4 | 3836.0 | 4388.3 | 2005.6 | 2609.7 | 4390.0 |
| Avg. Total | 7670.8 | 3062.2 | 2772.0 | 8553.5 | 4933.8 | 28928.3 | 5200.2 | 7171.8 | 10406.7 | 2078.2 | 4078.6 | 6025.0 |

Table 8.17. Average catch per haul by weight (g) for common species in offshore catches by depth and season at Aquarium.

| | 15 m | | | 50 m | | | 100 m | | | 200 m | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| English sole | 2511.6 | 1639.5 | 473.5 | 1753.2 | 4193.9 | 8873.3 | 63.9 | 2865.0 | 140.0 | | | |
| Dover sole | | | | 515.7 | 380.5 | 864.3 | | 711.1 | 2768.0 | 159.3 | | |
| Slender sole | | | | 322.2 | 118.1 | 503.4 | 316.6 | 1365.2 | 429.2 | 498.7 | 632.8 | 595.8 |
| Rock sole | 1390.0 | 2502.5 | 1497.5 | | 115.1 | 2491.7 | | 26.2 | 18.3 | | | |
| Flathead sole | | | | | | | | 35.6 | | 96.0 | 71.2 | 55.0 |
| Rex sole | 1.9 | | | 980.7 | 368.4 | 608.0 | | 498.1 | 170.0 | | | 7.3 |
| Pacific sanddab | | 181.8 | 31.4 | 1222.9 | 308.8 | 943.8 | | 367.9 | 105.0 | | | |
| Pile perch | | 21.5 | 13.5 | | | 412.4 | | | | | | |
| Striped seaperch | | | 12.9 | | | 20.0 | | | | | | |
| Shiner perch | | 235.0 | | | 21.4 | 51.0 | | 70.8 | | | | |
| Roughback sculpin | 20.1 | 6.9 | 30.9 | | | 32.5 | | | | | | |
| Quillback rockfish | | * | | 168.1 | 1507.5 | 1467.5 | | 300.4 | 525.0 | | | |
| Copper rockfish | 627.0 | 28.8 | 447.0 | | | | | | | | | |
| Rockfish juveniles | | | 38.7 | | | 3.5 | | | 12.5 | | | |
| Blackbelly eelpout | | | | 124.9 | | 8.7 | 259.6 | 533.6 | 282.7 | 33.9 | | 2.4 |
| Walleye pollock | | | | | 973.6 | 2430.5 | | 589.0 | 249.8 | | 376.7 | 289.8 |
| Pacific tomcod | | | | 0.43 | 97.3 | 216.7 | | 84.5 | 11.5 | | | |
| Plainfin midshipman | | 135.6 | | 127.1 | 171.3 | 388.5 | | 281.1 | 801.6 | | | |
| Ratfish | 3213.4 | 1345.3 | 2490.0 | 522.9 | 275.5 | 705.0 | 3912.2 | 4140.0 | 5792.5 | 1207.5 | 4280.0 | 1432.5 |
| Avg. Total | 7909.5 | 7466.9 | 7046.9 | 5785.8 | 8531.2 | 20562.9 | 4661.3 | 14030.6 | 11367.3 | 2000.6 | 5904.8 | 2385.2 |

*

### 8.4.7 Flatfish Ectoparasites

Overall incidence of flatfish ectoparasites (Philometra) collected in autumn offshore catches was 30-36%. Relative frequency of occurrence of these parasites was determined for rock sole, English sole, rex sole and Dover sole (Figure 8.8). Frequency of ectoparasite occurrence was greatest for rock sole (43-62%) and English sole (23-53%) (Table 8.18). The percent incidence was slightly higher at the Tramp Harbor and Aquarium stations than for Seahurst and Pt. Pully. Parasites were found on a few Tramp Harbor rex sole (4%) and Dover sole (3%). Slender sole, C-O sole, sand sole, flathead sole and Pacific sand dabs examined in fall were not parasite infested.

### 8.4.8 Midwater Fish Survey

Echogram analysis indicated that pelagic fish were not present in the study area. The only fish school target observed was during the day in shallow water at 3 m (10 ft) depth on transect four (Figure 8.9). The only nighttime target observed was a diffuse near surface (3-12 m) scattering layer (Figure 8.10) which probably was composed of macroplankton, based on the low voltage of the echos.

## 8.5 Discussion

### 8.5.1 Stream Fishes

Seahurst Park south stream habitat consists of a series of small pools and riffles with a clean gravel substrate. The majority of fishes were caught in the pools. The stream is a highly valued resource on the park (both aesthetically and for childrens' fishing) and should be protected.

### 8.5.2 Artificial Reef Fishes

The artificial reef located off Seahurst Park supports a good population

Table 8.18. Frequency of occurrence of ectoparasites in rock sole, English sole, rex sole, and Dover sole in autumn offshore catches.

| | Seahurst | | Pt. Pully | | Tramp Harbor | | Aquarium | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | % | n | % | n | % | n | % | n | % | n |
| Rock sole | 45 | 141 | 52 | 105 | 43 | 37 | 62 | 39 | 49 | 322 |
| English sole | 35 | 328 | 23 | 186 | 53 | 236 | 44 | 188 | 39 | 938 |
| Rex sole | 0 | 5 | 0 | 12 | 4 | 53 | 0 | 16 | 2 | 86 |
| Dover sole | 0 | 12 | 0 | 0 | 3 | 69 | 0 | 49 | 1 | 130 |

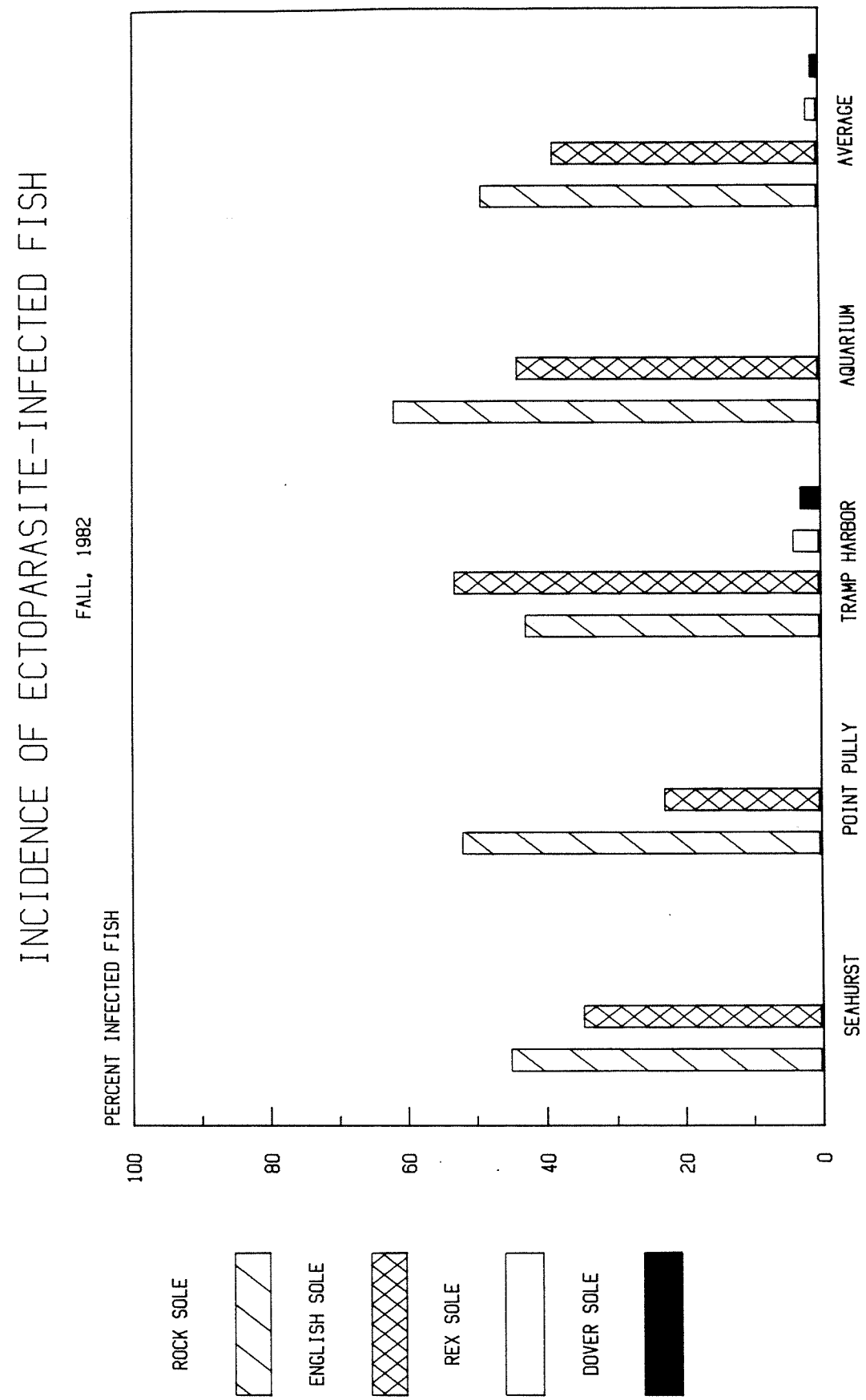



Figure 8.8. Incidence of ectoparasite infected fish collected at 4 locations in fall offshore catches.

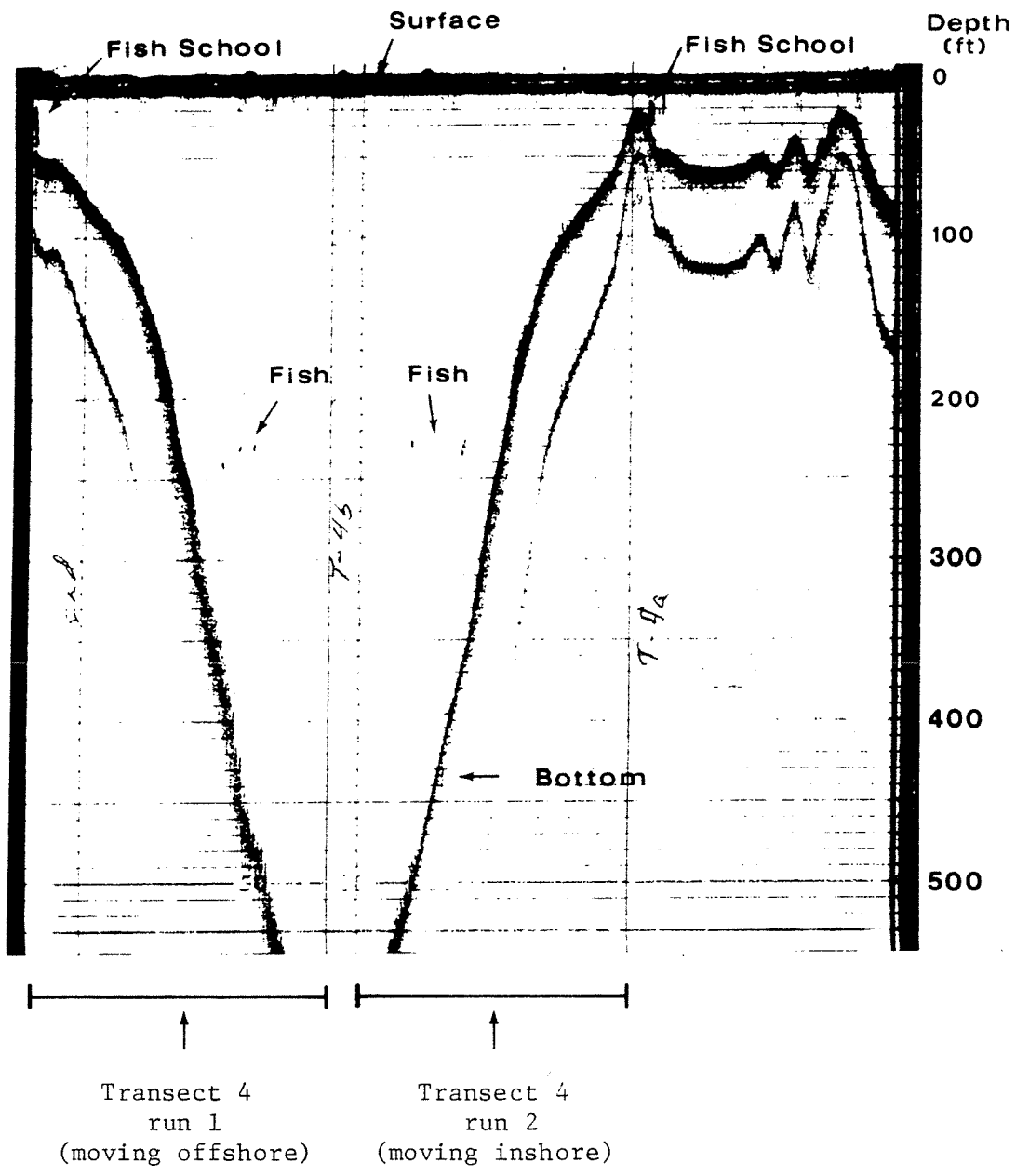



Figure 8.9. Echogram of acoustic transect and, runs 1 and 2, showing fish school in shallow water and single fish in deeper water.

of surfperch (striped seaperch and pile perch) and copper rockfish which makes the reef a good pre- and post- discharge monitoring site. The reef is easy to survey completely.

The rather pronounced increase of surfperch from spring-summer to autumn-winter was consistent with beach seining and trawling data. During the spring-summer period the adults congregate in the algae beds along the shoreline to release their young, and then in the autumn-winter move offshore when the algae abundance decreases.

8.5.3 Shoreline Fishes

The beach seine catch records demonstrate that all four shoreline study sites are habitats utilized by a diverse group of fish species and provide valuable baseline information for comparison with subsequent surveys.

Catch-per-haul by number tended to increase from spring to autumn (and decrease to a low level in winter) at all stations. This trend, however, was not reflected in the total weights of the catches, substantiating that larger fish (mainly English sole, rock sole, and adult striped seaperch) are inshore in greatest numbers in the spring, while smaller fish (juvenile perch and flatfish) are most abundant in the summer and autumn. The abundance of juvenile fishes of several species indicates the importance of the nearshore areas as nursery grounds.

While there were some general trends in CPH and the occurrence of the dominant species, there were considerable differences between sites as well as seasonal variations. Future surveys will determine whether these are consistent patterns.

8.5.4 Offshore Fishes

All four study sites showed basically similar bathymetric and seasonal patterns of species diversity and overall fish abundance. The general trend

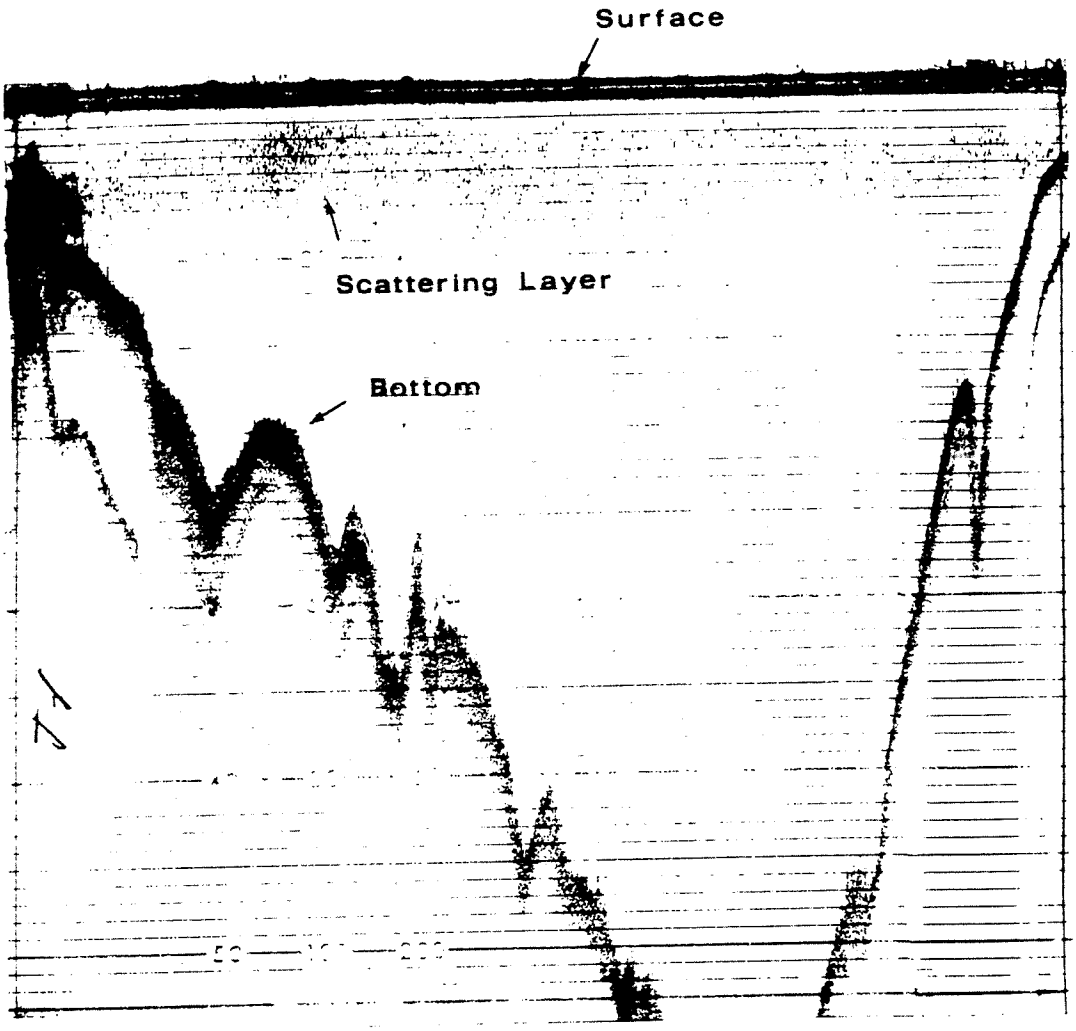



Figure 8.10. Near-surface scattering layer of macroplankton observed off Branch Point (transect 1) at night on 29 Oct. 1982.

of increasing average catch per haul from spring to autumn in all except the shallow (15 m) stations suggests a possible movement into deeper water or increased availability of demersal fishes in late summer and autumn.

The marked increase in CPH at 50 m in the autumn, primarily due to a large increase in numbers of English and rock sole, is similar to the findings of Miller et al. (1977) in Puget Sound.

The relatively low species diversity and abundance at the 200 m station suggests that an outfall at this depth would have the least potential for detrimental effect on fish populations.

8.5.5 Parasites

Incidence of Philometra-infested rock and English sole from Aquarium and Tramp Harbor was slightly higher than from Seahurst and Pt. Pully but did not vary from north to south sites as previously reported (Miller et al. 1977). Parasite occurrence in November 1982 (when data was considered most accurate) in rock sole and English sole catches was similar to November 1975 infestation levels (Miller et al. 1977).

8.5.6 Preliminary Recommendation for Outfall Location

Based on the surveys of fishes conducted in this study, a preliminary recommendation for location of the outfall at a depth of 200 m is made.

The south stream in Seahurst Park should be preserved in its present state.

# 9.0 FISH HEALTH

M. L. Landolt, D. Powell, R. M. Kocan

## 9.1 Introduction, Purpose and Objectives

The purpose of this study is to assemble predischarge information on pathological conditions existing in demersal and pelagic fishes inhabiting the area surrounding the proposed Renton sewage outfall at Seahurst. Assessment of predischarge conditions will provide the opportunity to determine whether any resulting post discharge alterations may be attributable to changes in environmental quality resulting in the receiving waters.

The objectives of this study are (1) to determine, by gross and microscopic examination, the incidence of pathological conditions existent in demersal fish species and (2) to determine by gross and microscopic examination, the incidence of pathological conditions existent in pelagic fish species of Puget Sound.

## 9.2 Description of Study Area and Stations

### 9.2.1 Seahurst Park

#### 9.2.1.1 Demersal Fish Studies

Demersal fish were collected from two stations (100 m, 200 m) off Seahurst Park on June 1, June 17, September 25, November 23, 1982 and February 15, 1983. In addition, a third station (50 m) was sampled on June 17, 1982.

#### 9.2.1.2 Pelagic Fish Studies

Pelagic fish were collected by beach seine at Seahurst Park on August 18,

November 4, 1982 and on January 28, 1983. Because of a communication error pelagic fish were not collected as planned in June, 1982.

9.2.2 Point Pulley

9.2.2.1 Demersal Fish Studies

Demersal fish were collected from two stations (100 m, 200 m) off Point Pulley (Three Tree Point) on June 1, June 17, November 23, 1982 and February 15, 1983.

9.2.2.2 Pelagic Fish Studies

Pelagic fish were collected by beach seine near Point Pulley on August 17, November 3, 1982 and on January 29, 1983. Because of a communication error pelagic fish were not collected as planned in June, 1982.

## 9.3 Materials and Methods

9.3.1 Fish Collection

9.3.1.1 Demersal Fish Studies

Demersal fish were collected by otter trawl (24 ft) aboard the research vessel Kittiwake (38 ft L.O.A.). Trawling times were 20 minutes at the 100 m station and 40 minutes at the 200 m station. The fish were brought on board the vessel, the four target species were sorted into separate containers and the remaining fish were discarded following examination by personnel from the Fisheries task group.

9.3.1.2 Pelagic Fish Studies

Pelagic fish were collected by sinking (set 30 m from the shore) and floating (set 60 m from the shore) beach seines (37 m; bag mesh 18 mm, wing mesh 29 mm). The target species were sorted into containers and the remaining fish were examined by personnel from the Fisheries task group.

### 9.3.2 Fish Species

#### 9.3.2.1 Demersal Fish Studies

Based on June, 1982, catch statistics, four species of fish were identified as target organisms for this study. These were English sole (Parophrys vetulus), Dover sole (Microstomus pacificus), Slender sole (Lyopsetta exilis) and Quillback rockfish (Sebastes maliger). These species were selected because they are benthic organisms which live in contact with the bottom substrate, because they are resident in the Seahurst area, and because they can be collected in reasonable numbers year round. In addition, all of these species have been used by other investigators to assess possible environmentally mediated illnesses (Mearns and Sherwood 1974; Sherwood and Mearns 1977; Miller et al., 1977; Malins et al., 1982). After trawl contents were brought onboard, the target species were sorted into separate containers, assigned an accession number, weighed (total weight in grams), measured (total length in mm), bled and sacrificed by a blow to the head.

#### 9.3.2.2 Pelagic Fish Studies

Based on August, 1982, catch statistics two species of fish were identified as target species for this portion of the study. These were striped sea perch (Embiotoca lateralis) and shiner perch (Cymatogaster aggregata). Unlike the demersal target species which were selected in part because comparable data were available from other studies of environmentally mediated disease, these two species have not been commonly used by investigators. Previous studies have focused little attention on nearshore pelagic fish and these species were selected for use in the current study primarily on the basis of their abundance and reliable presence in the Seahurst area throughout the year. In addition, true cod (Gadus macrocephalus), tomcod (Microgadus proximus), walleye pollock (Theragra

chalcogramma), steelhead trout (Salmo gairdneri), and chum salmon (Oncorhynchus keta) were collected when present. The target organisms were assigned an accession number, weighed (total weight in grams), measured (total length in mm) and sacrificed by a blow to the head.

9.3.3 Tissue Collection and Processing

At necropsy demersal and pelagic fish were examined for the presence of external lesions. Upon primary incision the general condition of the internal organs was noted and any unusual structures or lesions were collected.

Five target organs (liver, kidney, spleen, gonad, gills) were routinely excised and placed in 10% neutral buffered formalin. These organs were selected for several reasons. The liver is a major organ which is involved with a wide variety of physiological activities. In fish this organ has been shown to be extremely sensitive to the effects of contaminants (Sinnhuber et al., 1977). The kidney and spleen are important blood filtering organs which are involved, at different times, in hematopoiesis. The kidney, because of its excretory function, is a frequent site of absorption, excretion and retention of contaminants, and its epithelia and glomeruli are very sensitive to injury. The gill is a large, delicate organ whose tremendous surface area is continually exposed to the marine environment. It is essentially unprotected and subject to environmental damage. Finally, the gonad is a lipid rich organ which can act as a sump for lipid soluble contaminants. Examination of this organ permits evaluation of reproductive status and may, in addition, show injury from the presence of certain toxic compounds. After allowing sufficient time for fixation the tissues of randomly selected fish were trimmed, cleared, embedded in paraffin, sectioned (4 μm) and stained (hematoxylin and eosin). Blood smears were fixed in methanol, air dried and stained with Leishman-Giemsa.

### 9.3.4 Histopathological Evaluation

Prepared slides were examined histologically either by Dr. Landolt or Mr. Powell. Using a numerical coding system, tissues were identified by organ and suborgan and were examined for the presence of lesions. Lesions were described verbally and then scored in terms of their severity and degree of host response (low of 1, high of 5) and in terms of their pattern of distribution (focal-6, multifocal-7, diffuse-8).

### 9.3.5 Experimental Design and Statistical Power

To see what kind of statistical power is available from the sample sizes we are using, tables for selected values of n (the sample size) are presented (Tables 9.1, 9.2, 9.3). These tables show, given a present proportion of lesions for a given sample size, what the future proportion would have to be in order to be (1-B) x 100 percent sure of detecting such a change where (1-B) x 100 is known as the statistical power of the test, the ability to detect a change when in fact one has occurred. The three sample sizes chosen for illustration are n=25, 17, and 10. It is assumed that the same sample sizes are used each time. For different sample sizes, the power would need to be recalculated. A discussion on statistical power is presented in Conquest (1983) and Snedecor and Cochran (1980), which give the specific equations concerning two proportions.

## 9.4 Results

### 9.4.1 Numbers of Fish Collected

#### 9.4.1.1 Demersal Fish Studies

A total of 262 fish were collected in June, 176 in September, 152 in November and 125 in February. Of these, the following numbers were examined histologically: 121 from the June collections, 108 from the September

Table 9.1. Statistical power of test for n = 25.

| If the current (true) proportion is: | Then below is what the future true proportion must be in order to get a significant ($\alpha$ = .05) result with varying levels of power: | | | |
|---|---|---|---|---|
| | Power | | | |
| | .50 | .75 | .90 | .95 |
| $^{1}/_{25}$ | $^{6}/_{25}$ | $^{8}/_{25}$ | $^{9}/_{25}$ | $^{11}/_{25}$ |
| $^{2}/_{25}$ | $^{7}/_{25}$ | $^{9}/_{25}$ | $^{11}/_{25}$ | $^{12}/_{25}$ |
| $^{3}/_{25}$ | $^{9}/_{25}$ | $^{11}/_{25}$ | $^{13}/_{25}$ | $^{14}/_{25}$ |
| $^{4}/_{25}$ | $^{10}/_{25}$ | $^{12}/_{25}$ | $^{14}/_{25}$ | $^{15}/_{25}$ |
| $^{5}/_{25}$ | $^{11}/_{25}$ | $^{13}/_{25}$ | $^{15}/_{25}$ | $^{16}/_{25}$ |
| $^{6}/_{25}$ | $^{13}/_{25}$ | $^{15}/_{25}$ | $^{17}/_{25}$ | $^{18}/_{25}$ |
| $^{7}/_{25}$ | $^{14}/_{25}$ | $^{16}/_{25}$ | $^{18}/_{25}$ | $^{19}/_{25}$ |
| $^{8}/_{25}$ | $^{15}/_{25}$ | $^{17}/_{25}$ | $^{19}/_{25}$ | $^{20}/_{25}$ |
| $^{9}/_{25}$ | $^{16}/_{25}$ | $^{18}/_{25}$ | $^{19}/_{25}$ | $^{20}/_{25}$ |
| $^{10}/_{25}$ | $^{17}/_{25}$ | $^{19}/_{25}$ | $^{20}/_{25}$ | $^{21}/_{25}$ |
| $^{11}/_{25}$ | $^{18}/_{25}$ | $^{20}/_{25}$ | $^{21}/_{25}$ | $^{22}/_{25}$ |
| $^{12}/_{25}$ | $^{19}/_{25}$ | $^{20}/_{25}$ | $^{22}/_{25}$ | $^{23}/_{25}$ |
| $^{13}/_{25}$ | $^{19}/_{25}$ | $^{21}/_{25}$ | $^{23}/_{25}$ | $^{24}/_{25}$ |

Table 9.2. Statistical power of test for n = 17.

| If the current (true) proportion is: | Then below is what the future true proportion must be in order to act a significant ($\alpha$ = .05) result with varying levels of power: | | | |
|---|---|---|---|---|
| | .50 | .75 | .90 | .95 |
| $^{1}/_{17}$ | $^{5}/_{17}$ | $^{7}/_{17}$ | $^{8}/_{17}$ | $^{9}/_{17}$ |
| $^{2}/_{17}$ | $^{7}/_{17}$ | $^{9}/_{17}$ | $^{10}/_{17}$ | $^{11}/_{17}$ |
| $^{3}/_{17}$ | $^{8}/_{17}$ | $^{10}/_{17}$ | $^{11}/_{17}$ | $^{12}/_{17}$ |
| $^{4}/_{17}$ | $^{9}/_{17}$ | $^{11}/_{17}$ | $^{12}/_{17}$ | $^{13}/_{17}$ |
| $^{5}/_{17}$ | $^{11}/_{17}$ | $^{12}/_{17}$ | $^{13}/_{17}$ | $^{14}/_{17}$ |
| $^{6}/_{17}$ | $^{12}/_{17}$ | $^{13}/_{17}$ | $^{14}/_{17}$ | $^{15}/_{17}$ |
| $^{7}/_{17}$ | $^{13}/_{17}$ | $^{14}/_{17}$ | $^{15}/_{17}$ | $^{16}/_{17}$ |
| $^{8}/_{17}$ | $^{13}/_{17}$ | $^{15}/_{17}$ | $^{16}/_{17}$ | $^{17}/_{17}$ |
| $^{9}/_{17}$ | $^{14}/_{17}$ | $^{15}/_{17}$ | $^{16}/_{17}$ | $^{17}/_{17}$ |

Table 9.3. Statistical power of test for n = 10.

| If the current (true) proportion of lesions (or whatever) is: | Then below is what the future proportion must be in order to get a significant ($\alpha$ = .05) result with varying levels of power: | | | |
|---|---|---|---|---|
| | .50 | .75 | .90 | .95 |
| 1/10 | 5/10 | 6/10 | | 7/10 |
| 2/10 | 6/10 | 7/10 | 8/10 | 9/10 |
| 3/10 | 7/10 | 8/10 | 9/10 | 10/10 |
| 4/10 | 8/10 | 9/10 | | 10/10 |
| 5/10 | 9/10 | | 10/10 | |
| 6/10 | 9/10 | 10/10 | | |
| 7/10 | 10/10 | | | |

(Note: the "holes" in the table appear due to the large discrete jumps in the proportion values.)

collections and 86 from the November collections. Fish collected in February, 1983, are currently being processed.

9.4.1.2 Pelagic Fish Studies

As mentioned above, no pelagic fish were collected in June, 1982. A total of 65 fish were collected in August, 69 in November and 50 in January. Of these, the following numbers were examined histologically: 0 in June, 35 in August, 30 in November. The fish collected in January, 1983, are currently being processed.

9.4.2 Length/Weight Data

9.4.2.1 Demersal Fish Studies

The length/weight data obtained to date are shown in Tables 9.4 and 9.5.

9.4.2.2 Pelagic Fish Studies

The length/weight data obtained to date are shown in Tables 9.6 and 9.7.

9.4.3 Lesion Frequency

9.4.3.1 Demersal Fish Studies

A summary of general lesion types found in demersal fish is presented in Table 9.8. A detailed listing of individual findings will be compiled after the tissues collected in February, 1983, are examined histologically.

9.4.3.2 Pelagic Fish Studies

A summary of general lesion types found in pelagic fish is presented in Table 9.9. A detailed listing of individual findings will be compiled after the tissues collected in January, 1983 are examined histologically.

## 9.5 Discussion

Examination of the demersal and pelagic fish collected to date at Seahurst Park and at Point Pulley indicates that the areas are home to

Table 9.4. Total length (mm) of demersal fishes collected from June 1982 through February 1983.

| Date | Site | | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|
| Jun 1982 | Seahurst | Range[a/] | 217-412 | 90-650 | 110-237 | 170-362 |
| | | Average[b/] | 266 | 242 | 179 | 271 |
| | | No. fish[c/] | 52 | 66 | 47 | 8 |
| | Pt. Pulley | Range | 251-353 | 105-420 | 152-225 | 195-370 |
| | | Average | 284 | 284 | 197 | 330 |
| | | No. fish | 24 | 25 | 27 | 11 |
| Sep 1982 | Seahurst | Range | 230-360 | 221-400 | 133-243 | 220-341 |
| | | Average | 284 | 297 | 206 | 288 |
| | | No. fish | 23 | 25 | 34 | 7 |
| | Pt. Pulley | Range | 230-379 | 120-390 | 128-242 | 181-405 |
| | | Average | 280 | 289 | 199 | 303 |
| | | No. fish | 24 | 24 | 32 | 5 |
| Nov 1982 | Seahurst | Range | 125-373 | 205-396 | 135-248 | 210 |
| | | Average | 260 | 299 | 194 | -- |
| | | No. fish | 28 | 29 | 40 | 1 |
| | Pt. Pulley | Range | 224-325 | 138-298 | 149-236 | 212-332 |
| | | Average | 261 | 231 | 193 | 272 |
| | | No. fish | 16 | 11 | 23 | 2 |
| Feb 1983 | Seahurst | Range | 203-365 | 145-440 | 140-286 | 110-370 |
| | | Average | 270 | 318 | 214 | 264 |
| | | No. fish | 21 | 6 | 29 | 5 |
| | Pt. Pulley | Range | 238-330 | 162-487 | 132-249 | 334 |
| | | Average | 280 | 313 | 193 | -- |
| | | No. fish | 12 | 18 | 31 | 1 |

[a/] Range of total lenths (mm)

[b/] Average total length (mm)

[c/] Number of fish

Table 9.5. Body weight (g) of demersal fishes collected from June 1982 through February 1983.

| Date | Site | | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|
| Jun 1982 | Seahurst | Range[a/] | 85-650 | 3-1,700 | 5-80 | 60-900 |
| | | Average[b/] | 170 | 198 | 39 | 420 |
| | | No. fish[c/] | 52 | 66 | 47 | 8 |
| | Pt. Pulley | Range | 120-370 | 10-750 | 15-70 | 10-1,000 |
| | | Average | 180 | 223 | 45 | 658 |
| | | No. fish | 24 | 25 | 27 | 11 |
| Sep 1982 | Seahurst | Range | 130-450 | 110-730 | ND | 230-800 |
| | | Average | 229 | 282 | -- | 531 |
| | | No. fish | 23 | 25 | 34 | 7 |
| | Pt. Pulley | Range | 100-450 | 25-550 | ND | 100-1,100 |
| | | Average | 178 | 245 | -- | 589 |
| | | No. fish | 24 | 24 | 32 | 5 |
| Nov 1982 | Seahurst | Range | 100-550 | 143-830 | 20-125 | 190 |
| | | Average | 196 | 294 | 62 | -- |
| | | No. fish | 28 | 29 | 40 | 1 |
| | Pt. Pulley | Range | 105-270 | 15-240 | 25-110 | 160-850 |
| | | Average | 147 | 124 | 60 | 505 |
| | | No. fish | 16 | 11 | 23 | 2 |
| Feb 1983 | Seahurst | Range | 100-380 | 30-800 | 15-195 | 25-1,050 |
| | | Average | 190 | 391 | 74 | 491 |
| | | No. fish | 21 | 6 | 29 | 5 |
| | Pt. Pulley | Range | 110-350 | 50-1,270 | 15-125 | 675 |
| | | Average | 199 | 354 | 52 | -- |
| | | No. fish | 12 | 18 | 31 | 1 |

[a/] Range of total weights (g)

[b/] Average total weight (g)

[c/] Number of fish

Table 9.6. Total length (mm) of pelagic fishes collected from June 1982 through January 1983.

| Date | Site | | Striped sea perch | Shiner perch | Cod | Pollock | Tomcod | Steelhead | Chum |
|---|---|---|---|---|---|---|---|---|---|
| Jun 1982 | Seahurst | No fish collected | | -- | -- | -- | -- | -- | -- |
| | Pt. Pulley | No fish collected | | -- | -- | -- | -- | -- | -- |
| Aug 1982 | Seahurst | Range[a] | 87-92 | 60-136 | 90-139 | -- | -- | -- | 103-114 |
| | | Average[b] | 89 | 106 | 111 | -- | -- | -- | 110 |
| | | No. fish[c] | 10 | 10 | 10 | 0 | 0 | 0 | 4 |
| | Pt. Pulley | Range | 76-94 | 56-146 | -- | -- | -- | -- | 109-250 |
| | | Average | 92 | 106 | -- | -- | -- | -- | 129 |
| | | No. fish | 11 | 10 | 0 | 0 | 0 | 0 | 10 |
| Nov 1982 | Seahurst | Range | 237-302 | 127-155 | -- | -- | 225-266 | -- | -- |
| | | Average | 270 | 145 | -- | -- | 250 | -- | -- |
| | | No. fish | 10 | 10 | 0 | 0 | 4 | 0 | 0 |
| | Pt. Pulley | Range | 87-299 | 72-147 | -- | 88-105 | 255 | 259-352 | -- |
| | | Average | 156 | 96 | -- | 95 | -- | 305 | -- |
| | | No. fish | 10 | 21 | 0 | 10 | 1 | 2 | 0 |
| Jan 1983 | Seahurst | Range | 260-358 | 87-170 | -- | -- | 137-183 | -- | -- |
| | | Average | 310 | 13 | -- | -- | 151 | -- | -- |
| | | No. fish | 6 | 10 | 0 | 0 | 10 | 0 | 0 |
| | Pt. Pulley | Range | 108-270 | 80-112 | -- | 115-120 | 122 | -- | -- |
| | | Average | 134 | 96 | -- | 118 | -- | -- | -- |
| | | No. fish | 8 | 5 | 0 | 3 | 1 | 0 | 0 |

[a] Range of total lengths (mm)

[b] Average total length (mm)

[c] Number of fish

Table 9.7. Body weight (g) of pelagic fishes collected from June 1982 through January 1983.

| Date | Site | Weight (g) | Striped sea perch | Shiner perch | Cod | Pollock | Tomcod | Steelhead | Chum |
|---|---|---|---|---|---|---|---|---|---|
| Jun 1982 | Seahurst | No fish collected | | -- | -- | -- | -- | -- | -- |
| | Pt. Pulley | No fish collected | | -- | -- | -- | -- | -- | -- |
| Aug 1982 | Seahurst | Range[a/] | 10-12 | 4-23 | 7-18 | -- | -- | -- | 11-12 |
| | | Average[b/] | 11 | 16 | 11 | -- | -- | -- | 11 |
| | | No. fish[c/] | 10 | 10 | 10 | 0 | 0 | 0 | 4 |
| | Pt. Pulley | Range | 7-33 | 5-29 | -- | -- | -- | -- | 9-25 |
| | | Average | 12 | 18 | -- | -- | -- | -- | 12 |
| | | No. fish | 11 | 10 | 0 | 0 | 0 | 0 | 10 |
| Nov 1982 | Seahurst | Range | 217-469 | 22-48 | -- | -- | 101-193 | -- | -- |
| | | Average | 333 | 37 | -- | -- | 151 | -- | -- |
| | | No. fish | 10 | 10 | 0 | 0 | 4 | 0 | 0 |
| | Pt. Pulley | Range | 7-420 | 3-32 | -- | 5-10 | 148 | 148-490 | -- |
| | | Average | 116 | 12 | -- | 8 | -- | 319 | -- |
| | | No. fish | 10 | 21 | 0 | 10 | 1 | 2 | 0 |
| Jan 1983 | Seahurst | Range | 162-700 | 9-65 | -- | -- | 19-50 | -- | -- |
| | | Average | 454 | 29 | -- | -- | 28 | -- | -- |
| | | No. fish | 6 | 10 | 0 | 0 | 10 | 0 | 0 |
| | Pt. Pulley | Range | 15-292 | 4-15 | -- | 12-14 | 13 | -- | -- |
| | | Average | 53 | 12 | -- | 13 | -- | -- | -- |
| | | No. fish | 8 | 5 | 0 | 3 | 1 | 0 | 0 |

[a/] Range of total weights (g)

[b/] Average total weight (g)

[c/] Number of fish

Table 9.8. Significant lesions noted in demersal fishes collected from June 1982 through November 1982.

| Date | Station | Organ | Pathological condition | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|---|
| Jun 1982 | Seahurst | Liver | Lipid deposits in hepatocytes | | | | |
| | | | Mild | 0/17 | 2/25 | 4/23 | 1/8[a] |
| | | | Moderate | 3/17 | 5/25 | 8/23 | 2/8 |
| | | | Severe | 1/17 | 3/25 | 7/23 | 0/8 |
| | | | Lymphocyte aggregates | 4/17 | 9/25 | 7/23 | 3/8 |
| | | | Enlarged hepatocytes | 2/17 | 1/25 | 1/23 | 0/8 |
| | | | Necrosis | 0/17 | 1/25 | 0/23 | 0/8 |
| | | Gills | Aneurysms | 5/17 | 6/25 | 5/23 | 0/8 |
| | | | Epithelial hyperplasia | 4/17 | 2/25 | 1/23 | 1/8 |
| | | | Focal inflammation | 0/17 | 1/25 | 2/23 | 6/8 |
| | | General | External protozoan parasites | 2/17 | 0/25 | 4/23 | 2/8 |
| | | | Internal protozoan parasites | 3/17 | 5/25 | 1/23 | 0/8 |
| | | | External metazoan parasites | 3/17 | 0/25 | 1/23 | 0/8 |
| | | | Internal metazoan parasites | 17/17 | 0/25 | 10/23 | 0/8 |
| | | | Fin erosion | 0/17 | 7/25 | 1/23 | 0/8 |
| | | | Neoplasia | 0/17 | 1/25 | 0/23 | 0/8 |
| | | | Hemorrhage | 1/17 | 1/25 | 0/23 | 0/8 |
| | | | Increased number of melanin macrophage centers | 2/17 | 1/25 | 0/23 | 1/8 |
| | Pt. Pulley | Liver | Lipid deposits in hepatocytes | | | | |
| | | | Mild | 1/9 | 3/17 | 4/14 | 2/8 |
| | | | Moderate | 1/9 | 7/17 | 7/14 | 4/8 |
| | | | Severe | 0/9 | 2/17 | 1/14 | 2/8 |
| | | | Lymphocyte aggregates | 0/9 | 4/17 | 4/14 | 1/8 |
| | | | Enlarged hepatocytes | 0/9 | 2/17 | 0/14 | 0/8 |
| | | | Necrosis | 0/9 | 1/17 | 0/14 | 0/8 |
| | | Gills | Aneurysms | 3/9 | 2/17 | 2/14 | 1/8 |
| | | | Epithelial hyperplasia | 2/9 | 3/17 | 0/14 | 1/8 |
| | | | Focal inflammation | 0/9 | 4/17 | 2/14 | 5/8 |

Table 9.8 (continued).

| Date | Station | Organ | Pathological condition | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|---|
| | | General | External protozoan parasites | 0/9 | 0/17 | 0/17 | 0/8 |
| | | | Internal protozoan parasites | 5/9 | 2/17 | 2/14 | 0/8 |
| | | | External metazoan parasites | 0/9 | 0/17 | 0/14 | 0/8 |
| | | | Internal metazoan parasites | 6/9 | 0/17 | 6/14 | 0/8 |
| | | | Fin erosion | 1/9 | 0/17 | 6/14 | 0/8 |
| | | | Neoplasia | 0/9 | 0/17 | 0/14 | 0/8 |
| | | | Hemorrhage | 0/9 | 3/17 | 0/14 | 0/8 |
| | | | Increased number of melanin macrophage centers | 0/9 | 0/17 | 0/14 | 4/8 |
| Sep 1982 | Seahurst | Liver | Lipid deposits in hepatocytes | | | | |
| | | | Mild | 15/16 | 2/16 | 0/16 | 0/7 |
| | | | Moderate | 0/16 | 12/16 | 1/16 | 2/7 |
| | | | Severe | 1/16 | 2/16 | 15/16 | 5/7 |
| | | | Lymphocyte aggregates | 0/16 | 2/16 | 1/16 | 4/7 |
| | | | Enlarged hepatocytes | 0/16 | 0/16 | 0/16 | 0/7 |
| | | | Necrosis | 0/16 | 1/16 | 0/16 | 0/7 |
| | | Gills | Aneurysms | 1/16 | 2/16 | 6/16 | 0/7 |
| | | | Epithelial hyperplasia | 3/16 | 3/16 | 0/16 | 0/7 |
| | | | Focal inflammation | 6/16 | 5/16 | 1/16 | 3/7 |
| | | General | External protozoan parasites | 0/16 | 0/16 | 0/16 | 0/7 |
| | | | Internal protozoan parasites | 7/16 | 4/16 | 6/16 | 0/7 |
| | | | External metazoan parasites | 1/16 | 0/16 | 2/16 | 0/7 |
| | | | Internal metazoan parasites | 1/16 | 0/16 | 5/16 | 0/7 |
| | | | Fin erosion | 0/16 | 0/16 | 0/16 | 0/7 |
| | | | Neoplasia | 1/16 | 1/16 | 0/16 | 0/7 |
| | | | Hemorrhage | 0/16 | 1/16 | 0/16 | 0/7 |
| | | | Increased number of melanin macrophage centers | 2/16 | 0/16 | 0/16 | 0/7 |
| | | | Renal calculi | 0/16 | 0/25 | 4/16 | 0/7 |
| | | | Hemorrhagic splenitis | 0/16 | 0/25 | 0/16 | 0/7 |
| | | | Epitheliocystis | 1/16 | 0/25 | 0/16 | 0/7 |

Table 9.8 (continued).

| Date | Station | Organ | Pathological condition | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|---|
| | Pt. Pulley | Liver | Lipid deposits in hepatocytes | | | | |
| | | | Mild | 10/16 | 0/16 | 1/16 | 1/5 |
| | | | Moderate | 3/16 | 8/16 | 11/16 | 3/5 |
| | | | Severe | 1/16 | 6/16 | 4/16 | 1/5 |
| | | | Lymphocyte aggregates | 1/16 | 4/16 | 2/16 | 1/5 |
| | | | Enlarged hepatocytes | 0/16 | 0/16 | 0/16 | 0/5 |
| | | | Necrosis | 3/16 | 0/16 | 0/16 | 0/5 |
| | | Gills | Aneurysms | 5/16 | 0/16 | 5/16 | 0/5 |
| | | | Epithelial hyperplasia | 2/16 | 2/16 | 0/16 | 0/5 |
| | | | Focal inflammation | 7/16 | 6/16 | 5/16 | 2/5 |
| | | General | External protozoan parasites | 1/16 | 0/16 | 1/16 | 0/5 |
| | | | Internal protozoan parasites | 2/16 | 3/16 | 8/16 | 0/5 |
| | | | External metazoan parasites | 2/16 | 0/16 | 0/16 | 0/5 |
| | | | Internal metazoan parasites | 3/16 | 0/16 | 7/16 | 0/5 |
| | | | Fin erosion | 0/16 | 0/16 | 0/16 | 0/5 |
| | | | Neoplasia | 0/16 | 0/16 | 0/16 | 0/5 |
| | | | Hemorrhage | 0/16 | 0/16 | 0/16 | 0/6 |
| | | | Increased number of melanin macrophage centers | 4/16 | 0/16 | 0/16 | 0/5 |
| | | | Renal calculi | 0/16 | 0/16 | 2/16 | 0/5 |
| | | | Hemorrhagic splenitis | 1/16 | 0/16 | 0/16 | 1/5 |
| | | | Epitheliocystis | 1/16 | 0/16 | 0/16 | 0/5 |
| Nov 1982 | Seahurst | Liver | Lipid deposits in hepatocytes | | | | |
| | | | Mild | 4/11 | 2/11 | 0/20 | 0/1 |
| | | | Moderate | 7/11 | 3/11 | 4/20 | 0/1 |
| | | | Severe | 0/11 | 6/11 | 16/20 | 1/1 |
| | | | Lymphocyte aggregates | 2/11 | 3/11 | 0/20 | 1/1 |
| | | | Enlarged hepatocytes | 0/11 | 0/11 | 0/20 | 0/1 |
| | | | Necrosis | 0/11 | 0/11 | 0/20 | 0/1 |

Table 9.8 (continued).

| Date | Station | Organ | Pathological condition | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|---|
| | | Gills | Aneurysm | 1/11 | 2/11 | 6/20 | 0/1 |
| | | | Epithelial hyperplasia | 2/11 | 1/11 | 0/20 | 0/1 |
| | | | Focal inflammation | 5/11 | 6/11 | 5/20 | 1/1 |
| | | General | External protozoan parasites | 1/11 | 0/11 | 0/20 | 0/1 |
| | | | Internal protozoan parasites | 2/11 | 3/11 | 7/20 | 0/1 |
| | | | External metazoan parasites | | | | |
| | | | Internal metazoan parasites | 3/11 | 0/11 | 11/20 | 0/1 |
| | | | Fin erosion | 0/11 | 0/11 | 0/20 | 0/1 |
| | | | Neoplasia | 0/11 | 0/11 | 0/20 | 0/1 |
| | | | Hemorrhage | 0/11 | 0/11 | 0/20 | 0/1 |
| | | | Increased number of melanin macrophage centers | 0/11 | 0/11 | 0/20 | 0/1 |
| | | | Renal calculi | 0/11 | 0/11 | 5/20 | 0/1 |
| | | | Hemorrhagic splenitis | 0/11 | 0/11 | 0/11 | 0/1 |
| | | | Epitheliocystis | 0/11 | 0/11 | 0/11 | 1/1 |
| | Pt. Pulley | Liver | Lipid deposits in hepatocytes | | | | |
| | | | Mild | 11/12 | 3/14 | 5/15 | 0/2 |
| | | | Moderate | 1/12 | 8/14 | 7/15 | 1/2 |
| | | | Severe | 0/12 | 3/14 | 3/15 | 1/2 |
| | | | Lymphocytes aggregates | 1/12 | 2/14 | 1/15 | 1/2 |
| | | | Enlarged hepatocytes | 0/12 | 0/14 | 1/15 | 0/2 |
| | | | Necrosis | 0/12 | 0/14 | 0/15 | 1/2 |
| | | Gills | Aneurysm | 1/12 | 1/14 | 2/15 | 0/2 |
| | | | Epithelial hyperplasia | 2/12 | 5/14 | 0/15 | 1/2 |
| | | | Focal inflammation | 3/12 | 2/14 | 1/15 | 0/2 |

Table 9.8 (continued).

| Date | Station | Organ | Pathological condition | English sole | Dover sole | Slender sole | Quillback rockfish |
|---|---|---|---|---|---|---|---|
| | | General | External protozoan parasites | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Internal protozoan parasites | 3/12 | 5/14 | 4/15 | 0/2 |
| | | | External metazoan parasites | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Internal metazoan parasites | 1/12 | 2/14 | 7/15 | 0/2 |
| | | | Fin erosion | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Neoplasia | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Hemorrhage | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Increased number of melanin macrophage centers | 2/12 | 0/14 | 0/15 | 0/2 |
| | | | Renal calculi | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Hemorrhagic splenitis | 0/12 | 0/14 | 0/15 | 0/2 |
| | | | Epitheliocystis | 0/12 | 0/14 | 0/15 | 0/2 |

[a]Numbers indicate incidence (no. of fish affected/no. of fish examined).

Table 9.9. Significant lesions noted in pelagic fishes collected from June 1982 through November 1982.

| Date | Site | Organ | Pathological condition | Striped sea perch | Shiner perch | Cod | Tomcod | Pollock | Steelhead trout | Chum |
|---|---|---|---|---|---|---|---|---|---|---|
| June 1982 | | | No fish collected. | | | | | | | |
| Aug 1982 | Seahurst | Liver | Lipid in hepatocytes | | | | N/A | N/A | N/A | |
| | | | Mild | 2/5[a] | 2/5 | 3/5 | | | | 1/4 |
| | | | Moderate | 3/5 | 1/5 | 1/5 | | | | 1/4 |
| | | | Severe | 0/5 | 1/5 | 1/5 | | | | 0/4 |
| | | | Lymphocyte aggregates | 2/5 | 0/5 | 0/5 | | | | 0/4 |
| | | Gills | Aneurysms | 0/5 | 0/5 | 0/5 | | | | 0/4 |
| | | General | External protozoan parasites | 0/5 | 3/5 | 0/5 | | | | 0/4 |
| | | | Internal protozoan parasites | 0/5 | 0/5 | 0/5 | | | | 0/4 |
| | Pt. Pulley | Liver | Lipid in hepatocytes | | | N/A | N/A | N/A | N/A | |
| | | | Mild | 1/6 | 2/6 | | | | | 0/6 |
| | | | Moderate | 4/6 | 0/6 | | | | | 0/6 |
| | | | Severe | 0/6 | 1/6 | | | | | 0/6 |
| | | | Lymphocyte aggregates | 0/6 | 0/6 | | | | | 1/6 |
| | | Gills | Aneurysms | 1/6 | 0/6 | | | | | 0/6 |
| | | General | External protozoan parasites | 0/6 | 2/6 | | | | | 0/6 |
| | | | Internal protozoan parasites | 0/6 | 0/6 | | | | | 0/6 |
| Nov 1982 | Seahurst | Liver | Lipid in hepatocytes | | | | | | | |
| | | | Mild | 1/3 | 2/5 | N/A | 0/3 | N/A | N/A | N/A |
| | | | Moderate | 2/3 | 0/5 | | 0/3 | | | |
| | | | Severe | 0/3 | 3/5 | | 3/3 | | | |
| | | | Lymphocyte aggregates | 0/3 | 0/5 | | 0/3 | | | |
| | | | Necrosis | 1/3 | 1/5 | | 2/3 | | | |
| | | Gills | Aneurysms | 2/3 | 0/5 | | 0/3 | | | |
| | | | Hyperplasia | 1/3 | 2/5 | | 0/3 | | | |
| | | General | External protozoan parasites | 0/3 | 0/5 | | 1/3 | | | |
| | | | External metazoan parasites | 0/3 | 2/5 | | 0/3 | | | |
| | | | Neoplasia | 0/3 | 0/5 | | 0/3 | | | |

Table 9.9 (continued).

| Date | Site | Organ | Pathological condition | Striped sea perch | Shiner perch | Cod | Tomcod | Pollock | Steelhead trout | Chum |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pt. Pulley | Liver | Lipid in hepatocytes | | | | | | | |
| | | | Mild | 4/5 | 5/6 | N/A | 0/1 | 0/5 | 1/1 | N/A |
| | | | Moderate | 1/5 | 1/6 | | 0/1 | 2/5 | 0/1 | |
| | | | Severe | 0/5 | 0/6 | | 1/1 | 3/5 | 0/1 | |
| | | | Lymphocyte aggregates | 0/5 | 0/6 | | 0/1 | 0/5 | 0/1 | |
| | | | Necrosis | 0/5 | 0/6 | | 0/1 | 0/5 | 0/1 | |
| | | Gills | Aneurysms | 0/5 | 4/6 | | 1/1 | 1/5 | 0/1 | |
| | | | Hyperplasia | 4/5 | 1/6 | | 1/1 | 1/5 | 1/1 | |
| | | General | External protozoan parasites | 0/5 | 1/6 | | 0/1 | 0/5 | 0/1 | |
| | | | External metazoan parasites | 0/5 | 0/6 | | 0/1 | 0/5 | 1/1 | |
| | | | Neoplasia | 0/5 | 0/6 | | 0/1 | 0/5 | 0/1 | |

[a]Numbers indicate incidence (no. of fish affected/no. of fish examined).

relatively healthy populations. Most of the lesions found are of minimal significance to the health of the host and many represent traumatic injuries or normal physiological changes. The incidence of neoplasia has been quite low and limited to epidermal papillomas. No hepatic lesions of neoplastic appearance were noted.

The incidence and severity of some of the lesions found to date in this study are similar when compared to those found by other investigators in various Puget Sound environments. Miller et al. (1977) found incidences of fin erosion ranging from 0-66%; to date fin erosion incidence in this study has ranged from 0-43% with incidences most commonly being very low (0-5%) and with mild lesion intensity. Epidermal papillomas have been found in low numbers (0-6%) in our study. Miller et al. (1977) found somewhat higher incidences (0-67%) in fish collected at West Point, Alki Point and Point Pulley; however, the overall incidence was in the same general range was that in this study.

Other lesions found by previous investigators have not been found. Malins et al. (1982) found a number of idiopathic hepatic lesions which were determined to be of non-uniform distribution, and which were associated with urban areas. These lesions consisted of neoplastic and preneoplastic conditions, specific and nonspecific degenerative lesions and intracellular storage disorders. To date our study has not revealed the presence of similar lesions.

# 10.0 VIROLOGY

R. M. Kocan, C. Rockwell, V. Liguori

## 10.1 Purpose and Scope

The purpose of this task was to determine whether the bivalve mollusc populations in various areas of Puget Sound surrounding the proposed outfall site are contaminated with human enteric viruses. This baseline information will allow for future comparisons of infectivity rates and make it possible to determine the effect of effluent discharge on the virus burden of local shellfish populations.

The original proposal had three major objectives: (1) to determine any seasonal fluctuations of virus occurrence rates in bivalve molluscs in the Seahurst area, (2) to determine the relative virus occurrence rates among species and collection sites surrounding the proposed outfall site, and (3) to determine levels of occurrence of several human virus species in the various clam species encountered. Due to funding limitations only the collection of clams on a monthly basis was accomplished as well as the seeding of selected samples with vaccine strain polio virus. These samples were processed according to the protocol described in the original proposal and later modified and described in the 1st quarterly report. As was agreed to by both METRO and the University of Washington in 1982, the clam samples as well as the resulting data will be analyzed by METRO personnel when time and funds are available. All of the samples to date have been delivered to METRO for future virus isolation and identification. At the time of this writing we have not received any results on the presence of "natural" virus in the samples given

to METRO.

Twelve months of clam sampling will have been completed as of June 16, 1983, and the processed clam homogenates turned over the METRO staff.

Familiarization of Microbiology personnel with the collection sites will also have been completed as of June 16, 1983.

## 10.2 Materials and Methods

### 10.2.1 Sample Collection

Clams were collected on a monthly basis from the sites identified in Appendix 10A. Collection times were coordinated with the maximum low tides of the month to maximize the success of obtaining specimens.

Freshly dug clams were placed into plastic bags, identified as to location and time and placed on ice in a cooler until returned to the UW laboratory. Once at the lab the clams were identified to species and the percent of each species included in each sample recorded (Appendix 10B). Total data for the collection was then entered onto a standard data sheet. Clams were then processed for virus isolation and frozen in duplicate sterile plastic cups at -20C until picked up by METRO personnel.

### 10.2.2 Virus Isolation Protocol

1. Aseptically open clams and rinse in cold water to remove pallial water.
2. Homogenize 100 gm of clam meat in 500 ml of cold distilled $H_2O$ for 2 minutes.
3. Adjust pH to 4.5 by 1N HC1 slowly while stirring homogenate.
4. Check conductivity and reduce to less than 2000 µmho by addition of $H_2O$ (approx. 700 ml additional).

5. Stir for 15 minutes on magnetic stirrer on cold plate.
6. Centrifuge at 1900 X g for 10 minutes at 4C and discard supernatant.
7. Elute viruses from pellets with 150 ml of cold glycine-saline buffer (0.05M glycine + 8.0 gm/L NaCl) at pH 7.5.
8. Slowly adjust pH to 7.5 using 1N NaOH.
9. Centrifuge at 1900 X g for 10 minutes at 4C; decant and pool supernatant and discard pellets.
10. Add 15 ml freon to supernatant and stir for 5 minutes.
11. Centrifuge at 1900 X g for 10 minutes at 4C.
12. Decant upper aqueous layer into two plastic specimen cups to a final volume of approximately 60 ml/cup.
13. Add penicillin ($10^3$ units/ml) and streptomycin ($10^3$ ug/ml).
14. Mix thoroughly and freeze at -20C.

10.2.3 Procedural Controls

One sample each month was used for virus seeding experiments (i.e., spiked sample). Polio virus type 1 (vaccine strain) supplied by METRO was injected into clams prior to processing and freezing. A reference volume of the virus stock was also kept and frozen along with the clam samples to determine how much virus loss occurred during processing and freezing. These samples were to be tested by METRO for virus recovery efficiency and the data used to correct the raw data obtained from the field.

10.2.4 Responsibilities

Mr. Vinnie Liguori has had the major responsibility for organizing the first five months of the field and processing portions of this study. The work has subsequently been turned over to Mr. Chris Rockwell who has spent one month observing and training with Dr. Kocan and Mr. Liguori prior to assuming

his duties. Due to the delays resulting from night-winter low tides, two student assistants have also been hired to assist with the field collections. These people were accompanied by Dr. Kocan and Mr. Liguori on their initial trip to each collection site in order to insure uniformity in methods of collection and site location.

## 10.3 General Process

### 10.3.1 Routine Clam Collection

Monthly clam collections have been frequently limited by the level of maximum low tide for that particular month. Tides which do not fall below a 0.0 ft. level do not expose sufficient beach area to make clam collection efficient or even possible on many beaches. As a result of the short period of time available for collection during each low tide and the limited availability of clams, an excessive amount of manpower and time (in the form of multiple trips) have been expended in order to collect relatively few clams. This problem is compounded by the fact that the public usually does not attempt to collect clams on Puget Sound beaches at tide levels higher than -1 ft. Therefore, the data obtained from such collections is probably insignificant in terms of the effect of pathogenic viruses on humans consuming clams from Puget Sound during periods of relatively high tide.

### 10.3.2 Virus Recovery

On the basis of data currently obtained from METRO personnel, it appears that the spiked virus samples (polio virus 1; Sabin vaccine strain) from the first eight months of collections have proven to be negative when isolations were attempted after eight months of storage. Whether this is the result of a problem in the processing procedure or a combination of processing and storage

is not known at this time. Stock cultures of the virus used for the spiked samples have survived the frozen storage but were not subjected to the same manipulation as those which were injected into the clams. A modification in pH adjustment of the processed samples from February resulted in a 14% virus recovery. This may have solved the initial problem provided storage time was not a factor. If this problem persists throughout the first eight months of sampling, then it will not be possible to assess the levels of "naturally" occurring virus in the clams collected during that sampling period.

Thus far none of the clam samples have been evaluated for "naturally" occurring virus. If the unsuccessful recovery of spiked virus is an indication that there is a flaw in the procedure being used, further sampling effort should be suspended until the analytical techniques have been refined.

## 10.4 Recommendatons

### 10.4.1 Collection Schedule

Due to the problem of obtaining sufficient clams for meaningful analysis during periods of relatively high tides (>-1 ft.) and the relatively high cost in terms of time and manpower, it is recommended that any future projects which require the collection of clams for the purpose of public health evaluation consider collection only during those months which have tide levels which are -1 ft. or less. If there is concern over the possibility of missing potential problems in those animals which do occur at higher tide levels, such animals can be collected from the higher reaches of beach at the same time lower levels are being collected since the beach will be accessible for a longer period of time. This will increase the time needed for collections due to the scarcity of animals at the higher levels.

10.4.2 Virus Isolations

Due to the problems inherent in processing and long term storage of clam samples, it is recommended that clams be tested immediately upon collection in order to minimize loss of virus and lessen the risk of not recognizing problems which might jeopardize the project until it is too late to modify the research plan. This plan would also enable the team to concentrate efforts on those beaches which exhibit the highest risk and reduce effort on beaches which are relatively unaffected. An additional advantage to this system is that if samples are lost for some technical reason, they can be recollected and the entire sample period salvaged.

10.4.3 Positive Controls (Spiked Samples)

The practice of spiking samples which is currently being used should be continued as an assurrance that none of the manipulations being carried out on the clam samples are detrimental to the recovery of any "naturally" occurring virus in the clams.

10.4.4 Cooperative Efforts

If future laboratory projects require the same type of field material, and if simultaneous collections for all groups are desireable, then it is recommended that a specific team of field personnel be established to insure standardization of collections, efficiency, and dependability. This team would be responsible for obtaining materials for multiple user groups and would be supplied by each group with the appropriate materials and equipment needed to adequately collect and transport the animals, or other samples needed for laboratory analyses.

Such a field team would standardize the collection procedures for each laboratory project and eliminate the need for each group to independantly establish collection teams. If special equipment is needed to adequately

collect, store and transport field samples, then it would be the responsibility of the task requesting the material to supply the equipment and detailed protocol to the field team for collection and handling.

Such a team would be under the supervision of a faculty member who has experience in collecting and transporting field material. The team would consist of either a biologist or research assistant and part-time student help. The faculty member would be responsible for reviewing the protocols and equipment needs supplied by the various tasks and would directly supervise the field personnel.

## 10.5 Conclusions

At this time it is not possible to draw conclusions as to the extent of viral contamination of Puget Sound shellfish in the Seahurst area. The analysis of samples has lagged the collection to the extent that procedural corrections have not been possible and little data is available on which to draw conclusions.

# 11.0 MICROBIOLOGY

J. Matches, S. Fischnaller, E. Raghubeer,
D. Anderson, W. Campbell

## 11.1 Introduction

The presence of pathogenic bacteria in the marine environment can have a direct relationship to human health. There is limited contact between humans and most of the water column; however, a great deal of contact occurs between humans and the intertidal areas. These activities include beachcombing, shellfish harvest and consumption, bathing in warmer months, and skindiving throughout the year. Fishing can also be important in the shallower waters. The presence of pathogenic bacteria in the inshore areas can pose a potential public health hazard to users of these areas.

Phase I sampling began in July, 1982 and will continue thru June 1983. A total of 249 samples were collected to date by the Virology and Water Column task groups and processed by the Microbiology task group.

In this study the following indicator and pathogenic bacteria have been isolated from Puget Sound water and/or shellfish: fecal coliforms, enterococci, Salmonella, Yersinia enterocolitica and Vibrio parahaemolyticus. Clostridium perfringens has been isolated from intertidal sediment.

### 11.1.1 Objectives

The objective of this study is to measure both pathogenic and indicator bacteria from sampling sites in Puget Sound near the proposed Seahurst outfall. These data obtained from the bacteriological analysis of water column, shellfish, intertidal water, and sediment samples will serve as a control to which post-discharge data can be compared.

Pathogenic bacteria originating in the gut of man or other warm-blooded

animals often are present in waters in numbers too low for ease of detection (Cabelli 1980), therefore the indicator organism concept becomes important. These indicators of fecal pollution are also found in the gut of man and other warm-blooded animals but in higher numbers than the pathogenic bacteria. When these indicators of fecal pollution (fecal coliforms, enterococci, and Clostridium perfringens) are found in the environment, the potential for the presence of pathogens from the gut is high. This concept is well known and used in food, water, and sanitary microbiology. The indicator organism concept and the above indicators are being used in this study.

In addition to the above mentioned indicator organisms, three pathogenic bacteria are used in this study: Salmonella, Vibrio parahaemolyticus and Yersinia enterocolitica. These bacteria are potential pathogens which are capable of causing gastroenteritis, however, due to growth characteristics, Vibrio is found primarily during the warmer months of the year in Puget Sound while Yersinia is found primarily during the colder months.

## 11.2 Description of Sampling Areas

Figure 11.1 depicts approximate sampling station and site locations from which monthly samples were collected for microbiological analysis. Water column samples were collected from offshore sampling stations number 4, 5, 6, 7, and 8. Station locations are indicated on the Puget Sound map by a circle around each station number. Exact positions are the same as reported by the water column task group.

Shellfish, intertidal water, and sediment samples were collected from beach sampling sites that are indicated on the Puget Sound map by arrows. Beaches sampled include: Lincoln Park, Seahurst Park, Normandy Beach, Des

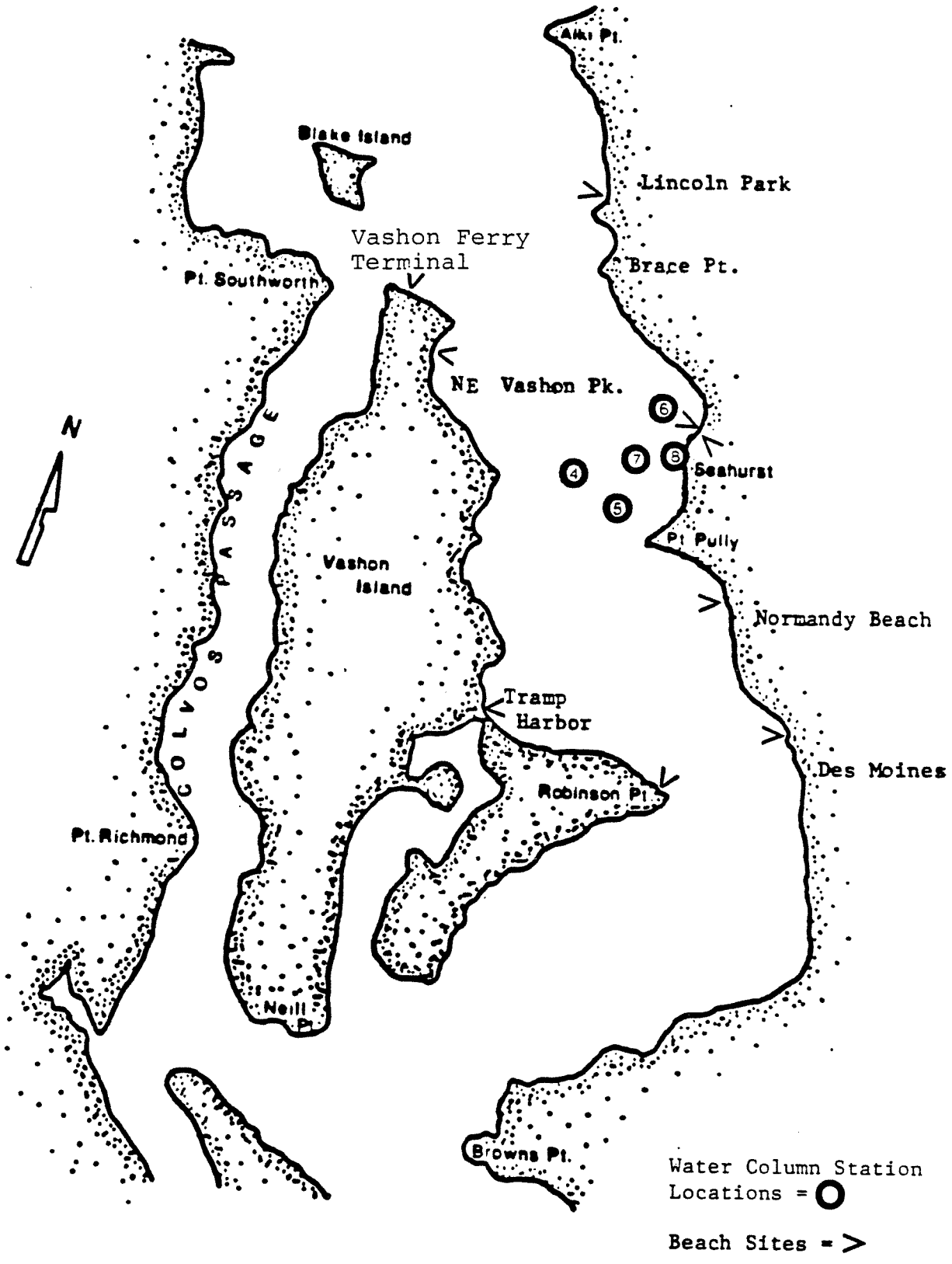



Figure 11.1. Bacteriological Sampling Sites

Approximate water column station locations and beach sampling sites. Beaches being sampled include; Lincoln Park, Seahurst, Normandy Beach, Des Moines, Vashon Ferry Terminal, N.E. Vashon Park, Tramp Harbor, and Robinson Point. Water column stations include; site numbers 4, 5, 6, 7, and 8.

Moines (Covenant) Beach, Vashon Ferry Beach, N.E. Vashon Park, Tramp Harbor, and Robinson Point.

Sections of a National Oceanic and Atmospheric Administration Navigational Chart (#18448) depicting individual beach sites are found in Figures 11.2, 11.3, 11.4, 11.5 and 11.6.

11.2.1 Lincoln Park Beach (Map 11.2)

This sampling site parallels the northern 100 yards of bulkhead at the north end of the park.

Primary sewage is discharged approximately 2.3 miles NNW of Lincoln Park from the S.E. side of Alki Pt.

11.2.2 Seahurst Park Beach (Map 11.3)

Two sampling sites are located on this beach between 250 and 400 yards north and south of the stream that flows through the park and into Puget Sound.

Primary sewage is discharged approximately 0.4 miles NNW of Seahurst Park, between Seola Beach and Seahurst, from the Salmon Creek discharge station (47° 29'14"N and 122°22'04"W).

11.2.3 Normandy Park Beach (Map 11.3)

This sampling site is located 50 yards to either side of a line running 240° (mag) from the parking lot at the end of the beach access road.

Primary sewage is discharged approximately 0.5 miles west of Normandy Park from the Miller Creek discharge station (47° 26'30"N and 122°21'52"W).

11.2.4 Des Moines - Covenant Beach (Map 11.4)

This sampling site is located 50 to 100 yards along a line running 310° (mag) from the third support piling of the public fishing pier and 50 yards to either side of this line.

Primary sewage is discharged approximately 0.4 miles south of Covenant

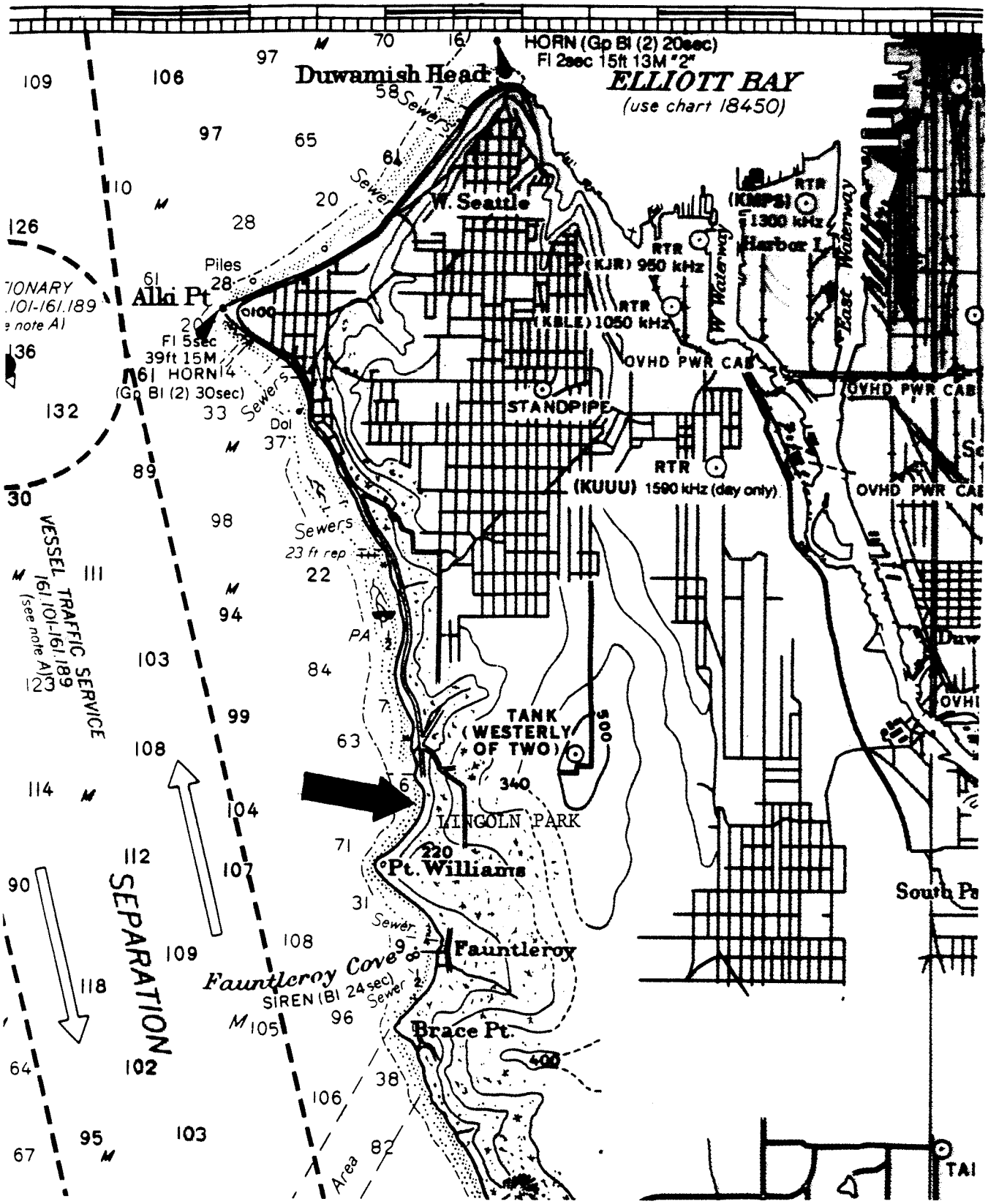



Figure 11.2 Lincoln Park

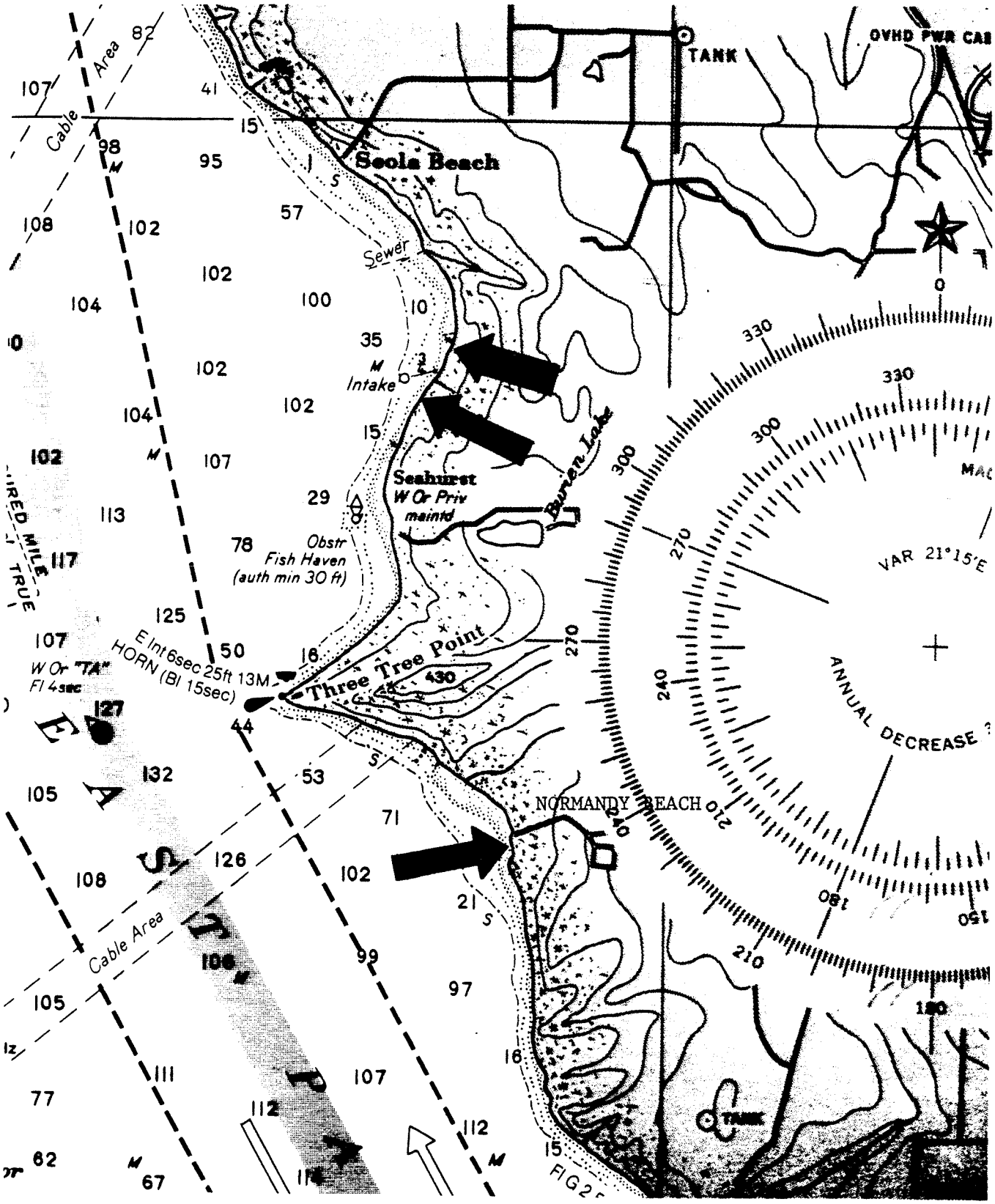



Figure 11.3 Seahurst Park North

Seahurst Park South

Normandy Beach

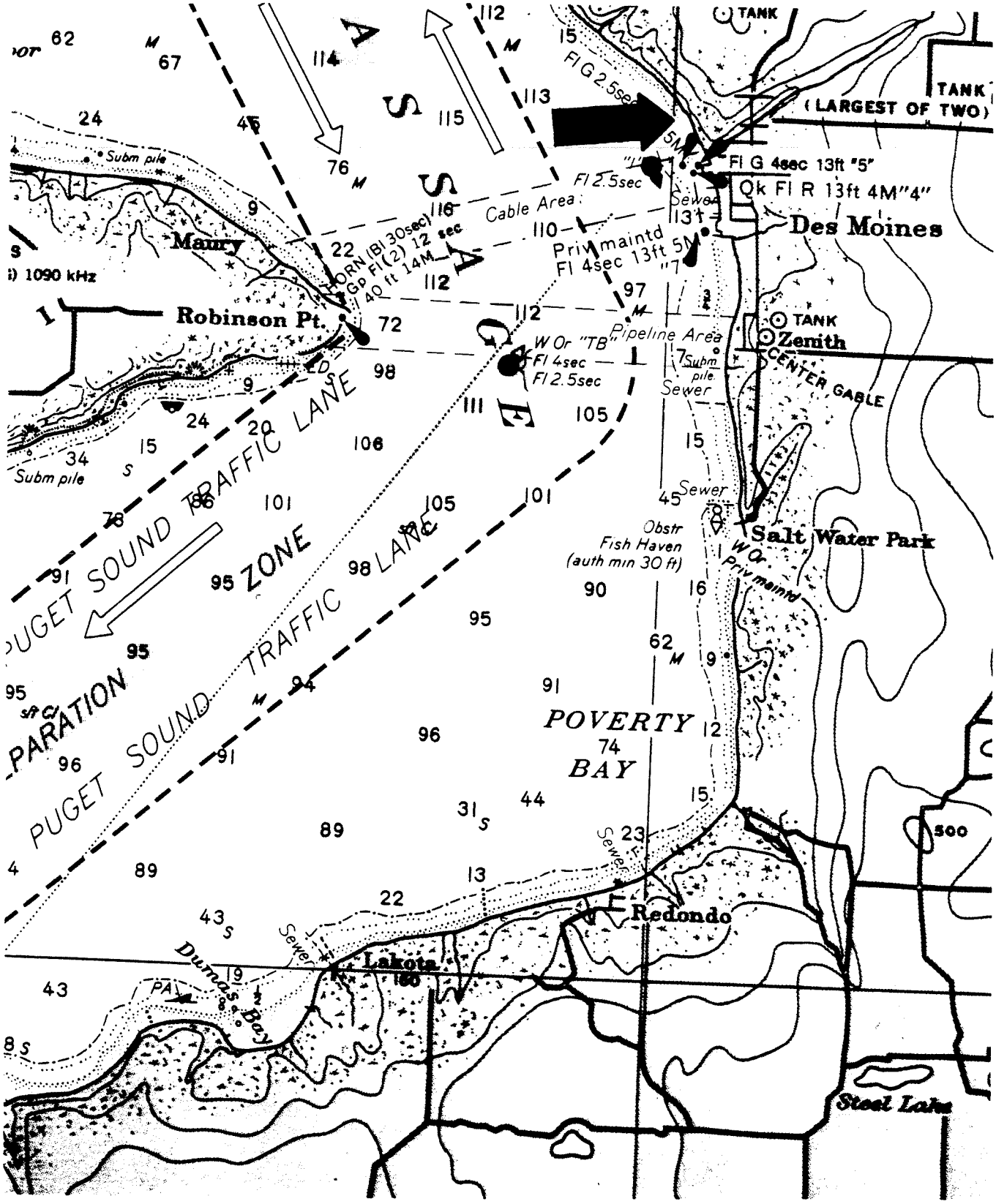



Figure 11.4 Des Moines Beach
(Covenant Beach)

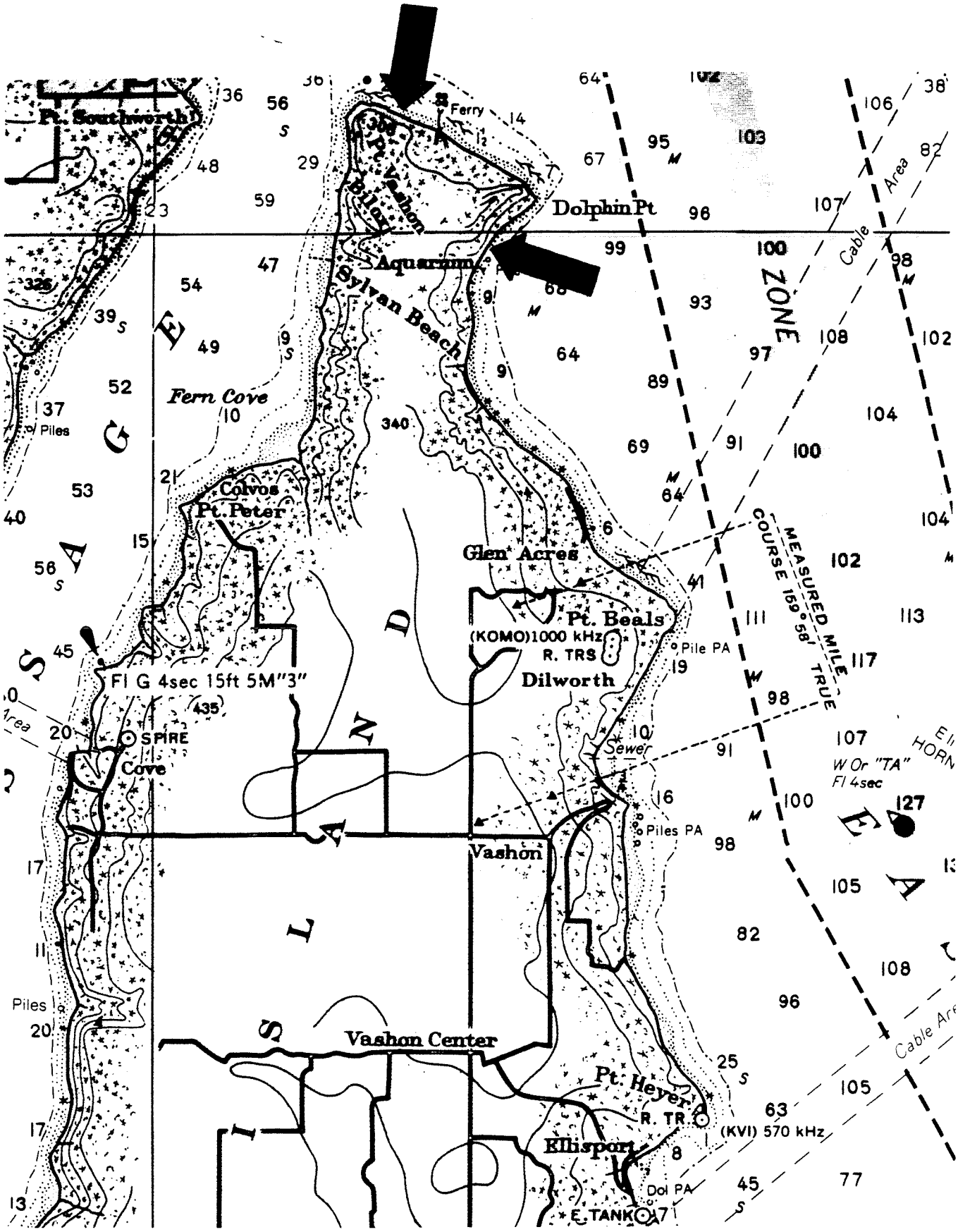



Figure 11.5 Vashon Ferry Beach

N.E. Vashon Park (N.E. of Aquarium)

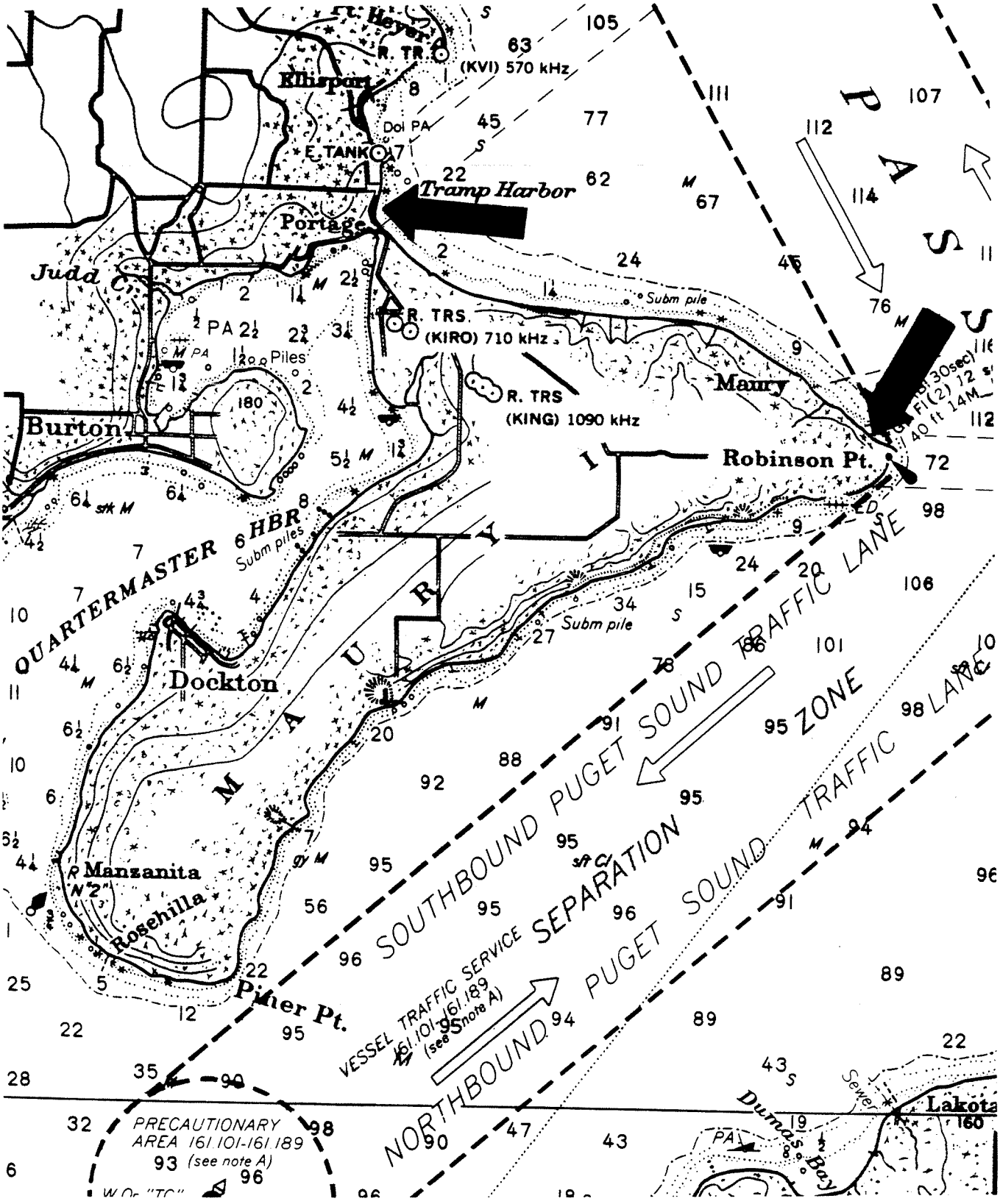



Figure 11.6 Tramp Harbor Beach

Robinson Pt. Beach

Beach from Des Moines, approximately 3.7 miles south of Covenant Beach from Redondo, and approximately 4.5 miles SSW of Covenant Beach from Lakota.

11.2.5 Vashon Ferry Beach (Map 11.5)

This sampling site lies between 200 and 300 yards from the ferry dock along a line 270° (mag) from the dock pilings.

11.2.6 N.E. Vashon Park Beach (Map 11.5)

This sampling site lies NNE of the access trail which approaches the beach from the town of Aquarium and intersects the beach on the north side of a large yellow house. The beach extends for about 200 yards to the NNE.

Primary sewage is discharged approximately 3.0 miles SSE of N.E. Vashon Park Beach from the Vashon Sewer District (47° 27'09"N and 122° 26'19"W).

11.2.7 Tramp Harbor Beach (Map 11.6)

This sampling site is located adjacent to the town of Portage, Vashon Island, where a line 180° (mag) from the KVI radio tower, on Pt. Heyer, intersects the riprap retaining wall adjacent to the road.

Primary sewage is discharged approximately 2.6 miles north of Tramp Harbor from the Vashon Sewer District (47°27'09"N and 122°26'19"W).

11.2.8 Robinson Pt. Beach (Map 11.6)

This sampling site is the 100 yards of beach just east of the cable crossing located west of the lighthouse on the eastern-most point of Maury Island.

## 11.3 Description of Samples

### 11.3.1 Shellfish Samples

Shellfish are known to "concentrate" microorganisms from the surrounding waters and were used by this study to enumerate bacteria which are indicators

of fecal pollution (fecal coliforms), to enumerate bacteria which are potential pathogens (Vibrio parahaemolyticus and Yersinia enterocolitica), and to monitor the intertidal environment for pathogenic bacteria (Salmonella sp.).

Samples were collected by the Virology task group, placed in plastic bags according to collection site, and transported on ice. Samples were processed the same day as collected. The shells were first washed under running tap water and then opened with a knife. The entire contents of the shells from a respective site (including commensal crabs) were transformed to a sterile and pre-weighed mason jar. The knife was disinfected and plastic disposable gloves were used for handling samples but were changed between the handling of samples from different locations to avoid cross contamination.

Shellfish were blended with 0.1% peptone for two minutes at 8000 r.p.m. to prepare a 1:2 dilution (Speck 1976).

11.3.2 Intertidal Water Samples

Microorganisms are continually released into the intertidal environment from outgoing streams, sewage discharges, storm sewers, animal sources, and drainage from septic tanks. Intertidal water samples were used by this study to enumerate bacteria which are indicators of fecal pollution (fecal coliforms and enterococci) and to monitor for the presence of pathogenic bacteria (Salmonella sp.).

Samples were collected by the Virology task group into plastic, pre-sterilized containers from intertidal water nearest to the respective shellfish sampling sites. Samples were transported on ice and were processed the same day.

11.3.3 Sediment Samples

Intertidal sediment samples were used by this study to enumerate bacteria

which are indicators of fecal pollution (Clostridium perfringens).

Samples were collected by the Virology task group into plastic, pre-sterilized containers from the respective shellfish sampling sites. Samples were transported on ice and were processed the same day as collected.

11.3.4 Water Column Samples

Water column samples represent the main water body of Puget Sound. They were used by this study to enumerate bacteria which are indicators of fecal pollution (fecal coliforms), to enumerate bacteria which are potential pathogens (Yersinia enterocolitica), and to monitor the environment for pathogenic bacteria (Salmonella sp.).

Samples were collected by the Water Column task group into sterile glass bottles, which were opened one meter beneath the surface. Samples were transported on ice and were processed the same day.

## 11.4 Methods

Procedures used for the isolation and identification of Vibrio and Yersinia were modified during the first five months of the study. These changes in procedures are listed respectively in the sequence that they occurred; beginning with the initial procedure and evolving to the procedure used to date.

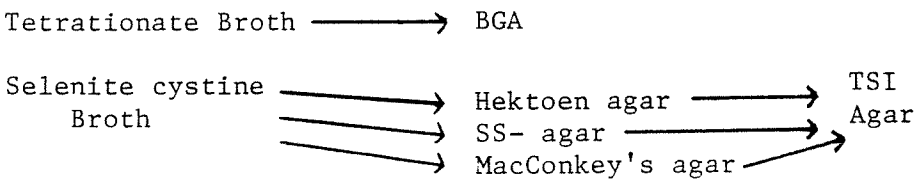
11.4.1 Salmonella Procedure

Tetrathionate broth and selenite cystine broth were used as the enrichment media for the detection of Salmonella sp. from shellfish, intertidal water, and water column samples.

Contract terms specified that one enrichment broth be used, either selenite-cystine broth or selenite F broth. We elected to use two enrichment

broths, selenite-cystine and tetrathionate, to increase the sensitivity of the erichment procedure.

Twenty-five ml of water sample or 50 ml of a 1:2 blended shellfish dilution (25 gm) were used to inoculate one bottle (125 ml) of each enrichment broth per sample. Following a 24 hour incubation period at 35 C the selenite-cystine broth cultures were streaked onto Hektoen agar, MacConkey's agar, and Salmonella-Shigella (S-S) agar and incubated for 24 hours at 35 C. Tetrathionate broth cultures were streaked onto Brilliant Green agar (BGA) and incubated for 24 hours at 35 C.




The plating media specified by the contract to be used in this procedure were Salmonella-Shigella (S-S) agar and Brilliant Green agar (BGA). In addition to these we elected to add two more plating media, Hektoen agar and MacConkey's agar, to increase the sensitivity of the plating procedure.

Bacterial colonies typical of Salmonella were picked from the above four plating agars and transferred to Triple Sugar Iron (TSI) agar slants. Each isolate showing a typical TSI reaction was then inoculated into the biochemical media listed in the Table 11.1 identification scheme for Salmonella. Isolates with a typical biochemical pattern for Salmonella were confirmed serologically and frozen for future reference.

Table 11.1. Identification Scheme for *Salmonella*

| Culture Media | Incubation Time | Incubation Temperature | Typical Reaction |
|---|---|---|---|
| Tetrathionate Broth | 24 hrs. | 35°C | Enrichment |
| Selenite Cystine Broth | 24 hrs. | 35°C | Enrichment |
| Brilliant Green Agar (BGA) | 24 hrs. | 35°C | Pink-red |
| Hektoen Agar | 24 hrs. | 35°C | Blue-green or colorless. |
| MacConkey's Agar | 24 hrs. | 35°C | Light pink or colorless. |
| S-S Agar | 24 hrs. | 35°C | Colorless |
| Triple Sugar Iron Agar (TSI) | 18-24 hrs. | 35°C | K/A,± $H_2S$,-gas |
| Urea Broth | 4-7 days | 35°C | - |
| Lactose Purple Broth | 48± 2 hrs. | 35°C | - |
| Malonate Broth | 48 hrs. | 35°C | - |
| Lysine Decarboxylase | 96 ± 2 hrs. | 35°C | + |
| Tryptone (Indole) | 48 ± 2 hrs. | 35°C | - |
| Methyl Red (MR) | 48 hrs. | 35°C | + |
| Voges-Proskauer (VP) | 48 hrs. | 35°C | - |
| Simmon's Citrate | 96 ± 2 hrs. | 35°C | +,(-) |
| Sucrose Purple Broth | 48 ± 2 hrs. | 35°C | - |
| Tryptic Soy Broth (TSB) | 48 hrs. | 35°C | Growth |

Note: If VP(-) repeat test at 22°C. VP(+) rules out *Salmonella*. *Hafnia* may be VP(-) at 35°C but will be VP(+) at 22°C. If MR-VP results are equivocal after 48 hours, repeat test for 4-5 days.

Note: TSI slants typically give an alkaline (K) slant and an acid (A) butt, with or without $H_2S$ production, and no gas production.

Slant/Butt,$H_2S$,Gas

K / A ± -

11.4.2 Fecal Coliform Procedure

A five (5) tube most probable number (MPN) test, using the rapid A-1 method developed by Andrews and Presnell (1972), was used for the detection and enumeration of fecal coliforms in shellfish, intertidal water, and water column samples. Five (5) dilutions (10, 1.0, 0.1, 0.01 and 0.001 ml) of each sample were prepared and used to inoculate five (5) tubes of A-1 medium per dilution (25 tubes per sample). Tubes were carried through the procedure outlined in Table 11.2A (APHA 1976 and EPA 1978).

Results were calculated from a MPN table and reported per 100 grams of shellfish or 100 ml of water.

The completed test procedure is outlined in scheme Table 11.2B, and was performed on 10% of all positive A-1 cultures to estimate the percentage of false positive reactions.

11.4.3 Enterococci Procedure

The membrane filter method of Levin et al. (1975) was used for the detection and enumeration of enterococci from intertidal water samples as outlined in Table 11.3A.

Results were reported as number per 100 ml of sample water. Enterococci verification was not performed on all samples due to the high degree of accuracy and sensitivity reported by Levin et al. (1975); however, the method was tested with the verification procedure outlined in Table 11.3B.

11.4.4 Clostridium perfringens Procedure

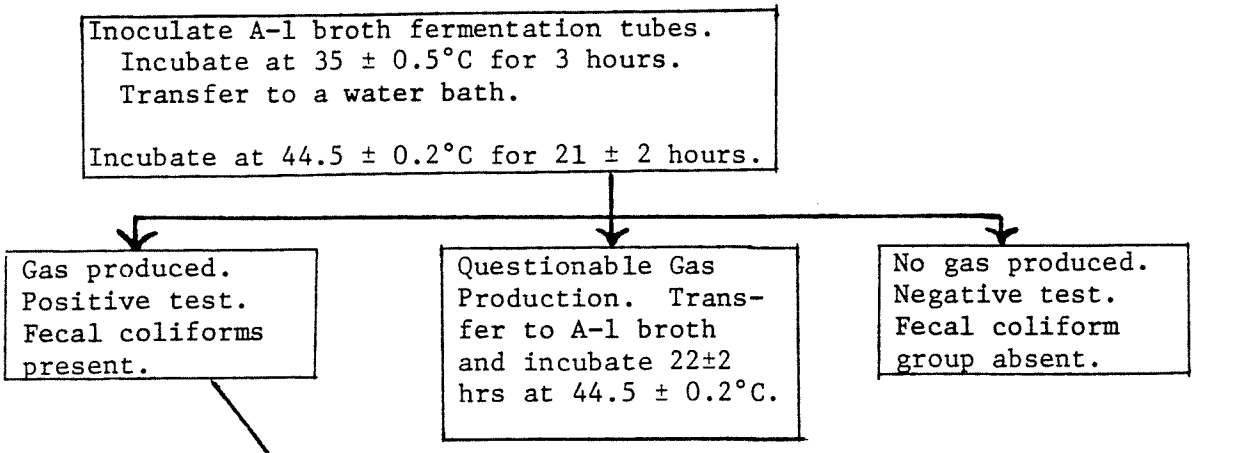
The method reported by St. John et al. (1982) was used for the detection and enumeration of Clostridium perfringens from sediment samples.

A three (3) tube MPN test was applied as outlined in Table 11.4. Results were calculated from a MPN table and reported per 100 grams of sediment.

Verification was not performed due to the high degree of accuracy and

Table 11.2. Schematic outline of the fecal coliform identification procedure.

A. Confirmed Test




B. Completed Test

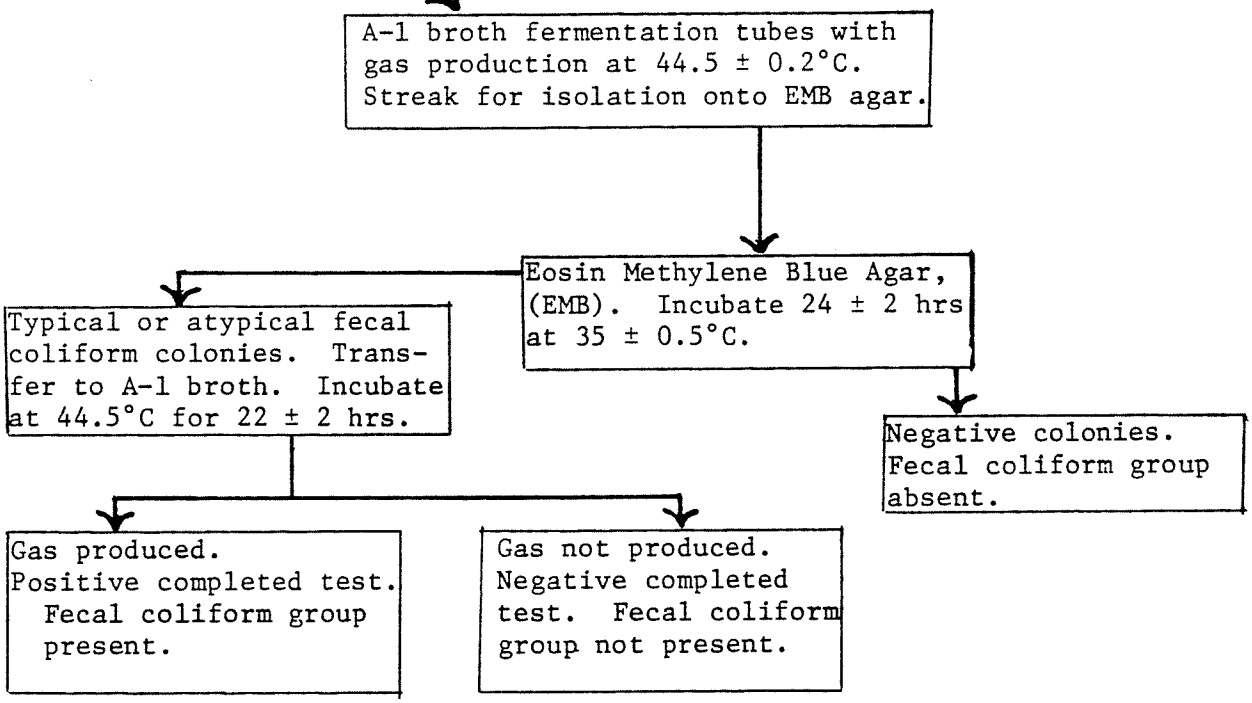


Table 11.3. Schematic outline of the enterococci identification procedure.

A. Membrane Filtration

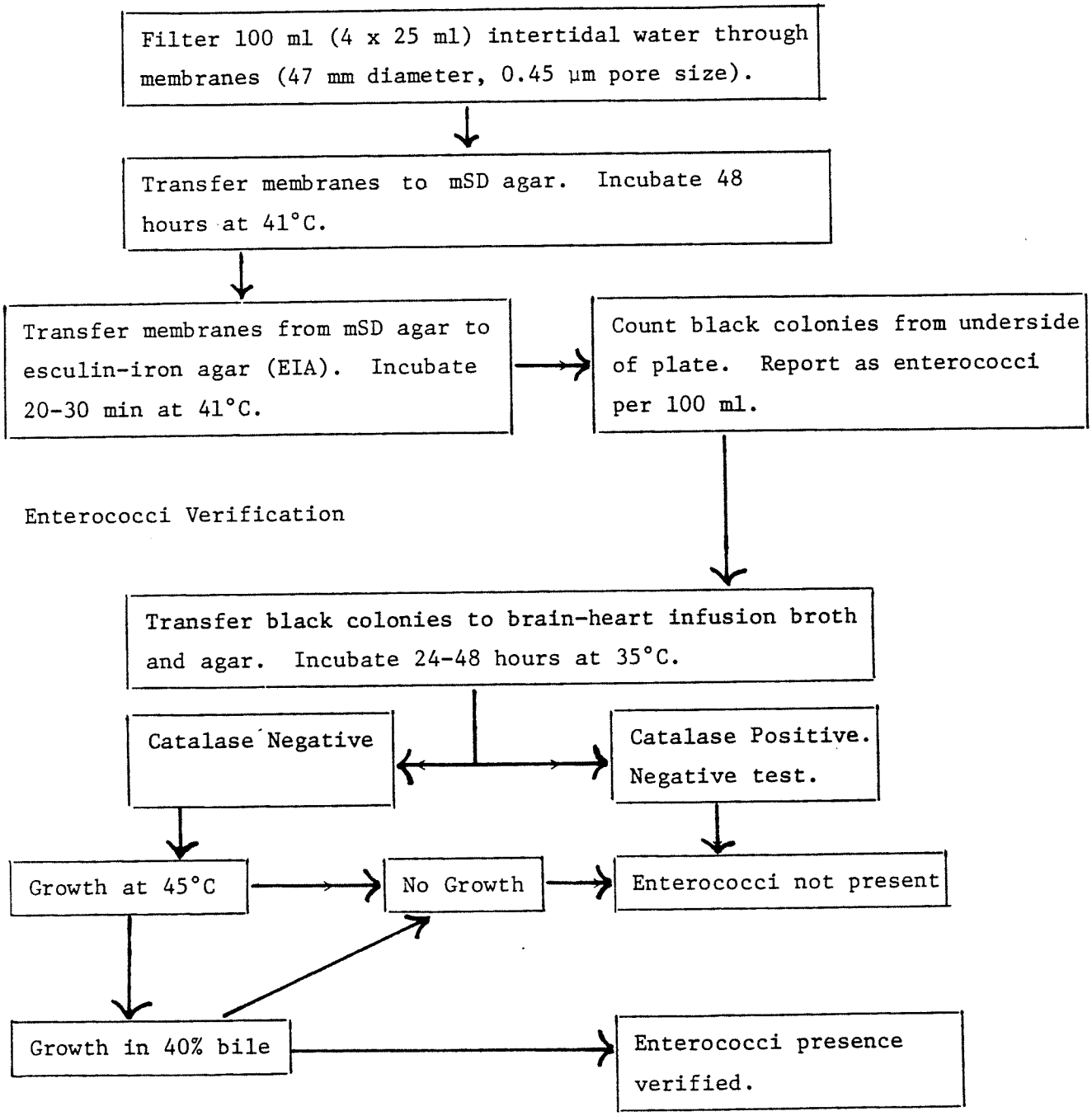
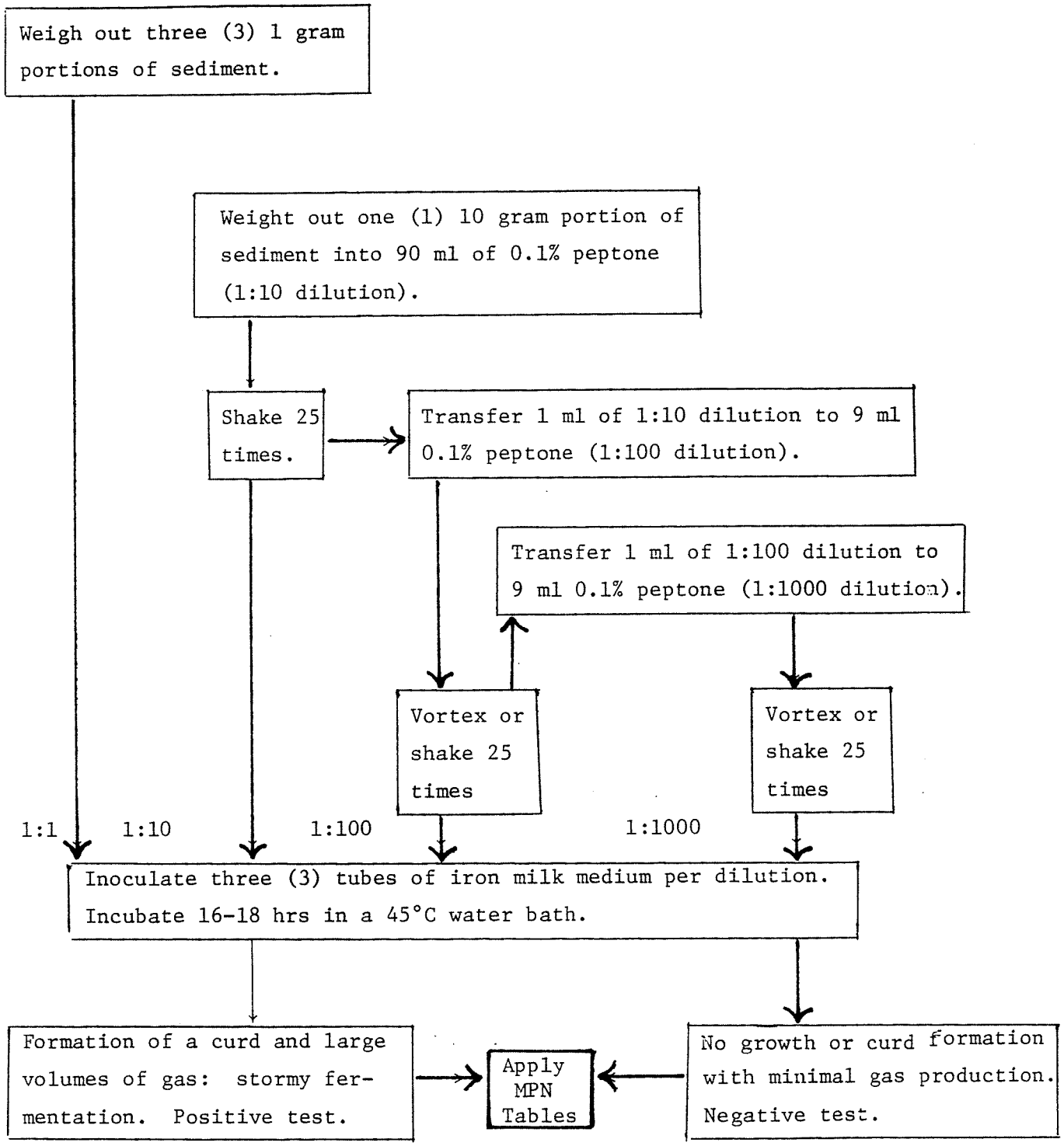


Table 11.4. Schematic outline of the Clostridium perfringens identification procedure.

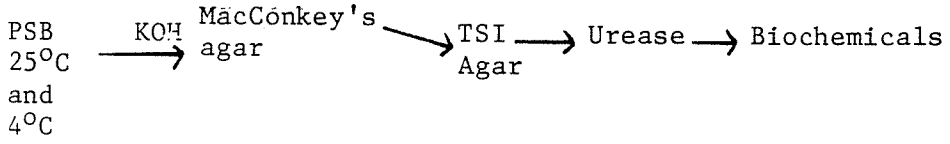


sensitivity reported by St. John et al. (1982).

11.4.5 Yersinia enterocolitica Procedure

A three tube most probable number (MPN) method using peptone sorbitol broth (PSB) as an enrichment media (Weagant and Kaysner 1983) was used for the detection and enumeration of Yersinia enterocolitica and Yersinia enterocolitica-like species from shellfish and water column samples. Contract terms specified that the presence of Yersinia enterocolytica be determined in water column samples. It also specified that the presence of either Yersinia enterocolytica or Vibrio parahaemolyticus be determined in shellfish. We elected to isolate and enumerate Yersinia enterocolitica year-round from both water column and shellfish samples in addition to isolating and enumerating Vibrio parahaemolyticus during the warm months of the year. Due to growth characteristics Vibrio is found primarily during the warm months and Yersinia is found primarily during the cold months of the year. Dilutions were prepared from shellfish (10 gm, 1.0 gm, 0.1 gm, 0.01 gm, and 0.001 gm) and water column (10 ml, 1.0 ml, 0.1 ml, 0.01 ml, and 0.001 ml) samples and used to inoculate three(3) tubes of PSB per dilution (15 tubes per sample). Tubes were incubated at room temperature for 8-12 days and then streaked onto MacConkey's agar using the pre-plating alkali treatment reported by Aulisio et al. (1980). In addition, duplicate sets of enrichment tubes (15 tubes per sample) were also prepared, incubated at 4 C for 20-30 days, and then streaked onto MacConkey's agar for isolation in the same manner. The MacConkey plates were incubated for 2-3 days and then both atypical and typical colonies were picked for isolation and transferred to TSI agar slants. Until laboratory personnel initially became familiar with the colonial appearance of Yersinia, all morphologically suspect colonies were picked in excess. TSI slants were incubated for 2 days at room temperature and then read for reactions typical

of Yersinia enterocolitica; an acid or alkaline slant over an acid butt, without $H_2S$ production, and minimal (bubble only) gas production. TSI cultures showing no change, $H_2S$ production, or moderate to heavy gas production were discarded. Isolates with a typical TSI pattern were used to inoculate urease broth as an initial screen. Isolates which were urease positive were then used to inoculate the remaining biochemical media listed in the Table 11.5 identification scheme. Biochemical sugars, inositol, mannitol, and sorbitol, were incubated at room temperature for 24 hours and then transferred to 35 C for an additional 24 hours.




The original presumptive identification scheme (Table 11.5) contained the biochemical media required for the presumptive identification of Yersinia enterocolitica (Buchanan and Gibbons 1974, FDA-BAM 1978, Weaver 1982, and Hawkins and Brenner 1978). Yersinia enterocolitica strains are reported as being greater than 95% positive for urease production (Kapperud, 1980; Huges and Jenson, 1981; DeBoer et al. 1982; Bartley et al. 1982; Kapperud, 1981; Doyle and Hugdahl, 1983; Stern and Pierson, 1979; Vidon and Delmas, 1981; Bottone et al. 1981; Weaver et al. 1982; and Shayegani et al. 1981). A significant reference to urease production is made by Weaver et al. 1982, U. S. Center for Disease Control, in which Yersinia enterocolitica strains are reported to be 100% positive for urease production (70% positive within 48 hours and 30% being positive with 3-7 days). Weaver (CDC) also reports the motility reactions to be 0% positive at 35 C and 100% positive at 22 C. The

presumptive identification scheme (Table 11.5) was based on current literature (BAM, 1978) and the current definition of Yersinia enterocolitica accepted by the majority of the scientific community. This presumptive identification scheme is valid and would not yield significant false negative results. Isolates not eliminated by this screen were to be frozen for further biochemical characterization, and identification as outlined in BAM (1978).

To increase the sensitivity of the MPN procedure from "less than 30" (<30) to "less than 3" (<3) and thus be able to detect a smaller number of organisms, a 10 gram innoculum was added to the enrichment procedure. The ratio of sample to enrichment broth (1:10) was maintained by inoculating 100 ml volumes of PSB with 10 grams of sample. When these cultures were streaked onto MacConkey's agar and incubated, they consistently showed less overall growth than the MacConkey plates streaked from the 1.0 gram and 0.1 gram enrichment tubes. Additionally, Yersinia was repeatedly isolated from the higher dilutions (1.0 gm, 0.1 gm, and 0.01 gm) but not from the lowest dilution of 10 grams. The 10 gram innoculum was therefore discontinued from the enrichment procedure due to apparent bacterial inhibition and false negative results of the cultures inoculated with 10 gm shellfish. Reported results were calculated from 1.0 gm, 0.1 gm, and 0.01 gm dilutions and MPN sensitivity was considered to be "less than 30" (<30).

To enable differentiation of Yersinia enterocolitica and Yersinia enterocolitica - like organisms additional biochemicals and one plating agar were added to the identification scheme. METRO personnel suggested that urease and motility tests be moved from a primary screen to a secondary screen position and these reactions be recognized as variable; that the double incubation temperature 25 /35 C procedure for biochemical sugars be discontinued and a single incubation temperature of 25 C be used; and that TSI

Table 11.5. Yersinia enterocolitica presumptive identification scheme.

| Culture medium | Typical reaction | Incubation time |
|---|---|---|
| PSB | Enrichment 25° | 8-12 days |
| | 4° | 20-30 days |
| ↓ | | |
| MacConkey's | Flat, pale pink to colorless | 2-3 days |
| ↓ | | |
| TSI | A/AO- or k/AO- | 48 hours |
| ↓ | | |
| LAIA | (0%) k/AO- | 48 hours |
| ↓ | | |
| Oxidase | (0%) (-) | 20 sec |
| ↓ | | |
| Gram reaction | (0%) (-) | |
| ↓ | | |
| Urease | (100%) (+) | 7 days |
| ↓ | | |
| Phenylalanine deamination | (0%) (-) (Genera) | 24 hours |
| ↓ | | |
| Motility | | 48 hours |
| 22°C | + | |
| 35°C | (0%) (-) | |
| ↓ | | |
| Ornithine decarboxylation | (90%) (+) (Species) | 48 hours |
| ↓ | | |
| Citrate | (-) | |
| ↓ | | |
| Inositol | (+) | |
| ↓ | | |
| Sorbitol | (+) | |
| Mannitol | (100%) + | |
| TSB 48 hrs | Add 10% glycerol and freeze | |

cultures not be eliminated on moderate gas production. The resulting scheme modification used for the identification of Yersinia enterocolitica and Yersinia enterocolitica - like organisms is shown in scheme Table 11.6.

11.4.6 Vibrio parahaemolyticus Procedure

The procedure used for the detection of Vibrio parahaemolyticus from clam samples is outlined in Table 11.7. This identification scheme contains the minimal number of media required for the identification of this organism, while still providing for accurate results. It was derived from the FDA Bacteriological Analytical Manual and from Bergey's Manual of Determinate Bacteriology.

In order to obtain quantitative data a three tube MPN method was applied to the Table 11.7 scheme using Horie's broth (Horie et al. 1964). Dilutions were prepared (10 gm, 1.0 gm, 0.1 gm, 0.01 gm, and 0.001 gm) from each clam sample with 0.1% peptone - 1.0% NaCl and each used to inoculate three (3) tubes of modified Horie's broth (15 tubes total per sample). The tubes were incubated at 42 C for 18 hours and then streaked onto TCBS Agar. Typical blue-green colonies were picked to TSI agar and each isolate was then inoculated into the biochemical media listed in scheme Table 11.7. Results were calculated using a MPN table and reported per 100 grams of clam.

Clam Dilutions → Hories Broth → TCBS Agar → TSI Agar → Biochemicals

The pH of Hories broth, after inoculation with shellfish and 12 hours of incubation, was measured at 5.6. This pH is below the growth range (pH 6.0 to 9.0) of Vibrio parahaemolyticus (Buchanan and Gibbons, 1974). To increase this culture pH 10 grams of calcium carbonate was added to each liter of

Table 11.6 Schematic outline of the modified identification scheme for Yersinia enterocolita and like species.

| | Culture Media | Incubation Time | Incubation Temperature | Typical Reaction |
|---|---|---|---|---|
| | PSB | 12-14 days | 26°C | Enrichment |
| | MacConkey's Agar | 2 days | 26°C | Flat, pale pink to colorless |
| | Y-M Agar | 2 days | 26°C | Raised margin, volcanic center, glossy sheen Underside red with narrow margin. Butyrous Sweet odor. |
| First Screen | TSI | 48 hrs | 26°C | A/AO or K/AO- |
| | LAIA | 48 hrs | 26°C | K/AO- |
| | Malonate | 48 hrs | 26°C | - |
| | Lactate | 48 hrs | 26°C | - |
| | Phenylalanine Deamination | 24 hrs | 26°C | - |
| Second Screen | Mannitol | 48 hrs | 26°C | + |
| | Cellobiose | 48 hrs | 26°C | + |
| | Ornithine Decarboxylation | 48 hrs | 26°C | + |
| | Urease | 7 days | 26°C | + - |
| | Sorbitol | 48 hrs | 26°C | + |
| | Oxidase | 15 sec | | - |
| | Catalase | immediate | | + |
| | Gram stain | | | - Rod |
| | Adonitol | 48 hrs | 26°C | - |
| | Inositol | 48 hrs | 26°C | + |
| | Motility | 48 hrs | 25°C | + |
| | | | 35°C | - |
| | Freeze 48 hr TSB culture with 10% glycerol. | | | |
| Third Screen | Indol | 4 days | 26°C | + - |
| | Sucrose | 48 hrs | 26°C | + - |
| | Rhamnose | 7 days | 26°C | + - |
| | Raffinose | 7 days | 26°C | + - |
| | Mellibiose | 7 days | 26°C | + - |
| | Dulcitol | 7 days | 26°C | - |
| | Lecithovitelline Agar | 60 hrs | 26°C | + - |
| | Citrate | 7 days | 26°C | + - |

NOTE: TSI → Discard cultures showing an alkaline butt or $H_2S$.

LAIA → Discard cultures showing an alkaline or tan butt (decarboxylation), or a red band in butt (deamination).

Table 11.7 Schematic outline of the identification scheme for Vibrio parahaemolyticus.

| Culture Media | Incubation Time | Incubation Temperature | Typical Reaction |
|---|---|---|---|
| Hories Broth | 18 hours | 35°C | Enrichment |
| Thiosulfate-Citrate-Bile salts-Sucrose Agar (TCBS) | 18 hours | 35°C | Round, blue-green colonies |
| Triple Sugar Iron Agar | 18-24 hours | 35°C | $^{K}/_{A}$ - - |
| Gram Reaction | None | | Short Gram Negative pleomorphic rod |
| Oxidase Reaction | None | | + |
| Motility | 24 hours | 35°C | + |
| Hugh-Liefson Glucose Broth (HLGB) | 48 hours | 35°C | Oxidation +, no gas, Fermentation +, no gas |
| Arginine Dihydrolase | 4 days | 35°C | - |
| Lysine Decarboxylase | 4 days | 35°C | + |
| Nutrient Gelatin | 1-7 days | 35°C | + rapid |
| Halophilism Salt Trypticase Broth (STB) | 24 hours | 35°C | |
| 0% NaCl | | | - |
| 6% NaCl | | | + |
| 8% NaCl | | | + |
| 10% NaCl | | | - or weak |
| Trypticase Soy Broth (TSB) | 24 hours | 42°C | + |
| Voges-Proskauer (VP | 48 hours | 35°C | - |
| Sucrose Purple Broth | 4-5 days | 35°C | -, + |
| Indol | 24 hours | 35°C | + |
| Mannitol | 4-5 days | 35°C | + |

Hories' broth and the pH adjusted to 9.0 prior to sterilization. This stabilized the pH at a mean of 6.1 with a range from 5.8 (10 gram inoculum) to 6.7 (0.001 gm inoculum) pH units. The adverse effects of the low pH when running shellfish samples has been encountered by other workers and is contributed to glycogen digestion and fermentation, this has not been encountered with water samples.

The incubation temperature for the enrichment broth was decreased from 42 C to 35 C. The combined effect of the above mentioned culture pH (5.6) and the high incubation temperature (42 C) may have been inhibitory to Vibrio parahaemolyticus.

To further define Vibrio isolates, Voges-proskauer (VP), indol, and mannitol biochemical tests were added to the identification scheme. The sucrose reaction was recognized to be variable instead of negative and therefore not definitive between Vibrio parahaemolyticus and Vibrio alginolyticus species. The Voges-proskauer reaction and growth in 10% NaCl are definitive of these species (Weaver 1982).

The 10 gram inoculum used in the enrichment procedure was discontinued due to apparent false negative results with this size of inoculum. Reported results were calculated from 1.0 gm, 0.1 gm, and 0.01 gm dilutions.

The analysis of shellfish samples for Vibrio parahaemolyticus was discontinued during the winter months of January, February, and March due to the organisms' sensitivity to cold. Analysis will continue with warmer weather.

## 11.5 Results and Discussion

Bacteria are continually being introduced into the Puget Sound environment from a myriad of sources. Some of these bacteria are known pathogens to man, while others are non-pathogenic. It is the pathogenic bacteria and closely related indicator organisms that this study is concerned with. A few of the more obvious sources of bacteria being discharged into Puget Sound include: sewage from municipal treatment plants, raw sewage from private sources (septic tank leakage), storm water runoff, raw sewage overflow from treatment plants overloaded with rain water, industrial wastes, and animal wastes.

Table 11.8 is a list of municipal sewage discharge points, from Alki Pt. to Poverty Bay, and the approximate distance to beach sampling sites.

Forty-six water column samples, 67 clam samples, 68 intertidal water samples, and 68 sediment samples have been collected and processed for a total of 249 samples. Bacteriological analysis of the majority of samples has been completed and the results listed in Appendices 11C, 11D, 11E, and 11F.

### 11.5.1 Salmonella

All known Salmonella bacteria are pathogenic for warm-blooded animals and man (EPA 1978). They cause gastroenteritis and acute enteric fevers such as typhoid and paratyphoid fever (Benenson 1975). They are found primarily in the gut of mammals and birds and have a well documented association with fecal contamination. Salmonella is an important pathogen, however its usefulness as an indicator of the presence of animal or human fecal contamination is often limited due to the sporadic occurrence of this organism in the environment. When it is present it is often in low numbers and therefore easily missed when a small sample is collected.

Table 11.8. Municipal sewage discharge. Sewage receives primary treatment prior to discharge. Raw sewage may be discharged during overload periods.

| Sampling beach | Sewage discharge point | Approx. direct./dist. from sampling beach |
|---|---|---|
| Lincoln Park | S.E. Alki Point | NNW 2.3 miles |
| Seahurst Park | Salmon Creek<br>47°29'14" N<br>122°22'04" W | NNW 0.4 mile |
| Normandy Park | Miller Creek<br>47°26'30" N<br>122°21'52" W | W 0.5 mile |
| Covenant Beach | Des Moines | S 0.4 mile |
| Covenant Beach | Redondo | S 3.7 miles |
| Covenant Beach | Lakota | SSW 4.5 miles |
| Seahurst Park | Vashon Sewer<br>47°27'09" N<br>122°26'19" W | WSW 3.4 miles |
| Normandy Park | Vashon Sewer | W 3.4 miles |
| N.E. Vashon Park | Vashon Sewer | SSE 2.9 miles |
| Tramp Harbor | Vashon Sewer | N 2.6 miles |

During the first eight months of this study only two confirmed Salmonella isolates were detected from a total of 182 water column, clam, and intertidal water samples (Table 11.9). These data are similar to those reported by METRO (Hayward et al. 1977 and Munger et al. 1979) in which only two Salmonella pullorium isolates were detected in shellfish on King County beaches.

Since Salmonella is found in sewage sporadically and in small numbers (relative to other indicator bacteria) the dilution of this organism that occurs when it is discharged into the environment often is large enough to make detection difficult. Therefore, indicator bacteria which are found in the gut consistently and in large numbers (fecal coliforms, enterococci, and Clostridium perfringens) are easier to detect and are used as indicators to fecal contamination.

It is important to note that negative Salmonella results (Table 11.9) do not imply the absence of fecal contamination in the environment, but instead imply the absence of Salmonella from the volume of sample actually analyzed. This concept is supported by results which show continual detection of other indicator bacteria (fecal coliforms, enterococci, and Clostridium perfringens) from the same samples which are consistently negative for Salmonella (Appendices 11C, 11D, 11E, and 11F).

### 11.5.2 Fecal Coliform

The fecal coliform bacterial group is a well established indicator of fecal pollution and the possible presence of enteric pathogens (EPA 1978, Train 1979, and Cabelli 1980). Fecal coliforms are found in the intestinal tract of warm-blooded animals and man, in high numbers, and thus are highly associated with fecal pollution. Pathogenic bacteria, viruses, and parasites are excreted in the feces of ill individuals who are carriers (Cabelli 1980, Benenson 1975, and Davis 1973). Fecal coliforms are differentiated from non-

Table 11.9. Salmonella results.

| | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb |
|---|---|---|---|---|---|---|---|---|
| Beach | | | | | | | | |
| Lincoln Park | - | - | - | - | - | - | - | - |
| Seahurst Park | - | - | - | - | - | - | - | - |
| Normandy Park | - | - | - | - | - | - | - | - |
| Des Moines Beach | - | - | - | - | - | - | - | - |
| Vashon Ferry | | + | * | * | * | * | - | * |
| N.E. Vashon Park | - | * | * | * | * | * | + | * |
| Tramp Harbor | - | * | * | * | * | * | - | * |
| Robinson Pt. | - | * | * | * | * | * | * | * |
| Water Column | | | | | | | | |
| Site #4 | - | - | - | - | - | - | - | |
| Site #5 | - | - | - | - | - | - | - | |
| Site #6 | - | - | - | - | - | - | - | |
| Site #7 | - | - | - | - | - | - | - | |
| Site #8 | - | - | - | - | - | - | - | |

*Sampled on a quarterly basis only.

fecal organisms by their ability to grow and ferment lactose with the production of acid and gas at an elevated temperature of 44.5 C. Bacteria from non-fecal sources are usually not able to grow at this temperature while fermenting lactose with the production of acid and gas.

Sewage contaminated water potentially contains all of the pathogens found in sewage. Swimming in these waters or ingesting raw shellfish from the same sewage contaminated water establishes a significant route for infection and resulting gastroenteritis (Ehlers 1965). More serious illnesses (shigellosis, salmonellosis, typhoid, cholera, and infectious hepatitis) have been reported but with a lower frequency (Cabelli 1980). As fecal coliform levels increase in water, the levels of potential pathogens also increase. Detectable health effects may begin to occur when the fecal coliform level of recreational water reaches 400 organisms per 100 ml water (Cabelli 1980).

The U.S. Environmental Protection Agency has established a microbiological guideline for marine recreational water at a fecal coliform limit of 200/100 ml water (Train 1979). This value is not meant as a standard, but as a guideline for the development of standards by state agencies. The Washington State Department of Ecology has developed a standard for class AA and class A marine waters, not to exceed a geometric mean of 14 fecal coliforms per 100 ml water, with not more than 10% of samples exceeding 43 fecal coliforms per 100 ml water (WAC, 1982). The U.S. Food and Drug Administration has established fecal coliform standards, for shellfish at the wholesale level, at an MPN of 230/100 gm meat (APHA, 1965), and for shellfish growing water, at a median of 14/100 ml, with not more than 10% of samples exceeding 43 fecal coliforms per 100 ml water (FDA, 1974).

The fecal coliform levels found in 46 water column samples analyzed to date by this study were low and, with one exception, fell well below the EPA

guideline of 200 fecal coliforms per 100 ml water. The levels found were also within the more stringent DOE standard previously cited. Out of the 46 samples, 4 (8.7%) had fecal coliform levels greater than 14, however, only 3 samples (7.0%) had fecal coliform levels greater than 43. This data is listed in Appendix 11E and in Table 11.10 by average MPN, MPN range, median, and geometric mean values.

Table 11.10. Water Column Fecal Coliform Levels.

| Water Column Station | No. Samples | Average MPN/100 ml | MPN Range/100 ml | MPN Median/100 ml | MPN Geometric Mean/100 ml |
|---|---|---|---|---|---|
| Site #4 | 8 | 14 | <2 - 79 | 2 | 5 |
| Site #5 | 8 | 6 | <2 - 13 | 2 | 4 |
| Site #6 | 8 | 47 | <2 - 330 | 5 | 6 |
| Site #7 | 8 | 9 | <2 - 33 | 4 | 5 |
| Site #8 | 7 | 12 | <2 - 49 | 2 | 5 |
| Site #9 | 4 | 11 | <2 - 13 | 11 | 8 |
| Site #10 | 3 | 9 | <2 - 4 | 4 | 5 |
| | 46 | | | | |

The fecal coliform levels found in water column samples ranged from <2 to 330/100 ml water. They indicate a low level of pollution and are not of significant public health importance. These sampling sites were however, off-shore some distance as shown in Figure 11.1.

The fecal coliform levels found in 66 intertidal water samples to date in this study are listed in Appendix 11D and in Table 11.11 by average MPN, MPN range, median, geometric mean, and density categories.

Table 11.11. Fecal coliform levels in Intertidal water samples.

| Intertidal Water Station | Total Number Samples | Average MPN/100 ml | MPN Median/ 100 ml | MPN Range | MPN Geometric Mean/100 ml | Number of Samples >200 | >400 | >14 | >43 |
|---|---|---|---|---|---|---|---|---|---|
| Lincoln Pk. | 13 | 77 | 20 | 2-540 | 22 | 2 | 1 | 6 | 4 |
| Seahurst Pk. | 18 | 155 | 19 | 5-2300 | 23 | 1 | 1 | 8 | 4 |
| Normandy Pk. | 15 | 168 | 33 | 13-540 | >5 | 5 | 3 | 12 | 7 |
| Des Moines Bch. | 13 | 193 | 130 | <20-790 | 106 | 4 | 2 | 11 | 9 |
| Vashon Bchs. | 4 | 145 | 150 | 49-230 | 126 | 1 | 0 | 4 | 4 |
| Tramp Harbor > Robinson Pt. | 3 | 14 | <20 | <2-<20 | 9 | 0 | 0 | 0 | 0 |
| | 66 | | | | | 13 | 7 | 41 | 28 |

Since the MPN term is a statistical estimate (APHA, 1976), any single result must be interpreted only as an estimate. The single result of 2300/100 ml (Table 11.13), obtained from a Seahurst Park intertidal water sample, has a 95% confidence interval of 700 to 7000 fecal coliforms/100 ml water. In addition to being statistical estimates these values do not differentiate between fecal coliforms from animal and human sources, but are inclusive of both. Fecal coliform levels ranged from <2 to 2300 per 100 ml water. Out of 66 intertidal water samples, 13 (20%) had fecal coliform MPN levels higher than the EPA guideline of 200/100 ml for marine recreational water, and 7 (11%) samples had MPN levels higher than the level of 400/100 ml, at which Cabelli reported detectable health effects may begin to occur for recreational swimmers.

In comparison to the previously cited DOE standard for class AA and class A marine water, and the FDA standard for shellfish growing water; 41 intertidal water samples (62%) had fecal coliform levels greater than 14/100 ml with 28 of these samples (42%) containing fecal coliform levels greater than 43/100 ml. With the exception of the results from Tramp Harbor and

Robinson Point beaches, these values represent a low but significant level of fecal pollution in the intertidal area. Monthly averages of these MPN fecal coliform levels are shown by bar graphs for Lincoln, Seahurst, and Normandy parks and for Des Moines (Covenant) beach in Figures 11.7, 11.8, 11.9, and 11.10, respectively.

Data available from intertidal water samples (Appendix 11D), indicate Lincoln Park and Seahurst Park to have slightly lower fecal coliform levels than do Normandy Park and Des Moines beach. These levels are compared in Table 11.13 by monthly sample results and by the calculation of the mean, median, and geometric mean fecal coliform results for each beach; however, additional data is necessary to confirm this and further characterize these beaches.

The fecal coliform levels found in 68 shellfish samples to date by this study are listed in Appendix 11C and Table 11.12 by average MPN, MPN range, median, and number of samples having a density >230 fecal coliforms per 100 grams of meat.

Table 11.12. Shellfish fecal coliform levels.

| Intertidal Water Stations | Total No. Samples | Average MPN/100 gm | MPN Range | No. Samples Results >230 | Median |
|---|---|---|---|---|---|
| Lincoln Pk. | 13 | 693 | 20-4900 | 7 | 330 |
| Seahurst Pk. | 18 | 5493 | 50-92,000 | 9 | 280 |
| Normandy Pk. | 16 | 680 | 50-2300 | 11 | 395 |
| Des Moines Bch. | 14 | 846 | 40-4600 | 7 | 395 |
| Vashon Bchs. | 4 | 440 | 50-1300 | 2 | 205 |
| Tramp Harbor > Robinson Pt. | 3 | 170 | 50-230 | 0 | 230 |
| | 68 | | | 36 | |

Fecal coliform levels found in shellfish ranged from 20 to 92,000 per 100 grams meat. Out of 68 shellfish samples 36 (53%) had fecal coliform MPN

Table 11.13. Comparison of fecal coliform levels found in intertidal waters (MPN/100 ml water).

| | Lincoln Park | Seahurst Park | Normandy Park | Des Moines Beach |
|---|---|---|---|---|
| July | < 20 | < 20 | < 20 | 20 |
| | < 20 | 20 | < 20 | |
| August | 50 | 20 | 170 | < 20 |
| | 7 | < 20 | 13 | |
| | 7 | 8 | 170 | |
| | | 17 | | |
| September | 49 | 2,300 | 140 | < 20 |
| | | 5 | | |
| October | 540 | 130 | 540 | 130 |
| | | 79 | 33 | 130 |
| November | 2 | 5 | 17 | 180 |
| | 240 | 13 | 23 | 130 |
| December | 11 | 79 | 330 | 230 |
| | 23 | 11 | | 220 |
| January | 22 | 13 | 33 | 110 |
| | | 13 | 33 | 33 |
| February | 5 | 8 | 490 | 790 |
| | | 23 | 490 | 490 |
| Total | 976 | 2,764 | 2,502 | 2,483 |
| Average per sample | 75 | 154 | 167 | 191 |
| Median | 20 | 18 | 33 | 130 |
| Geometric mean | 22 | 16 | 75 | 106 |

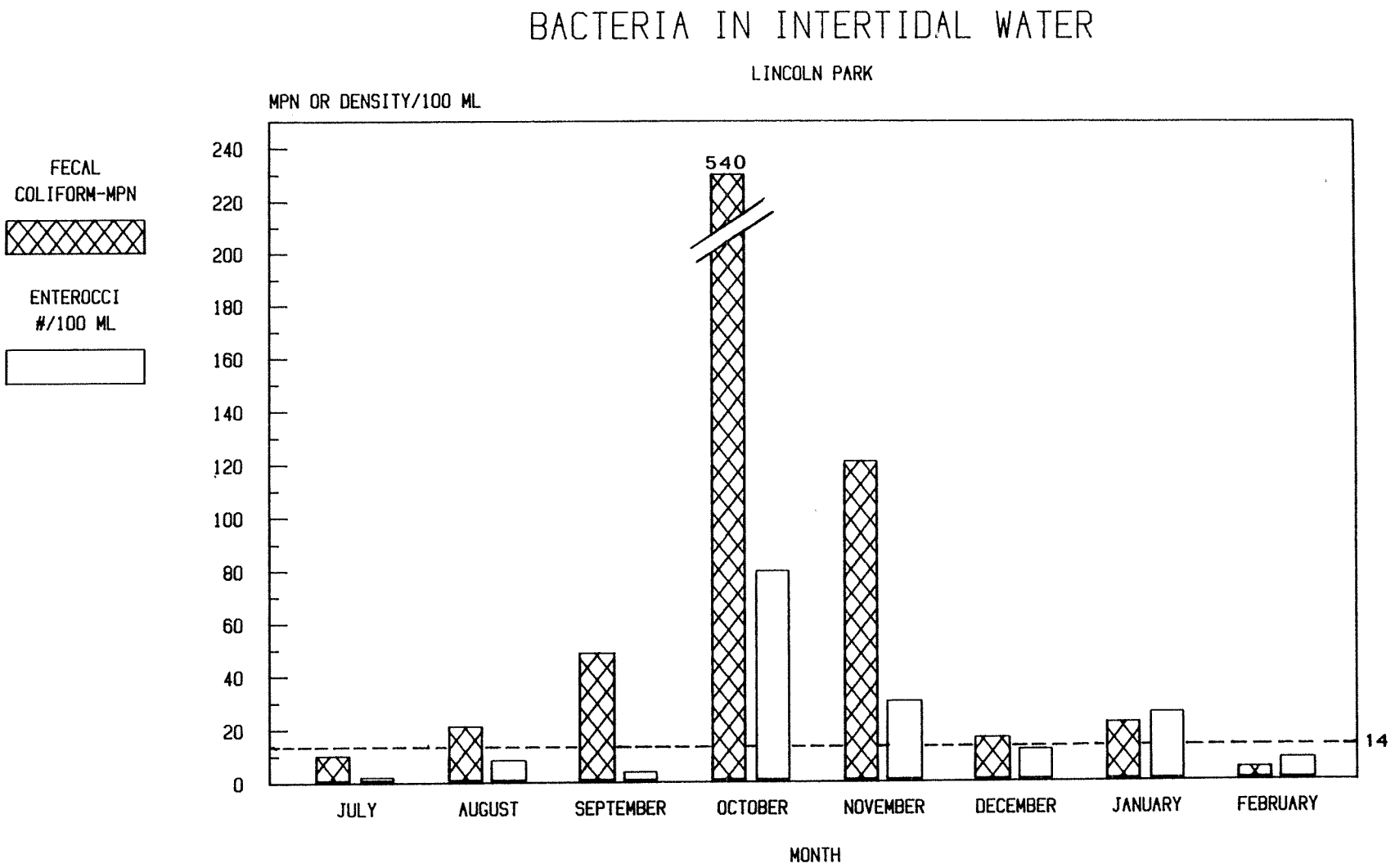



Figure 11.7 Lincoln Park intertidal water fecal coliform most probable number (MPN) levels compared to FDA shellfish growing water standard : maximum 14 fecal coliforms per 100 ml water

AND

Lincoln Park intertidal water enterococci levels per 100 ml water.

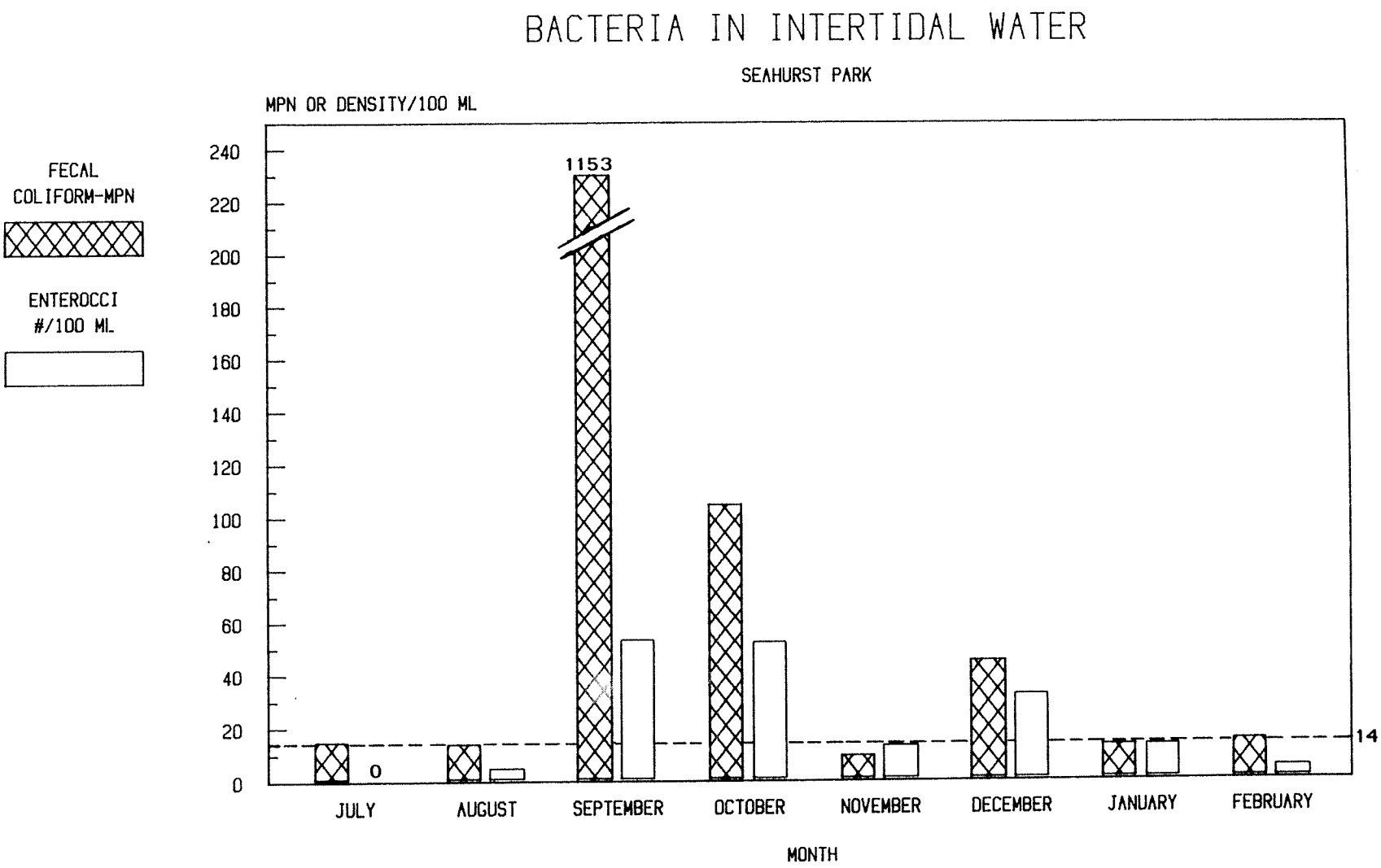



Figure 11.8 Seahurst intertidal water fecal coliform most probable number (MPN) levels compared to standard : maximum 14 fecal coliforms per 100 ml water

AND

Lincoln Park intertidal water enterococci levels per 100 ml water.

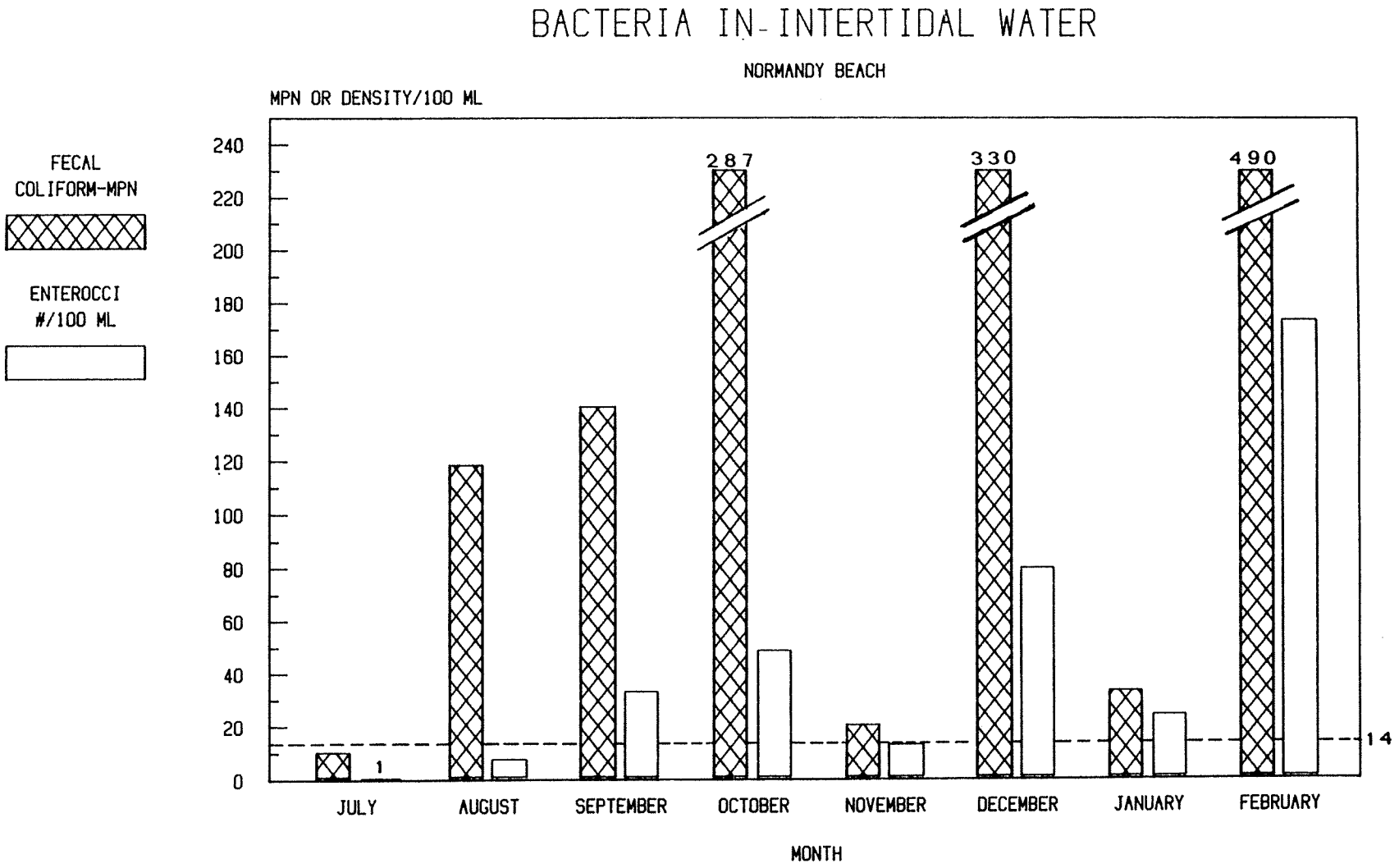



Figure 11.9. Normandy Beach intertidal water fecal coliform most probable number (MPN) levels compared to FDA shellfish growing water standard: maximum 14 fecal coliforms per 100 ml water and Normandy Beach intertidal water enterococci levels per 100 ml water.

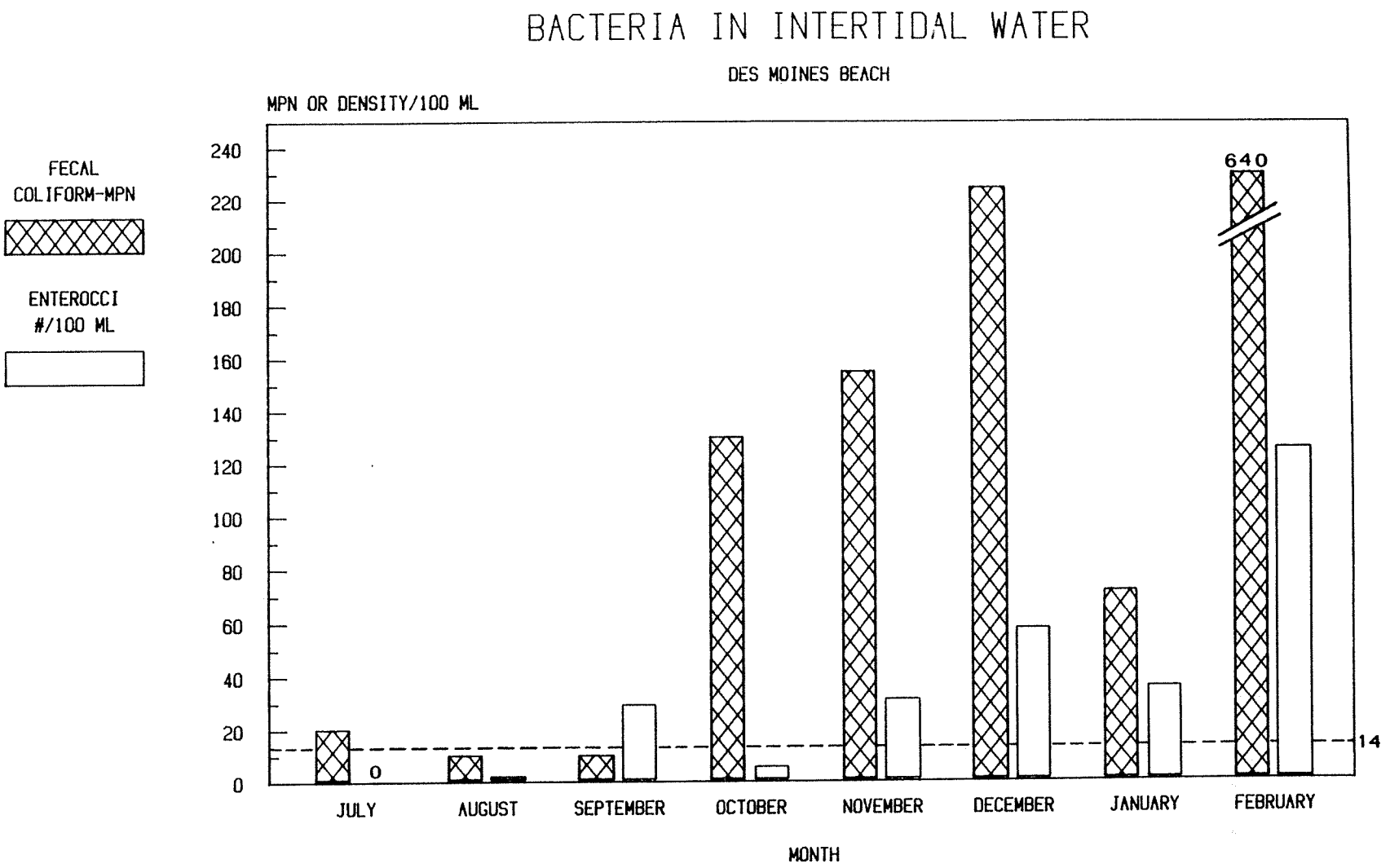



Figure 11.10. Des Moines intertidal water fecal coliform most probable number (MPN) levels compared to FDA shellfish growing water standard: maximum 14 fecal coliforms per 100 ml water and Des Moines intertidal water enterococci levels per 100 ml water.

levels higher than the FDA standard of a maximum of 230 fecal coliforms per 100 grams meat at the shellfish wholesale level. These high fecal coliform levels are of public health significance to individuals consuming raw shellfish. Under these conditions a significant route for infection and resulting gastroenteritis could be established. Monthly averages of MPN fecal coliform levels are shown by bar graphs for Lincoln, Seahurst, and Normandy parks and for Des Moines (Covenant) beach in Figures 11.11, 11.12, 11.13, and 11.14, respectively.

11.5.3 Enterococci

Bacteria belonging to the enterococ i group are used as indicators of fecal pollution. They are found in the intestinal tract of warm-blooded animals and man, and when found in the environment indicate fecal contamination and the potential presence of pathogenic bacteria and viruses. They are present in lower numbers in the intestinal tract than are fecal coliforms but have the advantages of dieing off more slowly than fecal coliforms and not normally multiplying in water (Skinner 1978). Under the adverse conditions of sewage treatment and the marine environment enterococci survival characteristics more closely resemble the survival characteristics of pathogens (Cabelli 1980).

A health effects criteria, using enterococci as the indicator system, was developed by the EPA for marine recreational waters and reported by Cabelli (1980). This criteria relates swimming associated gastrointestinal symptoms to the mean enterococcus density. It is represented by Figure 11.15 and will be used to interpret enterococci data from this study. The graph has a coefficient of correlation (r) of 0.75. This coefficient is used to measure the degree of association between two variables; such as gastrointestinal symptoms and enterococcus density. If r were to equal +1 it would indicate a

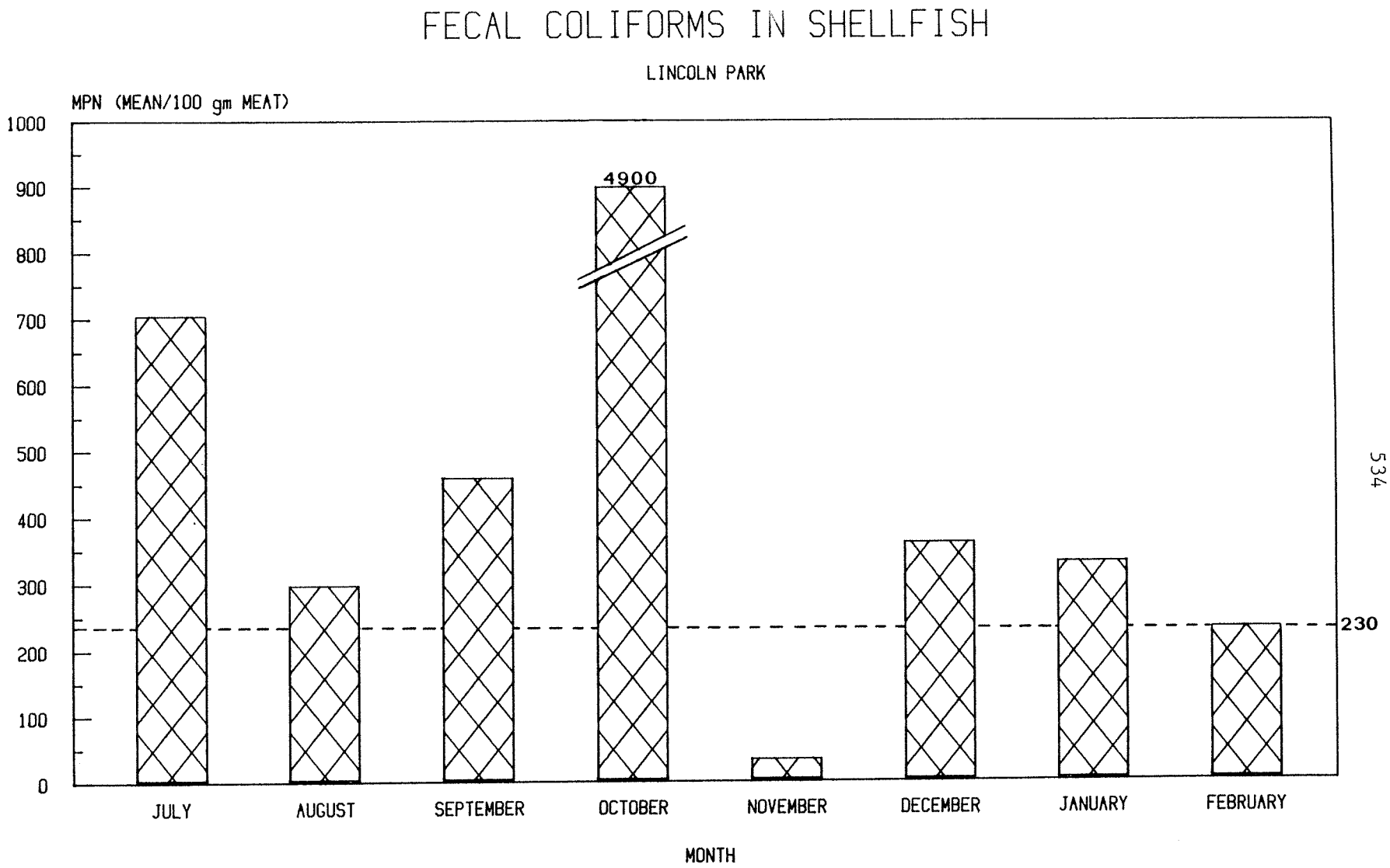



Figure 11.11. Lincoln Park shellfish fecal coliform most probable number (MPN) levels compared to FDA wholesale shellfish standard: maximum 230 fecal coliforms per 100 grams meat.

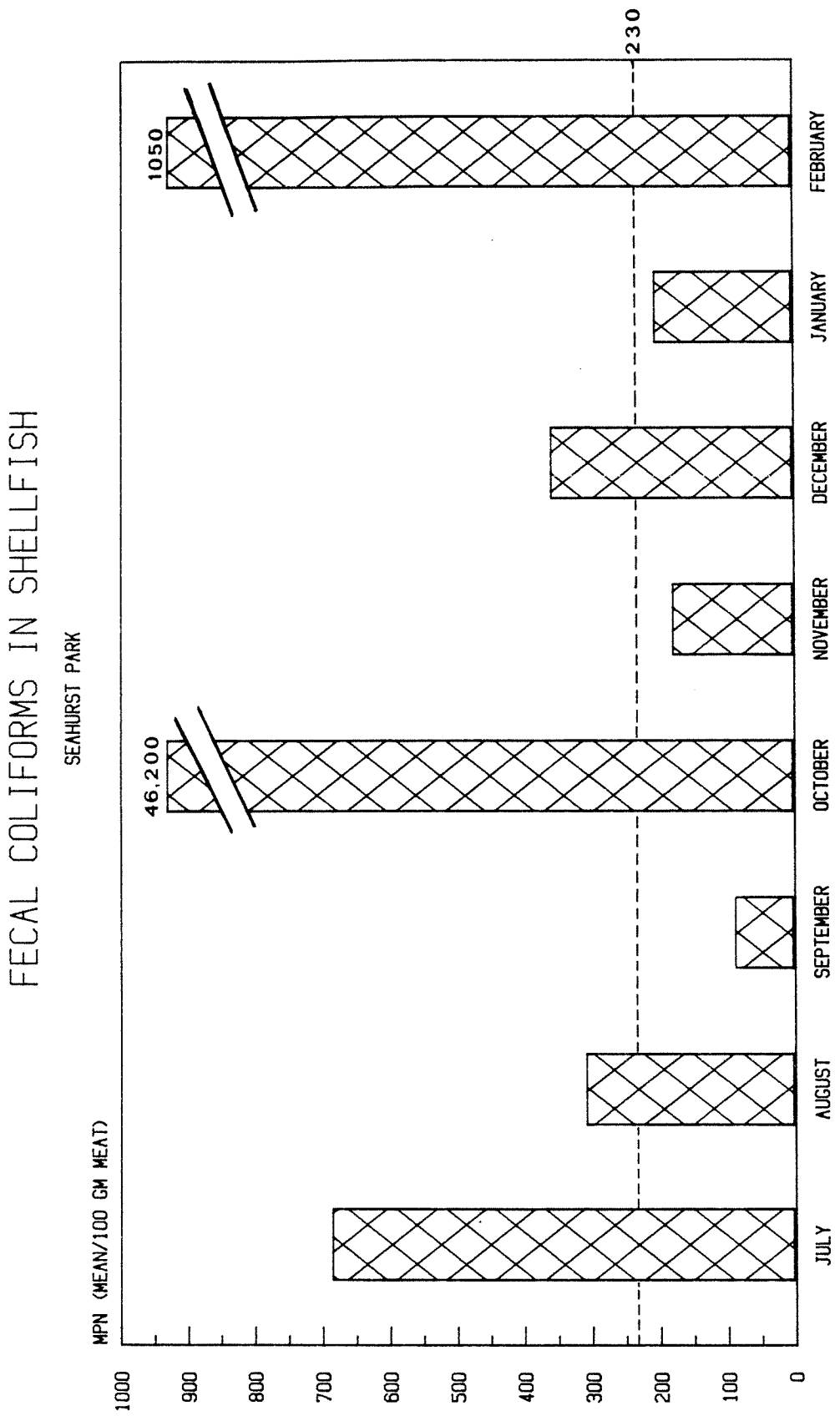



Figure 11.12. Seahurst Park shellfish fecal coliform most probable number (MPN) levels compared to FDA wholesale shellfish standard: maximum 230 fecal coliforms per 100 grams meat.

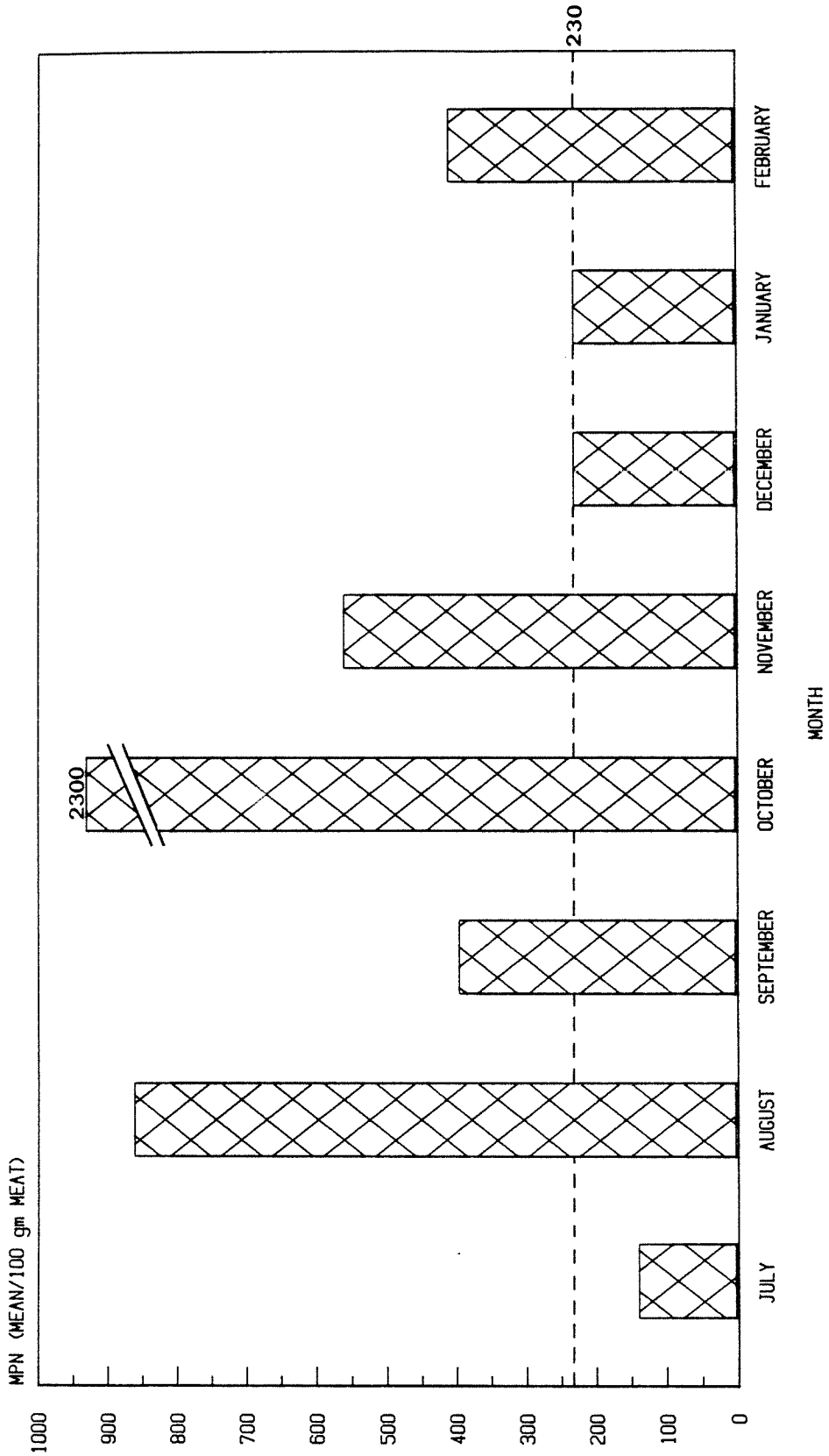



Figure 11.13. Normandy Beach shellfish fecal coliform most probable number (MPN) levels compared to FDA wholesale shellfish standard: maximum 230 fecal coliforms per 100 grams meat.

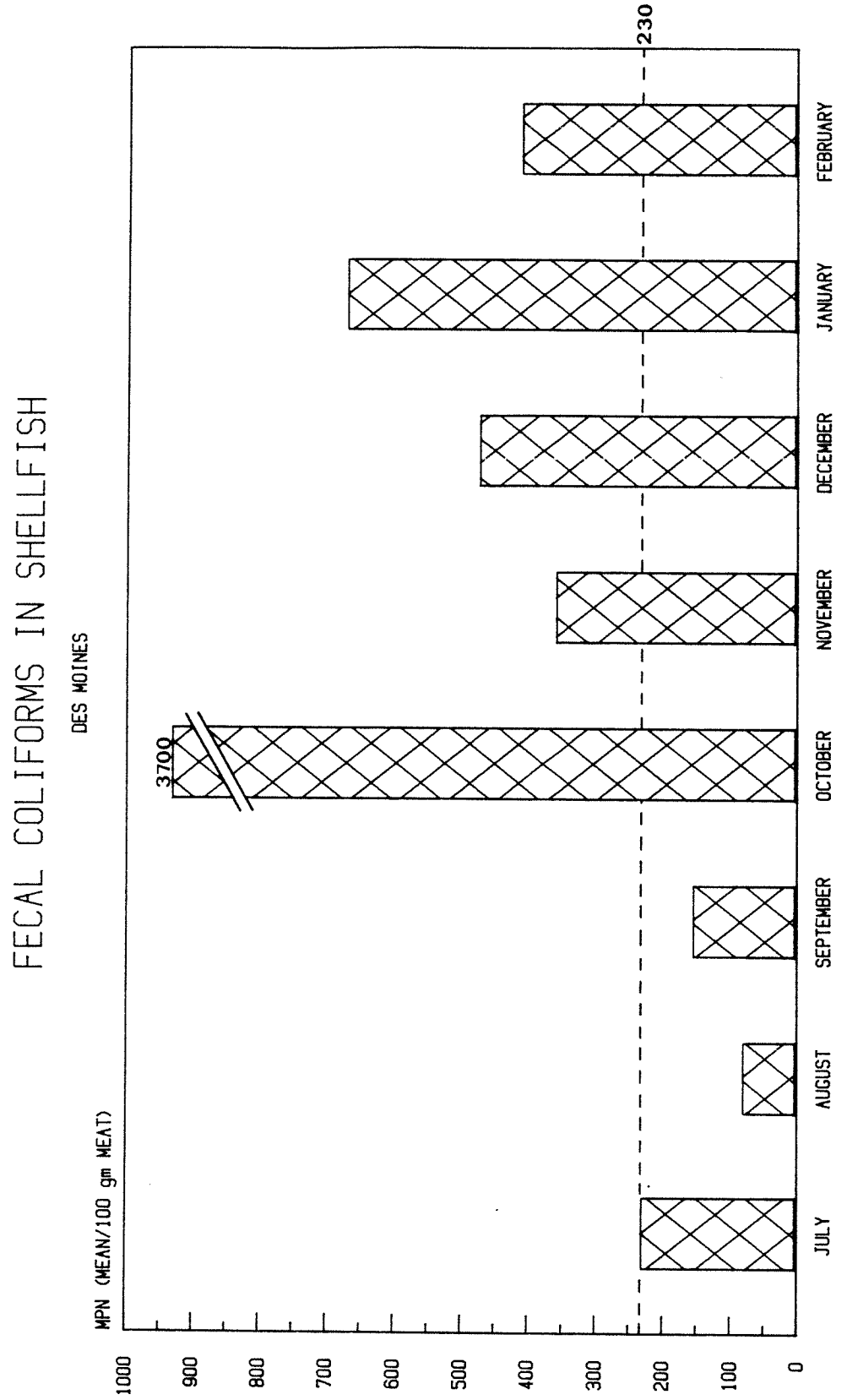



Figure 11.14. Des Moines shellfish fecal coliform most probable number (MPN) levels compared to FDA wholesale shellfish standard: maximum 230 fecal coliforms per 100 grams meat.

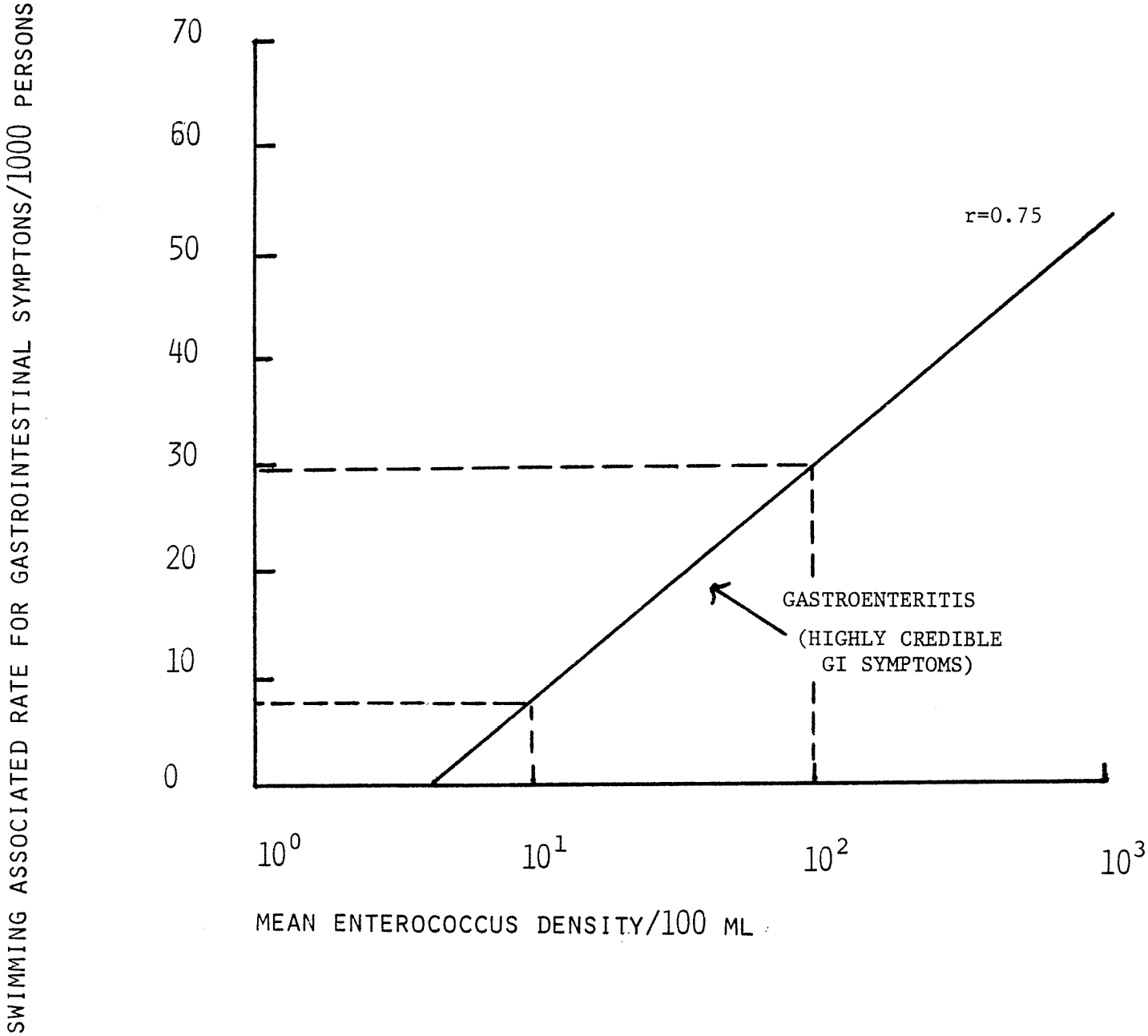



Figure 11.15. Recommended health effects criterion for marine recreation waters. (U.S. Environmental Protection Agency, Cabelli 1980).

Note: Cabelli reported the rate for highly credible gastrointestinal symptoms among swimmers to be twice that of non-swimmers when the enterococcus density reached 10 per 100 ml water.

direct linear relationship, and if r were to equal 0 it would indicate no linear relationship. Therefore, a coefficient of correlation value of 0.75 indicates a significant relationship between G.I. symptoms and enterococcus density.

The enterococcus levels found in 66 intertidal water samples to date by this study are listed in Appendix 11D and Table 11.14 by average counts per 100 ml water, range values, and density categories.

Table 11.14. Enterococci levels in Intertidal Water.

| Intertidal Water Beaches | Total Number Samples | Average Count/100 ml | Range | Density ≥10 | Density ≥100 |
|---|---|---|---|---|---|
| Lincoln Pk. | 13 | 17 | 0->80 | 5 | 1 |
| Seahurst Pk. | 18 | 18 | 0->80 | 10 | 2 |
| Normandy Pk. | 15 | 43 | 0-182 | 9 | 4 |
| Des Moines Bch. | 13 | 42 | 0-129 | 10 | 2 |
| Vashon Bchs. | 4 | 25 | 5-64 | 3 | 0 |
| Tramp Harbor / Robinson Pt. | 3 | 2 | 0-5 | 0 | 0 |
| | 66 | | | 37 | 9 |

Enterococci levels ranged from 0 to 182 per 100 ml water. Out of 66 intertidal water samples 37 (56%) had enterococci counts higher than 10 per 100 ml. Cabelli reported that at enterococcus densities of 10 per 100 ml of marine water, the rate of highly credible gastrointestinal symptoms among swimmers was twice that of non-swimmers, or approximately eight cases per 1000 people (Figure 11.5). When the enterococcus density reaches 100 enterococci per 100 ml water the rate of G.I. symptoms among swimmers increases to seven times that of non-swimmers, or approximately 29 cases per 1000 people.

Out of the 66 intertidal water samples from this study, approximately 9 (14%) had enteroccocci counts greater than 100 per 100 ml water (Table 11.14). These values represent a low, but significant level of fecal pollution in the

intertidal area. Additional data is necessary to further characterize these beaches.

Monthly averages of the enterococcus density found in intertidal water are shown by bar graphs for Lincoln, Seahurst, and Normandy parks and for Des Moines (Covenant) beach in Figures 11.7, 11.8, 11.9, and 11.10.

11.5.4 Clostridium perfringens

Clostridium perfringens is considered to be the most widely spread pathogen and is ubiquitous in low numbers. It is responsible for food poisoning and gas gangrene. The presence of this organism in high numbers indicates contamination by sewage or fecal material. Clostridium perfringens produces very stable endospores which can survive in the environment for long periods of time. In our studies (St. John and Matches 1982 and Matches et al. 1974) we found the organism to be present in environmental samples as the endospore rather than the less resistant vegetative cell. This has been reported by Smith and Holdeman 1968 and Smith 1972.

Clostridium perfringens spores can reach fish and shellfish in their water habitat (particularly near sewage outfalls) (Bryan, 1980). Also the numbers of C. perfringens are higher in sediments and fish gut contents near sewer outfalls and diminish as the distance from the outfall or source of pollution increases (Matches et al. 1974).

In these studies the data for each of the seven sampling areas were calculated by the MPN procedure and are shown in Appendix 11F and Table 11.15 as numbers of C. perfringens per gram of sediment.

Table 11.15. Clostridium perfringens Levels in Sediment.

| Station | No. Samples | Ave. count/g | Range/g | MPN Median | MPN Geometric Mean |
|---|---|---|---|---|---|
| Lincoln Park | 12 | 85 | 2.3 - 750 | 15 | 19 |
| Normandy Beach | 16 | 67 | 4.3 - 240 | 23 | 32 |
| Seahurst | 18 | 42 | 1.1 - 240 | 24 | 23 |
| Tramp Harbor | 2 | 14 | 4.3 - 23 | 14 | 10 |
| Point Robinson | 1 | 1100 | -- | -- | -- |
| Des Moines | 14 | 85 | 4.3 - 430 | 34 | 41 |
| Vashon | 4 | 20 | 4.3 - 4.6 | 14 | 12 |

Monthly mean MPN values are shown in Figures 11.16, 11.17, 11.18 and 11.19 for Lincoln Park, Seahurst Park, Normandy Park, and Des Moines, respectively. The numbers of C. perfringens in sediments in this study range from a low of 1.1 to a maximum of 750/gram of sediment. One other sample collected from Point Robinson was higher with 1100/gram. However, only one sample was collected from this station.

The average levels of C. perfringens in the 66 sediment samples analyzed to date in this study are low and do not indicate high levels of pollution. These data are therefore very useful as baseline levels of C. perfringens and will also be measured in clams which are filter feeders and concentrate bacteria present in water. These data from both clams and sediments will be the base with which to make comparisons in the future.

11.5.5 Yersinia enterocolitica

Contract terms specified that the presence or absence of Yersinia enterocolitica be determined in water column samples. It also specified that the presence or absence of either Yersinia enterocolitica or Vibrio parahaemolyticus be determined in shellfish samples. In addition to meeting the above contract terms, we elected to analyze shellfish samples for Yersinia while Vibrio analysis was being carried out (July thru December), and to apply an MPN procedure to the Yersinia method so as to be able to provide

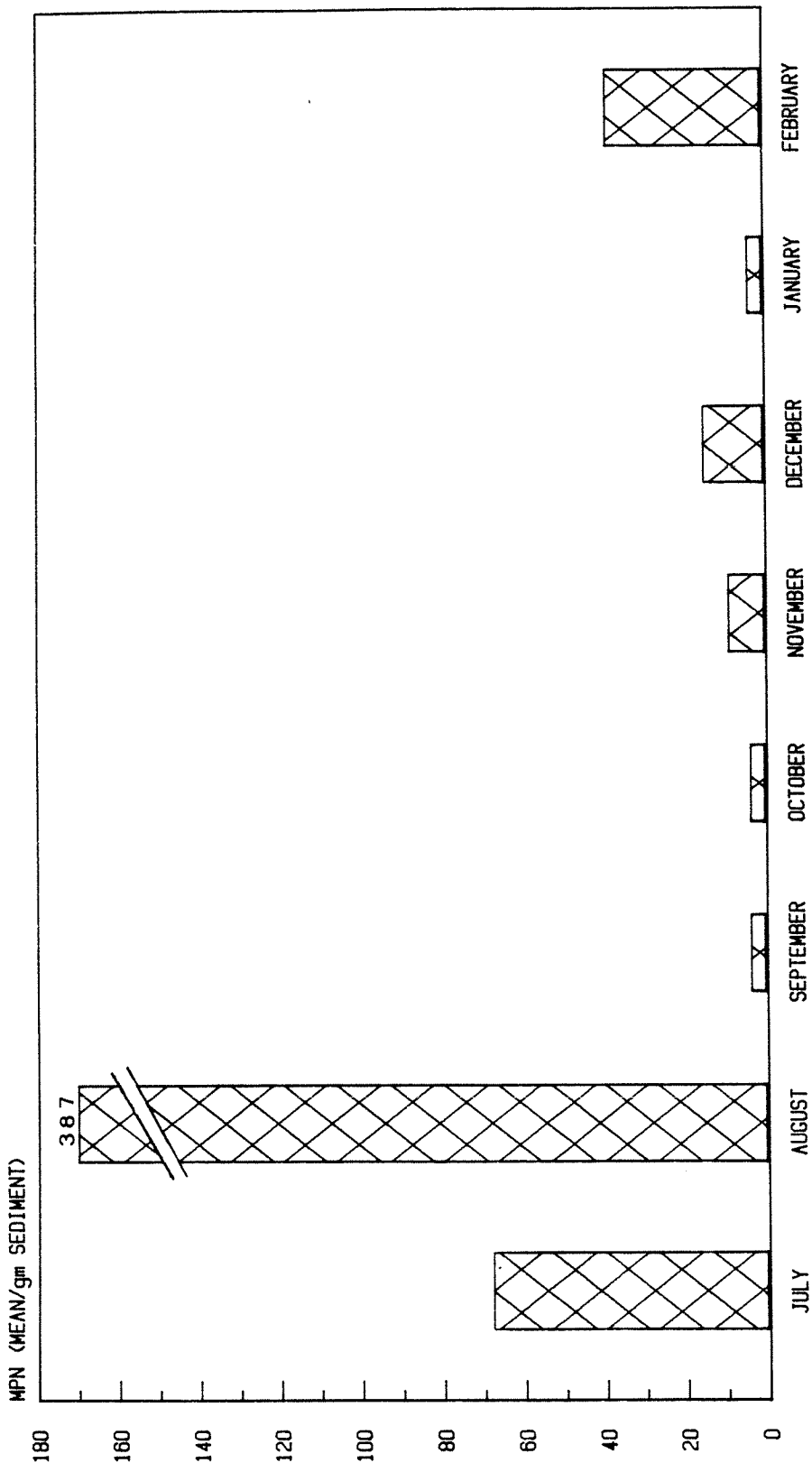



Figure 11.16. Lincoln Park most probable number (MPN) levels of Clostridium perfringens found in intertidal sediment.

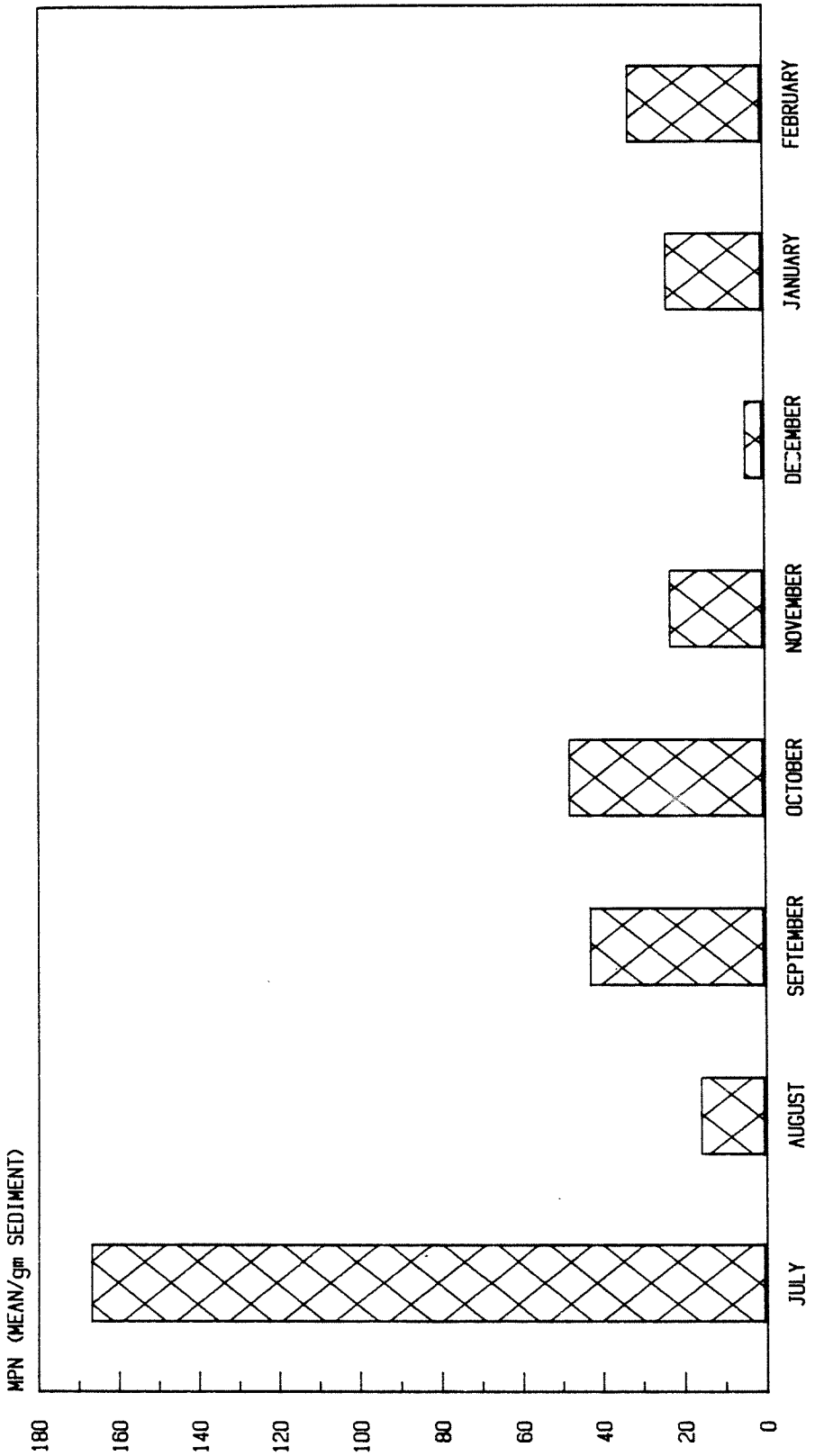



Figure 11.17. Seahurst Park most probable number (MPN) levels of Clostridium perfringens found in intertidal sediment.

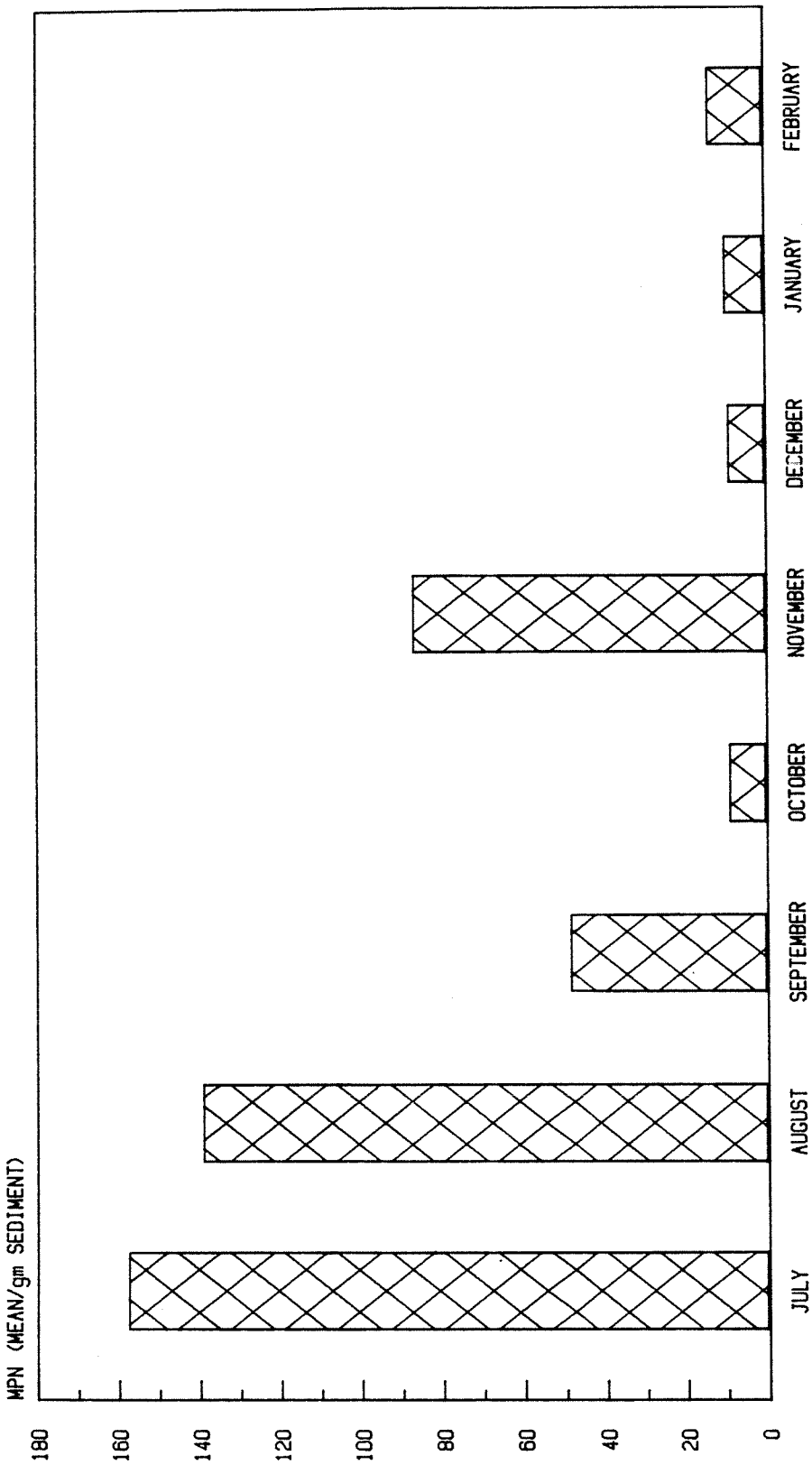



Figure 11.18. Normandy Park most probable number (MPN) levels of Clostridium perfringens found in intertidal sediment.

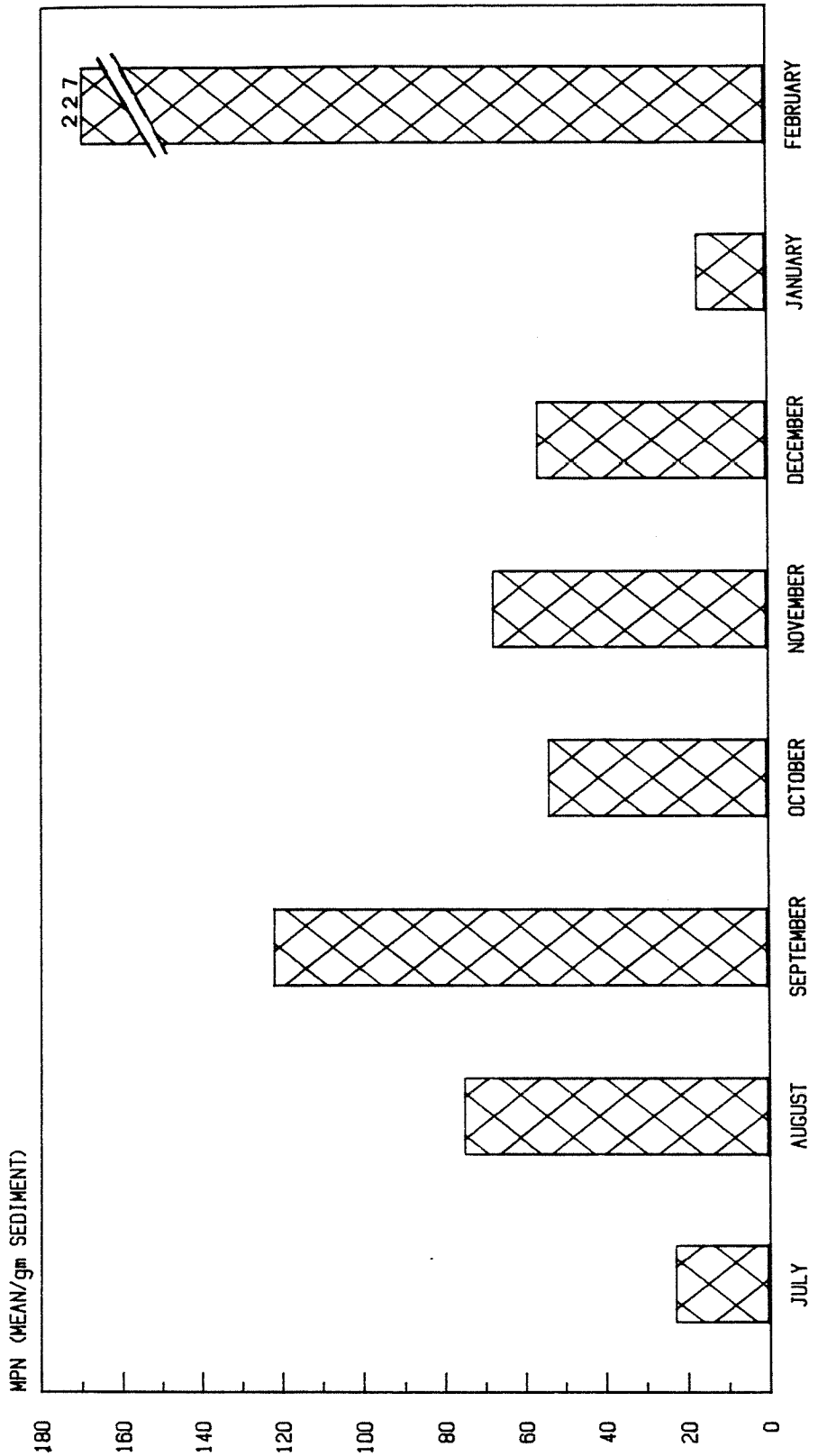



Figure 11.19. Des Moines most probable number (MPN) levels of Clostridium perfringens found in intertidal sediment.

quantitative data instead of qualitative data.

When we began the study we recognized Yersinia enterocolitica as having variable rhamnose, melibiose, raffinose, sucrose, and Voges-Proskauer biochemical reactions. Yersinia enterocolitica has since been reclassified into four species; Yersinia enterocolitica sensu stricto, Yersinia intermedia, Yersinia kristensenii and Yersinia frederiksenni (Kay 1982). The four species are characterized by the biochemical reactions listed in Table 11.16. This reclassification is of importance to note because only Yersinia enterocolitica sensu stricto is known to be of public health significance when found in the environment (Kay 1982). Yersinia enterocolitica sensu stricto was isolated from the sampling sites shown on Table 11.17. It is a human pathogen which is known to cause gastroenteritis and a variety of other infections. It is clinically significant as a human pathogen and is often found in sewage. Yersinia intermedia, Yersinia kristensenii and Yersinia frederiksenii are also found in sewage but are primarily associated with animal and environmental origins (Kay 1982, Hawkins 1978, Saari 1979, and Shayegani 1981). The clinical and epidemiological significance of the three new species is uncertain at present and Yersinia enterocolitica sensu stricto alone is recognized as the significant human pathogen (Kay 1982).

An organism that is to be used as an indicator system for sewage pollution should possess characteristics similar to those of the pathogenic organisms found in sewage (Train 1979). The indicator organism should not grow in the environment, but should remain alive in the environment for about the same duration that pathogenic organisms remain alive. Additionally, the indicator organisms should originate exclusively from fecal sources of warm blooded animals.

Yersinia enterocolitica and Yersinia enterocolitica-like species are

Table 11.16. Biochemical reactions characterizing the new Yersinia species.

| | Yersinia intermedia | Yersinia frederiksenii | Yersinia kristensenii | Yersinia enterocolitica (Wauters biotypes) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 |
| Voges-Proskauer | + | + | - | + | + | V | + | + |
| Sucrose | + | + | - | + | + | + | + | V |
| L-Rhamnose | + | + | - | - | - | - | - | - |
| Melibiose | + | - | - | - | - | - | - | - |
| Raffinose | + | - | - | - | - | - | - | - |

Table 11.17. Isolation of Yersinia enterocolitica sensu stricto from collection sites (Y. enterocolitica is sensitive to warm temperatures and is able to grow at 4°C; therefore, it is found in lower numbers in Puget Sound during the warmer months).

| Sampling station | Jul | Aug | Sep | Oct | Nov | Dec | Jan |
|---|---|---|---|---|---|---|---|
| Beach | | | | | | | |
| Lincoln Pk. low | - | - | - | - | - | - | + |
| Lincoln Pk. high | - | - | - | - | - | - | NO SAMPLE |
| Seahurst Pk. N. | - | - | - | + | - | - | - |
| Seahurst Pk. S. | - | - | - | - | - | - | + |
| Normandy Pk. low | - | - | - | - | + | - | + |
| Normandy Pk. high | - | - | - | - | + | NO SAMPLE | + |
| Des Moines Bch. low | - | - | - | - | + | + | + |
| Des Moines Bch. high | - | - | - | + | + | + | + |
| Vashon Ferry Bch. | - | | | | | | + |
| N.E. Vashon Pk | - | | | | | | + |
| Tramp Harbor | - | | | | | | + |
| Robinson Point | - | | | | | | NO SAMPLE |
| Water Column | | | | | | | |
| Site #4 | - | - | - | - | - | + | - |
| Site #5 | - | - | - | - | - | - | - |
| Site #6 | - | - | - | - | - | - | + |
| Site #7 | - | - | - | - | - | - | - |
| Site #8 | - | - | - | - | - | - | - |

reported to have been found in Puget Sound in low numbers during warm months and in higher numbers as the environment became colder during the winter months (Kaysner and Weagant, 1981). The MPN values (found by this study) for Yersinia enterocolitica and like species are similar in that Yersinia levels were non-detectable during July, August, and September; but as the environment became colder, Yersinia enterocolitica was detected in increasing numbers from October thru January (to date) as indicated by Figure 11.20.

Unpublished results generated by a local hospital laboratory from the bacteriological analysis of 7530 clinical fecal samples, over a period of 25 months, show the incidence of Yersinia to be relatively constant (120 positive samples) and to be significantly lower than the incidence of Salmonella (1320 positive samples). Environmental levels of these organisms has been found to be just the opposite, in that the ratio of Yersinia to Salmonella found in clinical fecal samples (<1) is inverse of the ratio between the same organisms (>>1) found in the Puget Sound environment by this study. This comparison indicates that Yersinia is, presumably, growing in the environment.

Additionally, a comparison of incubation temperatures (8° and 22° C), used in the enrichment procedure to recover Yersinia enterocolitica from shellfish, gave higher MPN results for 41% of the samples when incubated at 8° C, while 14% of the samples gave higher results when incubated at 22° C, and 45% of the samples gave equivalent results. Presumably, Yersinia is more often able to compete effectively and outgrow other marine bacteria at 8° C, than at 22° C.

An in vitro survival study has shown Yersinia enterocolitica sensu stricto to grow in saltwater with limited nutrients. Yersinia enterocolitica sensu stricto was inoculated into sterile saltwater and incubated at 8° C for 31 days; significant growth was observed. The initial Yersinia level,

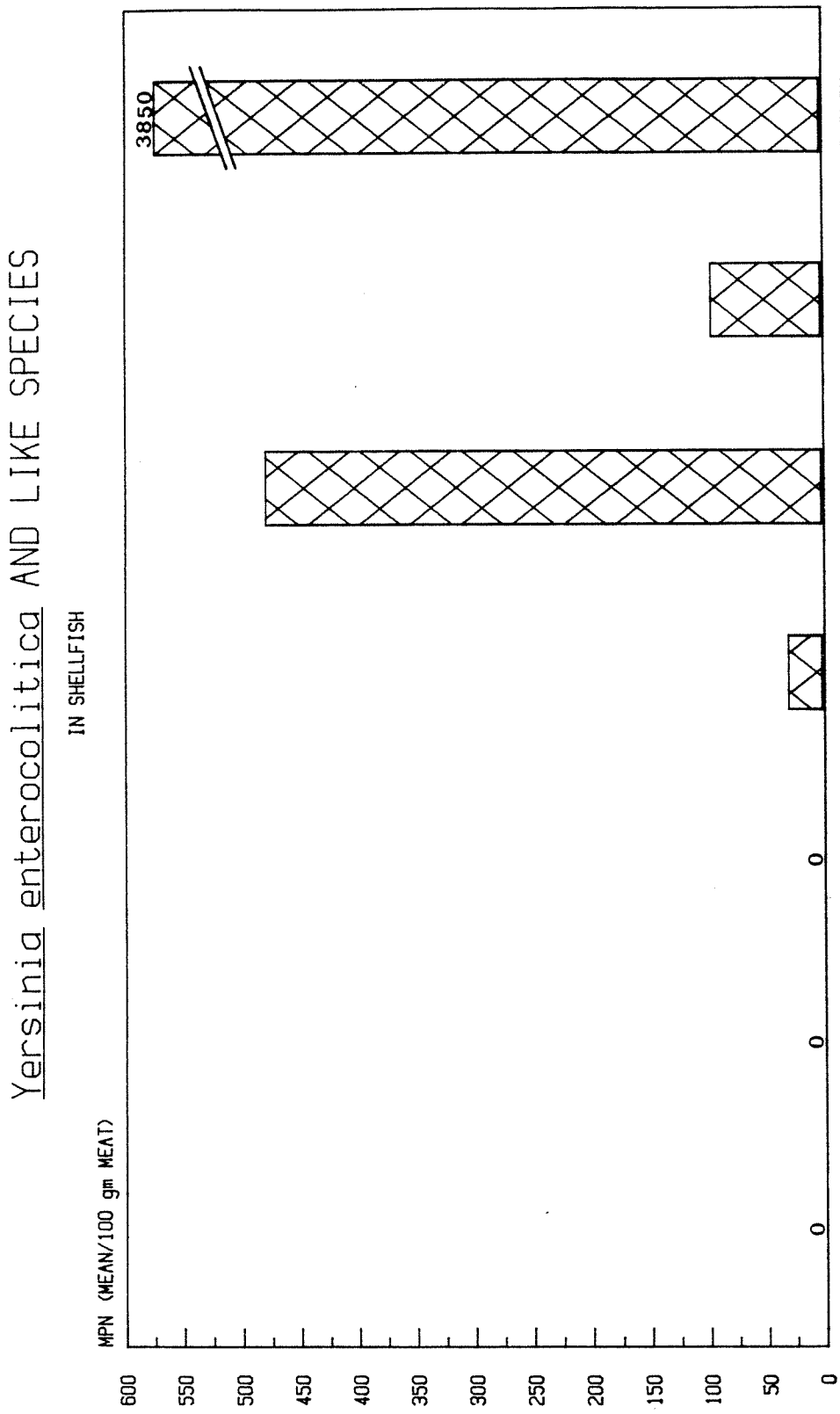



Figure 11.20. Mean most probable number (MPN) levels of Yersinia enterocolitica and like species found in shellfish.

immediately following inoculation was shown by plate count to be less than 1/ml of saltwater. The concentration of peptone added to the saltwater with the inoculum was calculated to be 0.0000013 grams per ml. Following 31 days of incubation at 8° C the Yersinia level was determined by plate count to be 160,000 per ml of saltwater.

The MPN results listed in Appendices 11C and 11E for "Yersinia enterocolitica and Yersinia enterocolitica like species" were calculated from the combined results of all four mentioned Yersinia species. Due to the presumptive ability of Yersinia species to grow in the environment at cold temperatures (based on in vitro survival studies) and the well documented ubiquitous nature of these organisms they are of questionable use as an indicating system for fecal pollution. Accordingly, the MPN values for Yersinia enterocolitica and Yersinia enterocolitica-like species should be interpreted as representative of environmental organisms only and without a discernable relationship to sewage pollution.

During the months of July, August, and September, MacConkey plates streaked from enrichment broths (PSB) for the isolation of Yersinia enterocolitica were consistently negative for Yersinia enterocolitica. Many of the plates were re-streaked with the same results. Laboratory personnel were trained by Steve Weagant, FDA Microbiologist, in the recognition of Yersinia species on MacConkey's agar. Training occurred in July, using the first samples and Yersinia enterocolitica controls, and consultation has continued to date. During the months of July, August, and September, the environment was warm and the levels of Yersinia were accordingly low. Table 11.18 shows the average number of colonies picked per sample to increase as the environment cooled off. In all months, the number of colonies picked from culture plates were in excess of the number of colonies required to represent

Table 11.18. Average number of Yersinia colonies picked per sample.

| Time period | Number samples analyzed | Number colonies picked | Average number colonies picked per sample | Number of samples that Yersinia was isolated from | Result range |
|---|---|---|---|---|---|
| Jul-Sep | 50 | 386 | 8 | 0 | < 30 |
| Oct | 17 | 388 | 23 | 2 | < 30-30 |
| Nov | 9 | 384 | 43 | 7 | < 30-2,400 |
| Dec | 12 | 362 | 30 | 8 | < 30-230 |
| Jan | 15 | 809 | 54 | 11 | 40-11,000 |

the individual plates.

In November, a second agar (Y-M) was added to the plating procedure for Yersinia. Y-M agar did not significantly increase the sample yield of Yersinia enterocolitica and like species.

The results obtained by this study for Yersinia enterocolitica and like species are realistic and valid. It is of interest to note that none of the Yersinia isolates would have been eliminated by the presumptive identification scheme (Table 11.5) and that all of the current Yersinia enterocolitica and Yersinia enterocolitica-like isolates identified from the modified scheme (Table 11.6) were urease positive and non-motile at 35 C.

11.5.6 Vibrio parahaemolyticus

Vibrio parahaemolyticus is a bacterium which is of marine origin and is found naturally in the marine environment. This organism is not used as an indicator of fecal pollution but instead is recognized as a pathogen to fish, molluscs, crustaceans, and humans. In humans, it is a food poisoning agent which causes gastroenteritis. Transmission of Vibrio parahaemolyticus, to humans, occurs by the consumption of raw or inadequately cooked seafood which is contaminated with the organism (Benenson 1975 and Bryan 1980).

When sewage is discharged into water the nutrient load in the water increases. As this happens the numbers of Vibrio parahaemolyticus have been shown to increase in the environment (Cabelli 1980). Shellfish are filter feeders and serve to concentrate this organism further.

The Vibrio parahaemolyticus levels found in shellfish samples to date in this study are listed in Appendix 11C, and Table 11.19. Vibrio parahaemolyticus was isolated during the months of September, October, and November. Samples collected during the months of July, August, and December were negative. Analysis for Vibrio parahaemolyticus was discontinued

Table 11.19. *Vibrio parahaemolyticus* results from shellfish samples.

| Sampling station | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|
| Lincoln Pk. low | - | - | - | - | - | - |
| Lincoln Pk. high | - | - | | | - | - |
| Seahurst Pk. North | - | - | - | - | - | - |
| Seahurst Pk. South | - | - | - | + | - | - |
| Normandy Pk. low | - | - | - | - | - | - |
| Normandy Pk. high | - | - | - | - | - | |
| Des Moines Bch. low | - | - | + | + | - | - |
| Des Moines Bch. high | | | + | - | + | - |

following the December samples because the organism is sensitive to cold and often occurs in numbers too low to detect during the winter months. Analysis will continue in April.

This baseline data will be useful to compare to data collected after sewage is being discharged from the selected sewage outfall site to detect biological changes occurring as a result of the increased nutrient loading of the water.

## 11.6 Conclusions

During this study samples have been collected monthly since July. Fecal coliforms, enterococci, Clostridium perfringens, and Salmonella data indicate some relatively low pollution levels at the intertidal sampling sites in Puget Sound. Indicator organisms were found in lower levels in the water column as would be expected because of the distance from shore. Due to variations in the environment and biological systems additional samples must be analyzed prior to the development of final conclusions.

# 12.0 MARINE TOXICOLOGY

P. A. Dinnel, F. S. Ott, J. Minikin,
D. A. Armstrong and Q. J. Stober

## 12.1 Introduction

Presently, METRO's Renton Sewage Treatment Plant discharges an average of approximately 40 million gallons per day (MGD) of dechlorinated secondary treated sewage effluent into the Duwamish River at Renton. However, rapid industrial and residential growth in suburban communities east of Lake Washington necessitate the expansion of the Renton treatment plant to a capacity of 72 MGD. Increased discharges of effluent into the Duwamish River have been determined to be in conflict with aquatic resource protection, especially during low-flow summer months. Therefore, METRO has proposed to discharge the effluent directly into Puget Sound via a tunnel terminating in East Passage off Seahurst Park.

Past toxicological studies by METRO biologists on the real or potential impacts of Renton treatment plant effluent have dealt exclusively with freshwater or anadromous species. The eventual move to an estuarine discharge requires a focus on the potential effects of the effluent on marine organisms.

As receiving waters for municipal wastes, estuarine systems differ in at least four significant ways from river systems: 1) estuaries are generally larger and therefore able to assimilate greater amounts of waste on a strictly volume-for-volume basis, 2) estuaries are oscillatory, partially recirculating flow systems instead of uni-directional, 3) the saline and generally higher pH waters of estuarine systems modify the physical, chemical, and biological interactions of waste compounds relative to freshwater, and 4) estuarine/marine waters play host to a much more diverse assemblage of plant

and animal life, especially sensitive embryonic/larval stages of many marine animals which undergo indirect development to the adult stage.

As part of the "Seahurst Baseline Studies" program, the Marine Toxicology investigations have addressed two specific needs: 1) assessment of present background toxicity in the proposed receiving waters and sediments, and 2) bioassays of the various stages of Renton Treatment Plant sewage with sensitive marine life stages to document the treatment plant effectiveness of toxicity reduction in its present operating state and to allow prediction of possible zones of toxicity and/or margins of safety relative to the receiving waters.

Specifically, the following bioassays were conducted during the Phase I studies:

1. Oyster (Crassostrea gigas) embryo and sand dollar (Dendraster excentricus) sperm bioassays were conducted on sets of receiving water samples collected periodically by the Water Column group.
2. Amphipod (Rhepoxynius abronius) bioassays were conducted on sediments from areas identified as "depositional environments" by the Subtidal Biology group.
3. Ten bioassays of the various stages of Renton sewage were conducted using each of the following sensitive marine organism life stages: oyster embryos, sand dollar sperm and eggs, green sea urchin (Strongylocentrotus droebachiensis) sperm, eggs, and embryos, and Dungeness crab (Cancer magister) zoea. The latter two organisms have been tested but the data are not included in this report as they have yet to be analyzed.

The oyster embryo bioassay for toxicants and receiving waters was developed by Woelke (1968, 1972) and has been used by the Washington

Department of Fisheries since 1961 as a biomonitoring tool for marine water quality. Likewise, echinoderm embryos of a variety of species have been extensively used as marine bioassay tools in Europe (Hagstrom and Lonning 1973; 1977), Japan (Kobayashi 1971, 1974; Okubo and Okubo 1962), and the United States (Dinnel et al. 1982; Oshida et al. 1981). Recently, the use of echinoderm gametes in a sperm/fertilization bioassay was developed and refined (Dinnel et al., 1982; Stober et al. in prep.) and used to monitor sewage impacts in marine waters (Oshida et al. 1981). Larval crustaceans have also been used for assessing the toxicity of a variety of compounds in seawater and have been found to be especially sensitive to organic compounds including pesticides (Armstrong et al. 1976; Martin et al. 1981).

Bioassays using small crustaceans or juvenile fish are being employed to characterize sediment toxicity from a growing number of areas including Baltimore Harbor, Chesapeake Bay, and Commencement Bay (Ott et al. in prep; Read et al. 1978; Swartz et al. 1982; Tsai et al. 1979).

Gammarid amphipods are known to be adversely affected by anthropogenic compounds and are currently being used extensively in sediment bioassay systems (Chapman, EVS, Vancouver, B.C. and McCain, NMFS, Seattle, WA, personnal communication; Swartz et al. 1979 and 1982; Levings et al. 1975). Gammarid amphipods are crustaceans with short life cycles and exceedingly high rates of production (Albright and Armstrong 1982). Densities may exceed 60,000/$m^2$ and these abundant amphipods constitute a major food source for commercial fish and crabs as well as birds (Albright 1977; Higley and Holton 1975; Smith 1981). Demise of this food source may represent a serious ecological impact.

The infaunal amphipod, Rhepoxynius abronius (used in this study) is available in the minimally contaminated areas of northern Puget Sound. The

free-burrowing habits ensure these animals will be continuously exposed to contaminants when the animals are in the sediments. It is likely that these amphipods also ingest contaminants when feeding. R. abronius is reported to feed on infaunal micro-organisms, bacteria, and detritus present in the interstitial waters of sand beaches (Oakden, 1981; Oliver et al. 1982). Female amphipods do not release larvae to the water column but carry developing embryos in abdominal brood chambers. This reproductive feature means exposure to sediment-borne contaminants lasts through the entire gestation period, and it also facilitates sampling schemes designed to look at inhibition of developmental rates and viability of embryos or emerging juveniles.

Results of bioassays conducted during the first three quarters of Phase I (April - December, 1982) are reported below. Results of bioassays conducted during the fourth quarter (January - March, 1983) will be reported at a later date.

## 12.2 Description of the Study Area and Stations

The primary study area is located in South Central Puget Sound between Alki Pt. and Brown's Pt. (Figure 12.1). A single "reference" water column station was located north of this area off West Point; a station for which historical physical/chemical water quality monitoring data exists from previous studies. METRO's present plans call for the construction of a tunnel from the Renton Sewage Treatment Plant to Puget Sound at Seahurst Park for the offshore discharge of secondary treated effluent. Ten specific sample stations described in the Water Column task were the same sites utilized in this task (Figure 12.1).

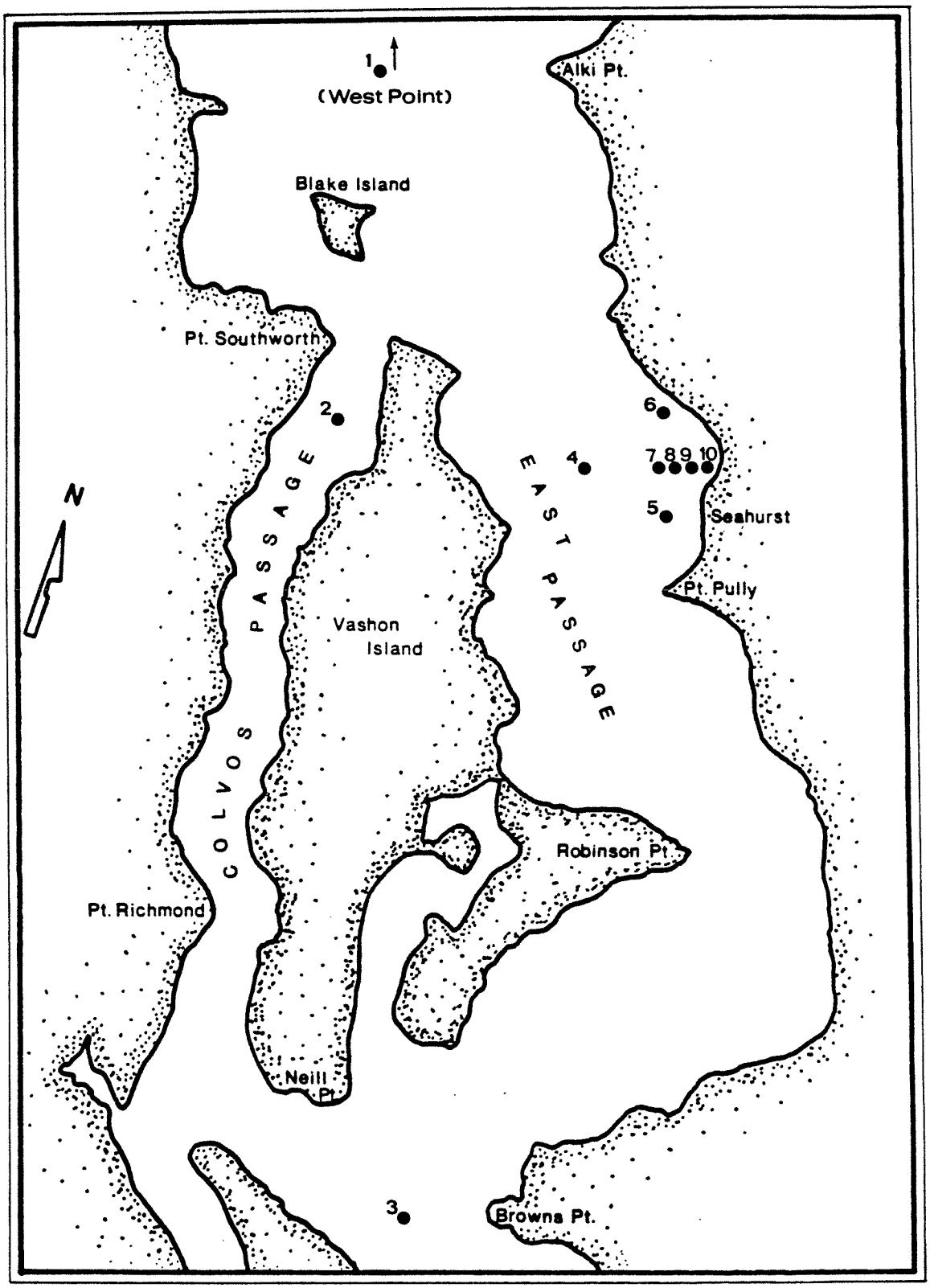



Figure 12.1. Map of south central Puget Sound showing the water column sampling stations.

## 12.3 Materials and Methods

### 12.3.1 General

All receiving water and sewage bioassays were conducted at the University of Washington's mobile marine laboratory presently located at METRO's West Point Sewage Treatment Plant, Seattle, Washington. Initially, the sediment bioassays were conducted at the Fisheries Research Institute's facilities on the University campus but the lack of sufficient seawater facilities on campus has resulted in the relocation of the sediment assay system to the West Point laboratory.

Seawater from Puget Sound was continuously supplied to the laboratory by 7.5-hp cast-iron pumps. The seawater was pumped from a depth of approximately 7 to 10 m depending on tide level. An 1800-liter fiberglass head-tank supplied seawater to the laboratory via gravity flow. All laboratory plumbing was constructed of polyvinyl chloride (PVC) pipe and fittings conditioned in seawater for more than five years. West Point "control" water and "dilution" water for the sewage bioassays was ambient West Point seawater filtered through a 5-um cellulose filter cartridge. Initially, control and dilution water for the sediment bioassay was hauled to the University campus from the Seattle Aquarium on Elliott Bay but subsequent sediment assays have used West Point filtered seawater.

### 12.3.2 Sample Collection, Handling, and Preparation

#### 12.3.2.1 Receiving Water

Receiving water samples were collected several times monthly during the summer by the Water Column group on board METRO's R/V Liberty. Samples were collected by PVC Niskin bottles at three depths (surface, mid-depth, and bottom or surface and bottom for shallow stations) at nine stations (stations

2-9) in the primary study area and at one station (station 1) off West Point (Figure 12.1). Several sampling depths were selected to provide a vertical profile of water column toxicity. The samples were drained into clean, seawater-aged 4-liter polyethylene bottles, packed in ice, and transported to the West Point laboratory upon docking at Shilshole Marina. All receiving water bioassays were started immediately upon reception of the samples at the West Point lab.

Four types of "control" water were tested along side each set of receiving water samples. The "primary" control water (used as the "standard" for comparing all other water types) was obtained from underground storage tanks at Kincaid Hall (Zoology) at the University. This water is collected by the truckload once or twice per year from the Anacortes ferry dock at high tide and is used for routine marine embryological work by the Zoology department. This water was selected as the "primary" control water since it was readily available and its quality was reasonably consistent through time. A "carry-along" control sample of Kincaid Hall water was sent along with the ice chests during each cruise. This sample was used to monitor any possible sources of sample contamination due to handling in the field. A third "control" sample consisted of West Point filtered seawater collected from the seawater system just prior to each bioassay. The fourth "control" sample was seawater previously collected at the University's Friday Harbor marine laboratory on San Juan Island. This water was collected in June, 1982 in 24 clean polyethylene 4-liter bottles, quickly frozen in a commercial food locker at $0^{o}$ F, transported back to the University in ice chests, and stored in the Fisheries cold storage room at $0^{o}$ F. The Friday Harbor water should give the best overall results as control water since it comes from an area well outside urban/industrial development. The quality should be very constant between

tests because it was frozen quickly. This water was not, however, used as the "primary" control during Phase I tests since the effect of freezing on water quality was undetermined.

Test sample preparation was accomplished by rinsing each 1-liter polypropylene (Tri-pour) beaker with the respective sample water and filling three replicate beakers to 1 liter with the sample or control water to be tested with oyster embryos. A 10-ml subsample was removed by pipette from each beaker and put into borosilicate glass test tubes (16 x 100 mm) for the sand dollar sperm assays. The beakers and test tubes were maintained in water baths during the proper exposure periods. Sperm assay tubes were held at ambient seawater temperature and oyster embryo beakers at 20 °C.

12.3.2.2 Sewage

Sewage samples were collected on ten separate occasions from the Renton Treatment Plant. Four-liter grab samples were collected at five steps in the treatment process including influent sewage, primary sewage, secondary sewage, chlorinated secondary sewage, and dechlorinated secondary effluent (Figure 12.2). An occasional sample of West Point unchlorinated primary sewage was also collected from the west effluent canal just prior to the post-chlorinators for the purpose of comparative testing.

Each batch of samples was packed in ice and transported (along with a bottle of Kincaid Hall "control" water) to the West Point Laboratory where bioassays were immediately started. For each sewage bioassay a series of eleven seawater dilutions of each sewage sample was prepared on a volume/volume (0.27 to 20.00% sewage) basis using West Point filtered seawater as the diluent. Each dilution was put into a 1-liter Tri-pour beaker for the oyster embryo assay and a 10-ml subsample removed to glass test tubes for the sperm assay. An additional test series was similiarly prepared using

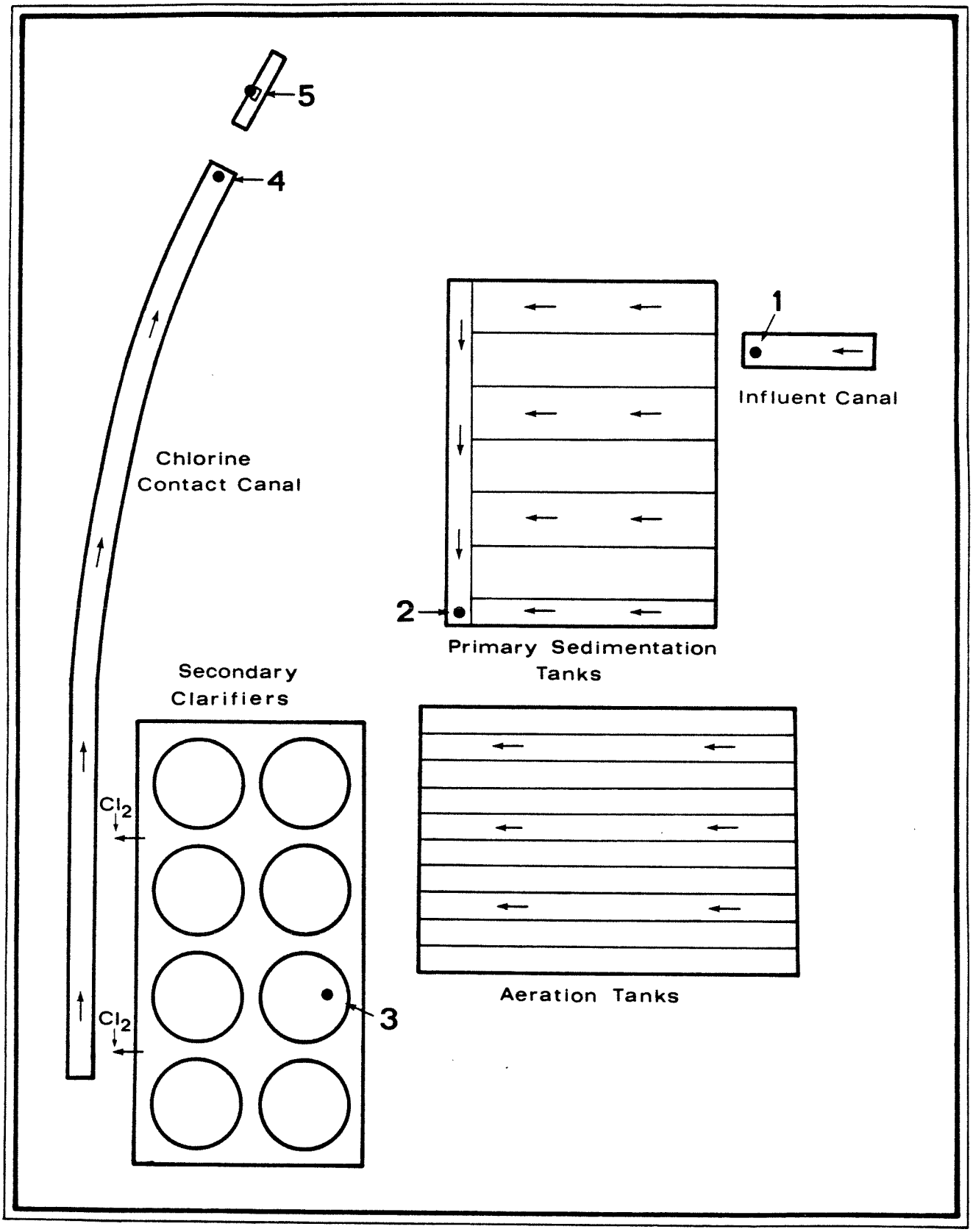



Figure 12.2. Diagrammatic map of the Renton sewage treatment plant showing sampling points for the sewage bioassays. 1 = influent sewage; 2 = primary sewage; 3 = secondary sewage; 4 = chlorinated secondary sewage; 5 = dechlorinated effluent (sampled at the composite sampler).

deionized freshwater instead of sewage so that the effects of reduced salinity alone could be separated from the overall "toxic" responses observed for each sewage type. Triplicate samples of two types of "control" water were tested with each sewage bioassay (Kincaid Hall and West Point filtered seawaters). Each set of beakers and test tubes were incubated the proper time in water baths at the respective test temperatures noted above.

12.3.2.3 Ammonia

Ammonia is one of the primary components of sewage which might impart a significant toxic response in sewage bioassays. Hence, a single set of bioassays using oyster embryos and sand dollar sperm were conducted to attempt to define the possible role of ammonia in relation to the toxic responses observed in the sewage assays.

Ammonia was tested as ammonia chloride ($NH_4Cl$) added to filtered West Point seawater in a concentration series from 0.5 to 100.0 mg/l at a seawater pH of 8.0 $\pm$ 0.1, salinity 30.1 o/oo, and an incubation temperature of 12.0 $\pm$ 1.0 $^{o}$C.

12.3.2.4 Sediment

Baseline sediment samples were collected with a modified 0.1-$m^2$ vanVeen grab from 20 depositional sites (Figure 12.3) identified by the Subtidal Biology group in the Seahurst study area and from 2 sites (Duw #1 and #2) in the Duwamish River Harbor (Figure 12.4). Oxygenated sediment, distinguished by the light coloration and lack of hydrogen sulfide odor, was removed from each grab sample. The depth of this layer varied from less than 1 cm (Duwamish sites) to greater than the sampled depth; i.e., the entire grab commonly contained aerobic sediment at stations with depths of $\geq$ 200 m off Seahurst. Collected sediment was placed in double plastic bags which were sealed and kept on ice or frozen (a period not exceeding 48 hrs) until use in

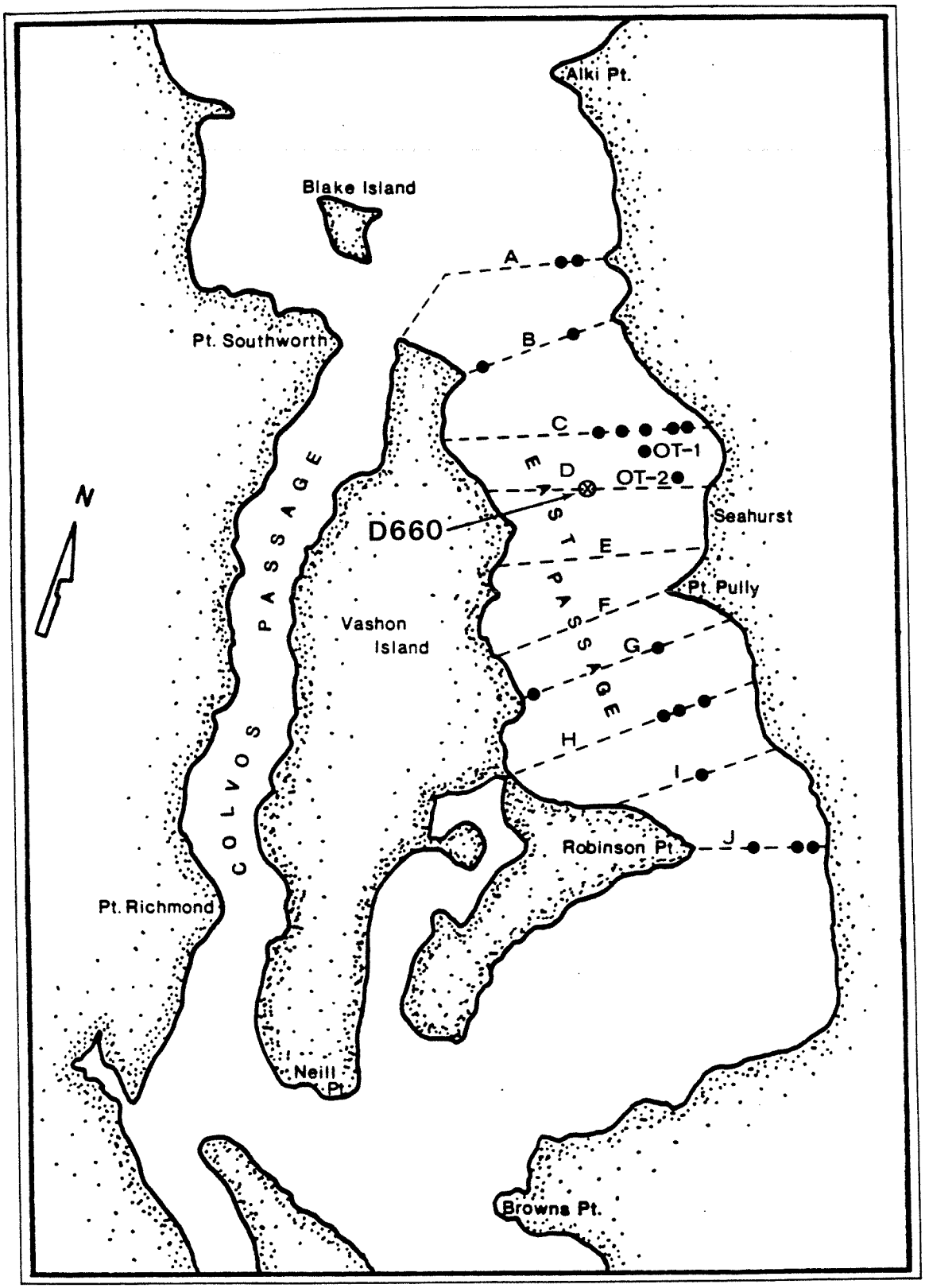



Figure 12.3. Map of south central Puget Sound showing the sites where sediment was collected for the fall 1982 sediment bioassays.

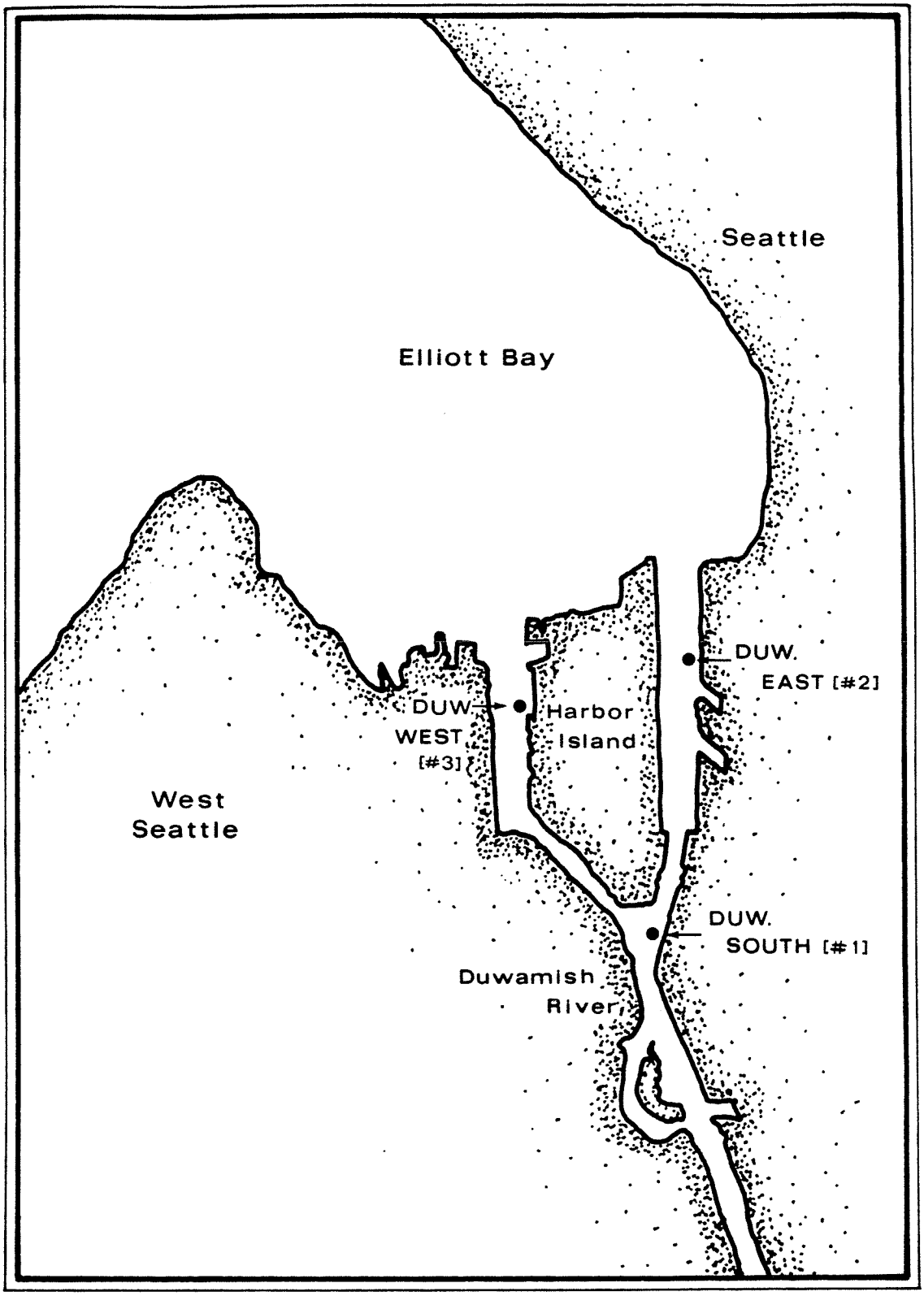



Figure 12.4. Map of the Duwamish River estuary showing the sites where "contaminated" sediment was collected for use in sediment bioassays during the fall of 1982 and winter of 1983.

bioassays. Sediment from West Beach State Park (North Whidbey Island) was obtained during animal collection by repeatedly towing a benthic sled parallel to the shore at a depth of about 8 m. Sediment washed through a 1.0-mm sieve was placed in either plastic bags, which were sealed and kept on ice (or frozen) until use in bioassays, or 20-liter plastic buckets which were immediately filled with seawater. Prior to initiation of a bioassay, West Beach sediment was washed through a 0.5-mm sieve to remove as many amphipods as possible.

Sediment for the "Methods Comparison" bioassays was collected from Seahurst site D660 (Figure 12.3) and Duwamish West Waterway (Duw #3) (Figure 12.4). Sediment was collected with a modified 0.1-$m^2$ vanVeen grab and water was poured off. Grab contents were pooled into a 500-liter white plastic container until approximately 60 liters of sediment were obtained. Sediment in this container was thoroughly mixed with a length of PVC pipe. Homogenized sediment was then transferred to 24 plastic bags in 2-liter aliquots. These samples were sealed and kept on ice until frozen (0 $^{o}C$) within 8 hours of collection. One sample of each sediment type was not frozen but kept on ice until use in a bioassay less than 48 hours after collection. Sediment from West Beach was collected as described for the Baseline Study and placed in plastic bags in 2-liter aliquots. Only approximately 8-liters were collected of which two bags were frozen and two were kept on ice until used in a bioassay.

12.3.3 Test Animal Collection and Handling

12.3.3.1 Oysters

Adult Pacific oysters were collected intertidally from several areas of Puget Sound and Hood Canal depending on time of the year. Sites of collection of ripe animals included Coast Oyster Company on Quilcene Bay, Hood Canal;

Oakland Bay on South Puget Sound; and Big Beef Creek on Hood Canal. All ripe oysters were transported to the West Point laboratory in a "dry" condition and held a maximum of four weeks in a 20 °C flow-through seawater system until used for testing.

For winter tests, oysters from Big Beef Creek were held in a basket at the Manchester dock on Central Puget Sound during summer (the cooler water retarded maturation) and conditioned at Manchester in 20° C seawater for 4-8 weeks. The conditioned oysters were fed phytoplankton cultures daily to insure proper maturation.

12.3.3.2 Sand Dollars

Sand dollars were collected intertidally from Kopachuck State Park on Carr Inlet, South Puget Sound, transported to the lab in ice chests, and maintained in a flow-through tank on a bed of sand at ambient seawater temperature. Ambient planktonic organisms in the seawater and detritus in the sand served as the only food sources.

12.3.3.3 Amphipods

The infaunal amphipod Rhepoxynius abronius (Phoxocephalidae, formerly named Paraphoxus epistomus) was collected subtidally at West Beach, Whidbey Island by towing a benthic sled at approximately 8-10 m depth. The benthic sled, formally named the Benedict Sea Mouse, has been described by Ott (in prep). After capture, sediment was sieved underwater through a 1.0-mm screen to remove the animals. Animals were held in covered 20-liter buckets which were lined with plastic bags and contained areated seawater and 1 liter of the fraction of West Beach sediment which passed through the 1.0-mm screen. Animals were held from 24 to 96 hr prior to use in bioassays to remove damaged individuals and to acclimate the animals to the 15 °C test temperature for the Baseline Study. For the "Methods Comparison," test animals were held at

held at approximately 10° C (ambient seawater).

12.3.4 Chemistry

Seawater temperatures were monitored with a standard mercury or electronic thermometer. Salinity was measured by a standard conductivity bridge at the U.W. School of Oceanography (Paquette 1958). An Orion research model 407A specific ion meter with appropriate electrodes and standard calibrating solutions was used to measure pH and ammonia. Chlorine in the sewage samples was determined with a titrator based on the design of Andrew and Glass (1974) utilizing dual platinum electrodes, a Keithly 602 electrometer, and a microburet calibrated to 0.1 mg/liter for addition of the titrant (Stober et al. 1978). The back titration method (APHA 1980) was used for determination of total residual chlorine (TRC) in sewage samples. Dissolved oxygen (DO) concentrations in the sediment bioassay tanks were determined with a Yellow Springs model 51B oxygen meter and model 5739 dissolved oxygen probe after "saturated air" calibration.

12.3.4.1 Receiving Water Bioassays

Each control and receiving water sample was measured for pH in the laboratory just prior to each set of bioassays. All other receiving water physical/chemical data cited in the results (salinity, ammonia, chlorophyll a, primary productivity, and Secchi disk depths) were collected by the Water Column group on board the RV Liberty (see section 4.2).

12.3.4.2 Sewage Bioassays

Each sewage sample was measured for pH, total residual chlorine, and total ammonia after initiation of each set of sewage bioassays. Measurements were not made in each sewage dilution as many of the chlorine and ammonia concentrations were below our limits of detection for the dilutions tested.

12.3.4.3 Sediment Bioassays

Dissolved oxygen and pH were measured in the test aquaria as noted above. Sediment oxidation/reduction potentials (Eh) were measured in an extra sediment chamber replicate without amphipods using an Orion Chem Cadet meter with an Orion Eh probe.

12.3.5 Testing Procedures

12.3.5.1 Oyster Embryo Bioassays

For each embryo bioassay approximately 6-8 sexually ripe adult oysters were spawned by raising the water temperature to 28-30 $^{o}$C for 2-4 hours and then adding sperm from a sacrificed male to the water. Spawning normally occurred in 30-60 minutes in some of the conditioned oysters. The eggs were fertilized and added to the 1-liter test beakers at a density of approximately 25,000-35,000 per beaker within one hour of fertilization. The embryos were incubated at 20 $^{o}$C for 48 hours. At the conclusion of each test a 10-ml subsample was removed from each beaker after thorough mixing and fixed with 10% formalin in glass test tubes.

Each embryo sample was later examined under a compound microscope and tabulated for number of embryos in each sample and number of embryos failing to mature to the normal straight-hinge veliger stage (Woelke 1972).

12.3.5.2 Sand Dollar Sperm Bioassays

For each set of sperm bioassays a male and female sand dollar was spawned separately by injecting approximately 0.5 ml of 0.5-molar potassium chloride (KCl) through the oral opening. The eggs were washed several times and adjusted to a density of 2,000/ml. The sperm were mixed, subsampled, killed in 10% acetic acid, counted with a hemacytometer at 400x magnification and the stock solution diluted to a density of $2.0 \times 10^{7}$/ml. For each bioassay series 0.1 ml of the sperm solution ($2.0 \times 10^{6}$ sperm) was added to each test tube and

allowed to incubate at ambient seawater temperature (13.0 ± 1 °C) for 60 min followed by addition of 1 ml of the egg solution (2,000 eggs) and further incubated for 20 min to allow fertilization of the eggs. The samples were then fixed with 10% formalin to arrest further fertilization and to preserve the samples until analysis (Figure 12.5).

The exact sperm assay time schedule has been standardized as follows (Stober et al. in prep.) (time in minutes):

T 0: spawn animals.

T30: mix sperm, subsample for counts.

T30-T150: wash eggs several times and dilute to 2,000/ml.

T90: dilute sperm to 2 x $10^7$ sperm/ml (density is species-dependent).

T120: Add 0.1 ml sperm solution to each test tube at 5-sec intervals.

T180: Add 1 ml of mixed egg solution to each test tube at 5-sec intervals.

T210: Fix each test tube with 10% formalin at 5 sec intervals and cork.

The sperm and egg densities cited above provide for a nominal sperm:egg ratio in each test tube of 1,000:1. For sand dollars this ratio optimizes the sensitivity of the test by assuring enough sperm to fertilize most eggs in the controls, but prevents the introduction of excess sperm which could reduce the test sensitivity (see Stober et al. (in prep.) for specific details regarding refined test methodology).

Later, each sample was tabulated for percentage of fertilized eggs in the sample as indicated by the presence or absence of a normal fertilization (vitelline) membrane around each egg in a subsample of 100-200 eggs.

12.3.5.3 Amphipod-Sediment Bioassays

In general, static bioassays were conducted in 15-liter aquaria each

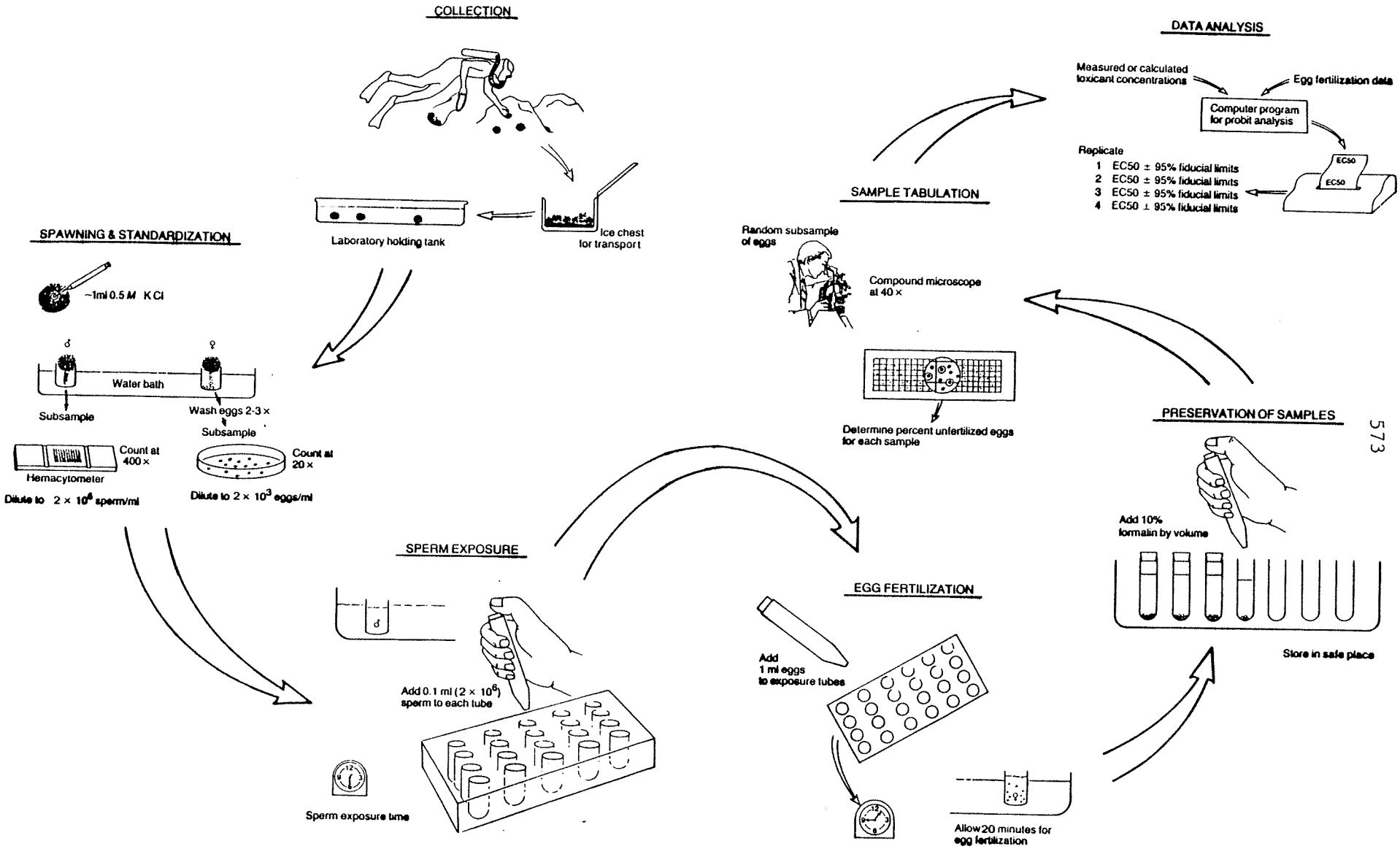



Figure 12.5. Sperm bioassay flow diagram (from Dinnel et al., 1982).

containing four or five replicate test chambers. A continuous movement of water through the test chambers was generated by either a water or air manifold system which varied between bioassays due to results of earlier testing. Several other modifications also occurred over time and are discussed below.

Test chambers were constructed from 10-cm diameter poly-vinyl chloride (PVC) pipe cut to 10-cm lengths. Two windows were cut in each 10-cm piece and Nitex screen (500-um mesh) glued with PVC cement around the outer circumference (Figure 12.6). The screen allowed water circulation through the test chambers. Close fitting lids for both ends of the test chambers were manufactured from 10-cm diameter PVC pipe coupling cut into 1.5-cm widths. Nitex screen (500-um) was glued with silicone caulking to the lid rings to complete the chamber assembly. All chambers and aquaria were aged in flowing seawater for a minimum of two weeks prior to use in bioassays to minimize leaching of possible glue or solvent-related toxicants.

For bioassays, 150 ml of test or control sediments were measured directly from the plastic bags into the test chambers which were placed into 15 $^{o}$C seawater in the aquaria. Amphipods were screened (1.0-mm mesh) underwater from the holding buckets and 20 animals of a selected size range (2-3 mm) were placed in each bioassay test chamber. Selection of this size range insured that all animals were subadults of approximately equal age, thus minimizing the effects of some biological variability. The test chambers were set on 1-cm diameter glass tubes, thus elevating them from the bottom. An airstone was situated equally between the replicate chambers. This arrangement was used to prevent sediments from becoming anaerobic by enhancing water circulation around sediment within the chambers.

Bioassays were run for 10 days under constant light. Upon termination of

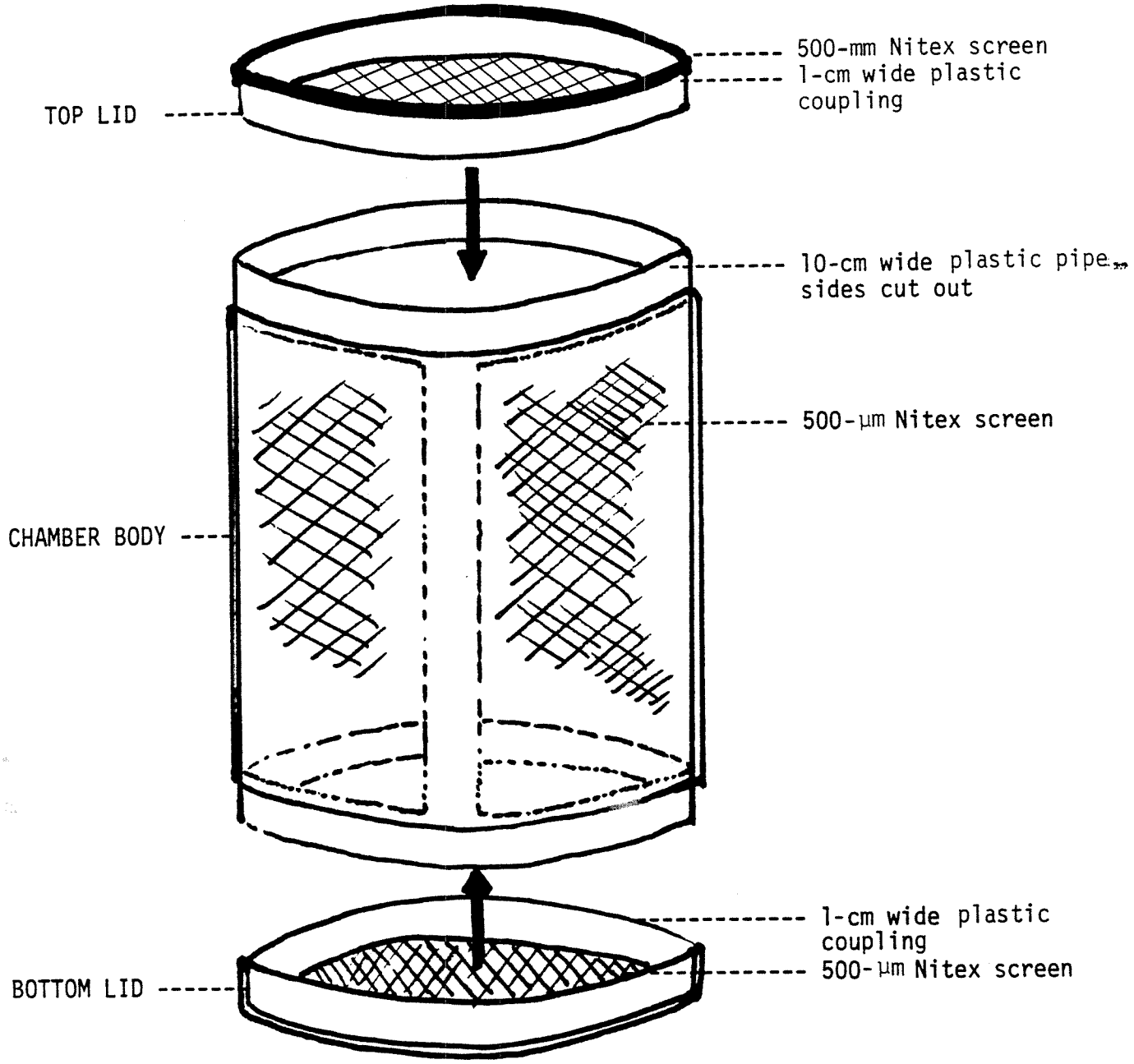


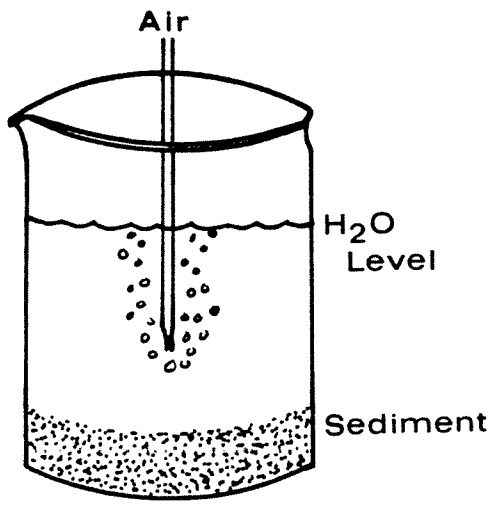

Figure. 12.6. Amphipod-sediment bioassay exposure chamber.

an experiment, chamber contents were rinsed onto a 1.0-mm mesh screen and animals counted. Survivors were placed in petri dishes containing (1.0-mm mesh) sieved West Beach sediment and 15 °C filtered seawater. Animals incapable of burying in five minutes, even with gentle prodding, were considered moribund.

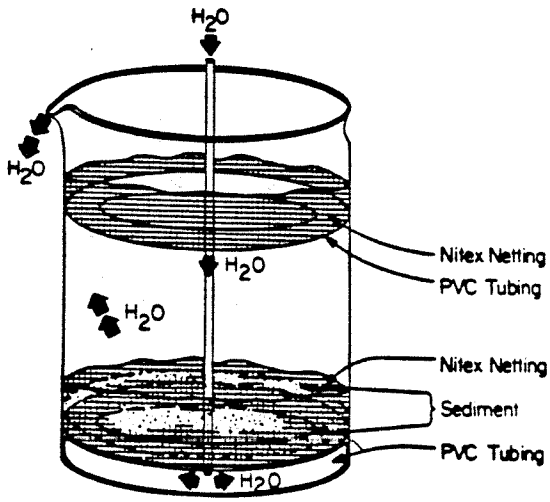
Between bioassays, aquaria, manifolds, and test chambers were washed in detergent, methanol, 0.1-normal nitric acid, and deionized water, respectively.

"Methods Comparison" bioassays were conducted at the West Point laboratory using the same test conditions noted above with the following exceptions: in all cases there were five replicates for each test sediment; fresh West Beach sediment only was sieved prior to use; juvenile amphipods were smaller (1-2 mm); and the tests were conducted at ambient seawater temperatures (10 $\pm$ 1 °C).

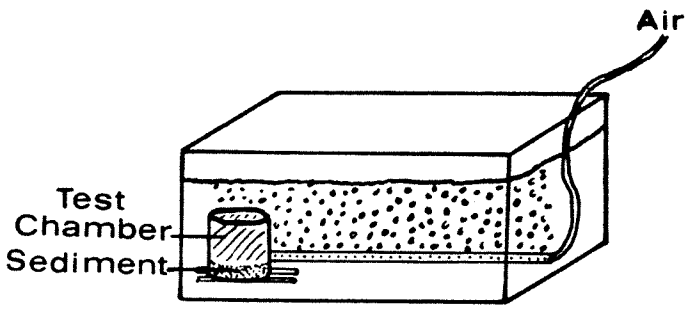
Run A compared three different bioassay techniques using fresh vs. frozen sediments from three sites (Seahurst D660, Duwamish West Waterway (Duw #3), and West Beach). The three bioassay techniques were: (1) "Ott" used by NMFS, Seattle, WA; (2) "Swartz" used by EPA, Newport, OR; and (3) "Pierson" used by Seattle Army Corps of Engineers. The techniques are illustrated in Figure 12.7. The "Ott" system was similar to the one described above except that the airstone was replaced by a 50-cm length of 6.3-mm ID PVC pipe with numerous small holes drilled in it. An airline, connected to an air pump, lead into the PVC manifold which lay lengthwise down the center of the aquarium. This provided a wall of small air bubbles between the chambers; a more controlled distribution than with the airstone alone. The "Swartz" technique has been described elsewhere (Swartz et al. 1982). Briefly, 1-liter beakers were set up with 200 ml of test sediment and seawater. Air was bubbled into beakers



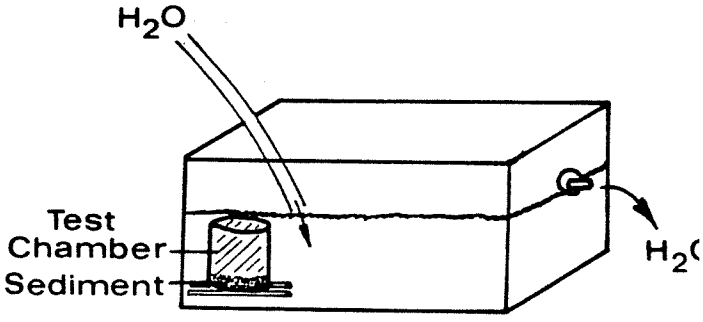

Swartz




Pierson




Ott static




Ott flow-through

Figure 12.7. Different amphipod-sediment bioassay systems used during the "method comparison" tests during Jan-Feb 1983. "Swartz" static system; "Pierson" flow-through system; "Ott" static system; "Ott" flow-through system. "Ott" static system was also used for Seahurst baseline sediment bioassay Run 3.

through pipettes attached to air pumps. Beakers were not covered. The "Pierson" technique has also been described (Pierson et al. 1982). Unlike the "Swartz" or "Ott" static system, the "Pierson" technique is a flow-through system conducted in 2-liter beakers. Seawater (100 ml/minute) was delivered through a 2-mm glass pipe to the underside of sediment suspended on 28-um mesh Nitex screen above the beaker bottom by rings of Tygon tubing. Water percolated up through the sediment and overflowed out the beaker lip. Animals were prevented from escaping by a piece of 750-um mesh Nitex screen held in place just under the beaker lip by another Tygon ring. Only fresh sediment of all three types was used in this technique.

Run B compared flow-through vs. static techniques using frozen sediment from the three sites in Run A. Additional tests were conducted: 1) with fresh West Beach sediment; 2) using adults vs. juveniles; and 3) for a between-tank effect. All tests were conducted as for Run A using 20 animals per each of 5 replicates per sediment, 0.5-um filtered seawater, constant lighting, ambient seawater temperature, and a 10-day exposure period. The static "Ott" and "Swartz" techniques were identical to the systems described for Run A. However, the "Pierson" technique was replaced by the "Ott flow-through" technique which was implemented by a slight variation of the "Ott static" system: the air manifold was replaced by a vertical glass pipe (8-mm ID) which delivered about 500 ml/min of seawater to each aquarium. At the opposite end of the aquarium, water flowed out through a 16-mm hole cut 16 cm above the aquarium bottom (Figure 12.7). The "Ott" system was less time-consuming to set up and monitor than the "Pierson" equivalent. Two identical tanks were set up using the "Ott flow-through" system with Duwamish sediment. These tanks contained six replicate chambers each: three chambers contained juvenile amphipods (1-2 mm) and three contained adults (>4 mm; non-gravid

females and males). Both fresh and frozen West Beach sediment were tested with all three techniques.

On days 2 and 9, pH and Eh were measured. The probes, filling solutions, and standards (pH and Zobell solutions) were equilibrated to the test temperature prior to their use. In anticipation of these measurements, additional chambers without animals had been set up in each of the aquaria. Lids were removed from these chambers and the probe was inserted directly into the test sediment (probes were inserted directly into the "Swartz" beakers). Readings were taken immediately and again after the instrument stablized. If a slow drift upward was observed prior to stabilization, the recorded reading was the initial one as insertion of the probe into the sediment sometimes allowed some of the overlying seawater, which invariably had a higher pH and Eh, to mix with the sediment, thereby slowly inflating these values. Measurements of pH were taken for all five replicates of the "Swartz" beakers; Eh was then measured only for those beakers which had the highest or lowest pH values. Values of pH and Eh were taken for only the one chamber without animals for all the "Ott" treatments.

12.3.6 Data Analysis

12.3.6.1 Receiving Water Bioassays

The biological responses observed in the receiving water samples and the "secondary" control samples (carry-along, West Point filtered, and frozen Friday Harbor seawaters) were adjusted for average net response relative to the "primary" control water from Kincaid Hall.

Two indices were calculated for the oyster embryo assays; average adjusted percent mortality and average adjusted percent abnormal. The average mortality for each set of replicates (n=3) was determined by first calculating the arithmetic mean of the survival:

$$\text{Average survival} = \frac{X_1 + X_2 + X_3}{n}$$

where X = number of embryos in each replicate

n = number of replicates

and then determining the percent mortality relative to the average "primary" control survival:

$$\text{Percent Adjusted Oyster Mortality} = 100 - \left( \frac{\text{Average Sample Survival}}{\text{Average Control Survival}} \right) \quad (100)$$

Positive mortality values indicate higher mortality than the control responses while negative values are indicative of better survival in the sample water.

The oyster percent abnormal index was determined in much the same way as above except the weighted mean:

$$\text{Average Weighted Abnormal} = \frac{(X_1 Y_1) + (X_2 Y_2) + (X_3 Y_3)}{X_1 + X_2 + X_3}$$

where X = number of embryos in each replicate

Y = number of abnormal embryos in each replicate

instead of the arithemetic mean was used to calculate average abnormal response in each set of replicates since this value tends to vary in relation to the degree of mortality in each set of replicates (Cardwell and Woelke 1979). The <u>average</u> percent abnormal was then determined by:

$$\underline{\text{Average}}\ \text{Percent Abnormal} = \frac{\text{Average Weighted Abnormal}}{\text{Average Survival}} \quad (100)$$

Finally, the adjusted percent abnormal response for each set of replicates was established by adjusting for the "primary" control responses using Abbott's formula (Finney 1971):

$$\frac{\underline{\text{Adjusted}}\ \text{Percent}}{\text{Abnormal}} = \frac{\text{(Ave. \% Sample Abnormal)-(Ave. \% Control Abnormal)}}{\text{100 - (Ave. \% Control Abnormal)}} \quad (100)$$

Again, the adjusted percent abnormal values may be either positive or negative since they are entirely relative to the "primary" control responses.

The sperm assay responses in the receiving water samples and the "secondary" control samples were also related to the "primary" control responses in much the same way as detailed for the oyster indices above. Specifically, the arithmetic mean was calculated for each set of replicates (sample and control) to yield an average percent response (percent eggs unfertilized) for each set. These responses were then adjusted to the "primary" control response using Abbott's formula:

$$\frac{\underline{\text{Adjusted}}\ \text{Percent}}{\text{Eggs Unfertilized}} = \frac{\text{(Ave. \% Sample Unfert.)-(Ave. \% Control Unfert.)}}{\text{100 - (Ave. \% Control Unfert.)}} \quad (100)$$

to again yield either a positive or negative value.

12.3.6.2 Sewage Bioassays

Renton sewage bioassays were designed to yield an average EC 50 (concentration of sewage equivalent to a 50 percent effective response) for

each type of sewage tested based on a series of ten repetitive tests with both oyster embryo and sand dollar sperm bioassays.

Ten bioassays (n=7 for oyster assays - three tests were unacceptable due to high mortality and/or abnormality in the control water) were conducted which tested eleven dilutions of sewage (0.27, 0.41, 0.64, 1.0, 1.5, 2.3, 3.6, 5.5, 8.4, 13.0, and 20.0 percent sewage in seawater). The average responses for each test type at each sewage concentration over the ten repetitive tests were calculated by methods similar to those discussed above and the responses adjusted for the controls (in this case West Point filtered seawater as this was used for the sewage dilution water). The average adjusted responses were then used to calculate the average EC50's using a Computer BMDO3S program for probit analysis (a type of non-linear regression analysis) (Finney 1971) with an attached FORTRAN program to calculate 95 percent fiducial limits by the method of Litchfield and Wilcoxon (1949).

12.3.6.3 Ammonia Bioassays

Results of a single bioassay of a series of ammonia concentrations in seawater with each bioassay test type were analyzed for EC50's and 95 percent fiducial limits as described for sewage bioassays above.

12.3.6.4 Amphipod - Sediment Bioassays

All bioassay data was generated as proportions F1/N and F2/F1, where N = total number of animals, F1 = total number of survivors (number able to rebury plus number unable to rebury), and F2 = number of moribund (number unable to rebury). The fractions which yielded proportion of survivors and proportion of moribund, respectively, were transformed ($X' = \arcsin \sqrt{x'}$) to obtain a more normal distribution of the variances (Zar 1974). Baseline bioassay data were then analyzed by a one-way analysis of variance (ANOVA) to test for differences between sediment treatments (Zar 1974). Data were analyzed

separately for proportion survival and proportion moribund. In all statistical tests, the significance level was set at $p = 0.05$. If ANOVA results were significant, data were further analyzed by Dunnett's test (Zar 1974) to determine which treatment mean differed from the mean of the West Beach controls.

Third quarter "Methods Comparison" bioassay data were analyzed independently using a Model I two-way ANOVA (Zar 1974) where the two factors considered were "sediment type" and "methodology" (since one of the three methods was not conducted using frozen sediment, a three-way ANOVA was inappropriate). Run B data were analyzed by a nested one-way ANOVA (Zar 1974). In one case, the main factor was separate tanks which were divided into two subgroups of adults and juveniles. In the other case, the main factor was methodology which tested both fresh and frozen sediment from the same station.

## 12.4 RESULTS

### 12.4.1 Receiving Water Bioassays

The bioassays of receiving water from 2 or 3 depths at each of the water column stations 1-10 are graphically presented in Figures 12.8 A through J. Only those responses that were greater than the control responses are shown in these figures. The exact calculated responses (both positive and negative) are recorded in Appendix Table 12.1.

"Variability" is probably the key word that comes to mind when viewing Figures 12.8A-J. Generally, these figures show that all three biological responses (oyster mortality, abnormality, and sand dollar eggs unfertilized) were least expressed at the wide area stations (1-3) away from the Seahurst

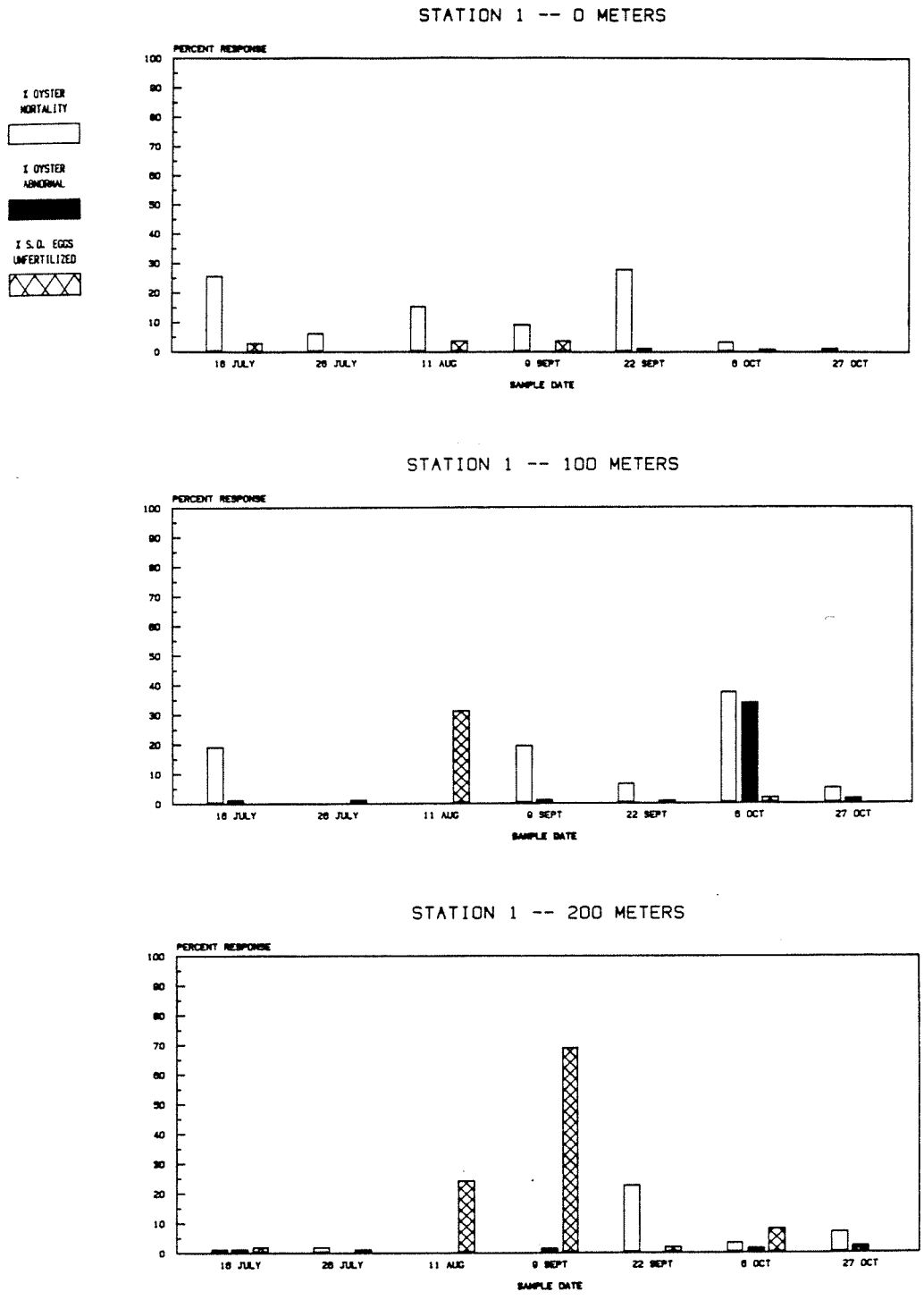



Figure 12.8A. Results of 1982 water column station No. 1 bioassays.

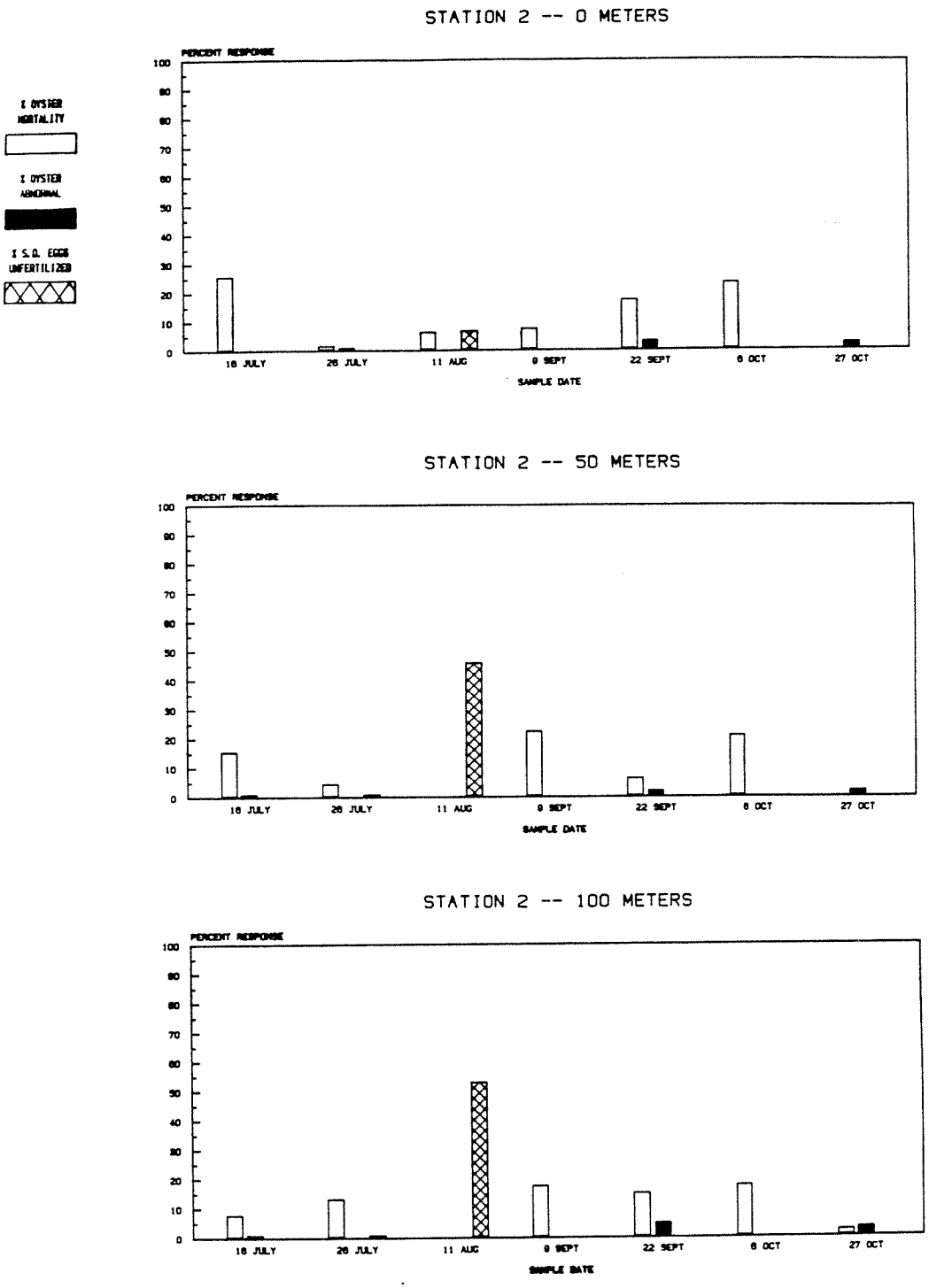



Figure 12.8B. Results of 1982 water column station No. 2 bioassays.

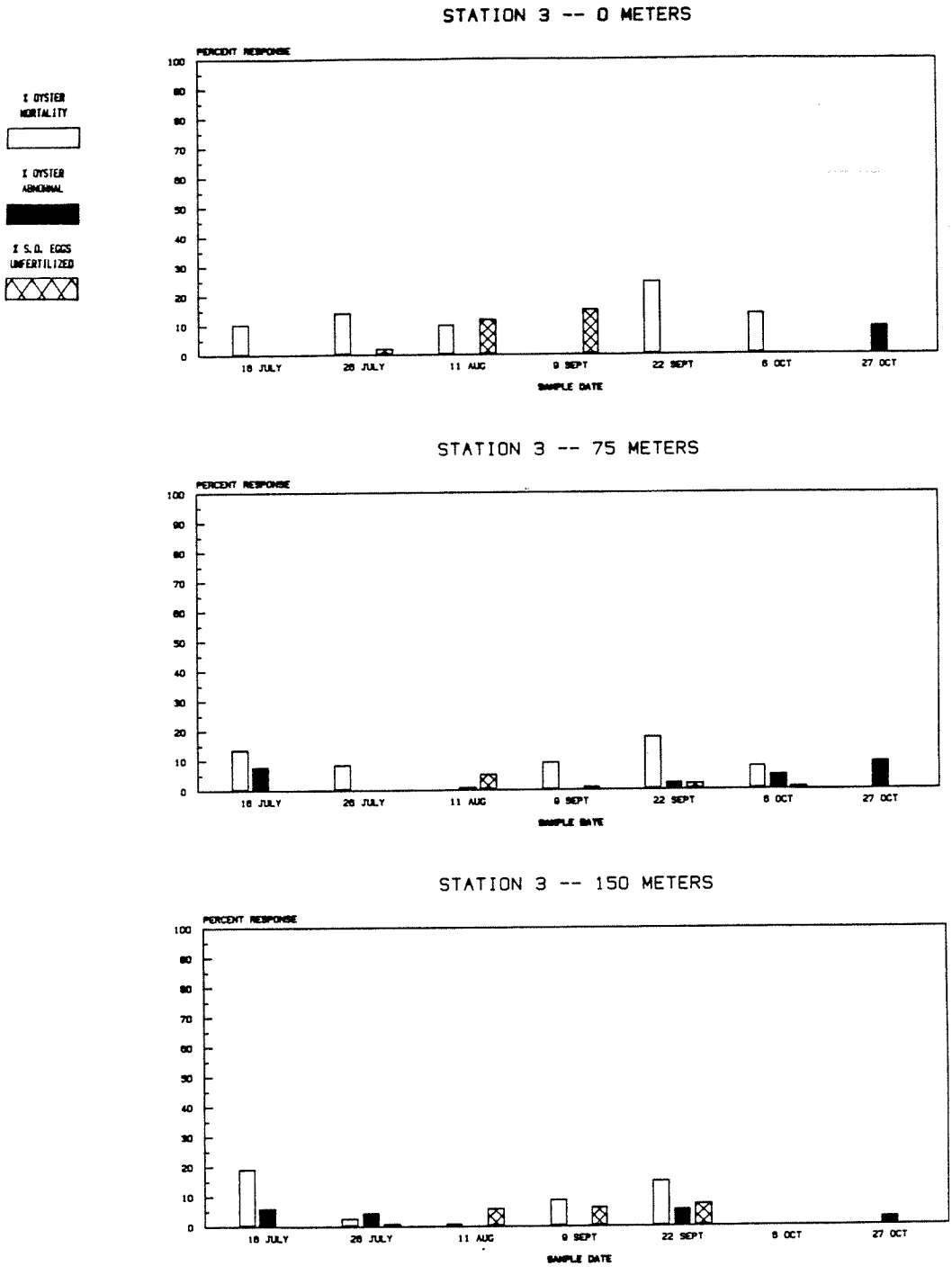



Figure 12.8C. Results of 1982 water column station No. 3 bioassays.

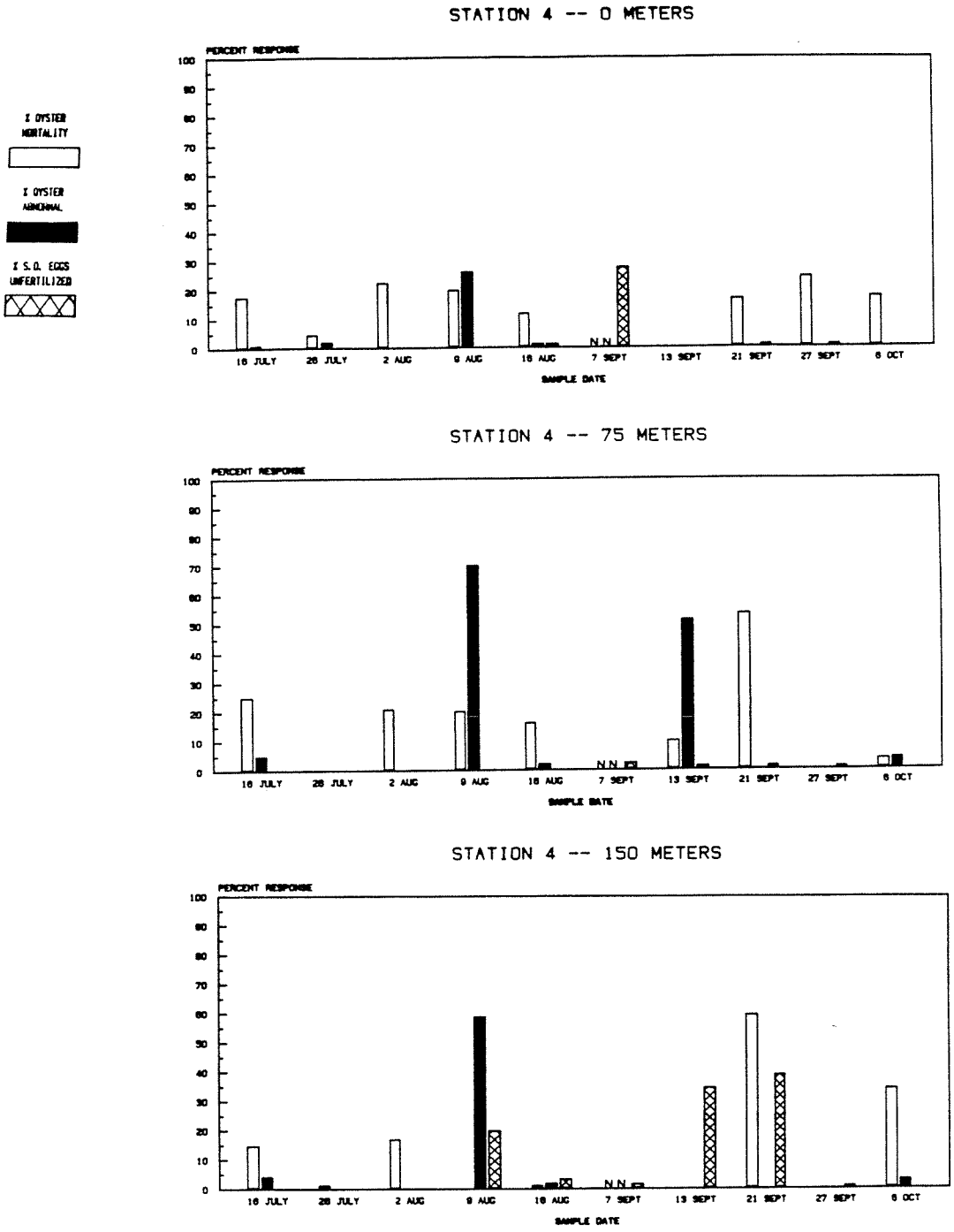



Figure 12.8D. Results of 1982 water column station No. 4 bioassays. N = not tested.

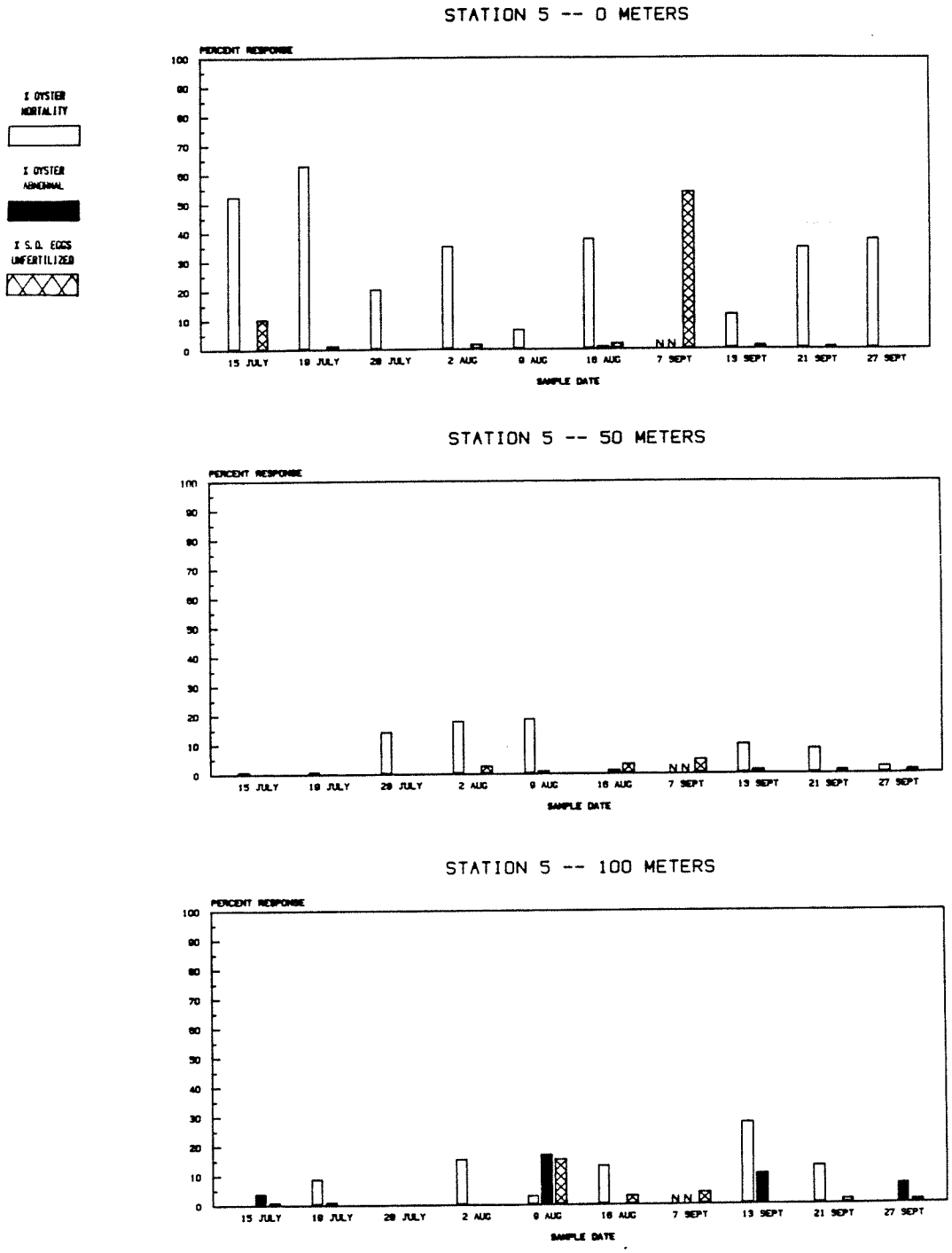



Figure 12.8E. Results of 1982 water column station No. 5 bioassays. N = not tested.

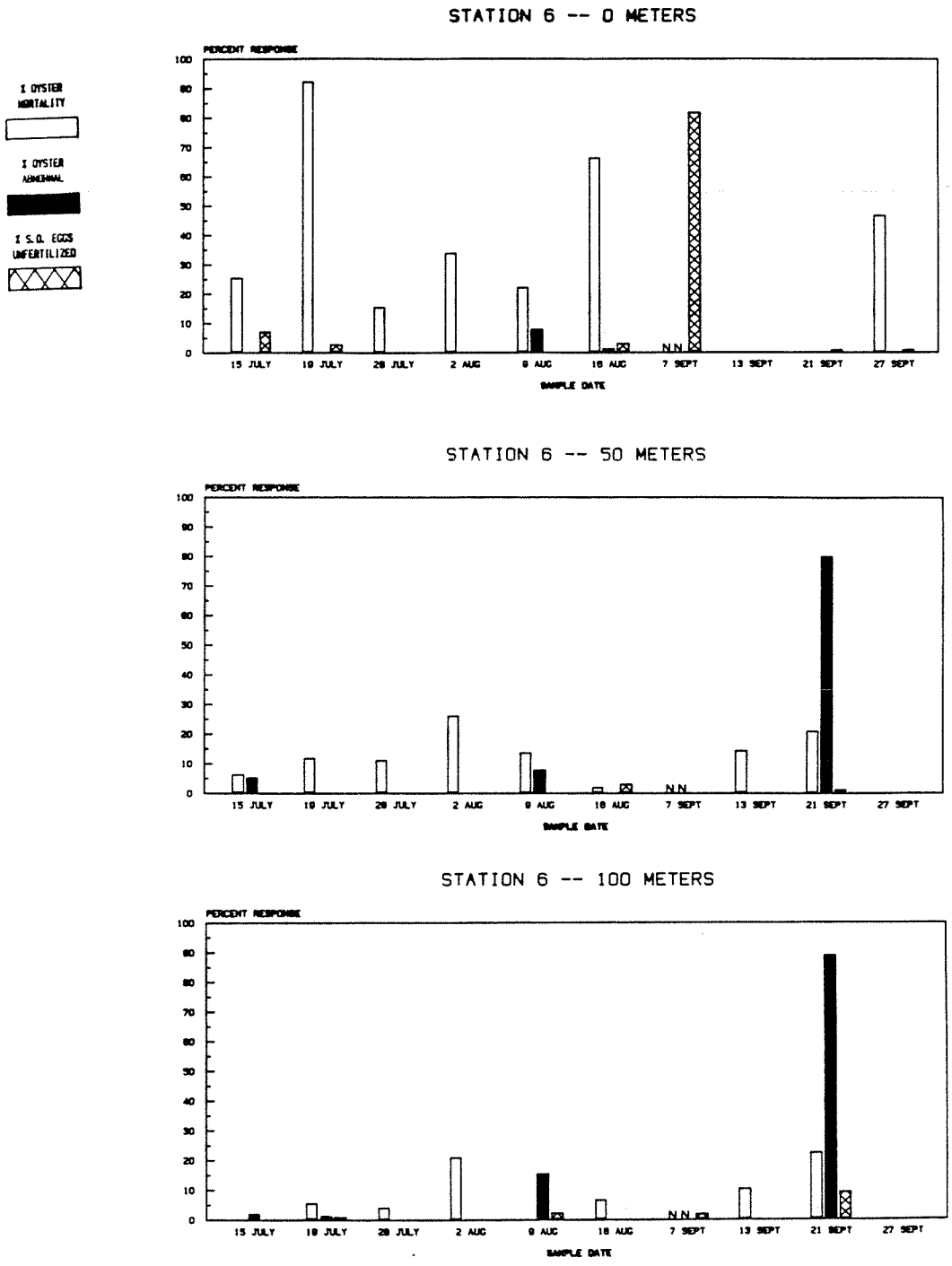



Figure 12.8F. Results of 1982 water column station No. 6 bioassays. N = not tested.

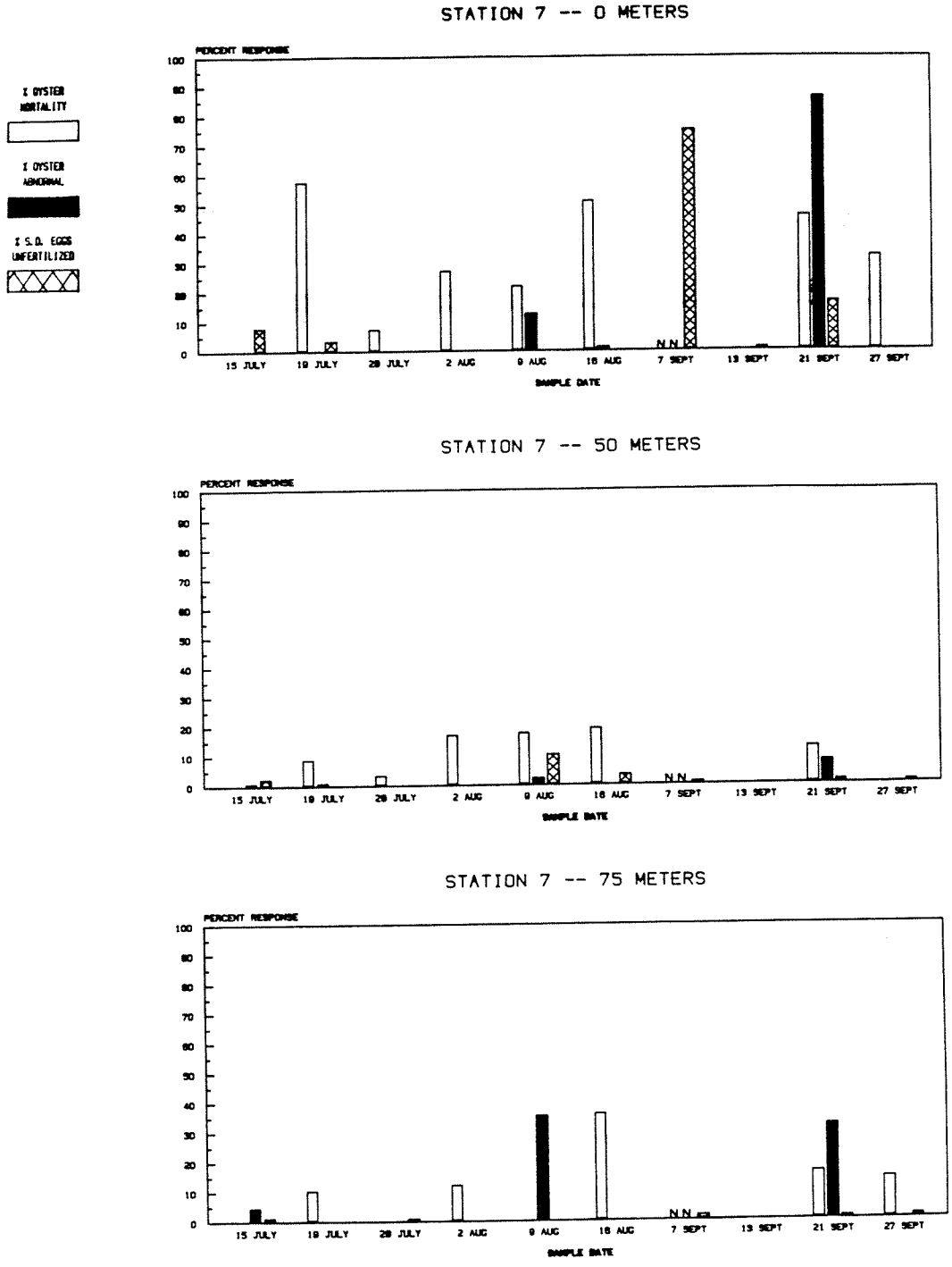



Figure 12.8G. Results of 1982 water column station No. 7 bioassays. N = not tested.

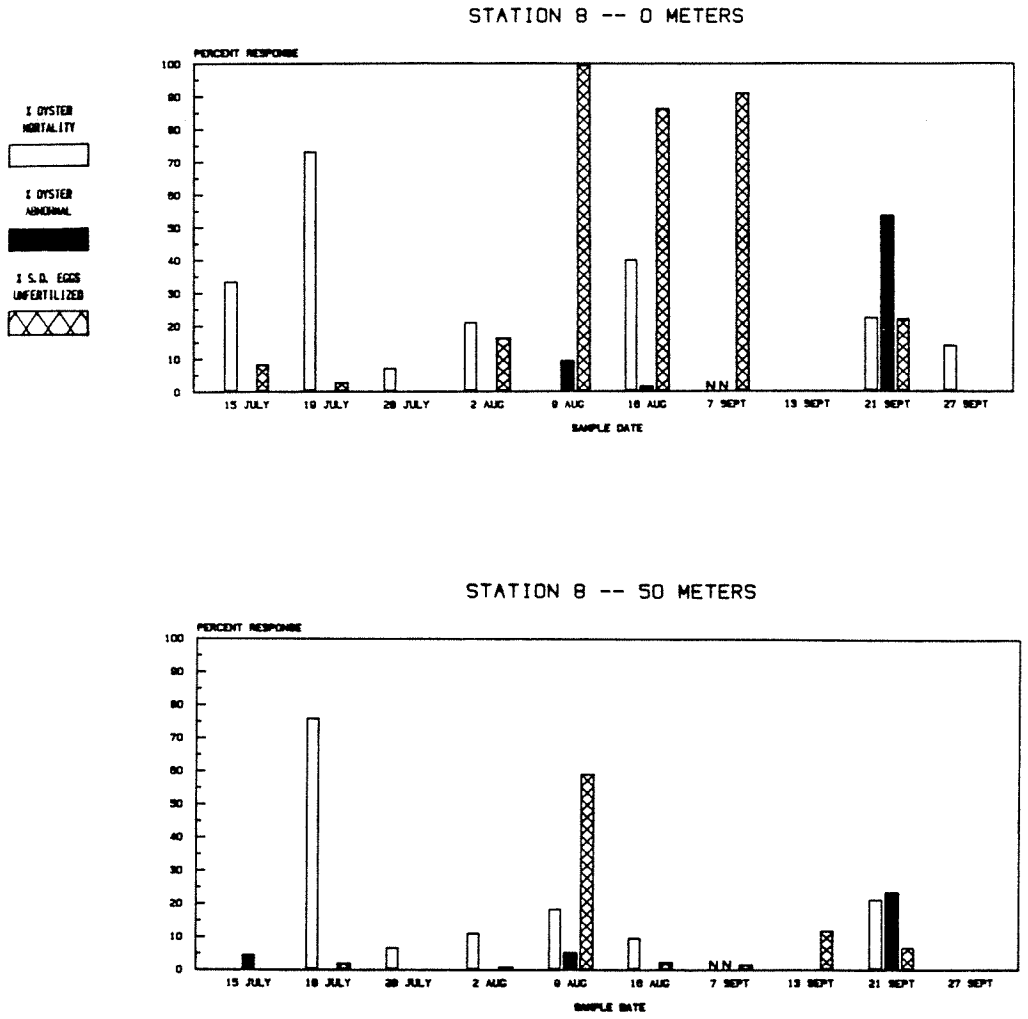



Figure 12.8H. Results of 1982 water column station No. 8 bioassays. N = not tested.

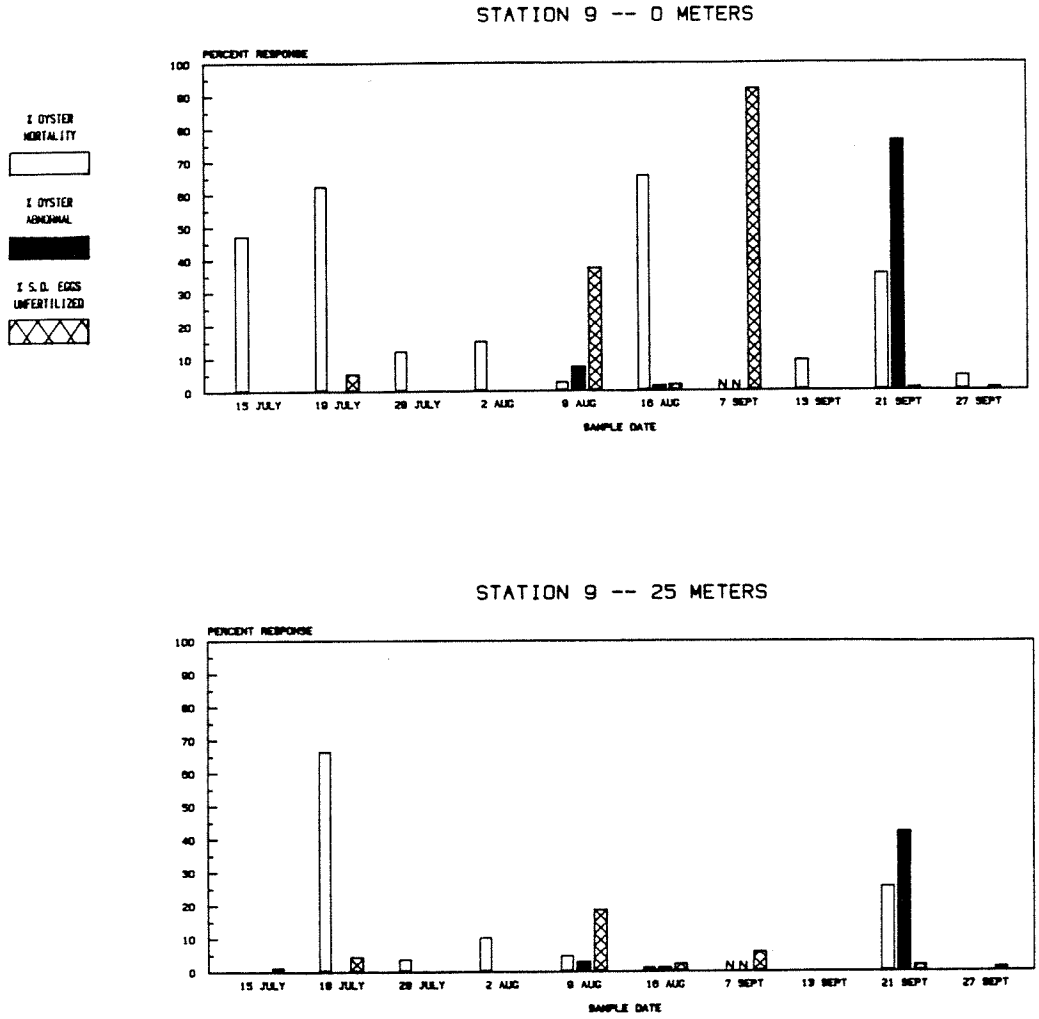



Figure 12.8I. Results of 1982 water column station No. 9 bioassays. N = not tested.

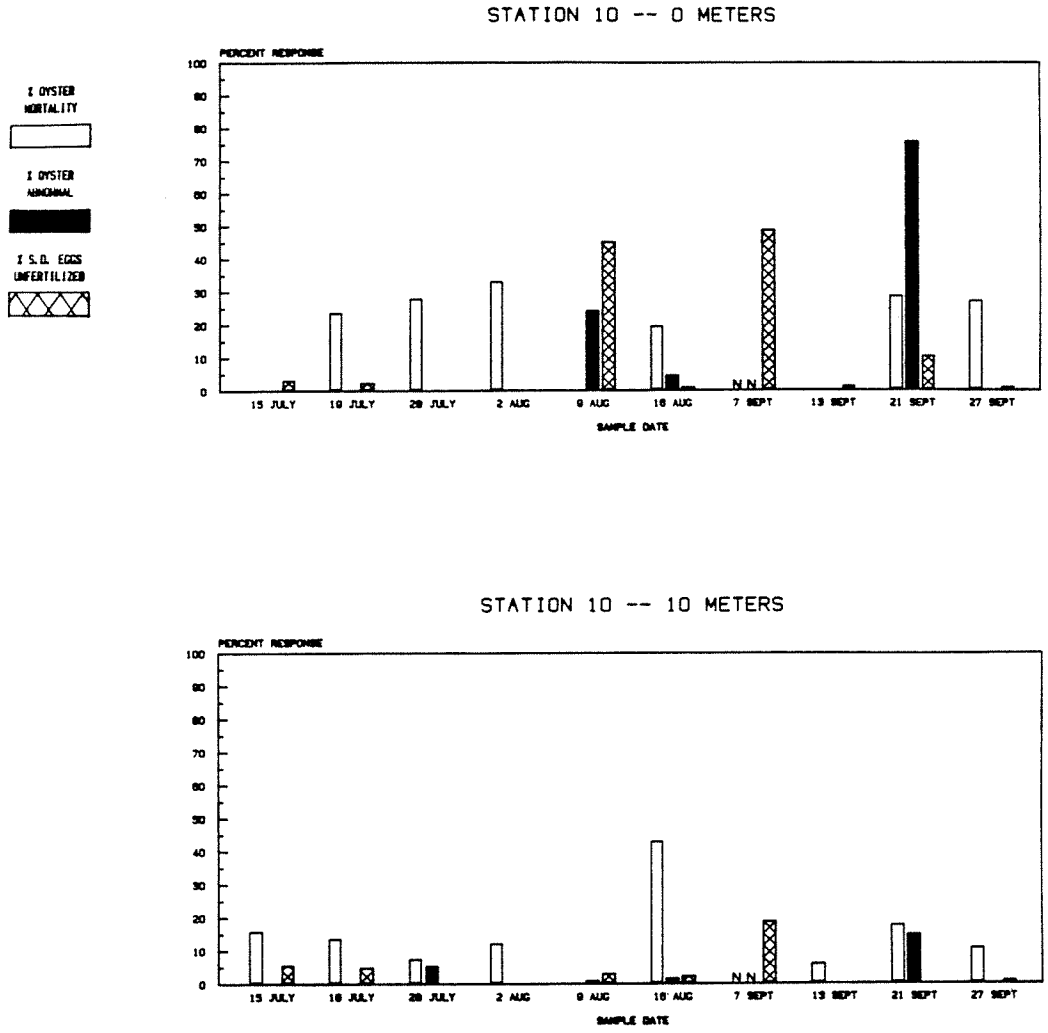



Figure 12.8J. Results of 1982 water column station No. 10 bioassays. N = not tested.

Bight. Within the Seahurst Bight (stations 4-10) the biological responses were greatest close to shore and in surface water.

Table 12.1 presents a consolidation of the receiving water biological responses together with some of the physical and chemical data collected by the Water Column group. The data are summarized both by station (or control water type) (Figure 12.9) and by depth (Figure 12.10). With these breakdowns, several trends by station are evident. Generally, average oyster mortality is greatest within the Seahurst Bight and least at the wide area stations while just the opposite is true for oyster abnormality, the Seahurst Bight stations showing consistently less abnormal development than the wide area samples (again, all values are adjusted relative to the Kincaid Lab Control (= "Primary" Control), hence these responses = 0.00). No trends by station are obvious for the sperm assay. The one high value of 19.82 for station 8 was primarily generated by poor egg fertilization on three consecutive sample dates between 9 August and 7 September 1982 (Figure 12.8 H) for reasons presently unknown.

Biological response trends by depth are fairly evident for all three bioassay indices. Average oyster mortality is greatest in the surface waters (especially at 1 m) and generally declines with depth. Average oyster abnormality, however, again shows a pattern the opposite of mortality with abnormality increasing with depth. Results of the sperm assay by depth suggest a bimodal response with highest percent eggs not fertilizing associated with surface and deep waters with minimum toxicity associated with the intermediate depths.

The physical/chemical data summaries presented in Table 12.1 show that there is very little to suggest that salinity, pH, ammonia, or Secchi disk depths are associated with the biological response trends. Average salinity

Table 12.1. Breakdown of average oyster embryo and sand dollar sperm (% egg unfertilized) assay responses and associated physical/chemical parameters measured at water column stations 1-10. Breakdown is by station and by depth.

| Breakdown | AVERAGE VALUES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Average % Oyster Mortality | Adjusted % Oyster Abnormal | Adjusted % Eggs Unfertilized | Salinity ($^{o}/_{oo}$) | pH | $NH_3$ (mg-at/l) | Chlorophyll (mg/l) | Primary Productivity (mg Carbon/$m^2$/day) | Secchi Disk Depth (meters) |
| By Station: | | | | | | | | | |
| 1 | 9.61 | 1.31 | 6.65 | 29.36 | 7.75 | 1.83 | 1.15 | -- | 9.50 |
| 2 | 9.86 | -0.46 | 4.45 | 29.56 | 7.81 | 1.54 | 1.61 | -- | 9.93 |
| 3 | 6.74 | 1.47 | 2.23 | 29.29 | 7.84 | 1.07 | 1.74 | -- | 5.50 |
| 4 | 13.78 | 0.34 | 4.13 | 29.86 | 7.86 | 1.58 | 1.13 | 20.55 | 11.00 |
| 5 | 15.70 | -7.08 | 2.74 | 29.76 | 7.94 | 1.35 | 1.99 | -- | 9.45 |
| 6 | 15.91 | -0.82 | 2.71 | 29.74 | 7.96 | 1.03 | 2.30 | -- | 9.40 |
| 7 | 9.48 | -4.12 | 3.72 | 29.70 | 7.95 | 1.38 | 2.74 | 55.75 | 8.70 |
| 8 | 16.10 | -5.91 | 19.82 | 29.46 | 7.98 | 1.42 | 3.02 | -- | 8.85 |
| 9 | 18.74 | -5.37 | 8.06 | 29.44 | 8.02 | 1.85 | 3.81 | -- | 8.65 |
| 10 | 11.19 | -3.32 | 6.86 | 29.40 | 8.01 | 1.07 | 4.33 | 89.30 | 8.83 |
| Kincaid Lab Control | 0.00 | 0.00 | 0.00 | 29.71 | 7.74 | -- | -- | -- | -- |
| Kincaid Carry Along | 1.68 | -2.18 | 0.86 | 29.71 | 7.74 | -- | -- | -- | -- |
| West Point Control | 11.69 | -1.44 | -0.16 | 29.52 | 7.82 | -- | -- | -- | -- |
| Friday Harbor (frozen) | -0.15 | -8.43 | -0.97 | 29.52 | 7.92 | -- | -- | -- | -- |
| By Depth (meters): | | | | | | | | | |
| 1 | 21.06 | -5.33 | 9.32 | 29.20 | 8.01 | 1.41 | 5.01 | 45.60 | 9.05 |
| 10 | 7.98 | -6.81 | 3.18 | 29.52 | 7.96 | 1.21 | 3.47 | -- | -- |
| 25 | 9.23 | -6.57 | 3.33 | 29.55 | 7.97 | 1.84 | 1.42 | -- | -- |
| 50 | 8.87 | -4.21 | 2.75 | 29.73 | 7.88 | 1.41 | 0.76 | -- | -- |
| 75 | 5.98 | 4.28 | 0.34 | 29.90 | 7.82 | 1.15 | 0.34 | -- | -- |
| 100 | 7.80 | 3.16 | 3.07 | 29.92 | 7.83 | 1.28 | 0.46 | -- | -- |
| 150 | 7.80 | 0.62 | 6.75 | 30.13 | 7.80 | 1.58 | 0.20 | -- | -- |
| 200 | 4.44 | 0.27 | 14.79 | 29.79 | 7.76 | 2.05 | 0.27 | -- | -- |

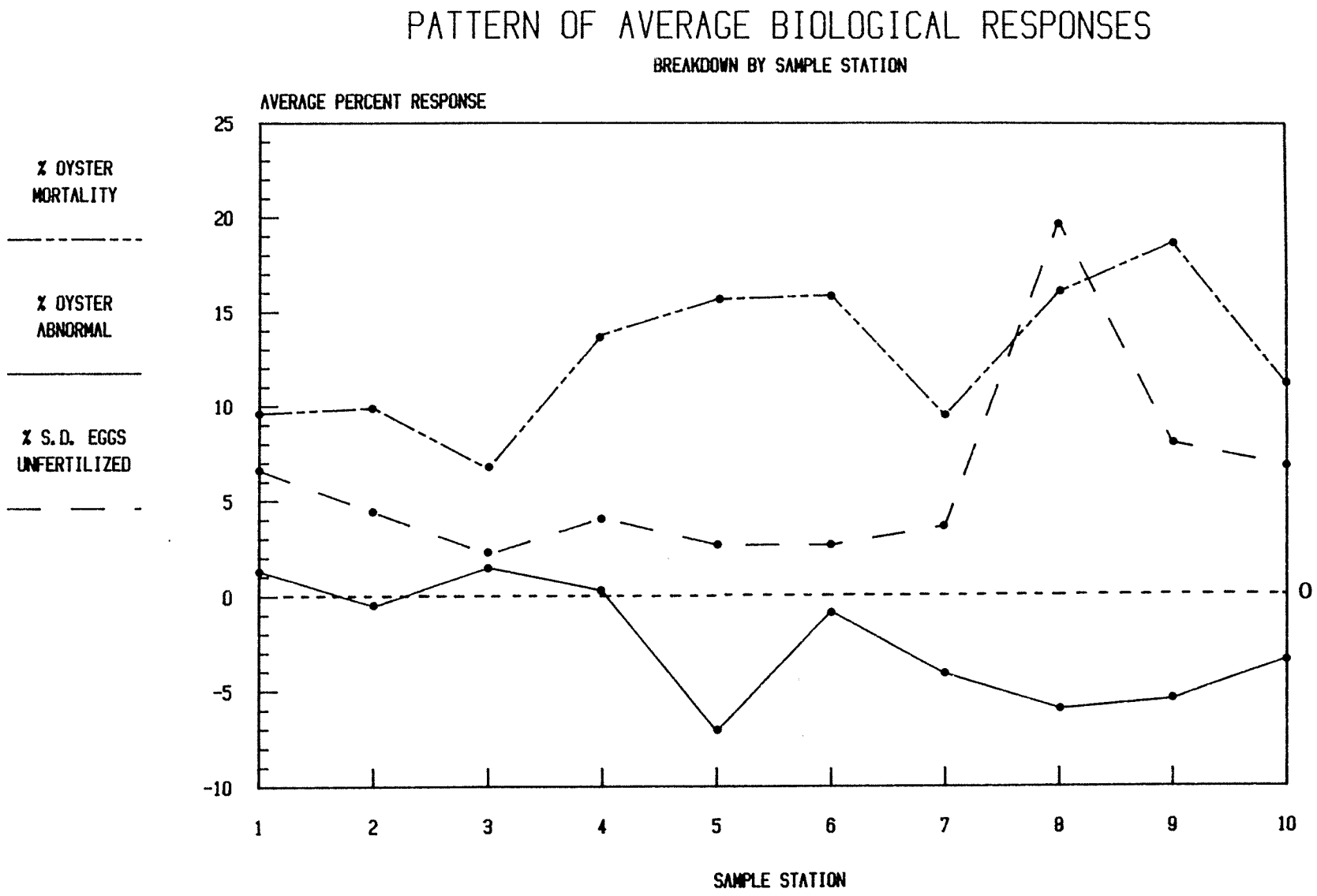



Figure 12.9. Comparison of the average oyster embryo and sand dollar sperm (% eggs unfertilized) bioassay responses by sample station for water column bioassays conducted during 1982. All values have been adjusted using the Kincaid Lab control sample responses as the baseline (i.e., 0.0%).

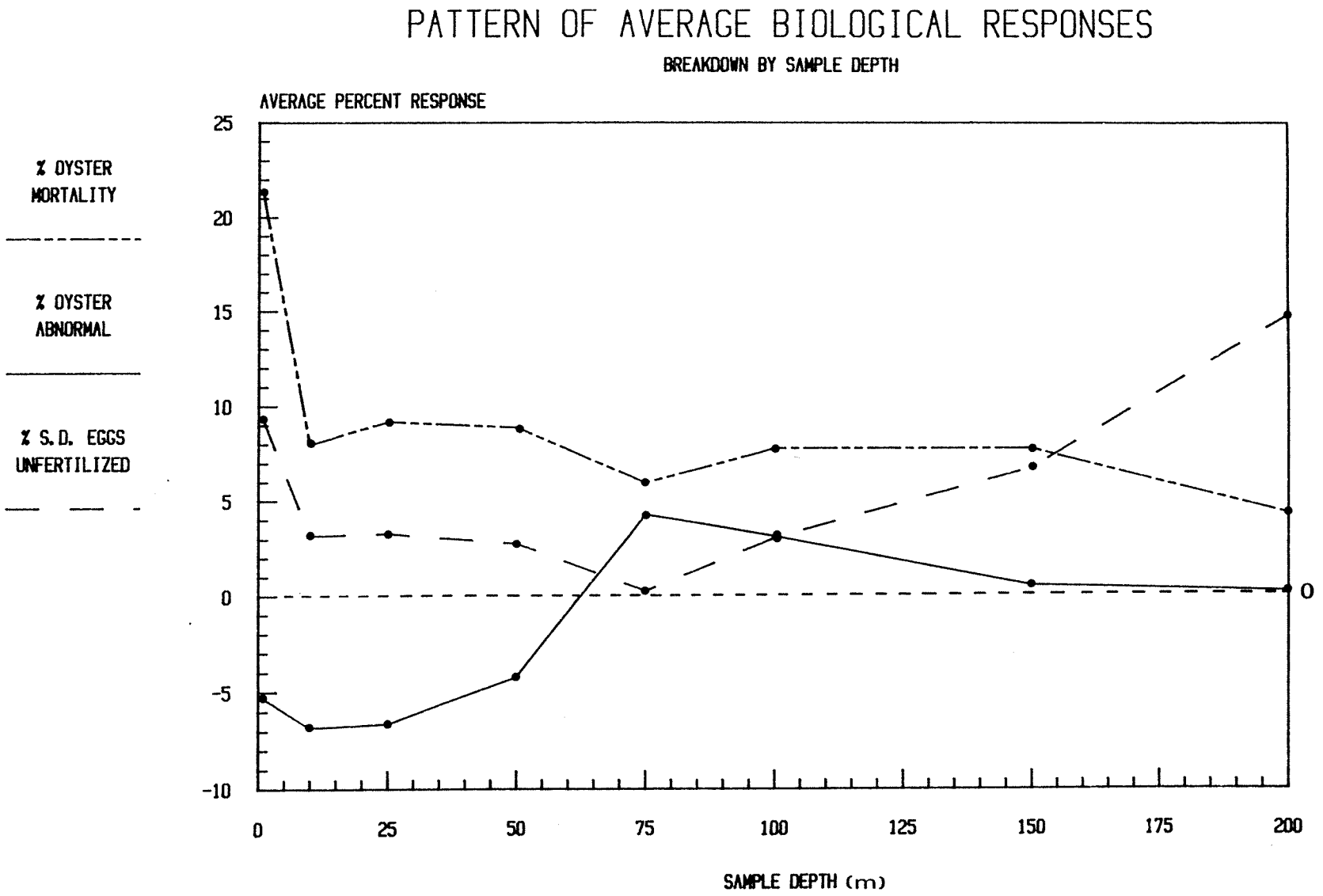



Figure 12.10. Comparison of the average oyster embryo and sand dollar sperm (% eggs unfertilized) bioassay responses by sample depth for water column bioassays conducted during 1982. All values have been adjusted using the Kincaid Lab control sample responses as the baseline (i.e., 0.0%).

values do increase with depth but only within a range of 1 o/oo. Likewise, there is a trend toward lower pH with depth, but again, only within narrow limits (0.25 pH units). Average chlorophyll, on the other hand, shows trends (high at inshore stations and in surface waters) reminescent of the pattern observed for oyster mortality.

To shed further light on possible relationships between the physical/chemical data and the biological responses, Pearson correlation coefficients (r) were calculated in a pairwise fashion for each of the variables presented in Table 12.1. The strongest meaningful correlation coefficients (Table 12.2) between the various physical/chemical measurements are between pH and chlorophyll (0.5960), salinity and depth (0.5037), pH and depth (-0.4819), Secchi disk depth and chlorophyll (-0.4396), ammonia and Secchi disk (0.4333), and depth vs. chlorophyll (-0.4201). These correlations suggest that chlorophyll increases with pH due to the respiratory/metabolic activity of the phytoplankton during a bloom, while Secchi disk depths decrease (more biomass in the water causing turbidity), and ammonia decreases (nitrogen being consumed by the phytoplankton). This pattern is inversely related to depth since most phytoplankton must remain in the photic zone for growth.

Most of the biological response coefficients are somewhat weaker than the physical/chemical associations. The strongest association between a biological response and a physical/chemical variable is between percent eggs unfertilized vs. chlorophyll (0.5648) followed by percent eggs unfertilized vs. pH (0.4231), which is predictable since there is a strong positive correlation between chlorophyll and pH. The strongest correlation with oyster mortality is with chlorophyll (0.2784) and for oyster abnormality is with ammonia (-0.3955), which is an inverse relationship. There are no strong

Table 12.2. Pearson correlation coefficients (r) between the oyster (mortality and abnormality) and sperm (% eggs unfertilized) responses and selected physical and chemical properties from water column station 1-10.

| Parameter | Station | Depth | Average % Oyster Mortality | Adjusted % Oyster Abnormal | Adjusted % Eggs Unfertilized | Salinity | PH | $NH_3$ | Chlorophyll | Primary Productivity | Secchi Disk Depth |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 1.000 | | | | | | | | | | |
| Depth | -.4521 | 1.000 | | | | | | | | | |
| Ave. oys. mortality | .0864 | -.2522 | 1.000 | | | | | | | | |
| Adj. oys. abnormal | -.0813 | .1205 | .1326 | 1.000 | | | | | | | |
| Adj. eggs unfertilized | .1032 | -.0521 | -.0361 | .0937 | 1.000 | | | | | | |
| Salinity | -.0315 | .5037 | -.1589 | .0947 | -.0093 | 1.000 | | | | | |
| PH | .4610 | -.4819 | .2743 | .0727 | .4231 | -.2627 | 1.000 | | | | |
| $NH_3$ | -.0518 | .0344 | -.0946 | -.3955 | -.0860 | .1563 | -.2915 | 1.000 | | | |
| Chlorophyll | .2189 | -.4201 | .2784 | .0585 | .5648 | -.2332 | .5960 | -.1692 | 1.000 | | |
| Primary Productivity | .2317 | -.2407 | .0062 | .0624 | .1058 | -.1080 | .2582 | -.0893 | .3006 | 1.000 | |
| Secchi Disk Depth | -.0428 | --- | .0289 | -.2057 | -.2027 | .5650 | -.1786 | .4333 | -.4396 | -.2387 | 1.000 |

correlations between each of the biological responses indicating that each toxicity index reacts to different variables (most of which are probably unmeasured and/or unknown at this time).

One of the foremost concerns in establishing any receiving water quality testing program is the selection of a proper "control" water to serve as the "reference standard." Traditionally in Washington State the 48-hr oyster embryo assay has served as the receiving water quality standard test and the control water was drawn from Quilcene Bay through a seawater pump system at the State Shellfish Laboratory at Brinnon, Washington. Occasionally, even this water proved unsatisfactory, possibly due to metabolites from phytoplankton blooms in Quilcene Bay. As such, the quality of the "standard" changed with the quality of the water pumped from the Bay - a less than ideal situation for long term comparative testing.

The toxicity studies reported here required that comparative bioassays be conducted to yield data which can be used to compare differences in toxicity both spatially and temporally. This is especially true for the interpretation of data collected in future post-discharge monitoring programs.

What, then, constitutes a satisfactory "control" water for long-term monitoring? Artificial seawater, while convenient, was dropped from consideration because of the multitude of different formulas available, potential unreliability of supply in future years, the possibility of contamination, and because it simply wasn't "natural" seawater. West Point seawater has traditionally served as the control water (usually filtered in a variety of ways) for many of our past studies and was included as a "control" water in this study - but it could not be considered the "reference standard" since it is drawn from the same body of water (Puget Sound) being tested (indeed, it is very close to the station 1 sampling site).

Therefore, the following requirements for a "reference standard" control water were enumerated.

1. It should be "natural" seawater.
2. It should come from a source outside Puget Sound of anticipated high quality (not close to significant urban/industrial development).
3. Salinity should be in the range of 30 $\pm$ 2 o/oo and pH 8.0 $\pm$ 0.5.
4. The water should be collected in a manner that assures an absence of phytoplankton metabolities.

Ideally, the reference water should also be collected fresh on the day of testing, but requirement #2 above plus the resulting variability between control samples effectively negates this possibility. Therefore, one-time collection and bulk storage seemed to be the only reasonable alternative.

Two sources of water were identified as coming reasonably close to the above stated requirements:

1. Seawater from bulk underground storage at Kincaid Hall (Zoology) on the U.W. campus. This water is pumped from the Anacortes ferry terminal at high tide, transported by truck in large plastic bags, and routinely used for marine embryological work without reported difficulties.
2. Water collected from the University's Friday Harbor Laboratory during a high tide in the Spring and quickly frozen in clean plastic bottles and kept frozen at $0^{o}$ F or less until used.

Little information is available on the quality of oyster development and survival in seawater that has been previously frozen. For this reason the Kincaid Hall water was established as the "Primary Control" water for Phase I bioassays and the other "control" waters tested along with the receiving water samples.

The results of the comparative control bioassays are tabulated by overall average responses (relative to Kincaid lab control water) for both embryo and sperm assays for each "control" water in Table 12.1 and graphically presented in Figure 12.11. Generally, there is little difference between the different waters with the exceptions of oyster mortality in West Point water (11.69 percent higher than the Kincaid lab control water) and oyster abnormality in the Friday Harbor water (8.43 percent less). These results suggest that West Point water is impacted by the same factors affecting oyster embryo survival (possibly phytoplankton metabolites) as are many of the receiving water surface samples throughout the Sound. Hence, this reinforces our selection criteria that water from within Puget Sound cannot serve as a satisfactory "reference standard." The Friday Harbor water, however, is substantially better relative to the abnormal index which is most closely associated historically with pollutants. This data suggests that the Kincaid Hall seawater may be subject to low levels of contaminants (sources or types unknown) which make it less desirable than frozen Friday Harbor water. Based on this information, we recommend the use of frozen Friday Harbor water collected in the spring during a high tide as the "standard reference" control water.

### 12.4.2 Sewage Bioassays

Bioassays were conducted to assess the toxicity of the various stages of sewage at the Renton Treatment Plant in order to: 1) determine present levels of toxicity to marine organisms, 2) document the effectiveness of the plant treatment process for removing toxicity, and 3) estimate potential impacts and/or margins of safety relative to the health of sensitive marine animal life stages in the proposed discharge area.

The results of the 48-hr oyster embryo and 60-min sand dollar sperm

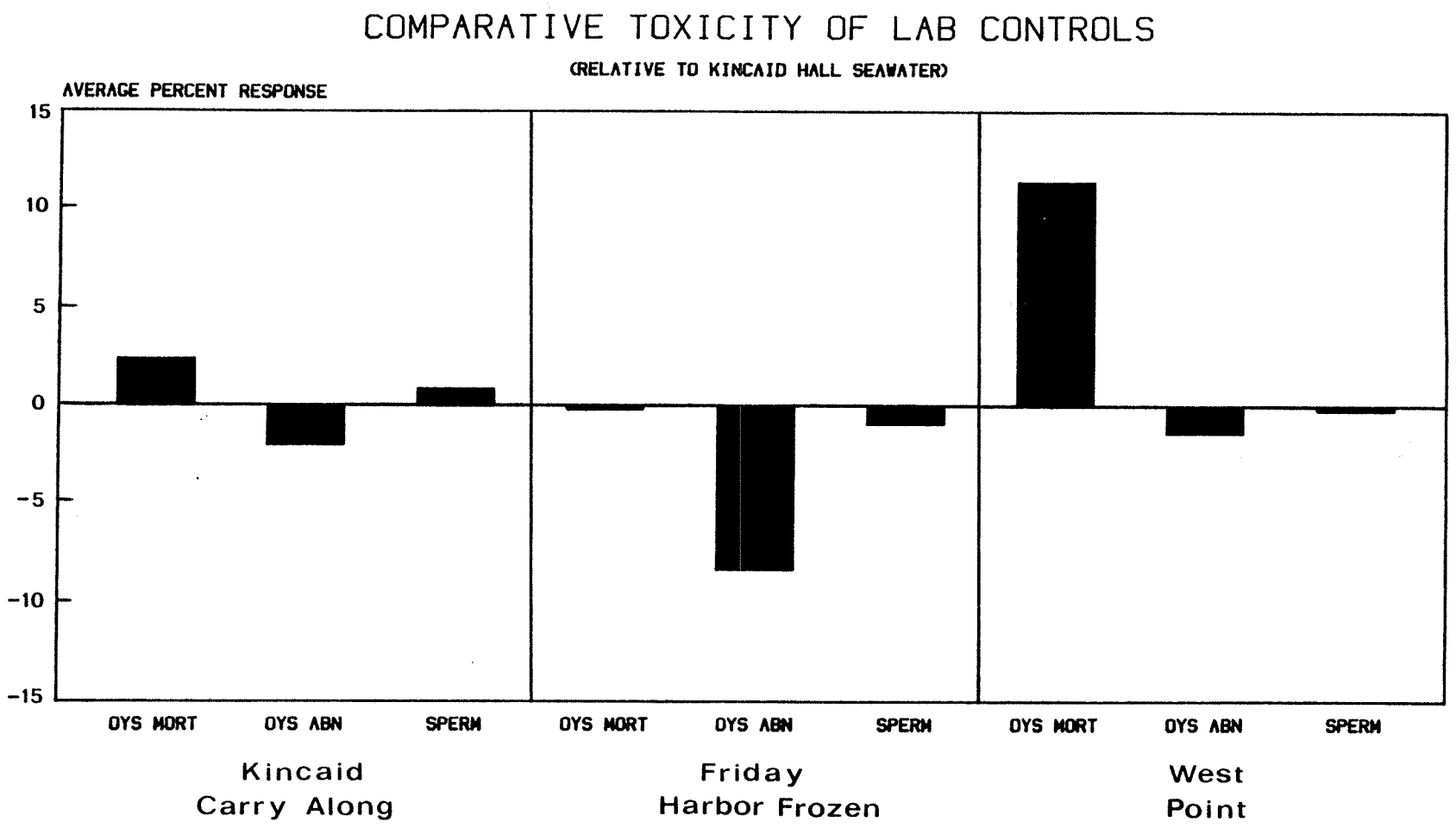



Figure 12.11. Comparative average responses of the oyster embryo and sand dollar sperm bioassays to the three "secondary" control waters. All responses are adjusted using the Kincaid Lab control ("primary" control) sample responses as the baseline (i.e., 0.0%).

bioassays of Renton sewage are presented in Table 12.3 by EC50's and 95 percent fiducial limits and in Appendix Table 12.2 (raw data) for each type of test and stage of sewage treatment (and a freshwater control series). The relevant chemical measurements from each sewage bioassay are listed in Appendix Table 12.3. The general order of toxicity was: Chlorinated Secondary > Influent > Primary > Dechlorinated Secondary > Secondary > Freshwater. This relationship is graphically illustrated by response surface plots of the results of all bioassays for the sperm assay (Figure 12.12) and for the oyster embryo abnormality index (Figure 12.13). Both plots show the relative toxicity of each stage as described above and also illustrate the fairly high degree of variability between test dates. Especially important to note is the high degree of toxicity removal between primary and secondary treatment, the high toxicity generated by chlorination and its subsequent mitigation by the dechlorination process. Indeed, oyster embryos are very little affected in concentrations of secondary sewage or dechlorinated secondary effluent as high as 20 percent by volume (the highest concentration tested).

The relative sensitivity of the three bioassay indices is: Sperm assay (fertilization) > Oyster abnormality (development) > Oyster mortality (survival). This relationship is graphically illustrated by response surface plots of the average test results for each sewage type (Figure 12.14). This figure illustrates again the relative toxicity of each sewage treatment stage.

In the past the sea urchin/sand dollar sperm assay was developed, refined, and validated with the support and cooperation of METRO, the U.S. Environmental Protection Agency, and the U.W. Sea Grant Program (Dinnel et al. 1981; Dinnel et al. 1982; Stober et al. in prep.). Early sperm assays using an unrefined methodology tested the toxicity of West Point primary effluent

Table 12.3. Comparison of the 50% effective concentrations (EC50) and 95% fiducial limits for oyster embryo and sand dollar sperm assays of five types of Renton Sewage and equivalent freshwater dilutions of seawater. The EC50's are based on the average results of 7-10 separate bioassays.

| Sewage Type | EC50 (95% Fiducial Limits) (% Sewage V/V) | | |
|---|---|---|---|
| | Sand dollar Sperm Assay | Oyster Embryo Abnormality | Oyster Embryo Mortality |
| Renton Influent | 1.88 (1.70-2.13) | 4.21 (3.30-5.63) | 5.68 (4.34-7.80) |
| Renton Primary | 2.90 (2.60-3.28) | 5.90 (5.41-6.46) | 7.31 (5.67-9.78) |
| Renton Secondary | 17.62 (14.72-21.35) | >20.0 | >20.0 |
| Renton Chlorinated | 1.02 (0.83-1.26) | 2.26 (2.11-2.43) | 3.24 (2.48-4.58) |
| Renton Dechlorinated | 7.13 (6.42-7.97) | >20.0 | >20.0 |
| Freshwater Dilutions | >20.0 | >20.0 | >20.0 |

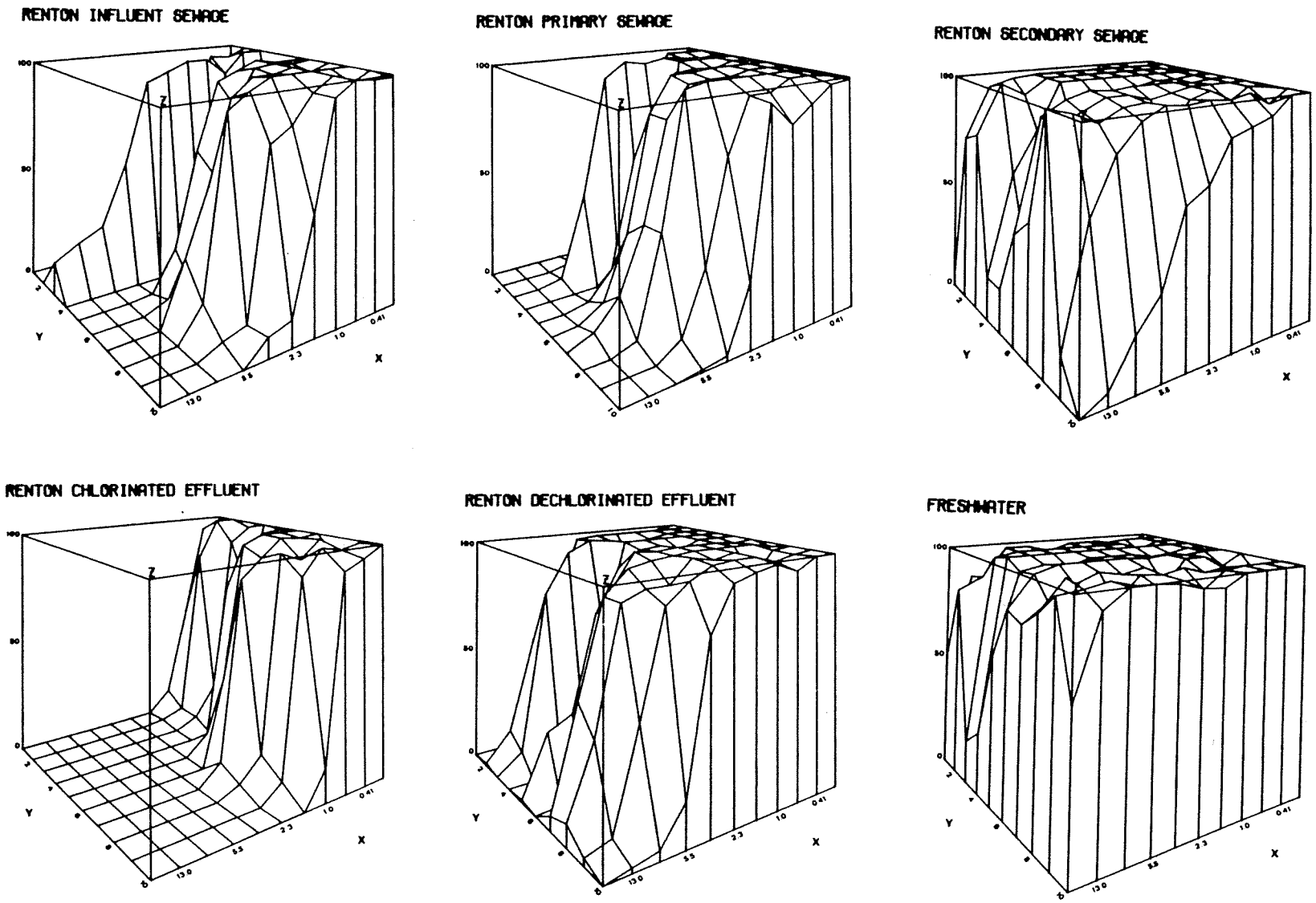
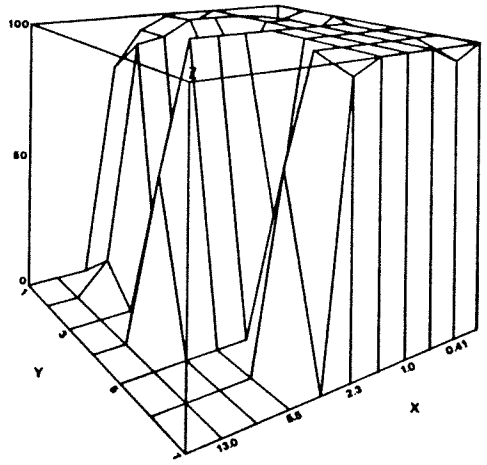


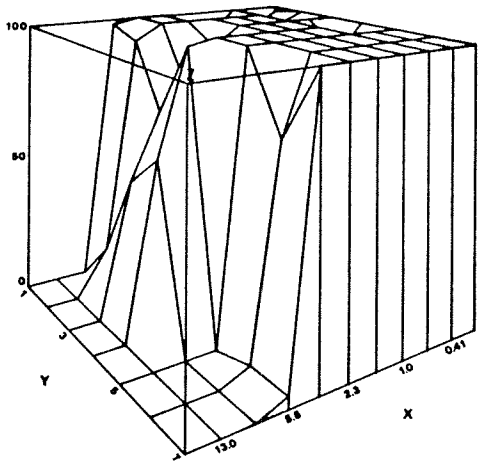

Figure 12.12. Response surface plots of sand dollar egg fertilization success following 60-min sperm exposures to dilutions of Renton sewage or freshwater during 10 bioassays conducted during the summer of 1982.

X-AXIS IS PERCENT SEWAGE. 20.0 - 0.27 PCT
Y-AXIS IS SAMPLE DATE
Z-AXIS IS PERCENT NORMAL DEVELOPMENT

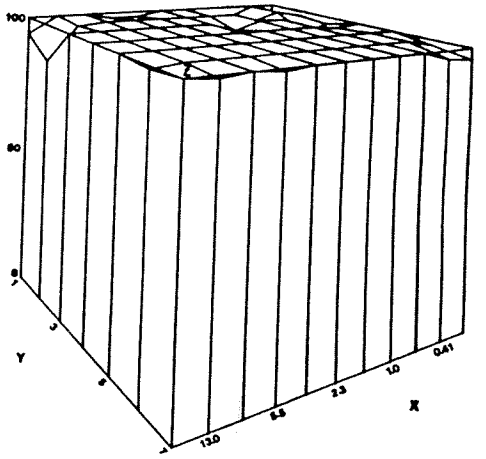
RENTON INFLUENT SEWAGE



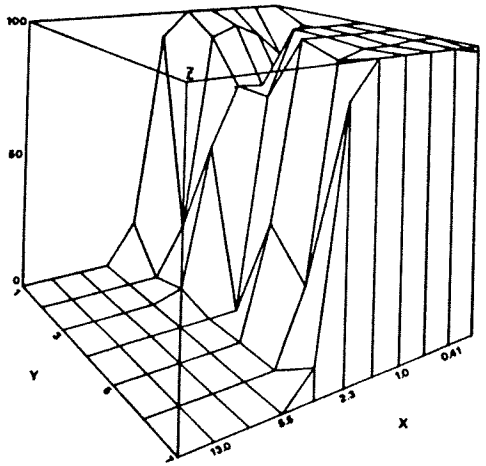

RENTON PRIMARY SEWAGE



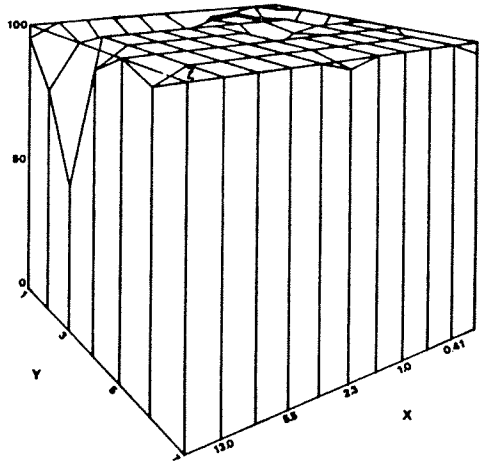

RENTON SECONDARY SEWAGE




RENTON CHLORINATED SECONDARY SEWAGE




RENTON DECHLORINATED SECONDARY SEWAGE




FRESHWATER

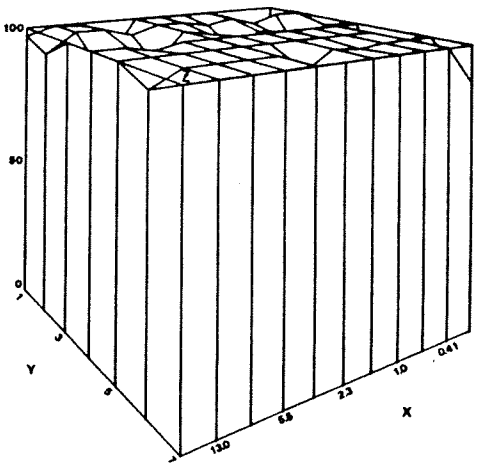





Figure 12.13. Response surface plots of oyster embryo normal development following 48-hr fertilized egg/ embryo exposures to dilutions of Renton sewage or freshwater during seven bioassays conducted during the summer of 1982.

RENTON SEWAGE TOXICITY BY BIOASSAY TYPE

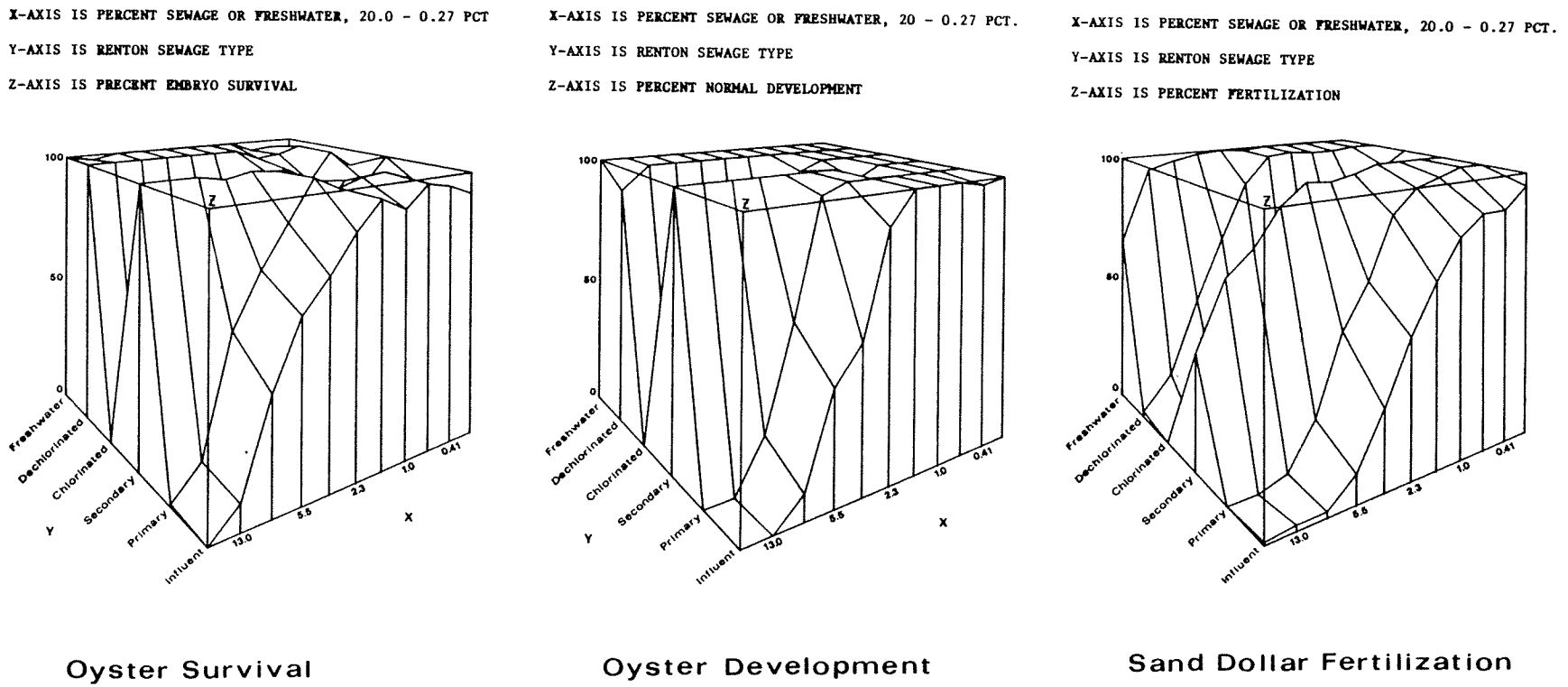



Figure 12.14. Response surface plots showing relative responses between the oyster embryo (survival and normal development) and sand dollar sperm (egg fertilization success) bioassays of dilutions of five stages of Renton sewage or freshwater conducted during summer 1982.

and related the results to previous 96-hr bioassays with fish and macroinvertebrates for the same effluent source (Dinnel et al. 1981). The results of these tests showed that the sperm assay was a quick and sensitive procedure which was 5-10 times more sensitive than 96-hr fish bioassays. These tests defined average 15-min sperm exposure EC50's of 2.2 and 4.8 percent for chlorinated and unchlorinated West Point primary sewage, respectively.

Subsequent to these tests, the sperm assay methodology was refined and "standardized" to make it more reliable (minimize variability associated with the test) and more sensitive. The assay has changed in three specific ways: 1) sperm exposure times have been standardized to 60 minutes, 2) the elapsed times between spawning, mixing and dilution of sperm, addition of the sperm to test solutions, egg additions, etc. have been standardized, and 3) the sperm:egg ratios (which are species specific) have been optimized to insure maximum sensitivity. Most recent tests with single toxicants (metals and pesticides) have shown that these refinements have generally improved the sperm assay sensitivity by about 2-4 times (Dinnel et al. 1981).

It was, therefore, desirable to "recalibrate" the sperm assay to sewage (a complex group of toxicants) in order to place the refined methodology in perspective to historical (but unrefined) measurements prior to assessment of the toxicity of Renton sewage. Five samples of unchlorinated West Point primary sewage together with the previously described Renton sewage samples were tested. The results showed that the present sensitivity of the sperm assay to unchlorinated West Point sewage was roughly 3-4 times greater (EC50 = 1.32 percent) than the previous methodology, a result in agreement with previous work with single toxicants. However, care must be used in making such a comparison for two simple reasons: 1) the high variability in toxicity

between sewage grab samples demands more than 5 assays for proper assessment and 2) long-term changes in sewage quality (related to input sources, treatment methods, efficiencies, etc.) which may affect toxicity are unknown. Indeed, recent information shows that split-flow experiments were being conducted with various chemical treatments during the West Point toxicity testing and the source of sewage tested (the chemically untreated flow) was not, in fact, typical of normal operating conditions of the plant or of the effluent (a combination of the treated and untreated flows). Exact relationships may never be known for these reasons but a "ball park" comparison nonetheless points to a greater sensitivity of the refined sperm assay in relation to sewage.

In addition to the sperm assays of West Point sewage, oyster embryo assays were conducted on the same five West Point samples. The results again show that oyster embryos are less sensitive indicators of sewage toxicity than sand dollar sperm with 48-hr EC50's of 6.12 and 7.13 percent primary sewage for abnormality and mortality, respectively (Table 12.4). Historically, a single oyster embryo bioassay of West Point primary (chlorinated) sewage by the Washington State Shellfish Laboratory (Mark Carr, pers. comm.) in 1973 found the toxicity to roughly equal an EC50 (for abnormality) of 2.5 percent. Assuming a 2x greater toxicity of chlorinated over unchlorinated primary sewage (Stober et al. 1977, Dinnel et al. 1981), their results agree with the present results for oyster abnormality (Table 12.4), suggesting that West Point sewage (aqueous phase) toxicity remains similar to past years. Again, "ball park" assessments are associated with a high degree of uncertainty and must be viewed with caution.

Since the toxicity testing of the West Point effluent was coincidental (i.e., side-by-side) with the Renton tests, a rough comparison of the toxicity

Table 12.4. Comparative toxicity of Renton and West Point Primary (unchlorinated) sewage as determined by oyster embryo and sand dollar sperm bioassays. The EC50's are based on the average results of 4-5 comparative bioassays.

| Sewage Type | EC50 (95% Fiducial Limits) (% Sewage V/V) | | |
|---|---|---|---|
| | Sand dollar Sperm Assay | Oyster Embryo Abnormality | Oyster Embryo Mortality |
| Renton Primary | 2.86 (2.55-3.27) | 7.16 (5.41-9.92) | 6.98 (4.62-11.79) |
| West Point Primary | 1.32 (1.27-1.39) | 6.12 (4.24-9.75) | 7.13 (6.04-8.55) |

Table 12.5. Comparative toxicity of ammonia (as $NH_4Cl$ added to seawater) as determined by oyster embryo and sand dollar sperm bioassays.

| | EC50 (95% Fiducial Limits) | | |
|---|---|---|---|
| | Sand dollar Sperm Assay | Oyster Embryo Abnormality | Oyster Embryo Mortality |
| Ammonia (mg/l) | 35.0 (30.2-40.5) | 11.7 (10.2-13.4) | 21.6 (18.5-25.4) |

of the primary sewage shows little, if any, difference in average toxicity between the two plants (Table 12.4 and Appendix Table 12.4). The sperm assay suggests a greater toxicity of the West Point primary but both oyster indices show no significant difference (based on similar fiducial limits). The utility of this comparison, however, is limited since it is only based on five tests and the fact that Renton discharges a high quality secondary effluent. Presently, the Renton plant, on rare occasion, does discharge up to 25 percent primary sewage during periods of plant overload (Richard Finger, pers. comm.) but this situation should cease with the scheduled plant upgrading associated with the new marine discharge.

12.4.3 Ammonia Bioassays

Bioassays of ammonia (as $NH_4Cl$) added to filtered West Point seawater yielded the following EC50's: oyster embryo abnormality index = 11.7 mg/l, oyster embryo mortality index = 21.6 mg/l, and the sperm assay index = 35.0 mg/l as total ammonia (Table 12.5).

12.4.4 Amphipod Sediment Bioassays

12.4.4.1 Baseline Samples

Baseline bioassays were conducted in three separate runs. Due to water quality problems (specifically, anoxic sediment conditions and zinc contamination) which may have influenced test results in the initial two runs, only data from Run 3 (which retested sediments from Runs 1 and 2 showing significant responses) are included (Appendix Table 12.5) and discussed in this report.

"Control" survival (i.e., mean survival statistically indistinguishable from the West Beach control sediment) was obtained for most of the twelve Seahurst sediments tested in Run 3 (Table 12.6A). The exception was site C640 in which mean survival was significantly reduced. Note, however, that

Table 12.6. Amphipod mean survival and mean moribund in Seahurst area baseline sediments from Run 3 conducted during the fall of 1982. Means are based on four replicates with twenty animals per replicate. Means followed by * are significantly different ($p < 0.05$) than the West Beach controls using Dunnett's test.

A. Mean Proportion Survival

| Station | Mean | S.D. |
|---|---|---|
| G50W | 1.000 | 0.000 |
| West Beach | 0.962 | 0.047 |
| OT-2E | 0.937 | 0.047 |
| J600E | 0.937 | 0.047 |
| G780 | 0.900 | 0.057 |
| I690 | 0.887 | 0.103 |
| OT-1E | 0.887 | 0.047 |
| H640 | 0.875 | 0.086 |
| A400E | 0.875 | 0.119 |
| B75W | 0.837 | 0.062 |
| C600E | 0.812 | 0.160 |
| C400E | 0.800 | 0.168 |
| C640 | 0.787 | 0.103 |
| Duw. #2* | 0.737 | 0.062 |

B. Mean Proportion Moribund

| Station | Mean | S.D. |
|---|---|---|
| A400E* | 0.057 | 0.043 |
| C640 | 0.029 | 0.058 |
| G780 | 0.014 | 0.029 |
| OT-2E | 0.013 | 0.027 |
| C400E | 0.013 | 0.026 |
| C600E | 0.013 | 0.000 |
| B75W | 0.000 | 0.000 |
| OT-1E | 0.000 | 0.000 |
| Duw. #2 | 0.000 | 0.000 |
| West Beach | 0.000 | 0.000 |
| J600E | 0.000 | 0.000 |
| I690 | 0.000 | 0.000 |
| H640 | 0.000 | 0.000 |
| G50W | 0.000 | 0.000 |

although mean survival in C640 is statistically distinct from the West Beach control, survival is not that much different from the other stations tested on transect C (range of 78%-81%). The lowest mean survival (73%) occurred in the negative control sediment, Duwamish #2.

Results from the reburial test (Table 12.6B) indicate that sediment which significantly depressed reburial activity did not always concurrently depress mean survival and vice versa. In Run 3 an increased number of moribund animals occurred in sediment from A400E despite the relatively high overall mean survival, while no moribund animals were observed in the significantly toxic Duwamish sediment. This seems to indicate that while some sediment may not be acutely toxic to amphipods, it may cause sublethal stress which could ultimately influence survival.

As another measure of sublethal stress, secondary stress tests involving a temperature and/or salinity shock to survivors of the 10-day bioassay were implemented following Run 1. However, due to the water quality problems noted above, results were deleted from this report. The potential of secondary stress tests as an indication of sublethally harmful sediment is being investigated in 1983 bioassays.

The generally lowered survival and elevated inability to rebury which occurred in amphipods exposed to some Seahurst sediments imply that the animals were stressed. The cause(s) of this stress could be attributed to chemical contamination and/or to physical differences in grain sizes of the test sediments when compared to West Beach control sand. The physical/chemical composition of the test sediments are currently being analyzed by the Chemistry group and METRO. Possible correlations between this data and amphipod mortality/moribundity data will be analyzed and reported at a later date.

Since differences between sediment grain sizes may be a confounding factor, we decided to conduct preliminary tests of grain size tolerances of R. abronius in a bioassay situation. As several other questions concerning bioassay protocol had arisen by this time, the experimental design for the grain size tolerance tests allowed concurrent testing of: 1) fresh vs. frozen sediment; 2) static vs. flow-through systems; 3) adults vs. juveniles; and 4) a between-tank effect. This series of two bioassay runs (called Runs A and B) composed the "Methods Comparison" tests.

12.4.4.2 "Methods Comparisons" Tests

It is necessary to realize at this point that three major amphipod sediment bioassay techniques are being used to test sediment from Puget Sound: the "Swartz" system (EPA, Newport, OR); the "Ott" system (NMFS, Seattle, WA and METRO); and the "Pierson" system (Army Corps of Engineers, Seattle, WA). Each system has been described in the methods section and the differences are summarized in Table 12.7. The point of interest is how results generated by different bioassay systems compare with each other. To test this, all three bioassay systems were run simultaneously with identical sediment and animals. However, since there was also a question regarding the effects of grain size vs. chemical contamination, three different types of sediment were chosen: West Beach, an uncontaminated sand; D660, a probably uncontaminated silt/clay; and Duwamish #3, a contaminated silt/clay. These three sediments were tested both fresh (within 48 hr of collection) and (previously) frozen. The three hypotheses of Run A of the "Methods Comparison" test were:

Ho1: Methodology does not affect results (Swartz = Ott = Pierson)

Ho2: Sediment type does not affect results (WB = Duw = D660)

Ho3: Results are not affected by freezing sediment

Run A was designed as illustrated in Table 12.8. The raw data and

Table 12.7. Comparison of sediment bioassay techniques.

| Contrast | | "Ott" (Static) | "Swartz" | "Pierson" | "Ott" (Flow) |
|---|---|---|---|---|---|
| Technique: | Static | X | X | | |
| | Flow-through | | | X | X |
| | Beaker | | 1-L | 2-L | |
| Container: | "Chamber" | X | | | X |
| | Glass | | X | X | |
| Material: | PVC | X | | | X |
| | Nitex | X | | X | X |
| Air/water interface available to animals? | (Yes/No) | N | Y | N | N |
| Replicates: | Number | 5 | 1-5 | 3 | 5 |
| | Isolated (Yes/No) | N | Y | Y | N |
| Animal: | Rhepoxynius abronius | X | X | | X |
| | Grandifoxus grandis | | | X | |
| Age: | Adult | | | X | |
| | Juvenile | X | X | | X |
| Sediment: | Frozen | | X | X | X |
| | Fresh | X | | | |
| Sediment volume: | 150-200 ml | X | X | | X |
| | 400 ml | | | X | |
| Water temperature: | 15° | X | X | | |
| | Ambient | | | X | X |
| Light: | Constant | | X | | X |
| | 14:10 (L/D) | X | | X | |
| Relative man-hours (Low/Medium/High): | | | | | |
| | Initial construction | H | L | M | H |
| | Bioassay setup | L | L | M | L |
| | Monitoring during 10 days | M | L | H | L |
| | Bioassay take-down and cleanup | H | L | M | H |
| Material cost (Low/Medium/High) | | M | M | M | M |

Table 12.8. Experimental design for "Methods Comparison" Run A.

I. Survival

| | Fresh Sediment | | |
|---|---|---|---|
| Method | Duwamish | D660 | West Beach |
| Method 1 Ott (static) | (Duw x Ott) | (D660 x Ott) | (WB x Ott) |
| Method 2 Swartz (static) | (Duw x Sz) | (D660 x Sz) | (WB x Sz) |
| Method 3 Pierson (flow-through) | (Duw x Pr) | (D660 x Pr) | (WB x Pr) |

II. Reburial

| | Frozen Sediment | | |
|---|---|---|---|
| Method | Duwamish | D660 | West Beach |
| Method 1 Ott (static) | (Duw x Ott) | (D660 x Ott) | (WB x Ott) |
| Method 2 Swartz (static) | (Duw x Sz) | (D660 x Sz) | (WB x Sz) |

Statistical Analysis

Effects of method, sediment, and freezing.

proportions for Run A are given in Appendix Table 12.6.

12.4.4.3 Survival

Methods Comparison (Ho1). The columns in Table 12.9, indicate that all three systems yielded similar results except for West Beach fresh sediment and Duwamish frozen sediment. The two West Beach columns indicate that mean survival was significantly different between the static and flow-through systems in the fresh sediment and between fresh and frozen sediment in the static systems.

In fresh sediment, very few animals survived the 10-day bioassay in the two static systems ("Sz" and "Ott") in direct contrast to the 100% survival observed in the flow-through system ("Pr"). The low survival in the fresh sediment also contrasts the high survival observed in the same two static systems in frozen sediment. Since this pattern of survival was not repeated in either D660 or Duwamish sediment, these results imply that the cause of high mortality in the West Beach sediment was 1) unique to the West Beach fresh sediment and 2) probably an artifact. The latter conclusion is based on the observations that the frozen West Beach sediment did not cause significant mortality and the flow-through system dilutes the effect as witnessed by the high amphipod survival in the "Pierson" flow-through fresh sediment. Additionally, past use of fresh West Beach sand in static amphipod bioassays has always resulted in high survival (Ott, in prep.; Cummins, EPA, pers. comm.) hence, results of the fresh West Beach, static tests will be deleted from further consideration.

Sediment Comparison (Ho2). The rows in Table 12.9, the results show that mean survival was significantly different among the three sediment types (in both fresh and frozen data sets). In the fresh sediment, mean survival in both D660 and Duwamish sediment was significantly, and equally, depressed from

Table 12.9. Mean (and standard deviations) amphipod survival in fresh and frozen sediments from Run A, Methods Comparison Tests. Means are based on four replicates with twenty animals per replicate. NS = not significant, * = significant at $p < 0.05$); two-way ANOVA.
(1) Ho: There is no effect of sediment on survival.
(2) Ho: There is no effect of method on survival.

A. Fresh Sediment

| Sediment: Method | Duwamish (Duw) | D660 | West Beach (WB) |
|---|---|---|---|
| "Ott" (Ott) | 0.750 (0.070) | 0.780 (0.027) | 0.280 (0.057) |
| "Swartz" (Sz) | 0.590 (0.320) | 0.770 (0.075) | 0.050 (0.050) |
| "Pierson" (Pr) | 0.711 (0.147) | 0.750 (0.200) | 1.000 (0.000) |

(1) Ho: $F_{2,36} = 12.550$*
(2) Ho: $F_{2,36} = 32.433$*

B. Frozen Sediment

| Sediment: Method | Duwamish (Duw) | D660 | West Beach (WB) |
|---|---|---|---|
| "Ott" | 0.580 (0.057) | 0.390 (0.134) | 0.840 (0.065) |
| "Swartz" (Sz) | 0.810 (0.089) | 0.360 (0.230) | 0.910 (0.089) |

(1) Ho: $F_{2,24} = 27.306$*
(2) Ho: $F_{1,24} = 2.301$ (NS)

survival in the West Beach x "Pierson" cell. (We have assumed in this data set that the survival in the West Beach sediment x static systems is abnormal and so have arbitrarly chosen the WB x "Pr" test as the "control.") These data were reanalyzed after deleting the WB x static tests using a one way ANOVA to determine significant results. In the frozen sediments, results are less clear: "control" survival was obtained in the Duwamish x "Sz" test, while survival in Duw x "Ott" and both D660 tests was significantly depressed from the West Beach controls.

Fresh vs. Frozen Sediment (Ho3). Columns of equal sediment type in Table 12.9, indicate that although mean survival was generally similar in both fresh and frozen Duwamish and West Beach sediments, mean survival was different between fresh and frozen D660 sediment (again, rejecting the WB x statics as abnormal). Presently, there is no good explanation for the differences observed for fresh vs. frozen D660 sediments.

12.4.4.4 Reburial Activity

Methods Comparison (Ho1). The differences within the columns in Table 12.10, appear to indicate that methodology influences reburial activity. Unlike the survival data, results were not even consistent between the two static systems. In fresh sediments, the Duwamish x Sz test alone yielded significantly higher inactivity than any other test (all others being indistinguishable from WB tests), while in frozen sediments the Ott method gave significantly higher inactivity in both Duwamish and D660 sediments.

Sediment Comparison (Ho2). Comparison of the rows in Table 12.10 indicate in general, Duwamish sediment resulted in the highest level of inactivity, D660 sediment an intermittent level of inactivity, and WB sediment no inactivity.

Fresh vs. Frozen Sediment (Ho3). The columns of equal sediment type

Table 12.10. Mean percent (and standard deviations) moribund amphipods in fresh and frozen sediments from Run A of the Methods Comparison Test. Means are based on four replicates (+ = N of 3) with twenty animals per replicate. NS = not significant, * = significant at $p < 0.05$; two way ANOVA.
(1) Ho: There is no effect of method on activity.
(2) Ho: There is no effect of sediment on activity.

A. Fresh Sediment

| Sediment / Method | Duwamish (Duw) | D660 | West Beach (WB) |
|---|---|---|---|
| "Ott" | 0.012 (0.060) | 0.050 (0.052) | 0 |
| "Swartz" (Sz) | 0.224 (0.189) | 0 | 0 |
| "Pierson" (Pr) | 0.164 (0.191) | 0 | 0 |

(1) Ho: $F_{2,36} = 0.776$ (NS)
(2) Ho: $F_{2,36} = 11.850$***

B. Frozen Sediment

| Sediment: / Method | Duwamish (Duw) | D660 | West Beach (WB) |
|---|---|---|---|
| "Ott" | 0.641 (0.384) | 0.306 (0.078) | 0 |
| "Swartz" | 0.253 (0.086) | 0.058 (0.081) | 0 |

(1) Ho: $F_{1,24} = 22.352$***
(2) Ho: $F_{2,24} = 52.141$***

between fresh and frozen, indicate that frozen sediment caused more inactivity in both Duwamish and D660 types than fresh sediment. Results in WB sediment remained unaffected by freezing.

Results of Run A raised further questions concerning validity of comparisons between methods, especially if the different methods also differ in use of fresh and frozen sediment types. Run B was designed to fill in the gaps from Run A and test a new system: an "Ott" flow-through system (Figure 12.7) was added (replacing the "Pierson" system) to test frozen sediment. Since a flow-through system yielded the most consistent results in Run A, it was decided to continue using such a system. However, the "Pierson" system was replaced with the more convenient "Ott" system. In addition, replicate tanks were introduced to determine if there was a between-tank effect, investigations of fresh vs. frozen sediment were continued, and the sensitivity of adults vs. juveniles was also tested.

The hypotheses of Run B were:

Ho1: Age does not affect results

Ho2: There is no between-tank effect

Ho3: Methodology does not affect results

("Ott" static = "Ott" flow = "Swartz")

Ho4: Sediment type does not affect results

(WB = Duw = D660)

Ho5: Freezing sediment does not affect results

Run B was designed as illustrated in Table 12.11. The raw data and proportions are given in Appendix Table 12.7 for Run B.

Between-Tank and Age Effect (Ho1 and Ho2). No differences were detected in mean survival or mean percent moribund in adults vs. juvenile amphipods either within or between two tanks of Duwamish sediment (Table 12.12A & B).

Table 12.11. Experimental design for "Methods Comparison" Run B.

I. Survival

| Method | Fresh Sediment |
|---|---|
| | West Beach |
| Ott static (Ott) | WB x Ott |
| Ott flow (flow) | WB x flow |
| Swartz (Sz) | WB x Sz |

II. Reburial

| Method | Frozen Sediment | | |
|---|---|---|---|
| | Duwamish | D660 | West Beach |
| Ott static (Ott) | Duw x Ott | D660 x Ott | WB x Ott |
| Ott flow (flow) | Duw x flow | D660 x flow | WB x flow |
| Swartz (Sz) | Duw x Sz | D660 x Sz | WB x Sz |

| Tank 1 | Tank 2 |
|---|---|
| Juveniles & Adults | Juveniles & Adults |

Statistical Analyses

Effects of tanks, age, method, sediment, and freezing.

Table 12.12A. Mean (and standard deviations) adult and juvenile amphipod survival in Duwamish sediment from methods comparisons, Run B (NS = no significant at 0.05; two-way ANOVA).

(1) Ho: There is no difference between age in affecting survival/activity.
(2) Ho: There is no difference in survival/activity due to tanks.

| Tank 1 | | Tank 2 | |
|---|---|---|---|
| Juvenile | Adult | Juvenile | Adult |
| 0.816 (0.115) | 0.950 (0.050) | 0.716 (0.202) | 0.733 (0.028) |

Table 12.12B. Mean (and standard deviations) adult and juvenile amphipods moribund in Duwamish sediment from methods comparisons, Run B (NS = not significant at 0.05; two-way ANOVA). (See hypotheses above.)

| Tank 1 | | Tank 2 | |
|---|---|---|---|
| Juvenile | Adult | Juvenile | Adult |
| 0.066 (0.115) | 0.069 (0.026) | 0.088 (0.153) | 0 |

(1) Ho: $F_{2,8} = 4.246$ (NS)
(2) Ho: $F_{1,2} = 0.017$ (NS)

Data from the tests using juveniles were pooled between tanks (n=6) and 1 replicate was randomly choosen and dropped (n=5) from further analyses along with the adult data. This pooled group became the Duw x Flow-through cell in the two-way ANOVA comparing combined effects of frozen sediment and method on animal survival.

Methodology and Sediment Effect (Ho3 and Ho4). Results of this experiment indicated there was no effect of the three sediments or the three methods on either mean survival or mean number moribund (Tables 12.14A & B). It is interesting to note that the high survival obtained in Duwamish and D660 sediments contrasts the previous results of Run A (see Table 12.13A & B).

Fresh vs. Frozen Sediment (Ho5). Significantly depressed mean survival and elevated mean percent moribund were found in the frozen WB sediment when compared to fresh WB sediment (Table 12.14 A & B). Mean survival is consistently higher throughout the three methods in fresh sediment and points strongly to a freezing effect. However, for the moribund index, only the "Ott" static test had significantly higher inactivity than any other test. Reburial activity in general was high and it is not apparent from the reburial data alone that freezing affects response.

12.4.4.5 Physical Measurements

Eh and pH values, recorded on days 2 and 9 of Run B, did not vary appreciably during the experiment (Table 12.15). In general, pH values declined slightly, more so in Duwamish and D660 sediments than in West Beach.

## 12.5 Discussion

METRO's present plans call for the discharge of up to an average of 72 (325 peak) MGD of secondary-treated, disinfected sewage effluent into the East

Table 12.13A. Mean (and standard deviations) amphipod survival in frozen test sediments from methods comparison, Run B (NS = not significant at p = 0.05; two-way ANOVA).

(1) Ho: There is no effect of sediment on survival/activity.
(2) Ho: There is no effect of method on survival/activity.

| Sediment: / Method | Duwamish (Duw) | D660 | West Beach (WB) |
|---|---|---|---|
| "Ott" static (Ott) | 0.920 (0.057) | 0.930 (0.057) | 0.720 (0.381) |
| "Ott" flow (Fl) | 0.770 (0.175) | 0.880 (0.115) | 0.910 (0.054) |
| "Swartz" (Sz) | 0.930 (0.067) | 0.950 (0.050) | 0.940 (0.041) |

(1) Ho: $F_{2,36} = 0.526$ (NS)
(2) Ho: $F_{2,36} = 1.437$ (NS)

Table 12.13B. Mean (and standard deviations) number moribund amphipods in frozen test sediments from methods comparisons, Run B (NS = not significant at p = 0.05; two-way ANOVA). (See hypotheses above.)

| Sediment: / Method | Duwamish (Duw) | D660 | West Beach (WB) |
|---|---|---|---|
| Ott | 0.106 (0.074) | 0,011 (0.024) | 0.246 (0.427) |
| Fl | 0.053 (0.119) | 0.021 (0.047) | 0 |
| Sz | 0.056 (0.068) | 0.021 (0.029) | 0 |

(1) Ho: $F_{2,36} = 0.897$ (NS)
(2) Ho: $F_{2,36} = 2.702$ (NS)

Table 12.14A. Mean (and standard deviations) survival of amphipods in fresh and frozen West Beach sediments from methods comparisons, Run B (NS = not significant at p = 0.05).

(1) Ho: There is no difference between fresh (Fr) and frozen (Fz) sediment affecting survival/activity.
(2) Ho: There is no difference in survival/activity due to method.

| "Ott" Flow | | "Ott" Static | | "Swartz" | |
|---|---|---|---|---|---|
| Fr | Fz | Fr | Fz | Fr | Fz |
| 0.970 (0.044) | 0.910 (0.094) | 0.930 (0.057) | 0.720 (0.381) | 1.000 (0.000) | 0.940 (0.041) |

(1) Ho: $F_{3,24} = 126.49$***
(2) Ho: $F_{2,3} = 0.593$ (NS)

***Significant difference at $p < 0.0005$; nested ANOVA.

Table 12.14B. Mean number of moribund amphipods in fresh and frozen West Beach sediments from methods comparisons, Run B (NS = not significant at p = 0.05). (See hypotheses above.)

| "Ott" Flow | | "Ott" Static | | "Swartz" | |
|---|---|---|---|---|---|
| Fr | Fz | Fr | Fz | Fr | Fz |
| 0.021 (0.029) | 0 | 0.023 (0.052) | 0.246 (0.427) | 0.050 (0.035) | 0 |

(1) Ho: $F_{3,24} = 4.831$*
(2) Ho: $F_{2,3} = 0.126$ (NS)

*Significant difference at p = 0.05; nested ANOVA.

12.15 "Methods comparison," Run B, Eh/pH values ("Swartz" values are high/low range for 5 beakers).

| | Day 2 | | Day 9 | |
|---|---|---|---|---|
| Station | pH | Eh(mv) | pH | Eh(mv) |
| Duwamish | | | | |
| "Flow I" | 7.5 | 70 | 7.0 | 55 |
| "Flow II" | 7.7 | 60 | 6.85 | 160 |
| "Ott" | 7.6 | 30 | 6.96 | 40 |
| "Swartz" | 7.75 | 45 | 7.01 | 55 |
| | 7.80 | 60 | 7.12 | 80 |
| D660 | | | | |
| "Flow" | 7.45 | 214 | 7.05 | 355 |
| "Ott" | 7.7 | 180 | 6.92 | 210 |
| "Swartz" | 7.45 | 115 | 6.80 | 55 |
| | 7.60 | 230 | 7.25 | 55 |
| West Beach (Fresh) | | | | |
| "Flow" | 7.55 | 385 | 7.48 | 245 |
| "Ott" | 7.55 | 310 | 7.26 | 230 |
| "Swartz" | 7.45 | 305 | 7.05 | 190 |
| | 7.65 | 305 | 7.55 | 265 |
| (Frozen) | | | | |
| "Flow" | 7.35 | 345 | 7.17 | 150 |
| "Ott" | 7.35 | 355 | 7.60 | 260 |
| "Swartz" | 7.20 | 310 | 7.30 | 165 |
| | 7.50 | 420 | 7.65 | 120 |

Passage of South-Central Puget Sound. These waters are presently classified by the State of Washington as class AA marine waters; that is, waters of the highest quality to be protected for "all or substantially all uses." Specifically, class AA water quality standards call for, in part, that "toxic, radioactive, or deleterious substances shall be less than the concentrations that may affect the health of humans or aquatic biota, or the desirability of the water for any use" (WAC 1982).

METRO has consistently maintained, based primarily on extrapolation from physical/chemical data, that little or no toxicity will be imparted to Puget Sound waters which will adversely affect the marine biota. However, the vast majority of responses by public agencies, citizen groups, and private citizens to the draft EIS concerning a potential marine discharge (EPA 1981) voiced great concern about the lack of studies and data directly addressing this problem, especially as related to long term effects.

In reply, METRO has initiated the Seahurst Baseline Studies to help assess the potential effects of a marine discharge at Seahurst. As part of these studies, the work reported here describes the pre-discharge levels of water column and sediment "toxicity" to various sensitive stages of marine life, and specifically addresses the potential acute "toxic" impacts of the discharge of Renton Treatment Plant effluent.

12.5.1 Water Column Toxicity

Measurable background water toxicity was found at all stations and depths sampled in varying degrees depending on sample date, location, and bioassay type. The oyster mortality index was generally highest within the Seahurst Bight and in surface waters. The oyster mortality response has most often been associated with natural biological metabolites ("toxins") produced by phytoplankton blooms (Cardwell et al. 1977a, 1979). The oyster abnormality

index, on the other hand, tends to be higher in samples from outside the Seahurst Bight and from deeper waters. The abnormality index has most often been associated with "pollutant" toxicity rather than with biological toxins (Cardwell et al. 1977a). This trend suggests a higher pollutant load at the "wide area" stations (1-3) relative to the Seahurst stations (4-10) but the lack of supporting chemical toxicant data makes any such conclusion completely untenable at this time. The sperm assay responses appear to be intermediate between the oyster mortality and abnormality responses and are generally greater in surface and bottom waters. Further interpretation of the sperm assay responses are not presently possible since this methodology is new for testing receiving water quality.

Historically, somewhat similar patterns of toxicity have been defined for many areas of Puget Sound using the oyster embryo assay. Cardwell and Woelke (1979) have summarized approximately 12 years of annual water quality monitoring and generally found embryo mortality most often associated with plankton blooms and embryo abnormality most dramatically affected by pollutant discharges (especially from pulp and paper mills).

State historical data for testing conducted close to some of the Seahurst sampling stations are presented in Figures 12.15A and B. These figures show high variability from year to year with occasional high peaks in both mortality and abnormality, a pattern fairly typical of the results presented in this report.

In comparing the oyster embryo results presented in this report with the historical data two important qualifications should be noted. First, the State tests were conducted only once per year with oysters carefully conditioned in the laboratory while the present tests were conducted several times per month and relied heavily on naturally ripe oysters from the field.

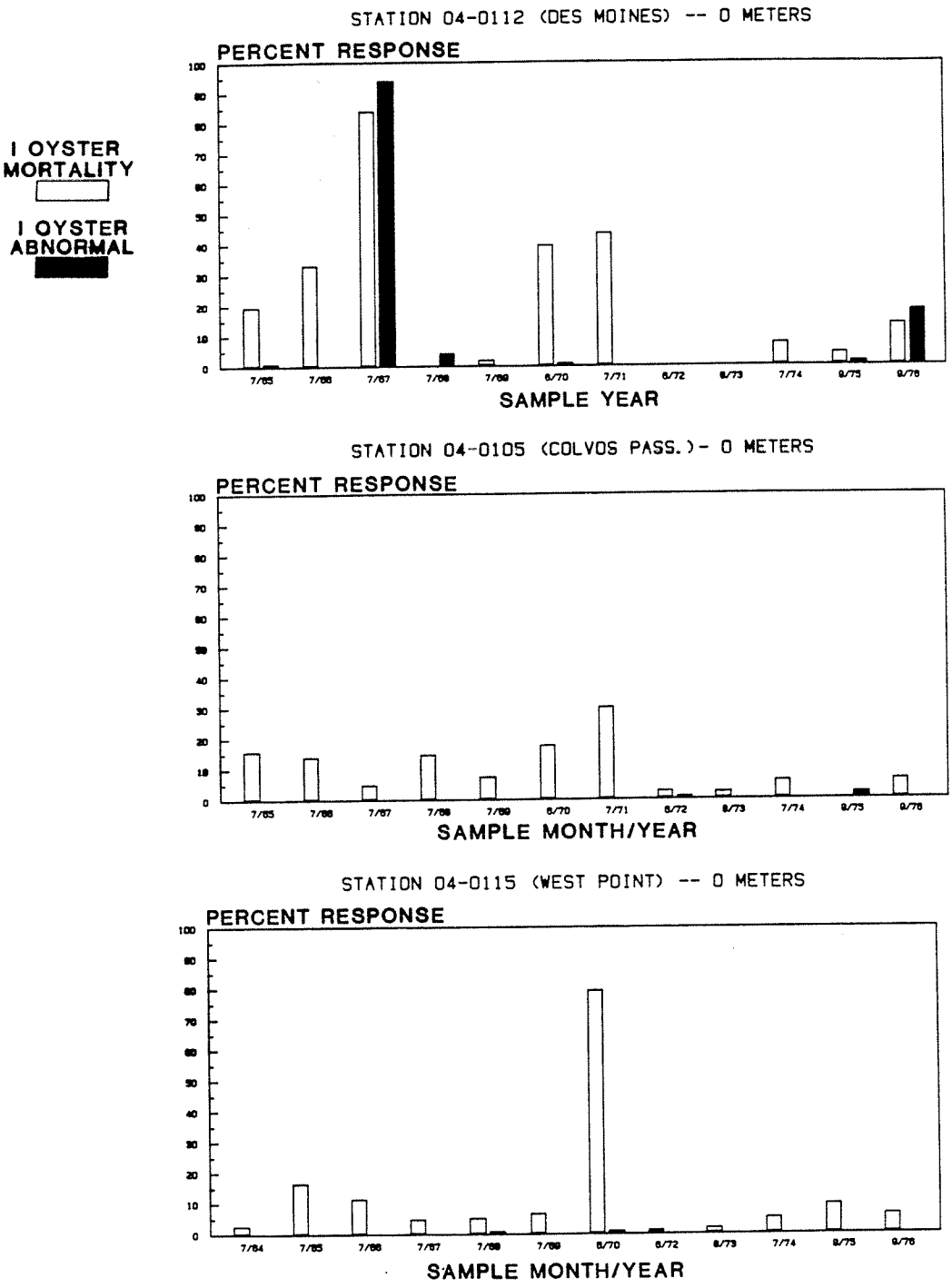



Figure 12.15A. Washington State Department of Fisheries' historical data showing 48-hr oyster embryo responses in surface water collected from Des Moines, Colvos Passage, and West Point stations, 1964-1976 (adapted from Cardwell and Woelke 1979).

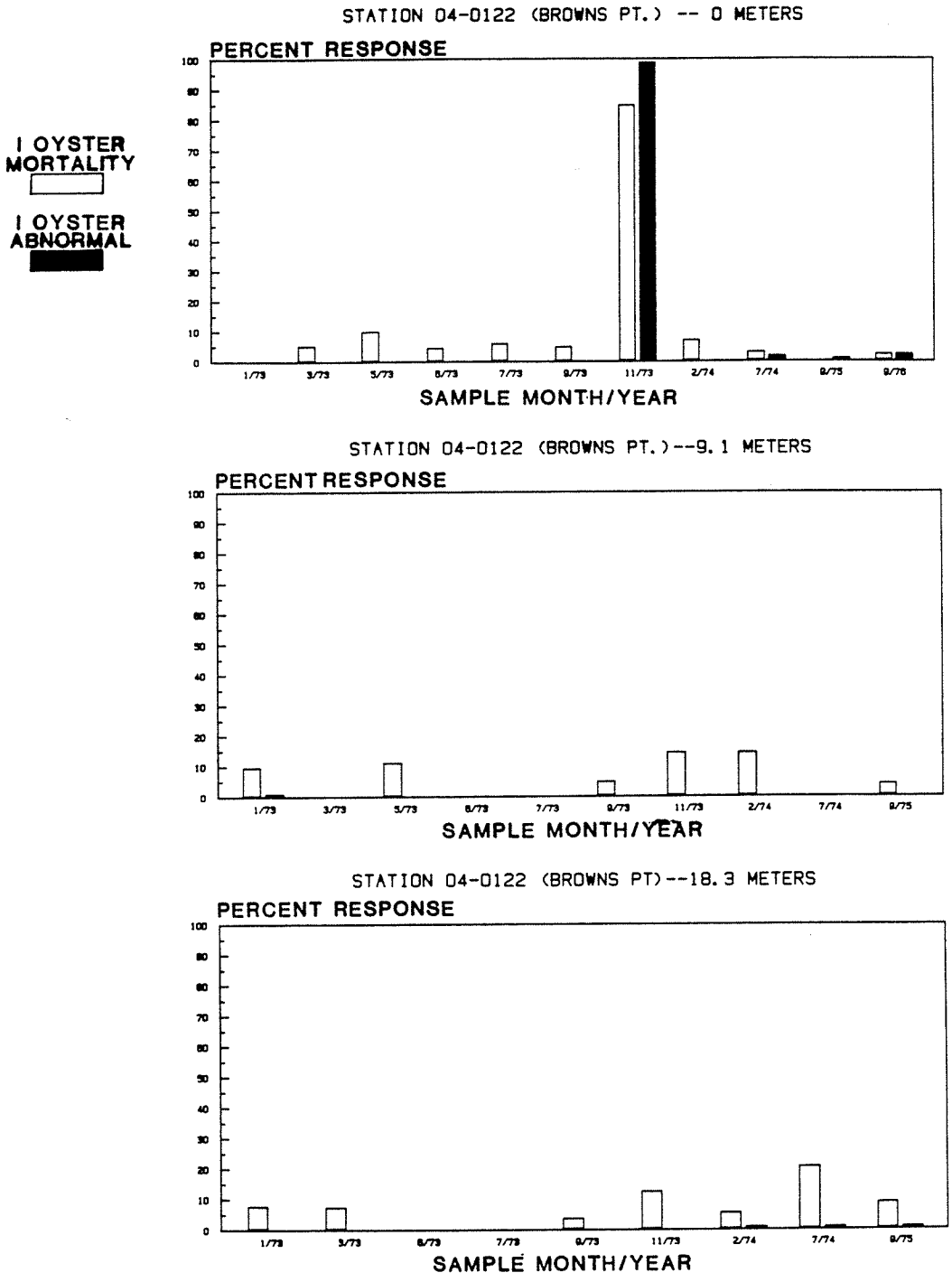



Figure 12.15B. Washington State Department of Fisheries' historical data showing 48-hr oyster embryo responses in water collected from the Brown's Point station at three depths, 1973-1976 (adapted from Cardwell and Woelke 1979).

The relationship between test results and the ripeness/quality of gametes from a variety of oysters throughout the spawning season is presently unknown but may be quite significant.

The second factor to be noted involves a slightly different approach to the calculation of oyster mortality. The "standard" oyster embryo assay (ASTM 1980) relates mortality in the samples and controls to the density of embryos in the beakers at 48 hours vs. the initial density as determined from counts made at the time of fertilized egg inoculation. If the control mortality exceeds 30 percent (or the control abnormality exceeds 10 percent) the test is considered invalid and must be repeated. Obviously, the invalidation of test results means lost data - much of which may still provide valuable relative data if not required in a strictly "legal" or regulatory context. If tests may be easily repeated then only time and money is lost. However, if the tests are temporally related (as in this study), then lost data cannot be retrieved. Therefore, the following modification was made in the calculation of oyster mortality: the average "primary" control (i.e., Kincaid laboratory water) survival level was set as the baseline for mortality calculations in all other test or "secondary" control samples. This method allows use of data with "primary" control mortality (as calculated from initial counts at time zero) greater than 30 percent.

The justification for this modification is not arbitrary. Historical Washington State oyster embryo assays have used control water collected from Quilcene Bay at the time of the assays - water of unknown quality, especially as related to phytoplankton blooms and metabolites - hence, the possibility of high mortality due solely to the <u>control water quality</u>. In the tests reported here, this factor has essentially been eliminated by the use of two "control" waters carefully selected to be of high and <u>consistent</u> quality through the

test season. The important key word here is "consistent" and is most highly exemplified by the frozen Friday Harbor control water.

In support of this contention is the relationship between the Kincaid and Friday Harbor control mortalities. If variability in control water mortality is water-related, then the relationship of mortality between the two types of control waters should be a random one. If, on the other hand, the between-test mortality is not water-related but caused by some other extraneous factor(s), then the relative change between the two should be the same - each will change the same degree relative to the extraneous factor(s). This is, indeed, the case as illustrated by a scattergram of the two variables (Figure 12.16). The general trend (as described by the regression line with a positive slope of 0.882 and a correlation coefficient of +0.883) clearly shows that between-test mortality in each type of control water changes by a factor that is common to both, and, therefore, independent of water quality.

If the control water is eliminated as a source of variability which may cause fluctuating mortality between tests, then the most probable causes are 1) inconsistency in test methodology, or 2) gamete quality between different groups of oysters.

Close attention to detail and methodology was given during the conduct of all bioassays. The highest probable source of variability related to the test methodology was fertilization of the eggs. Over- or under-fertilization could produce a high mortality index in the controls, but this factor was closely controlled by adding only dilute sperm densities ($<10^7$/ml) to minimize polyspermy (multiple fertilization) and by checking fertilization success by monitoring polar body formation in each batch of fertilized eggs.

Therefore, the second factor (gamete quality) is the most probable source of between-test control mortality differences. Quite simply, gametes within

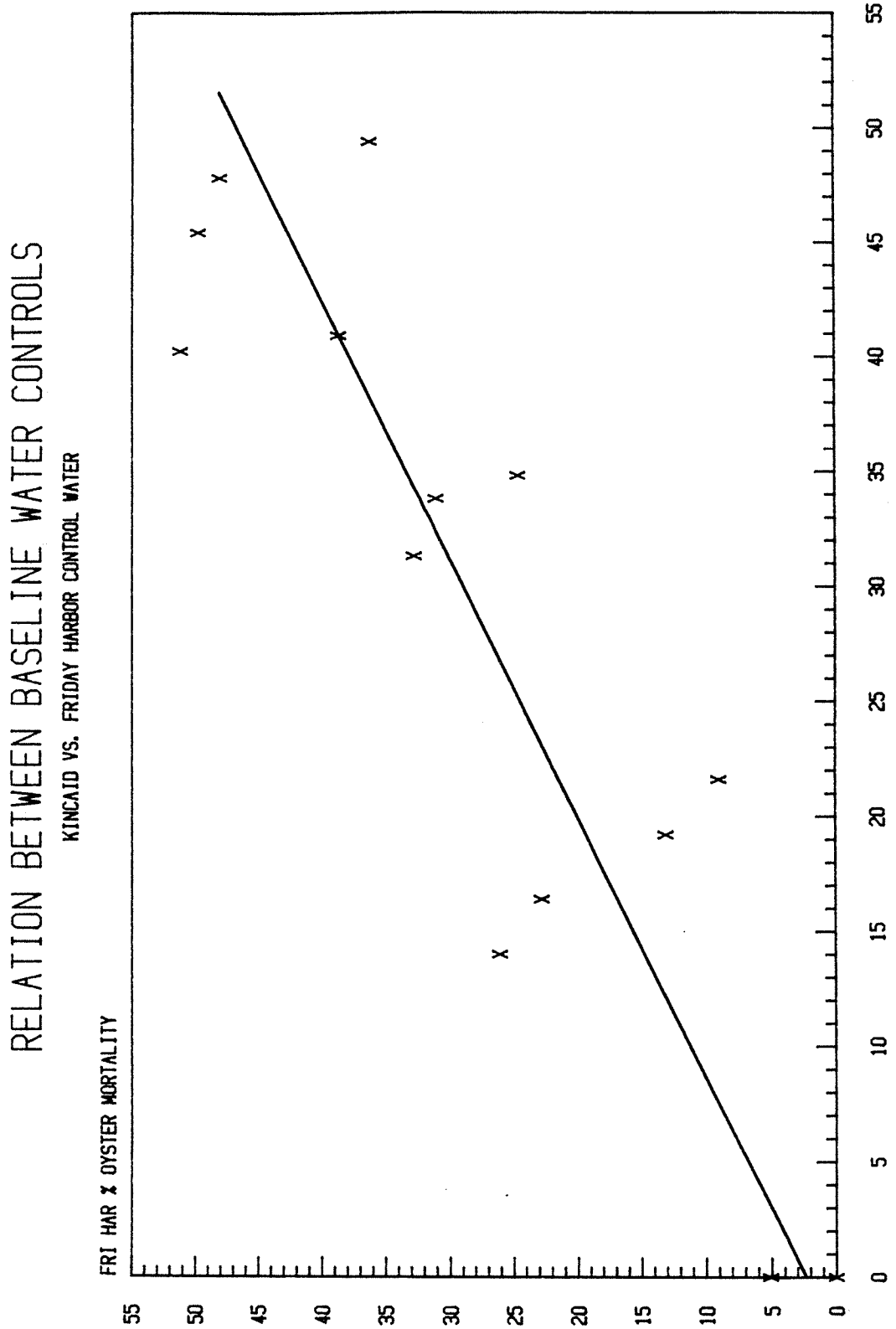



Figure 12.16. Scattergram of the relationship between average percent Kincaid Lab control oyster embryo mortality and average percent Friday Harbor (frozen) control oyster embryo mortality. The regression line slope is 0.882, Y-intercept is 2.90 and the correlation coefficient is +0.883.

any given adult oyster will be at a peak of ripeness only during a portion of the time in which they contain gametes. If eggs from a very underripe or overripe female are used, high embryo mortality will probably result with gradations of mortality being related to degree of over- or under-ripeness. Therefore, egg (and possibly sperm) quality will be the primary controlling factor of survival in any given test (with good, consistent test methodology and control water). Thus, if 50 percent of the eggs cannot develop due to being over- or underripe but the remaining half do develop, then the simple dismissal of the undeveloped eggs from consideration should not invalidate the responses of the remaining 50 percent of the eggs in the test samples. While this concept is a departure from past views, it does have experimental support behind it in the works of Lannan (1980a, b, c) and Cardwell et al. (1977b).

Certainly there is a point where decreasing survival leaves too few embryos to count in the subsamples to give a good sample representation. Five out of 28 oyster embryo tests were discarded when control mortality was 80-100 percent. All other embryo tests had "primary" control mortalities of <50 percent with about half of the total being between 30 and 50 percent (Table 12.16). The decision to accept or reject a test in the 50-80 percent range is somewhat arbitrary at this point, and will probably have to be considered in future work. The relationship between gamete quality and control abnormality is presently unknown.

Table 12.16. "Primary" (Kincaid Lab water) control mortalities and abnormalities for each oyster embryo test set for both receiving water and sewage bioassays conducted during 1982 (as determined by initial counts at time zero and compared with 48-hr control densities).

| Date | Percent control mortality | Percent control abnormal |
|---|---|---|
| Receiving water bioassays | | |
| *15 July | 49.4 | 20.7 |
| 16 | 16.4 | 1.1 |
| *19 | 31.3 | 8.8 |
| *26 | 40.9 | 15.7 |
| *28 | 33.8 | 13.9 |
| * 2 Aug | 40.2 | 23.6 |
| * 9 | 47.8 | 11.9 |
| 11 | 14.7 | 3.4 |
| 16 | 14.0 | 2.6 |
| 30 | > 80 (discarded) | -- |
| 7 Sept | > 80 (discarded) | -- |
| 9 | 0.0 | 7.4 |
| *13 | 21.6 | 44.9 |
| *21 | 34.8 | 27.2 |
| 22 | 0.0 | 6.0 |
| 27 | 19.2 | 5.7 |
| * 6 Oct | 45.4 | 16.2 |
| 27 | 12.0 | 5.3 |
| Sewage bioassays | | |
| *21 July | 14.5 | 15.0 |
| 23 | 25.7 | 5.2 |
| *30 | 23.5 | 27.3 |
| 4 Aug | 23.8 | 6.0 |
| * 6 | 30.6 | 20.5 |
| *13 | 29.6 | 13.7 |
| * 3 Sept | 25.4 | 13.3 |
| 15 | > 80 (discarded) | -- |
| 20 | > 80 (discarded) | -- |
| 28 | > 80 (discarded) | -- |

* = Control mortality and/or abnormality does not meet ASTM (1980) standards.

12.5.2 Sediment Toxicity

Results from the Baseline bioassays indicate that sediment from the Seahurst sites is generally non-toxic to amphipods with the possible exception of C640 and A400E which elicited a (barely) significant toxic or sublethal response, respectively. These results occurred in sediment regarded as being relatively free of chemical contaminants and contrast the significantly reduced survival incurred in sediment from the Duwamish South Harbor site, an area of known biological toxicity and high chemical contamination (Malins et al. 1980 and 1982). The Duwamish sediment served as a "negative standard" or control against which mean survival and animal activity in sediment from baseline sites could be compared.

Despite the lack of significant response from Seahurst sediments, the amphipods appear to be stressed as evidenced by the general trend towards lower mean survival and higher mean inactivity of animals exposed to many baseline sediments when compared to West Beach. This may not be an indication of chemical contamination of the sediment, but could reflect instead the extreme differences in sediment grain size between the sandy West Beach control and the toothpaste-like consistency of the sediment from stations located 200' and deeper.

There is disagreement concerning the effects of various grain sizes on these animals (Oakden 1981; Swartz et al. 1979). Since these animals are found in sand within a very narrow grain-size range in their natural environment (Oakden 1981; Ott, observation), it is possible they may not be as tolerant of very fine-grained sediment as Swartz indicates (Swartz et al. 1979).

At this point, it is necessary to determine if R. abronius can physically tolerate the range of grain sizes it encounters in the baseline sediment

bioassays. It is reasonable to assume that any one species will not be suitable as a test organism in all different sediment types as many infaunal amphipods demonstrate a preference for a certain grain size range (Fenchel et al. 1975; Meadows 1964) and grain size also is a major factor influencing distribution of small invertebrates (Wieser 1959). The reason R. abronius was used as a test animal, besides the fact that it is sensitive to chemical contamination (Swartz et al. 1979 and 1982; Ott et al. in prep.), is that this amphipod occurs subtidally in dense populations of this single species which facilitates rapid collection and sorting of the large numbers used in bioassays. The density of amphipods inhabiting the deep water baseline sites does not approach the abundance of R. abronius found at West Beach. In addition, these deep water infaunal amphipods occur in a mixed species assemblage which would be virtually impossible to live-sort. A population of R. abronius also occurs within the geographic area encompassed by the Baseline study so changes in this in-situ population could be monitored over time if desirable.

Since R. abronius remains the most desirable test organism, a series of tests were designed to investigate potential extraneous variables which may influence amphipod responses and data interpretation. Three main conclusions resulted from Run A of this Methods Comparison test series. First, the three different methods tested generally yielded similar survival results (excluding the fresh West Beach x static tests). Secondly, some between-test differences occurred in Duw frozen sediment (lower survival with "Ott" method) and in the reburial results. Thirdly, differences in survival were also incurred between fresh and frozen D660 sediment, although here, unlike the WB sediment, lower survival occurred in the frozen sediment. It is unknown what effect freezing would have on sediment other than killing the bacteria and meiofauna and

possibly slightly altering sediment grain size by physically fracturing the particles. Before further statements could be made concerning these data however, it was necessary to retest fresh vs. frozen sediment, this time including a flow-through system with both sediment types. From the Run A data alone, it is not clear if frozen sediment alone affects survival or if frozen sediment in combination with a static system affects results. It seems, however, that freezing sediment does have some effect on results.

The similar survival obtained for both D660 and Duwamish sediment indicate that grain size may influence survival. Further comments concerning this matter must wait until the grain sizes of these sediments, along with their chemical compositions, have been determined.

Run B of the Methods Comparison test was designed to further test the hypotheses and conclusions of Run A and test original hypotheses (i.e., animal age and between-tank effects). Of primary interest in the results of Run B are: 1) the lack of a difference in effect between adults and juveniles; 2) the high mean survival in both frozen D660 and Duwamish sediment; and 3) the significantly higher overall mean survival in fresh WB sediment.

The lack of an observable difference between adult and juvenile amphipods was unexpected, especially when one considers the numerous pollution studies demonstrating a heightened sensitivity in juvenile and larval crustaceans (Caldwell et al. 1978; Costlow 1979; Epifanio 1971; Roesijadi et al. 1976; Vernberg et al. 1977). Oakden (1981), however, noted that it was not surprising to find no behavioral differences in sediment grain size preference experiments between different sizes (ages) of several species of amphipods "since young phoxocephalids are released from the marsupium directly into the sediment that their mother is inhabiting." For infaunal animals, one could rationalize that mechanisms of pollutant uptake (and therefore effect) might

be more similar between adults and juveniles in the benthic environment than for crustaceans which release their young as larvae (a totally different lifeform) into the water column (a totally different environment).

In general, the sediments tested in Run B, although identical to Run A, seemed to have less impact on the animals. Mean survival in frozen D660 sediment was over twice as high in Run B as in Run A (88-95 vs. 36-39 percent, respectively; Tables 12.9 and 12.13) and even exceeded mean survival in fresh D660 sediment from Run A (75-78 percent, Table 12.9). Mean moribund in Run B ranged between 3-7 percent compared to 6-31 percent in Run A. In Run B the means were consistent between all methods. In Duwamish sediment, mean survival also appeared higher in Run B (77-93 percent, Table 12.13) compared to both Duwamish frozen (58-81 percent, Table 12.10) and fresh (59-75 percent, Table 12.9) in Run A. The cause for this apparent difference between results of nearly identical runs (closely spaced temporally) is unknown. It does point out the necessity of including a "negative control" such as Duwamish sediment to monitor when these periods of overall higher (lower) mean survival occur so data can be compared over time.

Eh and pH values during Run B varied slightly during the experiment but apparently not enough to influence survival. DO was not measured because the available DO probe was not appropriate for measuring interstitial DO (Niels et al. 1980) and DO values of the overlying water are irrelevant. In the absence of an adequate DO probe, Eh values (measuring the oxidation/reduction potential) satisfactorily indicate the relative amount of DO present in the interstitial waters (R. Carpenter, Oceanography, UW, personal communication).

The fresh vs. frozen sediment test in Run B involved only West Beach sediment due to sampling constraints. Mean survival was significantly higher (ANOVA $p < 0.0005$) in fresh than in frozen WB sediment (Table 12.14A) and this

pattern of survival was consistent between all three methods.

12.5.3 Potential Impacts of Sewage Effluent

The prime objective of this portion of the testing is the assessment of the potential impacts related to acute toxicity of the proposed effluent discharge to sensitive stages of marine organisms. Three aspects are of immediate concern: 1) direct toxicity of the diluted effluent to sensitive life stages in the water column, 2) indirect water column toxicity due to secondary chemical or biological changes induced by the effluent, and 3) accumulation of toxic components in the sediment caused by solids deposition.

12.5.3.1 Direct Water Column Toxicity

The present design specifications for an effluent diffuser in Puget Sound call for a minimum dilution factor of 100:1 to be achieved within an established "zone of initial dilution" (ZID). Recent oceanographic findings suggest that the dilution may be as great as 300:1 (METRO 1982) but for the sake of a "worst case" approach, a dilution factor of 100:1 is assumed in the following discussion.

Based on this assumption, the Renton effluent will be reduced to at least 1 percent by volume at the boundries of the ZID. To give an idea of potential impacts related to acute toxicity a term called a "Margin of Safety" (MS) can be calculated for each type of effluent by the following formula:

$$MS = \frac{\text{Highest Average "No Effect" (i.e., < 10\% Response) Concentration}}{\text{Percent Effluent After Initial Dilution}}$$

The margins of safety are specific for each bioassay and sewage type since the "No Effect" concentrations generated by each are different. Calculated MS values >1 indicate margins of safety directly related to the magnitude of the

value. A value of 1.0 indicates no margin of safety and values <1 indicate situations of possible impact.

METRO presently discharges chlorinated-dechlorinated secondary effluent to the Duwamish River. Final decisions have not been made about the final effluent condition relative to chlorination and dechlorination. Three potential discharge choices exist: 1) unchlorinated secondary, 2) chlorinated secondary, and 3) chlorinated-dechlorinated (with $SO_2$) effluent.

"Margins of Safety" have been calculated for each type of Renton sewage tested during 1982 for each bioassay index (Table 12.17). MS values for influent and primary sewage are included here only to provide a frame of reference relative to the effectiveness of the sewage treatment process for removing toxicity since sewage at these two "treatment levels" will not be discharged.

From the MS values listed in Table 12.17 the oyster embryo assay results predict no acute toxic impact (i.e., $\leq$10% responses) outside the ZID for discharges of any sewage type. The sperm assay predicts that only secondary and secondary dechlorinated effluents will provide margins of safety. However, the conclusions noted above are based on average "No Effect" sewage concentrations from 7-10 tests rather than the worst case "No Effect" concentrations based on individual tests. Table 12.18 lists the margins of safety based on the worst case approach. By this approach, the oyster embryo bioassay predicts margins of safety for only secondary and secondary dechlorinated sewage while the sperm assay only identifies secondary dechlorinated sewage as having a consistent margin of safety. However, the margin of safety values presented in Tables 12.17 and 12.18, are probably "worst case" estimates since these estimates were generated during the low-flow (hence least toxicant dilution) summer months. Additionally, the values

Table 12.17. Calculated "margins of safety" for each type of Renton sewage based on each average "no effect" concentrations and a dilution factor of 100:1 (i.e., 1%).

| Renton sewage type | Margins of safety* | | |
|---|---|---|---|
| | Sand dollar sperm assay | Oyster embryo abnormality | Oyster embryo mortality |
| Influent | 0.27 | 1.5 | 1.5 |
| Primary | 1.0 | 3.6 | 2.3 |
| Secondary | 3.6 | >20.0 | >20.0 |
| Secondary chlorinated | 0.41 | 1.5 | 1.5 |
| Secondary dechlorinated | 2.3 | >20.0 | >20.0 |

*Margin of safety = $\frac{\text{Highest average "no effect" (i.e., < 10\% response) concentration}}{\text{\% Effluent after initial dilution}}$

Table 12.18. Calculated "Margins of Safety" for each type of Renton sewage based on worst case "no effect" concentrations and a dilution factor of 100:1 (i.e., 1%).

| Renton sewage type | Margins of safety* | | |
|---|---|---|---|
| | Sand dollar sperm assay | Oyster embryo abnormality | Oyster embryo mortality |
| Influent | <0.27 | 1.0 | 0.41 |
| Primary | 0.41 | 2.3 | 1.0 |
| Secondary | 0.64 | 13.0 | 13.0 |
| Secondary chlorinated | 0.27 | 0.27 | <0.27 |
| Secondary dechlorinated | 1.5 | 13.0 | 13.0 |

*Margin of Safety = $\frac{\text{Worst case "no effect" (i.e., < 10\% response) concentration}}{\text{\% effluent after initial dilution}}$

for the dechlorinated sewage would probably improve since a new system recently installed at the Renton Treatment Plant reduces chlorine residuals to essentially zero, and, as noted above, the dilution factor may turn out to be greater than 100:1.

Based on the EC50 values in Table 12.3, chlorinated secondary sewage is substantially more toxic than either unchlorinated or dechlorinated secondary sewage with EC50's lower than for either influent or primary sewage. Chlorine has been shown to be very toxic to marine organism reproductive stages (Dinnel et al. 1981; Bellanca and Bailey 1977; Capuzzo 1979; Muchmore and Epel 1973). The chlorinated sewage EC50's are associated with average values of 0.017 and 0.037 mg/l total residual chlorine for the sperm assay and oyster embryo abnormal index, respectively. The toxicity of chlorinated sewage may, however, be quite different in a qualitative sense than the toxicity associated with either the influent or primary sewages. The oxidative component of chlorine decays quickly when chlorine is added to seawater due to its interaction with such seawater constituents as naturally occurring organics (Goldman et al. 1979) and bromide (Wong and Davidson 1977). Hence, the most toxic aspect of chlorine (the oxidative potential) is simply "diluted out" fairly quickly. Certain chlorinated compounds may be formed by chlorination (many are present prior to chlorination) but these are relatively non-toxic compared to its oxidative potential.

The toxicity of influent and primary sewage, on the other hand, is probably associated with a large variety of chemically conservative compounds (i.e., metals, petroleum products, surfactants, xenobiotic organic compounds, etc.) which do not lose their toxicity as dramatically when added to seawater. Hence, care must be used in interpretation of the relative EC50 and MS values reported here.

Ammonia toxicity was tested in one set of bioassays and found to be toxic at levels between 11.7 to 35.0 mg/l as total ammonia (Table 12.5). Ammonia toxicity is primarily dependent on chemical state. The following equlibrium:

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

is characteristic of ammonia in aqueous solutions (NAS 1972). This equilibrium is dependent primarily on pH, temperature, and to a small degree, water salinity (Emerson et al. 1975). Un-ionized ammonia ($NH_3$) has been shown to be the toxic component of ammonia solutions, as ionized ammonia ($NH_4^+$) apparently is unable to pass tissue barriers (Milne et al. 1958). Based on equilibrium models, the expected concentration of $NH_3$ in marine waters (pH 8.0, temperature 10°C, salinity 30 o/oo) is only about 2 percent of the total ammonia. The EC50's for the sperm assay and oyster embryo abnormality would equate to approximately 0.23 to 0.70 mg/l as un-ionized ammonia. The average concentration of 13.7 mg/l total $NH_3$ in the Renton effluent (EPA 1981) would translate to a value of 0.003 mg/l for un-ionized ammonia outside the ZID after an initial dilution of 100:1, a value roughly two orders of magnitude less than that causing toxicity in the bioassays. Hence, no direct toxicity is expected due to ammonia.

12.5.3.2 Indirect Water Column Toxicity

As noted above, significant direct toxicity of the effluent to marine organisms is improbable due to the high level of treatment of Renton treatment plant effluent and the expected dilution. However, the potential for indirect toxicity must be considered.

Presently, there is one possible scenario which appears plausible, although a large degree of speculation must be incorporated into the

discussion at this point. In brief, background toxicity has been observed in ambient water samples and is most highly associated with surface and inshore stations (Figures 12.9 and 12.10). This data suggests that a portion of this toxicity is associated with toxic phytoplankton metabolites. If the discharged effluent serves to stimulate greater than "normal" phytoplankton blooms, "background toxicity" in Puget Sound could gradually increase with possible adverse effects on the sensitive larval stages of a variety of marine animals. There are many bits and pieces of experimental data, causal observations, and experiences with eutrophication associated with other marine outfalls, some of which support this scenario, and some of which do not. Outlined below are some of the major considerations involved both for and against the potential for stimulated blooms and increased "background toxicity:"

1. The nutrient found to be most limiting to marine phytoplankton growth is nitrogen (Welch 1980; Thomas et al. 1974). Nitrogen compounds are relatively high in sewage effluents and may provide forms of nitrogen (nitrate and urea) preferentially used by some forms of algae (Mahoney and McLaughlin 1977).
2. While nitrogen has been shown to stimulate algal growth in laboratory experiments, nitrogen seems to be rarely limiting in estuaries (as contrasted to open ocean waters) and only small amounts ($\sim$10 percent) are actually used for primary production (Garside et al. 1976; Ingram 1979).
3. Sewage may contain other factors which serve to stimulate certain types of algae. These include natural organic (humic) substances, and chelators which affect the biological availability of trace metals (Saunders et al. 1982).

4. Physical factors controlling water column stability and light availability probably exert the biggest control over phytoplankton bloom dynamics. These factors include winds, convective heating or cooling, tidal currents, turbidity, cloud cover, storm activity and water depth. Some algal species, however, are heterotrophs which do not require residence in the photic zone for growth.

5. In recent years paralytic shellfish poisoning (PSP) caused by toxic species of dinoflagellates has spread to previously unaffected areas throughout the world, and the outbreaks appear to be increasing in intensity. This trend has become apparent locally in recent years with the spread of PSP into the central Puget Sound basin (Saunders et al. 1982). The relationship between PSP increases and eutrophication processes are presently unknown but cannot be discounted at this time.

6. Oyster embryo bioassays conducted by the State of Washington have repeatedly associated high water toxicity (as related to larval mortality) with blooms of certain phytoplanktonic organisms (dinoflagellates), especially in areas with high water column stability (Cardwell et al. 1977a and 1979). Confirmation laboratory bioassays of water in which the dinoflagellates Ceratium fusus and Gymnodinium splendens were grown imparted high toxicity to oyster embryos (Cardwell 1979). Additional evidence suggests that bloom metabolites are also toxic to other species of bivalve larvae and may extend to adult mortalities as well. Cardwell et al. (1979) conclude that "with continued urbanization of the innermost southern Puget Sound region, it is conceivable that receiving water toxicity problems due simply to blooms of toxic dinoflagellates and perhaps

other phytoplankters could be exacerbated."

It should be noted that all of the comments outlined above are discussed in a generic sense and not directed at any one point discharge. If eutrophication within Puget Sound does become a future concern, all anthropogenic sources (both point and non-point) must be addressed.

Relative to the placement of a specific outfall, several factors seem important for minimizing the potential for stimulating phytoplankton growth:

1. Location of the outfall as close to the main channel as possible to maximize effluent dispersion and minimize effluent concentration in areas of relatively high water column stability.
2. Maximize the potential for the effluent dispersal in an ocean-bound direction.
3. The deeper the discharge the greater the dilution of the effluent before it gets into the photic zone. If, however the net flow at depth is into, rather than out of, central and southern Puget Sound, this siting may conflict with the objective cited in #2 above.

12.5.3.3 Sediment Toxicity

The results of the first set of amphipod bioassays of sediments from the Seahurst area show no significant toxicity as related to amphipod survival in West Beach (Deception Pass) control sediments with the possible exceptions of C640 and A400E. A generally reduced survival was apparent, however, in many of these sites and there is some question whether this lowered survival was caused by chemical or physical (grain size) differences in test sediment relative to the WB control.

Tests designed to compare different sediment bioassay designs and test factors, coupled with the results mentioned above, suggest the following important points:

1. Anoxic sediment conditions, if excessive, can cause amphipod mortality and/or stress. Our experience suggests that sediments very rich in organic detrital material are especially prone to anoxic conditions and the resulting generation of toxic $H_2S$. Anoxic sediment conditions can be minimzed by providing for circulation around the test sediments and by maximizing the water:sediment ratio in static systems or by using a flow-through system.
2. Preliminary comparative data suggests that amphipod survival in test sediments is generally equal in both static beaker and flow-through aquaria systems.
3. Amphipod survival is slightly less in frozen sediments when compared to the same fresh sediments.
4. Juveniles in one comparative test were no more sensitive to a contaminated sediment than the adults.
5. The interactions between sediment grain size (and/or food supply) and survival in amphipod bioassays are presently unknown.

Because of these findings, an improved test design will be used for all subsequent sediment bioassays. The improved design will test sediments in a slow flow-through aquaria system at ambient seawater temperatures with the replicate test chambers elevated from the tank bottom to allow water flow on all sides of the test sediments. This system should eliminate problems of possible water contamination during transport, anoxia in the sediments, and stress due to possible generation of biological metabolites. Yet to be resolved, however, is the question of sediment grain-size interactions. Future tests are anticipated to help shed some light on this factor.

The relatively high survival of amphipods in the Seahurst area sediments was anticipated due to the isolation of south-central Puget Sound from

significant industrial or municipal discharges. This assumption may have been premature. Recent work by NOAA-PMEL researchers (Curl et al. 1982) suggest that the East Passage may be a depositional site for sediments (and sediment bound toxicants) being discharged into and around Elliott Bay. Their work in Elliott Bay and the main Puget Sound basin show that both metal and organic pollutants entering the bay undergo flocculation reactions when the freshwater discharges encounter saline waters.

Several detailed studies have been conducted relative to the impact of Renton Treatment Plant effluent on sediment and water quality in the lower Duwamish River estuary and Elliott Bay (Curl et al. 1982; Baker 1982; Massoth et al. 1982). These studies document the flocculation of metals (up to 62 percent) and organics and subsequent concentration in the lower Duwamish River and Elliott Bay sediments. Finer portions of the flocculant load are transported into Elliott Bay and the main basin along with the Duwamish River plume. Some of the finer suspended solids may find their way into East Passage to be deposited in areas of slow flow (Curl et al. 1982).

The importance of these studies are twofold: 1) the Seahurst Bight sediments may not be as "pristine" as once envisioned, and 2) the same flocculation reactions observed in the Duwamish River estuary may be expected to occur at any discharge location in Puget Sound. The final EIS (EPA 1981) predicts some heavy metal accumulation in the sediments adjacent to a marine outfall. As in the Duwamish River, toxic organic substances would also tend to form flocculants and settle out in the deposition zone. The exact depositional areas and magnitude of the expected flocculation/sedimentation are presently unknown.

Additional concerns must be voiced relative to amphipod-sediment bioassays. Very few basic toxicological studies have been designed and

conducted to test the sensitivity of amphipods to a variety of toxic substances. The bulk of the available data exists as results of bioassays of sediments known or suspected to be contaminated with a wide variety of chemicals. These test results often are associated with a high degree of variability and rarely equated to the actual toxicant burdens in the test sediments. Presently, there is poor agreement between amphipod testing laboratories on the degree of toxicity of Commencement Bay sediments (Swartz et al. 1982; Pierson et al. 1982; Chapman et al. 1982). This may be exacerbated by an incomplete understanding of the habitat requirements, behavior, and food habits, and sensitivities to toxicants of the amphipods utilized.

The results of sediment bioassays reported here suggest that Duwamish Harbor sediment (obviously contaminated with at least petroleum products) is only slightly toxic to amphipods in a 10-day test. This raises the question of whether or not the amphipod test is sensitive enough to define the type and magnitude of toxicity expected to result from the discharge of secondary sewage effluent into marine waters. Realistic laboratory tests using simulated "spiked" sediments would be difficult to conduct and interpret. However, the work by Curl et al. (1982) documenting the zones of suspected Renton Treatment Plant effluent-contaminated sediments or sediments settled out of an actual discharge in the lower Duwamish River may provide a starting place. Testing of these specific sediments or sediments settled out of an actual discharge with the amphipod test system may provide valuable information concerning the future utility of this test for measuring effluent related toxicity in marine sediments.

## 12.6 Conclusions and Recommendations

### 12.6.1 Conclusions

1. "Background" water column toxicity was detected in receiving water samples from all baseline water stations. The toxicity responses were highly variable between sample dates, station number, water depth, and type of bioassay. In general, the most sensitive response was oyster embryo mortality, especially in surface waters and at stations within the Seahurst Bight. Embryo mortality is suspected to be most sensitive to natural biological toxins produced by phytoplankton. Oyster embryo abnormality was slightly higher on the average in deeper waters and at the wide-area stations outside the Seahurst Bight. The abnormality index is considered to be most sensitive to anthropogenically-derived toxicants. Trends in the sperm assay responses suggest highest toxicity in surface and bottom waters with no obvious trends between stations. The water column factors most likely to affect the sperm assay response are presently unknown but a good positive correlation was found between sperm assay responses and chlorophyll "a" concentrations.
2. Oyster embryo and sand dollar sperm bioassays of five stages of Renton sewage determined the following relative toxicities: Chlorinated Secondary > Influent > Primary > Dechlorinated Secondary > Secondary sewage. The relative sensitivities of the bioassay indices was: Sperm Assay > Oyster Abnormality > Oyster Mortality. The high sensitivity of the sperm assay suggests that it may prove to be a valuable tool for determining any *in situ* toxicity in the discharge plume during post-discharge monitoring.
3. Calculated "Margin of Safety" values for the different types of sewage

(assuming a 100:1 dilution) show that both secondary or dechlorinated secondary effluents would probably not produce a toxic response after initial dilution. Chlorinated secondary (as well as primary and influent sewage if they were discharged) could possibly produce a detectable toxic response outside the zone of initial dilution, but chlorine toxicity may "decay" to insignificant levels fairly rapidly. If nutrients or other factors related to the effluent discharge serve to stimulate phytoplankton growth, increased "background" toxicity may result due to the toxicity associated with phytoplankton metabolites.

4. Generally, little significant toxicity was detected in Seahurst area sediment samples using an amphipod bioassay although these results must be considered tenative due to a variety of complications and subsequent test modifications. Trends do suggest, however, that sediment samples from the "C" transect may produce slightly lower amphipod survival relative to other Seahurst samples.

5. Sediment bioassays conducted to compare amphipod survival between several bioassay methods and between fresh vs. frozen sediments suggest that a flow-through bioassay design with all replicates contained in a single aquarium is most appropriate although the testing of sediments in a static system may also be satisfactory. Differences in sediment grain sizes may produce additional stress which are presently not quantified.

6. The discharge of Renton Treatment Plant effluent can be expected to produce flocculants which will contain relatively high concentrations of trace metals and organic compounds. Precipitation of the flocculants to the sediments will occur but the areas and magnitude of impact are not presently known.

### 12.6.2 Recommendations

1. Continue monitoring "background" toxicity in water column and sediment samples during Phase II studies.
2. Conduct bioassays of "aged" Renton sewage to determine how conservative toxicity is, especially in relation to chlorination and the possible buildup of toxicity due to possible effluent recirculation in the Seahurst Bight.
3. Initiate experiments to determine the toxicity of water associated with phytoplankton blooms.
4. Use a refined flow-through sediment bioassay system to minimize confounding factors such as anoxic sediment and between-replicate variability.
5. Conduct additional comparative sediment bioassays to partition the effects of sediment grain size, differences in sensitivity of amphipods from different sites, etc.
6. Investigate the use of several amphipod sublethal test indices for enumerating the toxicity of sediments.

## 12.7 Summary

Toxicology studies during Phase I of the Renton Baseline studies determined "background" toxicity associated with receiving water and sediment samples. Water column toxicity was monitored using standard 48-hour oyster embryo and 60-min sand dollar sperm bioassays. Sediment toxicity was determined using a 10-day amphipod test which monitored survival and degree of inactivity (number moribund) as a sublethal indication of stress. Samples of Renton Treatment Plant sewage were also tested with oyster embryo and sand dollar sperm bioassays to allow prediction of any possible post-discharge

acute toxicity effects and/or "Margins of Safety."

Water column toxicity was highly variable depending on a variety of factors. The oyster embryo mortality index was generally highest in water from surface samples and within the Seahurst Bight, possibly due to the presence of phytoplankton metabolites. The oyster embryo abnormality index showed highest responses in deeper water and in water outside the Seahurst Bight. The responses of the sperm assay were generally intermediate between the two oyster indices.

Results of Renton sewage bioassays suggest that no direct water column toxicity should be observed after initial dilution with the discharge of either unchlorinated or dechlorinated secondary effluent. Toxicity may be detectable outside the zone of initial dilution if chlorinated effluent is discharged, but the "non-conservative" nature of chlorine in seawater may serve to mitigate this source of toxicity.

The stimulation of "indirect" water column toxicity must be considered if the effluent discharge serves to stimulate greater-than-normal phytoplankton production. Increased algae growth could produce additional metabolites which might add to the present levels of "background" water toxicity.

Amphipod survival was generally high in the Seahurst area sediment samples. However, trends toward higher mortality were suggested for samples from transect "C" an area known to be depositional in nature. Amphipod test results must be viewed with caution since several confounding factors (sediment anoxia, sediment grain size differences) may have played an interactive role in some of the tests. A refined flow-through sediment bioassay system has been designed and tested to minimize these problems in future tests.

The biological implications of the proposed sewage discharge are

discussed in relation to the test results and data generated by other studies with suggestions for outfall siting to help mitigate future biological effects.

# 13.0 MARINE CHEMISTRY

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## 13.1 Introduction

Central Puget sound receives industrial and municipal wastes from a population of about two million people. Some 25% of the total wastewater entering central Puget Sound is from municipal wastewater treatment plants. So far, the sewage treatment plants appear to have had relatively little effect on the budget of heavy metals in the Sound when compared with other input sources, Cline et al. (1979). However, increased amount of combustion and industrial waste products appear to be related to atmospheric input in the area.

The main objective of the chemistry task is to study the baseline trace metals in the Seahurst area and to predict the impact that additional effluent discharge may have upon the present levels of trace metals in this area. In addition, the chemistry task provides analytical and measurement services for the entire Seahurst baseline program.

## 13.2 Chemical Studies

One of the main objectives of the chemical studies was evaluation of the biogeochemistry of trace metals in the study area. During Phase I, surface sediments, sediment cores, and biological samples were collected for trace metal measurements. Water, suspended particulate matter, and sediment trap contents will be collected and processed during Phase II. Sediment cores for lead-210 dating and trace metals were collected jointly with Battelle

Northwest Marine Laboratory and NOAA laboratories. Surface sediments for trace metals were collected by the Intertidal and Subtidal tasks, and biological samples for trace metals were collected by the Toxicology and Fish Health tasks. Although analysis of most of these samples, except biota, has been completed, discussion and interpretation of the results will be carried out during Phase II.

13.2.1 Sediment Core Collection

In Puget Sound, a number of sediment cores have been collected and lead-210 dated using a 3-inch open barrel gravity corer (Schell and Nevissi 1976). Recently Hongre and Erlandsen (1979) showed that gravity cores become shorter than the distance of penetration of the corer in the sediment. The shortening depends on barrel diameter and the velocity of penetration into the sediment.

To investigate the effect of the type of gravity corer on sediment cores a 3-inch diameter and a Kasten corer were used. The latter is an open barrel gravity corer, eight feet long, with a square cross-section of 6 x 6 inches. The advantage of this corer is that after the collection the corer is placed on deck horizontally and one side of the barrel is removed without disturbing the core. Hence, the entire sediment column can be examined visually and subsamples taken for analysis. Both devices were used at each station to collect sediment cores in the Seahurst area.

Several attempts were made to collect cores at the 200, 400, and 600 foot depths; however, it turned out that sediments at the 200 and 400 foot depths near Seahurst were very hard to penetrate. Gravity, Kasten, and box corers failed to penetrate the bottom, even with a weight load of 2,000 pounds on the Kasten corer. Hence, all three sets of cores were collected at the 600 foot depth where sediments consisted mainly of mud (Figure 13.1). At each station both sets of cores were lead-210 dated, whereas trace metal profiles were

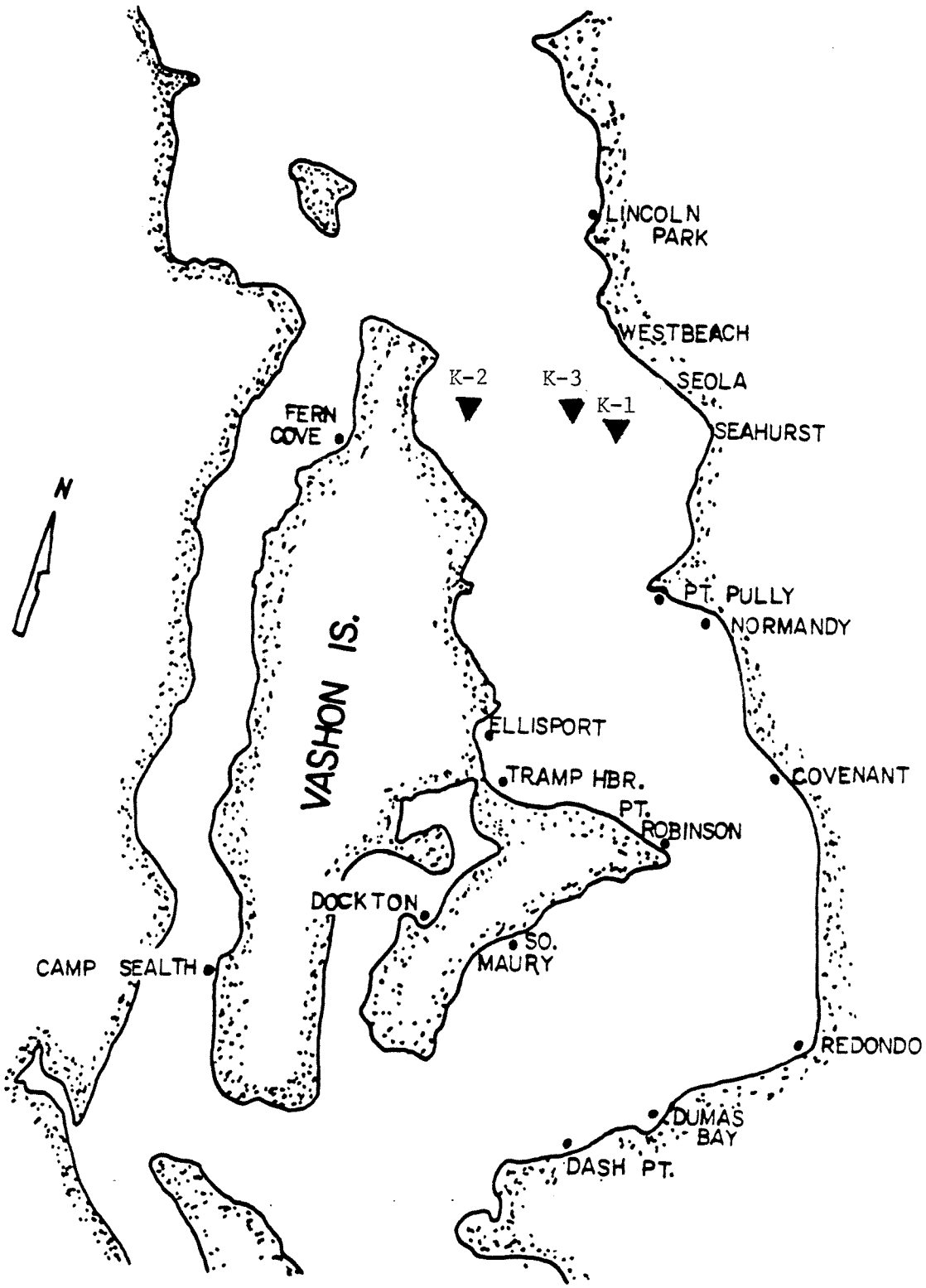



Fig. 13.1. Location of coring stations. One Kasten and one gravity core were collected at each station.

measured only in Kasten cores.

13.2.2 Core Dating

The results of $^{210}Pb$ analysis for Kasten and gravity cores are shown in Tables 13.1 and 13.2, respectively. Measurement of sedimentation rates and comparison between the two coring techniques are presented in Figures 13.2-13.5. The data points for K-1 and G-3 are not sufficient to determine precise sedimentation rates (dashed lines). Additional sections of these cores will be analyzed in order to obtain better sedimentation rate values. Although the analytical results are far from being complete at this time, a brief evaluation of the results is presented below.

The top portion of all six cores shows almost constant concentration of $^{210}Pb$. This could be due to a very rapid sediment accumulation, bioturbation, or physical mixing of sediments by other processes. The depths of mixed layers for Kasten cores are, for K-1, 30 cm, for K-2, 12 cm, and for K-3, 30 cm.

Sections of the Kasten cores were also gamma counted to measure $^{137}Cs$, $^{226}Ra$, and $^{7}Be$. The results of $^{137}Cs$ and $^{226}Ra$ measurements are shown in Table 13.3, but no $^{7}Be$ was detectable in the core profiles. The mixing depths inferred from $^{137}Cs$ measurements are, for K-1, 35-40 cm, for K-2, 15-20 cm, and for K-3, 55-60 cm. These values are somewhat higher than those obtained from $^{210}Pb$ profiles.

Mixing of top sediment layers was also observed in gravity cores, but to a much lesser degree than in the corresponding Kasten cores. This may be due to the overall core shortening as described by Hongre and Erlandsen (1979). The sedimentation rates obtained by the two coring techniques are also markedly different for each station. Generally, gravity cores yield lower sedimentation rates than Kasten cores. Experiments of the above authors show

Table 13.1. Lead-210 activity measured in Kasten core sections. Dashes mean not measured.

| Sediment depth, cm | Pb-210 (pCi/g dry) K-1 | K-2 | K-3 |
|---|---|---|---|
| 0-1 | 4.0 ± 0.35 | 2.30 ± 0.25 | 4.83 ± 0.54 |
| 5-6 | 3.90 ± 0.34 | 2.28 ± 0.22 | 3.76 ± 0.34 |
| 9-10 | 3.46 ± 0.30 | 2.31 ± 0.22 | 4.37 ± 0.45 |
| 14-15 | 3.35 ± 0.29 | 2.07 ± 0.20 | 3.58 ± 0.33 |
| 19-20 | -- | -- | -- |
| 25-26 | 3.58 ± 0.35 | 1.56 ± 0.15 | -- |
| 29-30 | -- | -- | 4.08 ± 0.38 |
| 40-41 | 2.53 ± 0.23 | 1.16 ± 0.12 | -- |
| 50-51 | -- | -- | 2.67 ± 0.26 |
| 70-71 | 1.04 ± 0.11 | -- | -- |
| 90-91 | -- | 0.15 ± 0.05 | 1.52 ± 0.18 |
| 110-111 | 0.37 ± 0.07 | -- | -- |
| 120-121 | -- | 0.07 ± 0.05 | 1.00 ± 0.12 |
| 140-141 | 0.34 ± 0.06 | -- | -- |
| 160-161 | -- | -- | 0.60 ± 0.09 |
| 180-181 | 0.31 ± 0.06 | -- | -- |
| Ra-226 (Mean value) | 0.43 ± 0.07 | 0.37 ± 0.05 | 0.48 ± 0.13 |

Table 13.2. Lead-210 activity measured in gravity core sections. Dashes mean not measured.

| Sediment depth, cm | Pb-210 (pCi/g dry) G-1 | G-2 | G-3 |
|---|---|---|---|
| 0-1 | 3.46 ± 0.32 | 2.53 ± 0.23 | 3.61 ± 0.32 |
| 1-2 | -- | 3.18 ± 0.28 | -- |
| 2-3 | 3.41 ± 0.30 | -- | -- |
| 3-4 | 3.67 ± 0.33 | 3.17 ± 0.27 | 4.32 ± 0.38 |
| 4-5 | 3.61 ± 0.31 | -- | -- |
| 5-6 | -- | -- | 4.26 ± 0.38 |
| 6-7 | 3.76 ± 0.33 | 2.20 ± 0.21 | -- |
| 9-10 | -- | -- | 3.80 ± 0.33 |
| 10-11 | 3.24 ± 0.28 | 1.42 ± 0.16 | -- |
| 15-16 | 2.18 ± 0.20 | 0.72 ± 0.09 | 4.30 ± 0.38 |
| 17-18 | -- | 0.58 ± 0.08 | -- |
| 19-20 | -- | 0.69 ± 0.09 | -- |
| 20-21 | 1.66 ± 0.16 | -- | 3.55 ± 0.32 |
| 25-26 | 1.37 ± 0.14 | -- | |
| 30-31 | -- | -- | 2.66 ± 0.25 |
| 35-36 | 0.97 ± 0.11 | | |
| 40-41 | -- | -- | 1.33 ± 0.14 |
| 50-51 | -- | -- | 1.79 ± 0.17 |
| Ra-226 (Mean value) | 0.43 ± 0.07 | 0.37 ± 0.05 | 0.48 ± 0.13 |

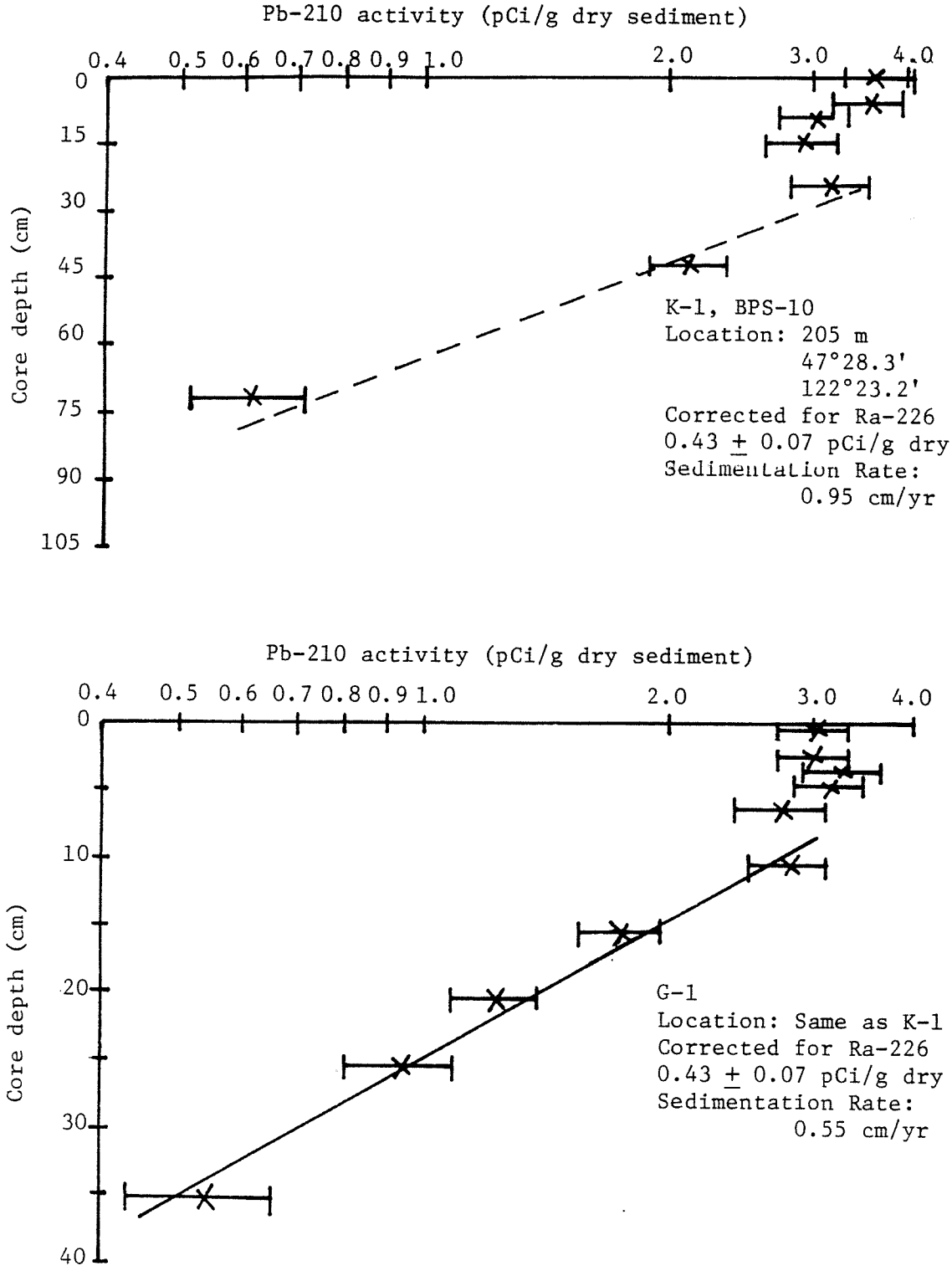



Fig. 13.2. Comparison of Pb-210 dating using Kasten (K-1) and gravity (G-1) corer for sediment collection.

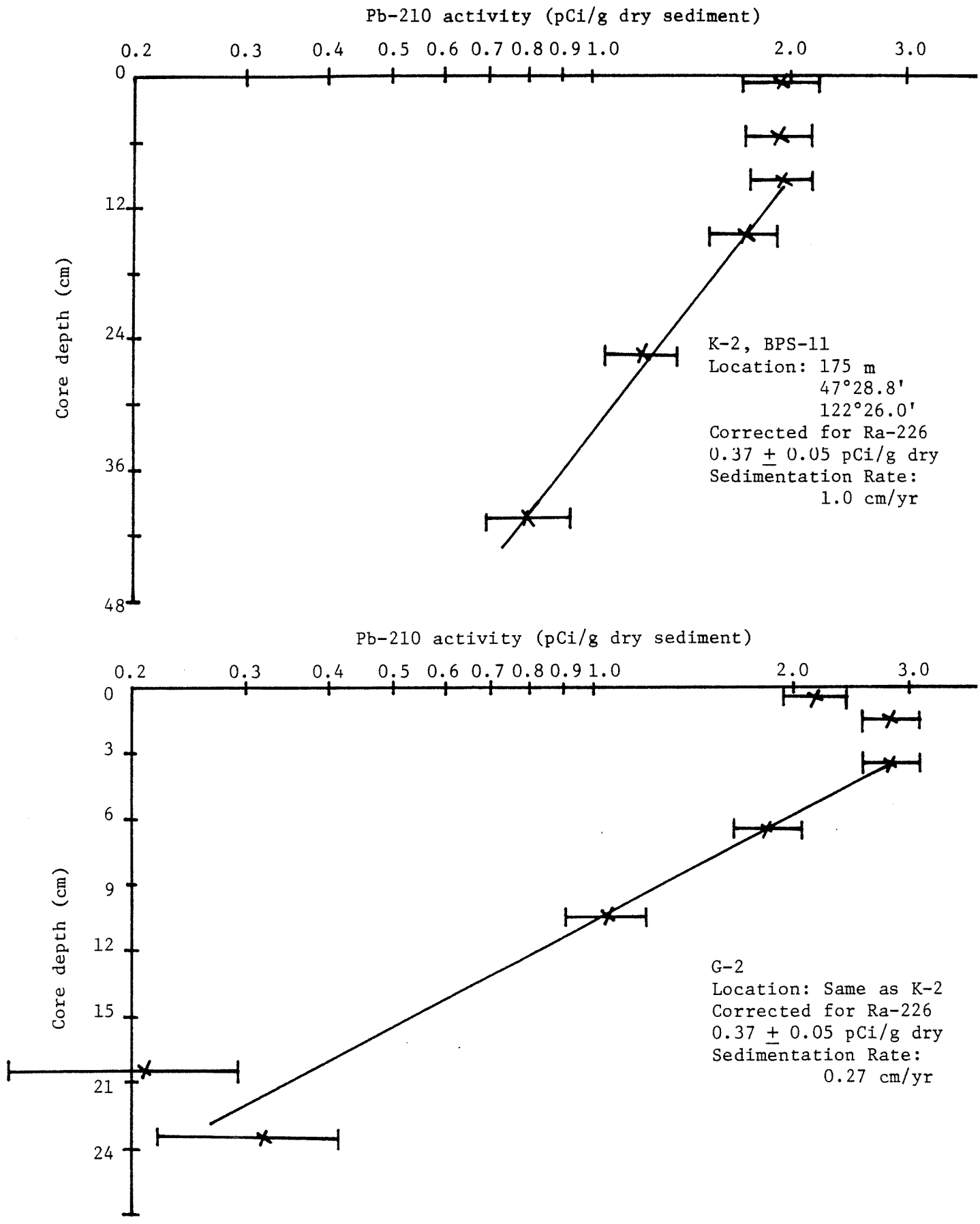



Fig. 13.3. Comparison of Pb-210 dating using Kasten (K-2) and gravity (G-2) corer for sediment collection.

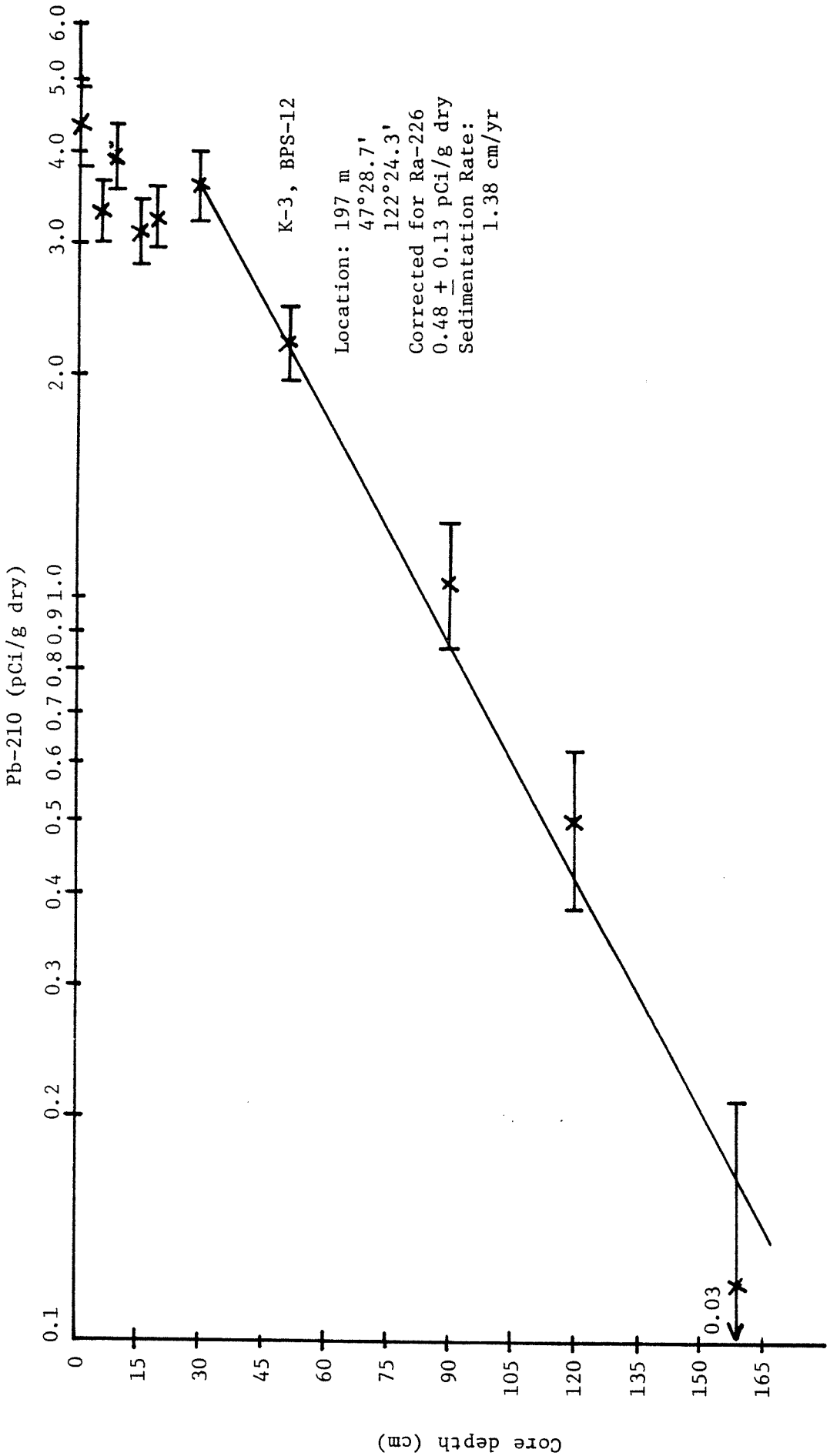



Fig. 13.4. Comparison of Pb-210 dating using Kasten (K-3) and gravity (G-3) corer for sediment collection.

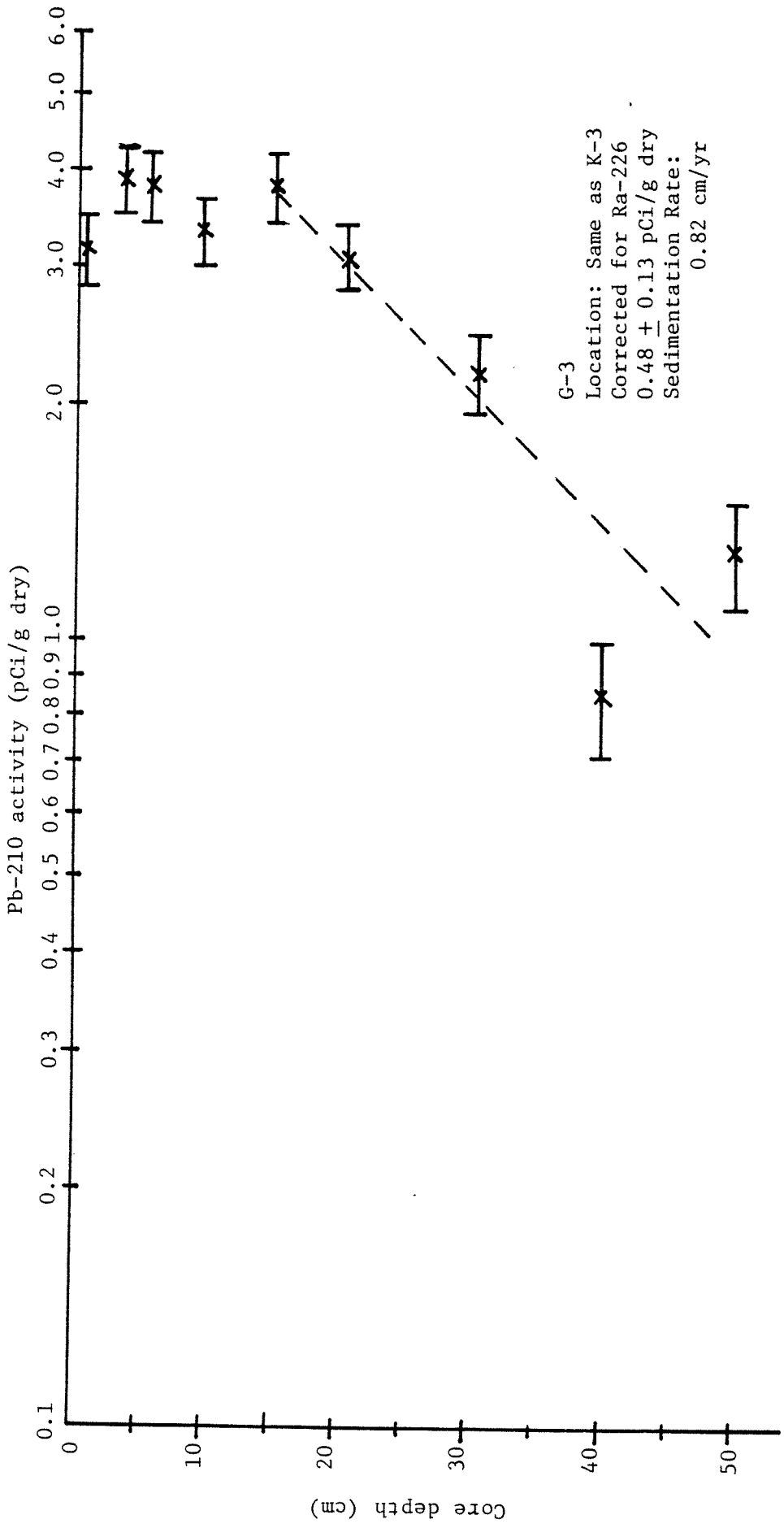



Fig. 13.5. Comparison of Pb-210 dating using Kasten (K-3) and gravity (G-3) corer for sediment collection.

Table 13.3. Cs-137 and Ra-226 activities in Kasten core sections.

| Sediment depth (cm) | pCi/g dry sediment | | | | | |
|---|---|---|---|---|---|---|
| | K-1 | | K-2 | | K-3 | |
| | Cs-137 | Ra-226 | Cs-137 | Ra-226 | Cs-137 | Ra-226 |
| 0-5 | 0.2 ±0.02 | 0.58±0.034 | 0.17 ±0.014 | 0.34±0.026 | 0.27±0.016 | 0.53±0.032 |
| 5-10 | 0.2 ±0.013 | 0.35±0.023 | 0.12 ±0.012 | 0.33±0.034 | 0.26±0.028 | 0.56±0.063 |
| 15-20 | 0.22 ±0.013 | 0.39±0.032 | 0.12 ±0.012 | 0.34±0.026 | 0.28±0.016 | 0.32±0.035 |
| 35-40 | 0.19 ±0.013 | 0.43±0.025 | 0.083±0.013 | 0.34±0.035 | -- | -- |
| 55-60 | 0.083±0.013 | 0.49±0.039 | 0 | 0.43±0.045 | 0.23±0.021 | 0.33±0.045 |
| 75-80 | 0 | -- | -- | 0.34±0.017 | 0 | 0.49±0.025 |
| 100-105 | 0 | 0.39±0.038 | 0.018±0.005 | 0.45±0.023 | 0 | 0.69±0.022 |
| 120-125 | 0 | 0.45±0.028 | 0 | ? | 0 | ? |
| 150-155 | 0 | 0.42±0.034 | 0 | 0.42±0.016 | 0 | ? |
| 180-185 | 0 | 0.34±0.031 | -- | -- | 0 | 0.44±0.03 |
| Mean and S.D. | | 0.43±0.07 | | 0.37±0.05 | | 0.48±0.13 |
| Number | | 9 | | 8 | | 7 |

that soft layers become more reduced in thickness than stiffer ones. This may be one reason that the ratios of Kasten/gravity sedimentation rates are not constant for all three stations sampled.

As part of the $^{210}Pb$ dating, the density and wet/dry ratios of sediments were also measured for calculation of sediment accumulation rates in terms of $g/cm^2/yr$. However, because of the incompleteness of $^{210}Pb$ results, the accumulation rates will be calculated during Phase II.

13.2.3 Trace Metals in Sediment Cores

Trace metal concentrations were measured in one centimeter sections of Kasten cores. The analytical results together with the dry/wet ratio for the sections are given in Tables 13.4-13.7. The concentrations of trace metals against sediment depths are plotted in Figures 13.6-13.26. Because of the uncertainties on sedimentation rates, no date was assigned to the core sections at this time. Hence, the geochronology of trace metals in sediment cores is not demonstrated. Generally, two distinct types of trace metal profiles are evidenced in the figures. Profiles of metals such as cadmium show constant concentration from top to bottom of the core. This means that no significant anthropogenic input has changed the natural background. On the other hand, metals such as Pb, Cu, and Hg show significant increase over the natural background, indicating strong anthropogenic input.

The metal profiles are far from smooth curves, probably because of the inherent inhomogeneity of the sediments. Since only a small fraction of the sediment sample, 0.3-1.0 g, is used for analysis, a change in sediment particle size composition may introduce a corresponding change in analytical results.

The metal concentrations in core profiles should be considered a first approximation at this time. A rigorous evaluation and interpretation of the

Table 13.4. Dry/wet ratios in Kasten core sections.

| Core depth | K-1 | K-2 | K-3 |
|---|---|---|---|
| 0-1 | 0.296 | 0.418 | 0.305 |
| 5-6 | 0.323 | 0.475 | 0.334 |
| 9-10 | 0.343 | 0.505 | 0.327 |
| 14-15 | 0.371 | 0.477 | 0.344 |
| 19-20 | 0.367 | 0.492 | 0.330 |
| 25-26 | 0.383 | 0.464 | 0.357 |
| 29-30 | 0.382 | 0.465 | 0.350 |
| 40-41 | 0.382 | 0.485 | 0.357 |
| 50-51 | 0.376 | 0.513 | 0.376 |
| 70-71 | 0.385 | 0.608 | 0.390 |
| 90-91 | 0.396 | 0.516 | 0.386 |
| 110-111 | 0.393 | 0.573 | 0.412 |
| 120-121 | 0.372 | 0.567 | 0.432 |
| 140-141 | 0.415 | 0.516 | 0.394 |
| 160-161 | 0.396 | | 0.421 |
| 180-181 | 0.385 | | 0.399 |
| 190-191 | 0.417 | | 0.391 |
| #71 | 0.340 | | |

Table 13.5. Concentration of trace metals in sediment core K-1. All values are in ppm, except for Cd and Hg which are in ppb.*

| Sediment depth (cm) | Ag ppm | Cr ppm | B ppm | Ba ppm | Be ppm | Cd ppb | Co ppm | Cu ppm | Hg ppb | Mn ppm | Ni ppm | Pb ppm | V ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | 0.95 | 29 | 50 | 22 | 1.8 | 924** | 6.6 | 23 | 38.4 | 192 | 15 | 12.7 | 21 | 37 |
| 5-6 | 0.99 | 30 | 44 | 25 | 2 | 97 | 7.4 | 26 | 47.5 | 207 | 15 | 13.1 | 24 | 41 |
| 9-10 | 1.0 | 29 | 48 | 27 | 2.1 | 74 | 7.6 | 28 | 91.1 | 220 | 16 | 13.7 | 26 | 40 |
| 14-15 | 1.1 | 31 | 47 | 30 | 2.2 | 82 | 8.4 | 26 | 49.1 | 189 | 17 | 14.7 | 29 | 45 |
| 19-20 | 1.2 | 33 | 47 | 34 | 2.3 | 64 | 8.6 | 27 | 126 | 204 | 18 | 15.5 | 30 | 46 |
| 25-26 | 1.3 | 36 | 63 | 35 | 2.5 | 81 | 9.1 | 28 | 142 | 194 | 19 | 15.9 | 32 | 52 |
| 29-30 | 1.1 | 33 | 45 | 29 | 2.3 | 78 | 8.5 | 28 | 135 | 184 | 19 | 17.5 | 29 | 53 |
| 40-41 | 1.2 | 32 | 46 | 27 | 2.3 | 76 | 8.2 | 30 | 129 | 155 | 17 | 17.2 | 28 | 46 |
| 50-51 | 1.2 | 38 | 45 | 35 | 2.4 | 130** | 9.2 | 26 | 127 | 161 | 19 | 19.0 | 32 | 50 |
| 70-71 | 1.0 | 29 | 49 | 27 | 2.2 | 70 | 8.3 | 26 | -- | 168 | 17 | 17.2 | 27 | 38 |
| 90-91 | 1.0 | 32 | 49 | 29 | 2.4 | 56 | 9 | 17 | 38.5 | 199 | 18 | 6 | 30 | 34 |
| 110-111 | 0.96 | 30 | 48 | 27 | 2.2 | 81 | 8 | 15 | 19.4 | 179 | 17 | 0.4 | 27 | 30 |
| 120-121 | 0.99 | 32 | 46 | 27 | 2.3 | 97 | 8.5 | 23 | 19.9 | 187 | 18 | 1.8 | 29 | 34 |
| 140-141 | 0.99 | 34 | 51 | 29 | 2.5 | 63 | 9.1 | 20 | 234 | 191 | 19 | 1.7 | 30 | 38 |
| 160-161 | 1.0 | 31 | 47 | 27 | 2.3 | 217** | 8.6 | 16 | 101 | 177 | 18 | 1.5 | 28 | 37 |
| 180-181 | 0.85 | 30 | 46 | 23 | 2.1 | 79 | 7.8 | 15 | 59.4 | 167 | 17 | 0.9 | 27 | 36 |
| 190-191 | 0.79 | 30 | 49 | 22 | 2.2 | 81 | 8.1 | 17 | 160 | 170 | 18 | 1.1 | 26 | 34 |

*Values are for wet sediment; for dry sediment the concentrations should be divided by the corresponding dry/wet ratio.

**Section to be remeasured.

Table 13.6. Concentration of trace metals in sediment core K-2. All values are in ppm, except for Cd and Hg which are in ppb.*

| Sediment depth (cm) | Ag ppm | Cr ppm | B ppm | Ba ppm | Be ppm | Cd ppb | Co ppm | Cu ppm | Hg ppb | Mn ppm | Ni ppm | Pb ppm | V ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | 0.91 | 29 | 58 | 21 | 2 | 75 | 8.7 | 20 | 80 | 183 | 18 | 10.9 | 24 | 39 |
| 5-6 | 1.1 | 33 | 59 | 27 | 2.5 | 109 | 10 | 23 | 80 | 178 | 21 | 11.6 | 29 | 46 |
| 9-10 | 1.3 | 36 | 48 | 30 | 2.7 | 221 | 11 | 25 | 98 | 187 | 23 | 12.2 | 32 | 51 |
| 14-15 | 1.3 | 36 | 45 | 34 | 2.7 | 137 | 11 | 27 | 70 | 196 | 22 | 13.1 | 33 | 50 |
| 19-20 | 1.2 | 37 | 49 | 34 | 2.5 | 244 | 11 | 25 | 120 | 185 | 21 | 12.5 | 32 | 51 |
| 25-26 | 1.1 | 33 | 46 | 28 | 2.4 | 131 | 10 | 24 | 100 | 170 | 21 | 12.9 | 30 | 46 |
| 29-30 | 1.2 | 38 | 50 | 32 | 2.6 | 95 | 11 | 25 | 101 | 181 | 23 | 12.7 | 33 | 46 |
| 40-41 | 1.3 | 38 | 51 | 34 | 2.7 | 277 | 12 | 28 | 103 | 190 | 23 | 14.5 | 35 | 47 |
| 50-51 | 1.2 | 36 | 52 | 34 | 2.7 | 137 | 12 | 25 | 79 | 186 | 23 | 11.2 | 35 | 44 |
| 70-71 | 1.2 | 38 | 60 | 34 | 2.9 | 110 | 13 | 16 | 50 | 216 | 25 | 2.6 | 36 | 40 |
| 90-91 | 0.83 | 30 | 35 | 25 | 2.3 | 112 | 9.6 | 15 | 9.7 | 175 | 20 | 1.8 | 28 | 36 |
| 110-111 | 0.91 | 36 | 46 | 22 | 2.6 | 121 | 11 | 16 | 77 | 202 | 24 | 1.7 | 26 | 34 |
| 120-121 | 1.1 | 40 | 45 | 25 | 2.8 | 170 | 12 | 16 | 14.9 | 217 | 26 | 1.7 | 32 | 43 |
| 140-141 | 0.99 | 36 | 46 | 26 | 2.5 | 149 | 10 | 15 | 19.5 | 202 | 22 | 0.4 | 30 | 35 |

*Values are for wet sediment; for dry sediment the concentrations should be divided by the corresponding dry/wet ratio.

Table 13.7. Concentrations of trace metals in sediment core K-3. All values are in ppm, except for Cd and Hg which are in ppb.*

| Sediment depth (cm) | Ag ppm | Cr ppm | B ppm | Ba ppm | Be ppm | Cd ppb | Co ppm | Cu ppm | Hg ppb | Mn ppm | Ni ppm | Pb ppm | V ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | 0.33 | 16.5 | 42 | 29 | 1.6 | 71 | 5.2 | 21 | 142 | 139 | 10 | 13 | 21 | 31 |
| 5-6 | 0.32 | 12 | 44 | 25 | 1.2 | 34 | 4.1 | 13 | 160 | 136 | 7.7 | 8.7 | 16.5 | 26 |
| 9-10 | 0.18 | 13 | 54 | 25 | 1.2 | 29 | 3.9 | 14 | 107 | 119 | 9.2 | 7.7 | 16 | 23 |
| 14-15 | 1.2 | 28 | 69 | 46 | 2.5 | -- | 8.6 | 28 | 138 | 227 | 17 | -- | 35 | 51 |
| 19-20 | 0.41 | 12 | 53 | 21 | 0.96 | 29 | 3.4 | 11 | 128 | 86 | 5.9 | 12.3 | 14 | 17 |
| 25-26 | 1.2 | 27 | 71 | 46 | 2.5 | 26 | 8.6 | 28 | 144 | 191 | 17 | 19.2 | 34 | 48 |
| 29-30 | 1 | 23 | 59 | 37 | 2 | 89 | 7 | 23 | 131 | 142 | 14 | 15.2 | 28 | 41 |
| 40-41 | 1.2 | 29 | 67 | 47 | 2.6 | 14 | 8.7 | 28 | 136 | 169 | 18 | 17.8 | 35 | 50 |
| 50-51 | 1.3 | 30 | 60 | 46 | 2.5 | 0.07 | 8.9 | 27 | 146 | 178 | 18 | 18.3 | 36 | 49 |
| 70-71 | 0.44 | 13 | 51 | 26 | 1.2 | 19 | 4.3 | 13 | 184 | 89 | 7.9 | 8.8 | 18 | 23 |
| 90-91 | 1.1 | 26 | 58 | 34 | 2.6 | 13 | 9.1 | 27 | 142 | 205 | 18 | 61.1 | 33 | 46 |
| 110-111 | 1.2 | 28 | 66 | 43 | 2.6 | 39 | 9.6 | 27 | 137 | 202 | 18 | 17.4 | 36 | 45 |
| 120-121 | 1.2 | 30 | 68 | 48 | 2.8 | 55 | 10 | 31 | 140 | 218 | 19 | 21 | 39 | 48 |
| 140-141 | 1.4 | 29 | 71 | 44 | 2.6 | 61 | 9.7 | 27 | 97.3 | 205 | 18 | 12.2 | 38 | 42 |
| 160-161 | 1.2 | 31 | 74 | 45 | 2.9 | 69 | 10 | 19 | 39.2 | 244 | 19 | 66.9 | 39 | 41 |
| 180-181 | 1.1 | 28 | 66 | 43 | 2.5 | 54 | 9.4 | 16 | 29.5 | 203 | 18 | 3.3 | 37 | 36 |
| 190-191 | 0.89 | 25 | 62 | 35 | 2.4 | 81 | 8.1 | 15 | 9.7 | 188 | 16 | 2.1 | 32 | 32 |

*Values are for wet sediment; for dry sediment the concentrations should be divided by the corresponding dry/wet ratio.

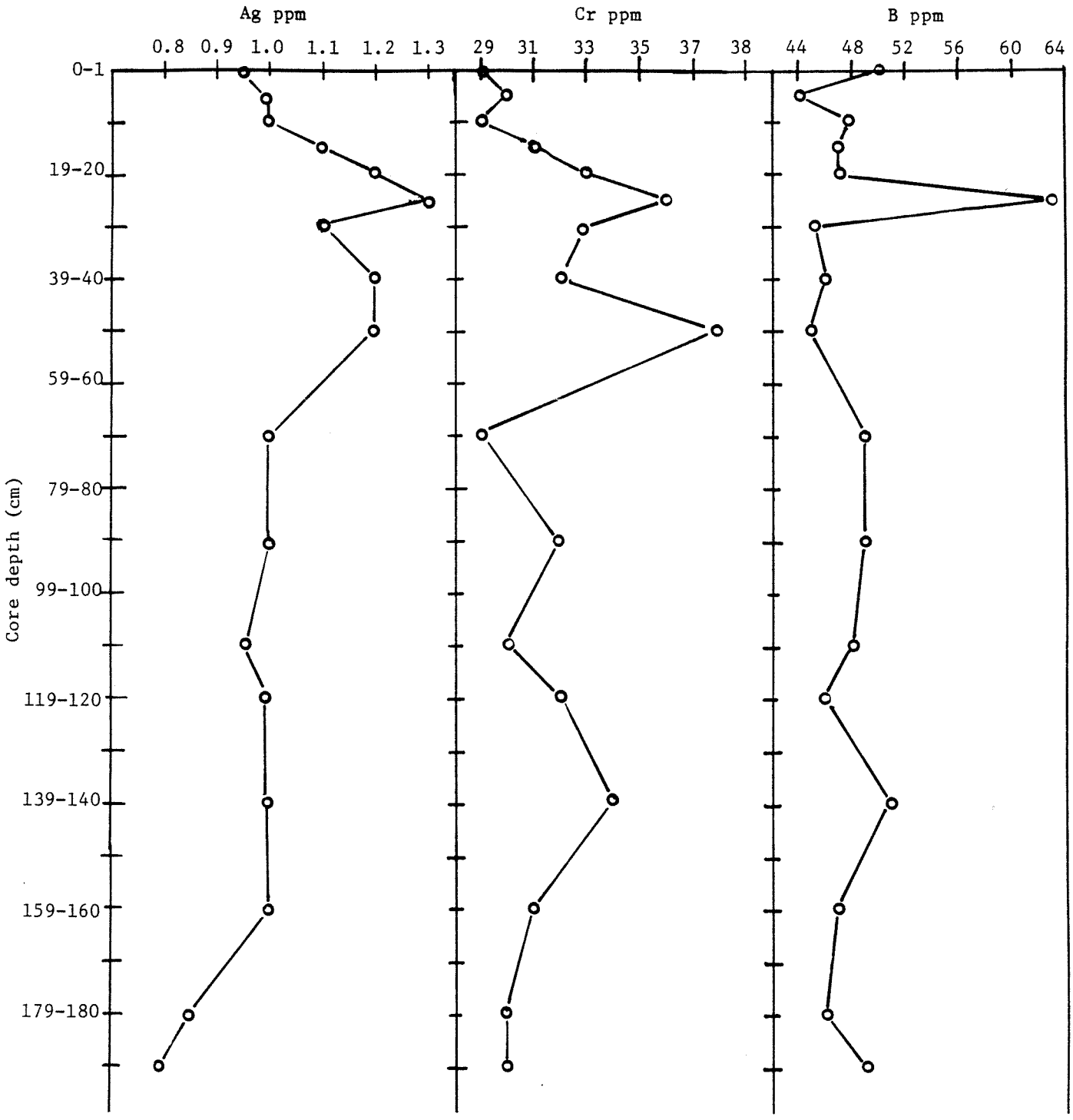



Fig. 13.6. Concentrations of Ag, Cr, and B in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

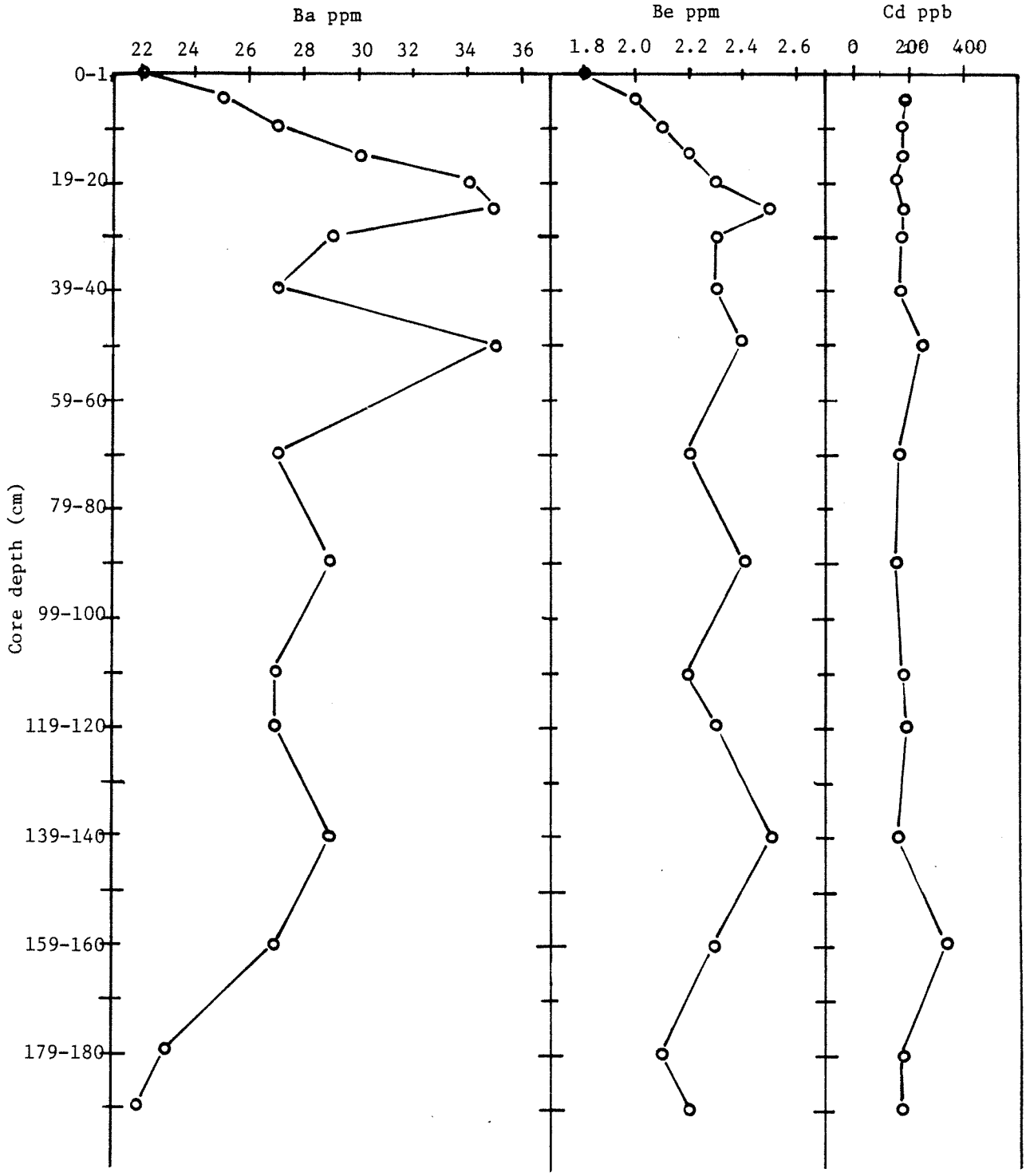



Fig. 13.7. Concentrations of Ba, Be, and Cd in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

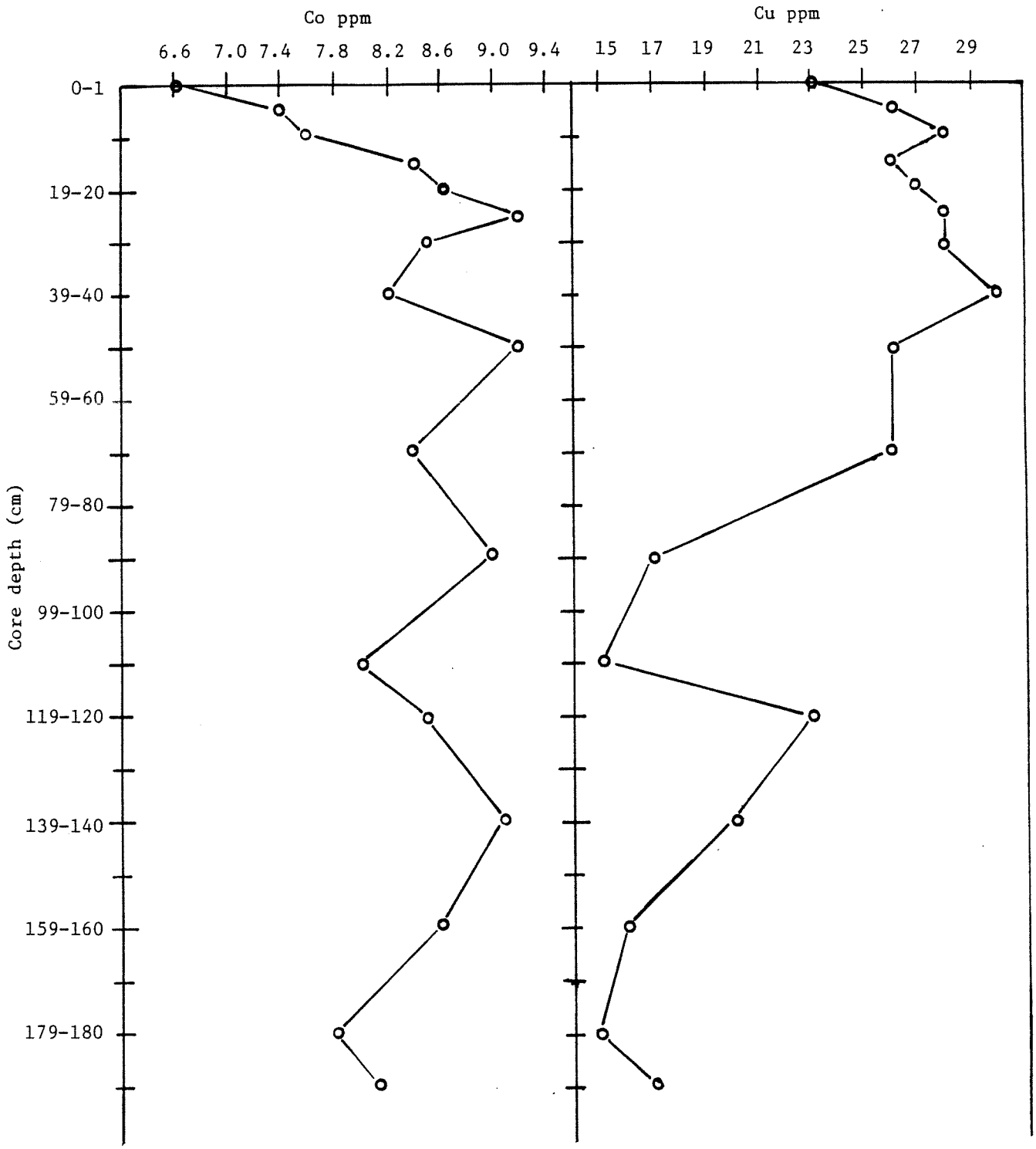



Fig. 13.8. Concentrations of Co and Cu in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

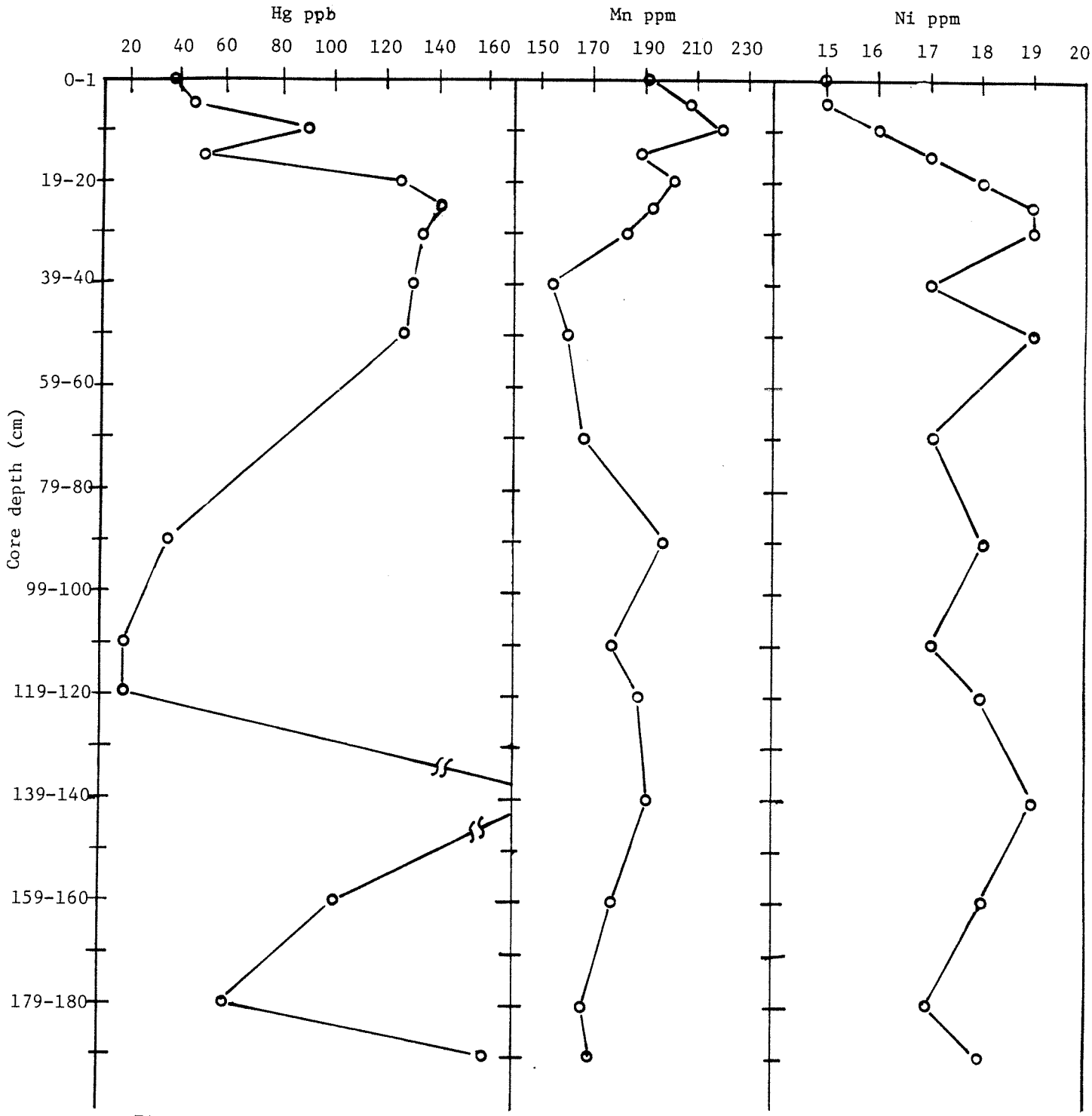



Fig. 13.9. Concentrations of Hg, Mn, and Ni in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

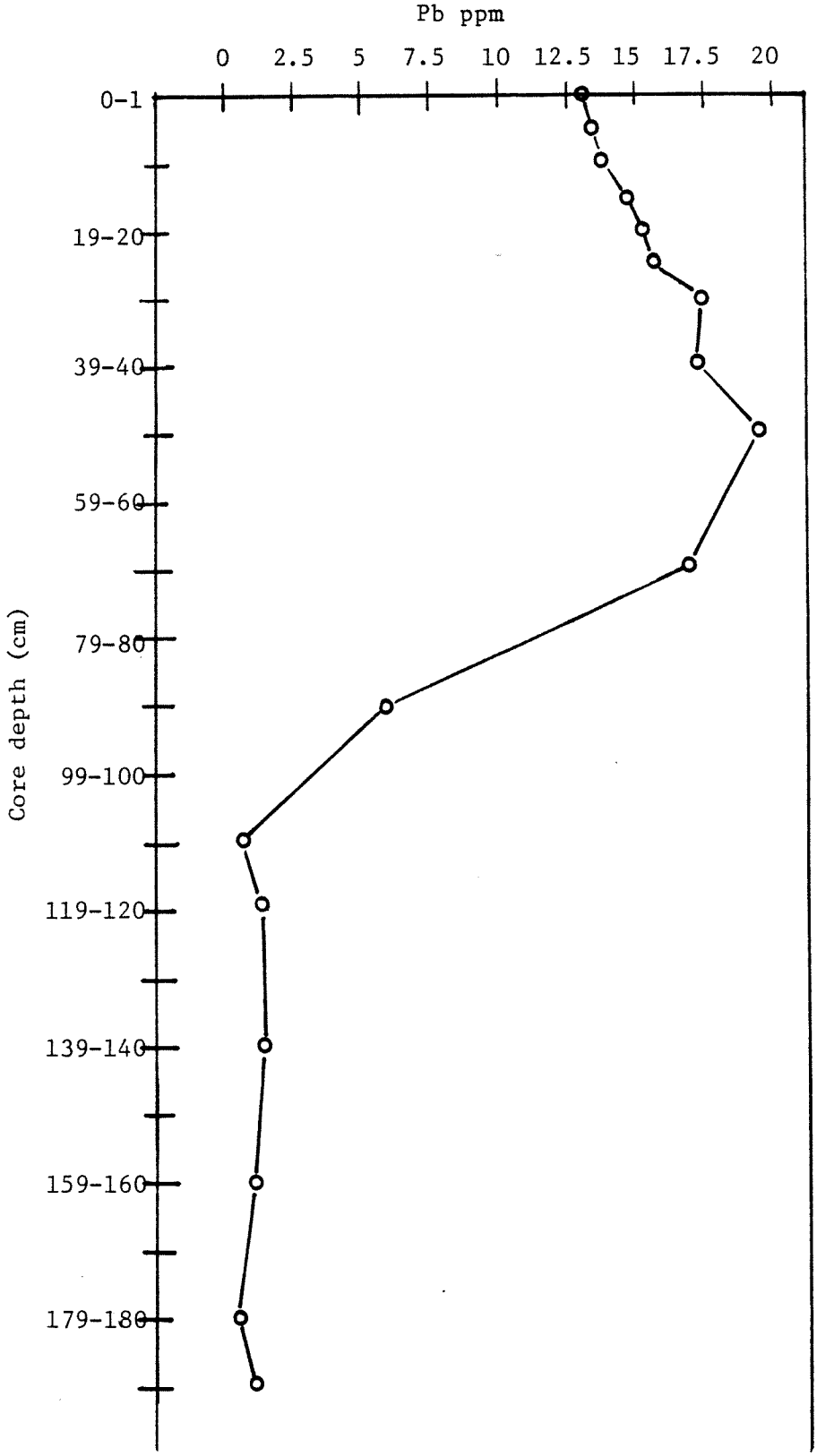



Fig. 13.10. Concentrations of Pb in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

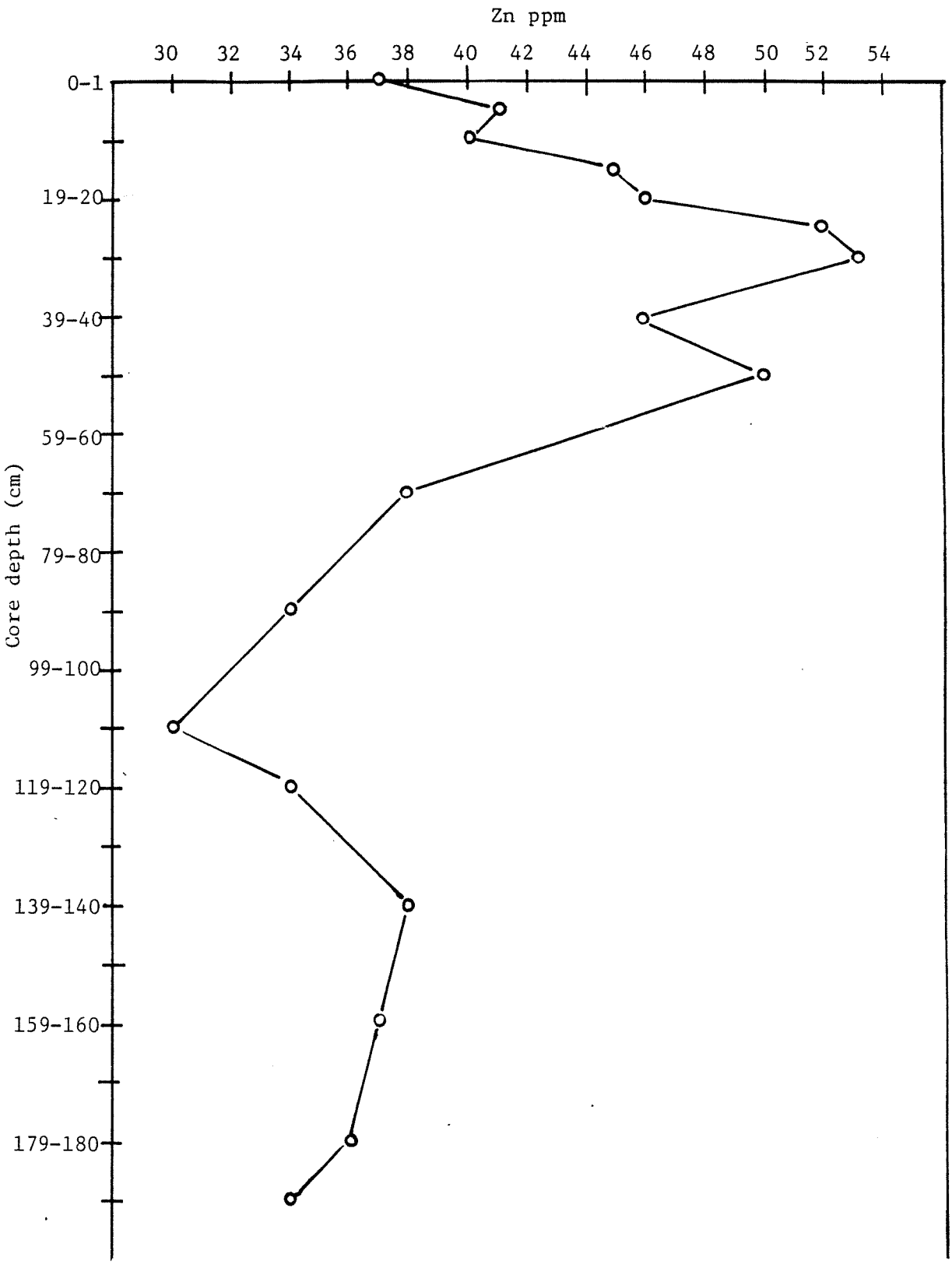



Fig. 13.11. Concentrations of Zn in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

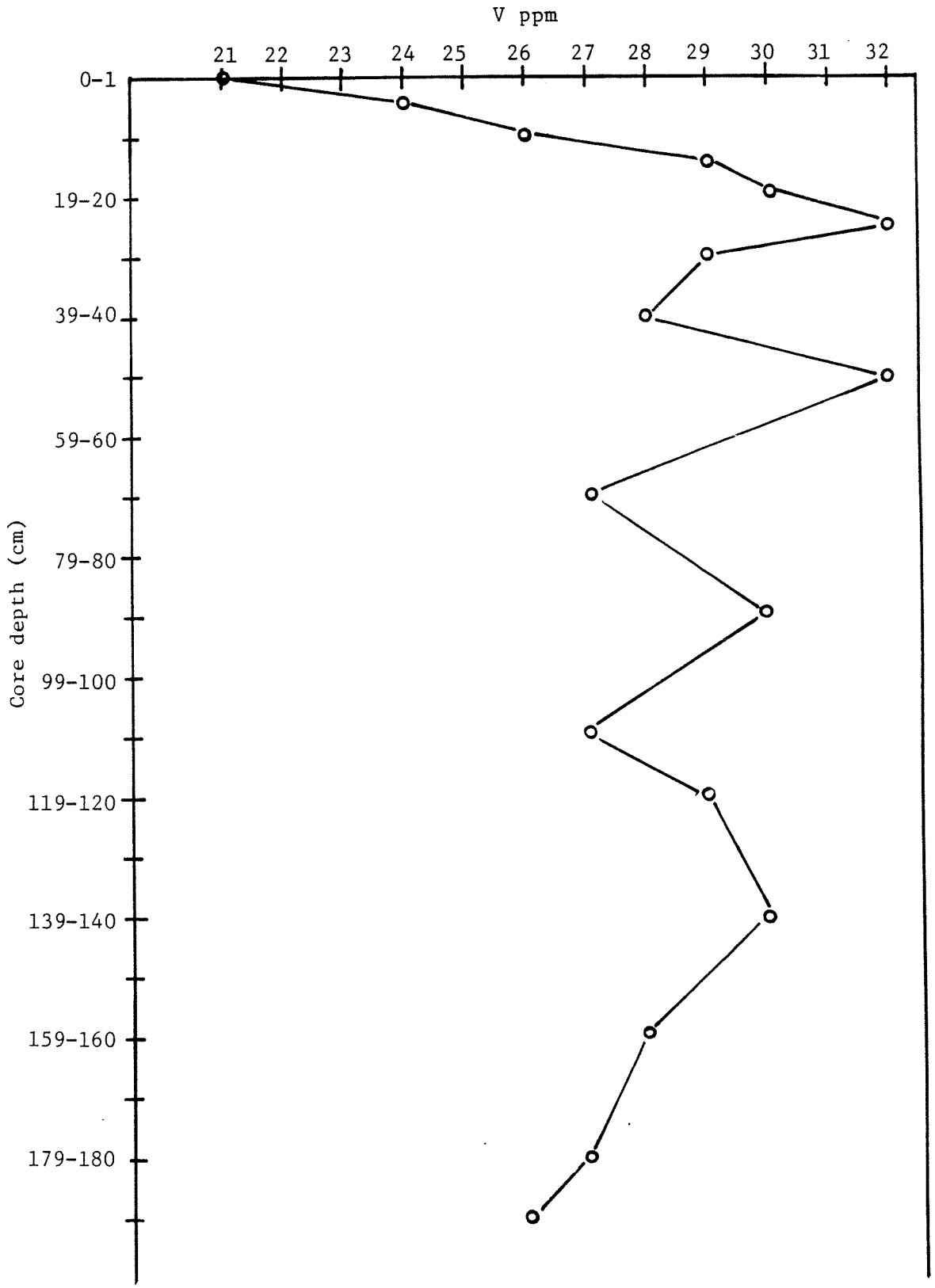



Fig. 13.12. Concentrations of V in sediment core K-1. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

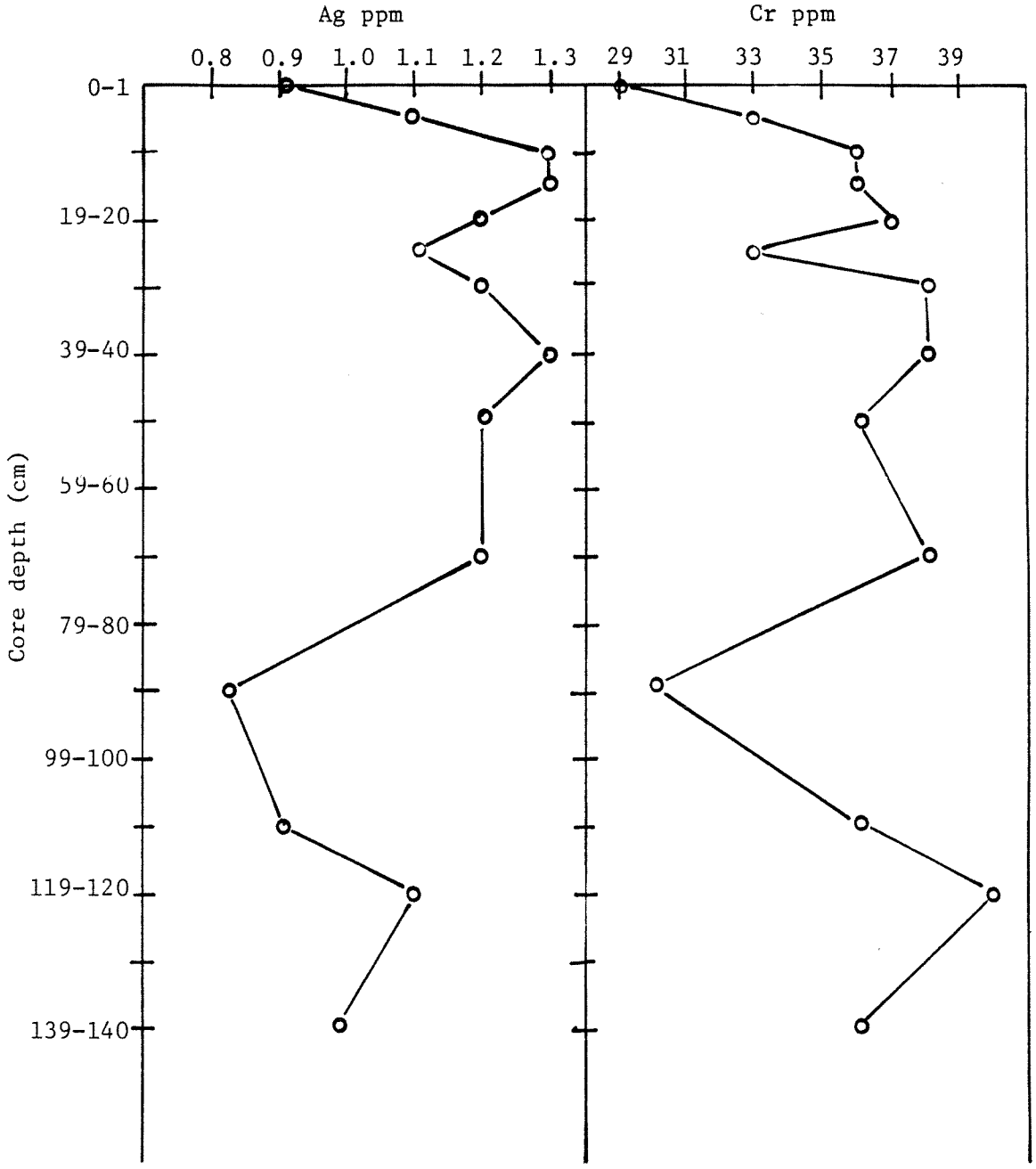



Fig. 13.13. Concentrations of Ag and Cr in sediment core K-2. Profiles are for wet sediment; to obtain similar profiles for dry sediments, the values for dry sediment should be used.

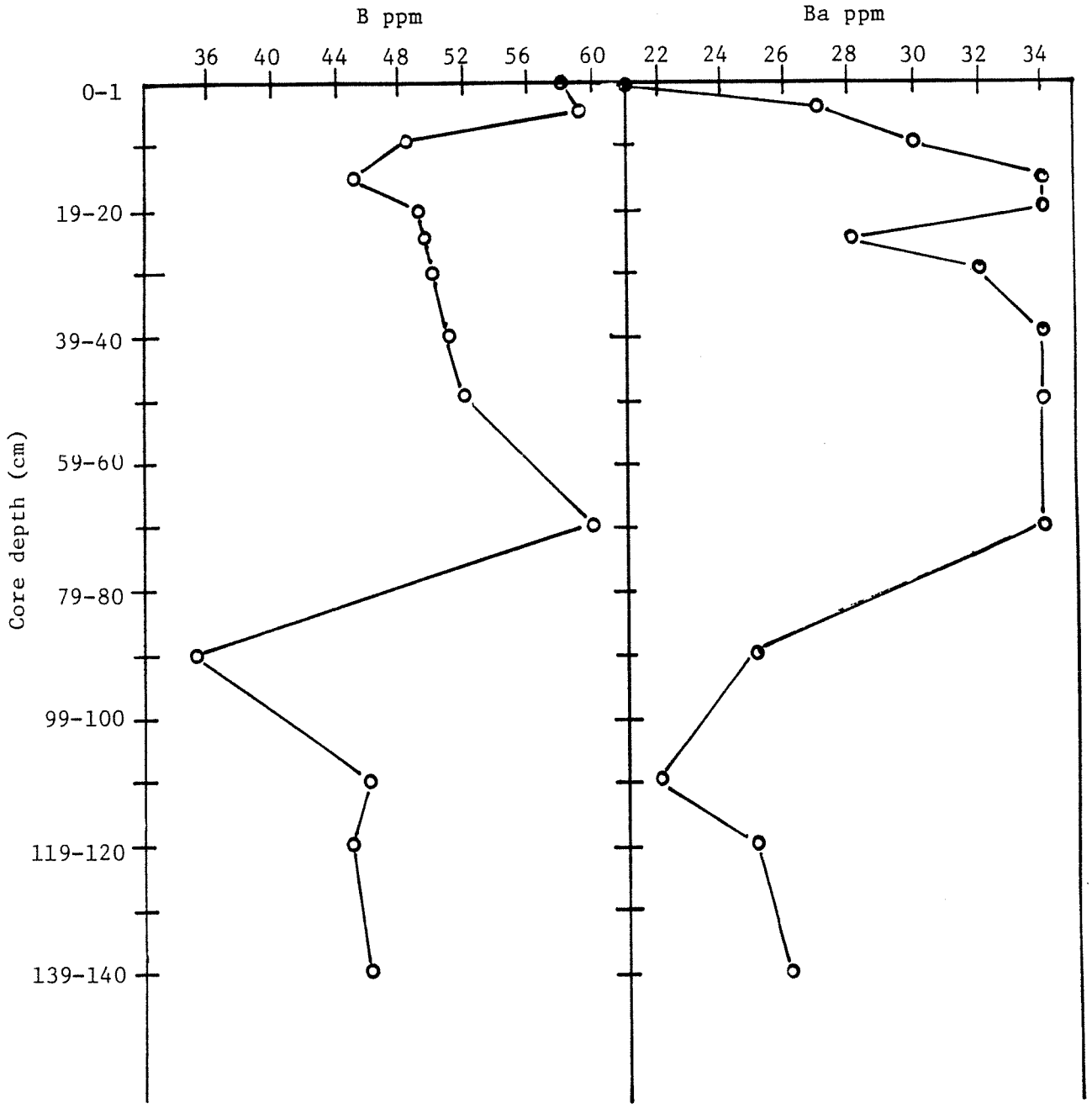



Fig. 13.14. Concentrations of B and Ba in sediment core K-2. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

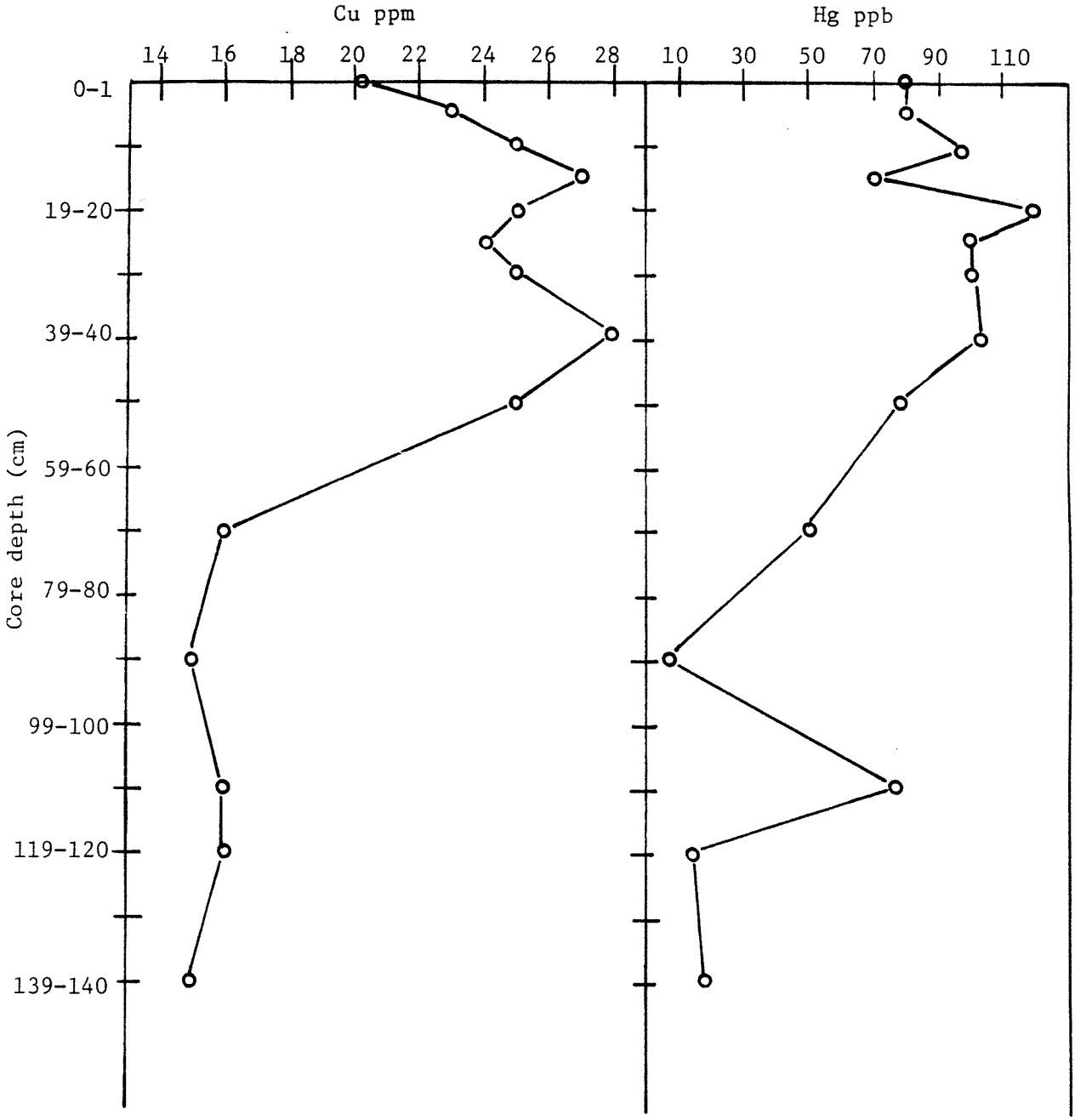



Fig. 13.15. Concentrations of Cu and Hg in sediment core K-2. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

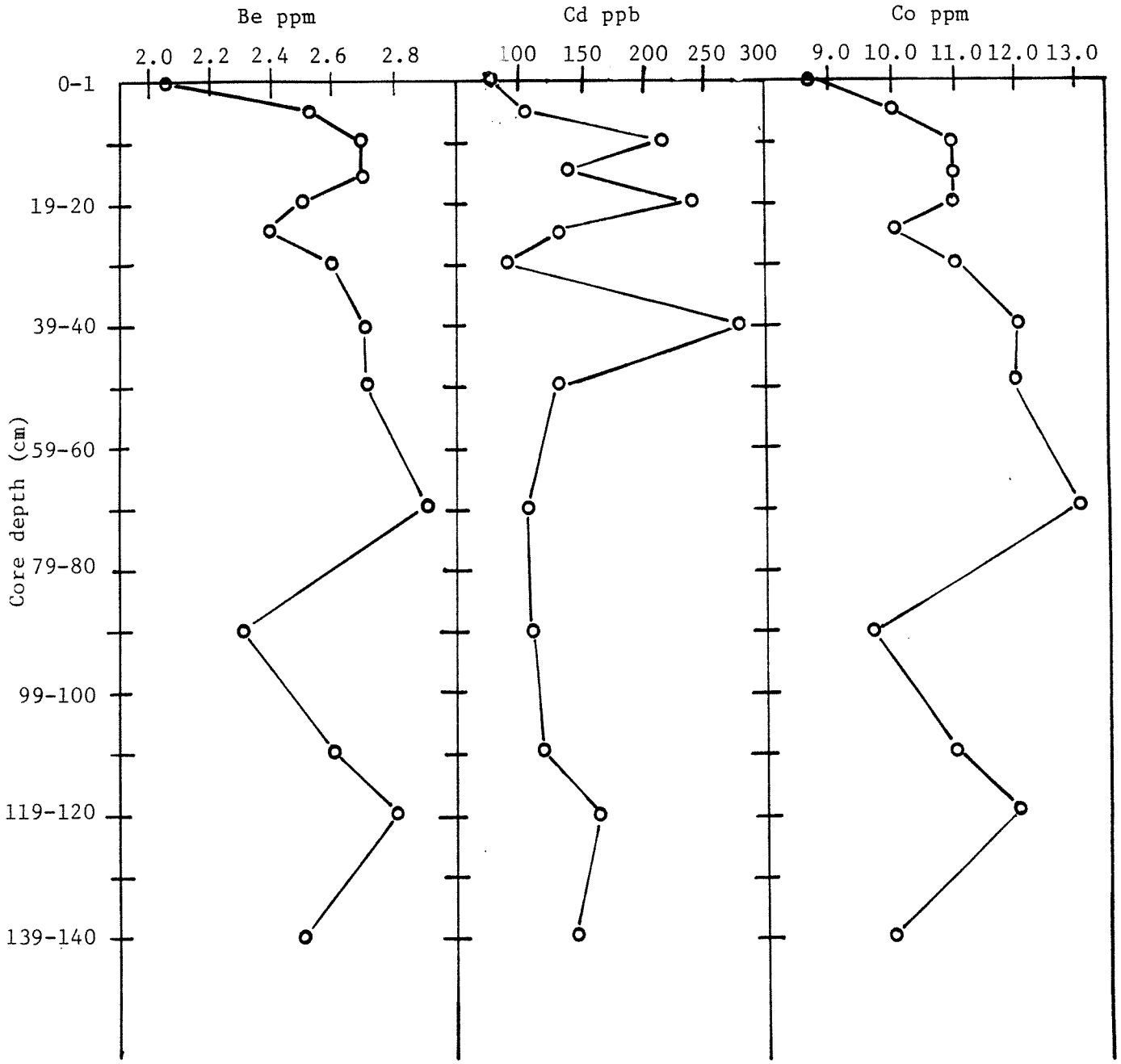



Fig. 13.16. Concentrations of Be, Cd, and Co in sediment core K-2. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

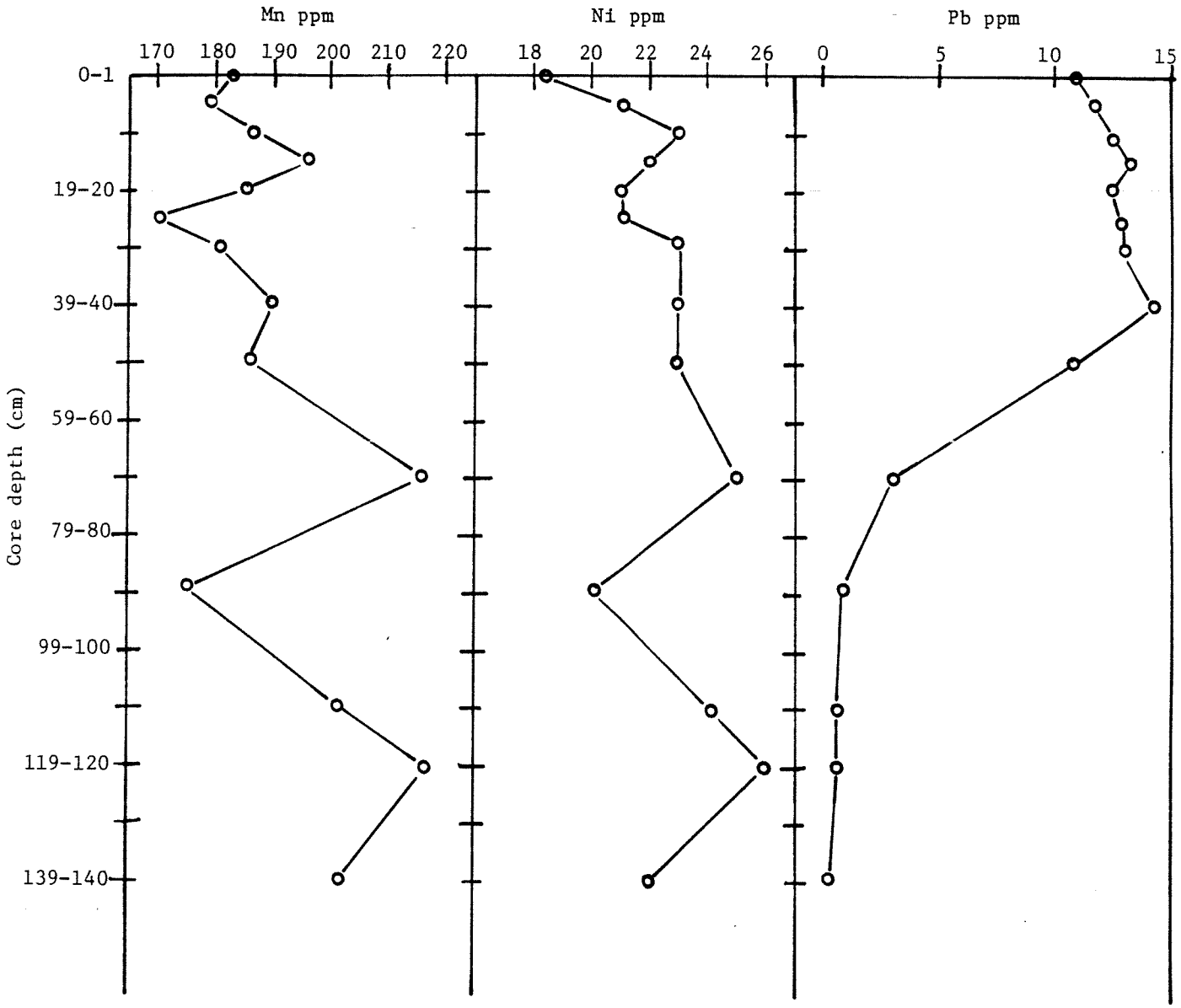



Fig. 13.17. Concentrations of Mn, Ni, and Pb in sediment core K-2. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

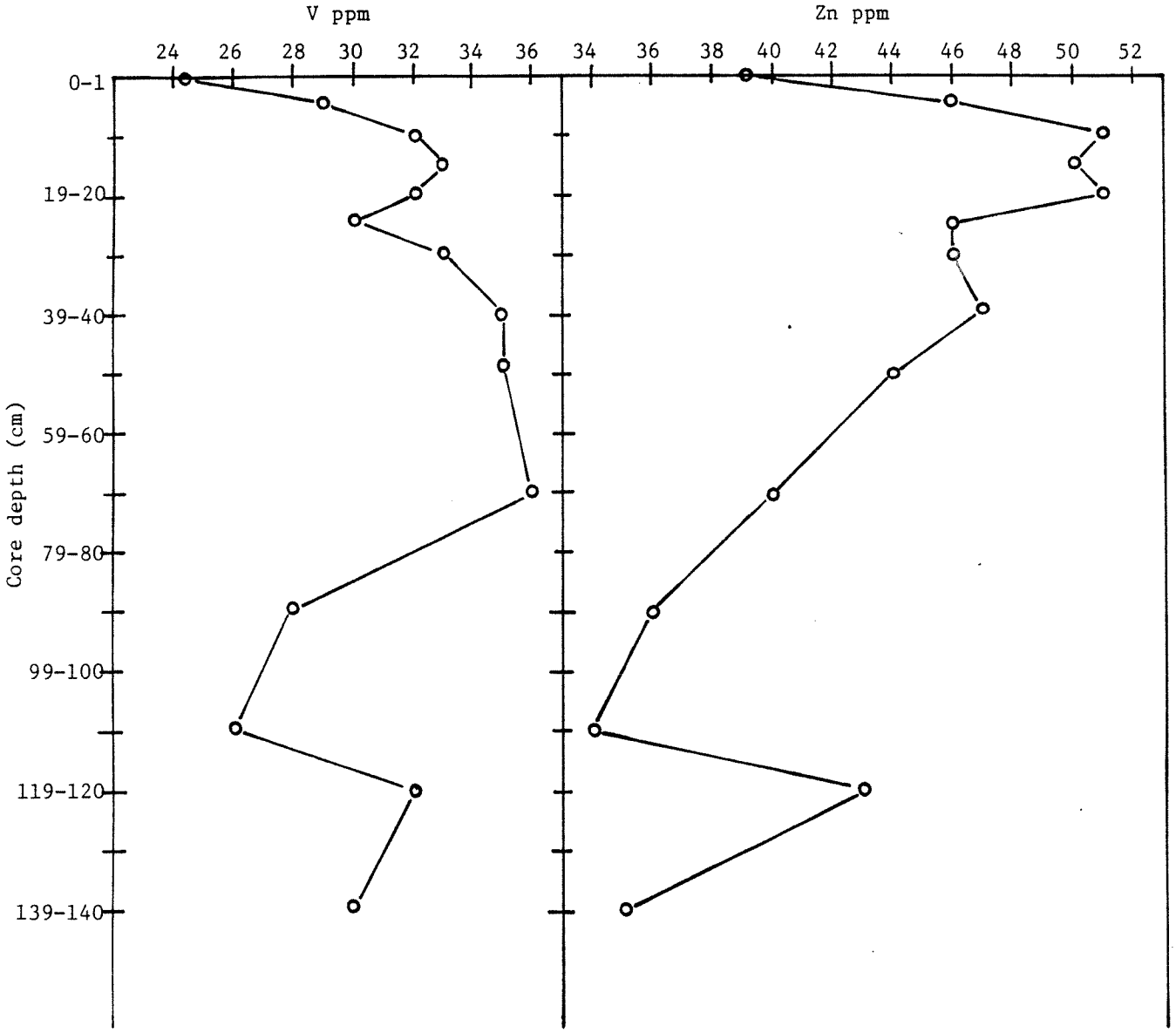



Fig. 13.18. Concentrations of V and Zn in sediment core K-2. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

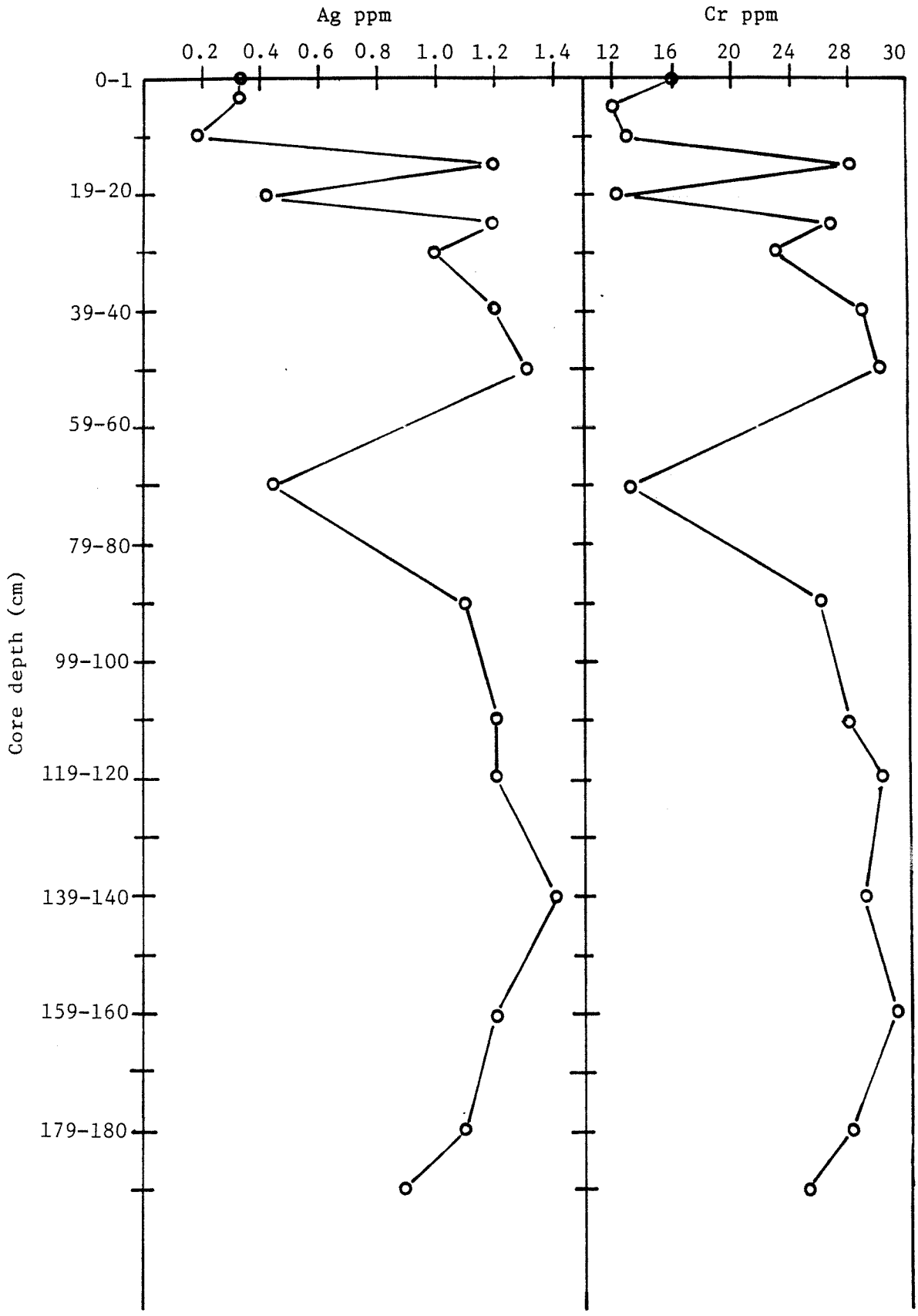



Fig. 13.19. Concentrations of Ag and Cr in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

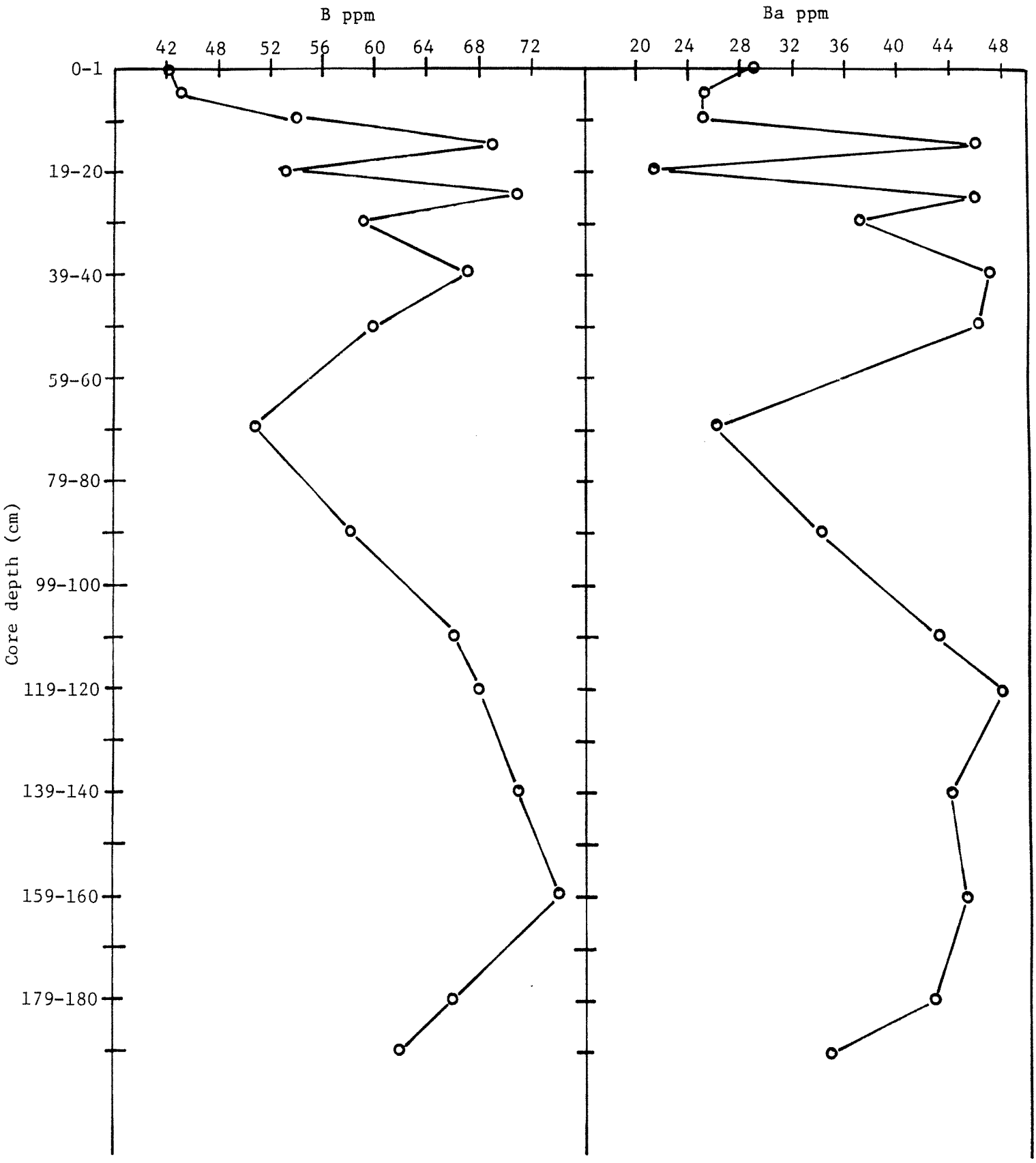



Fig. 13.20. Concentrations of B and Ba in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

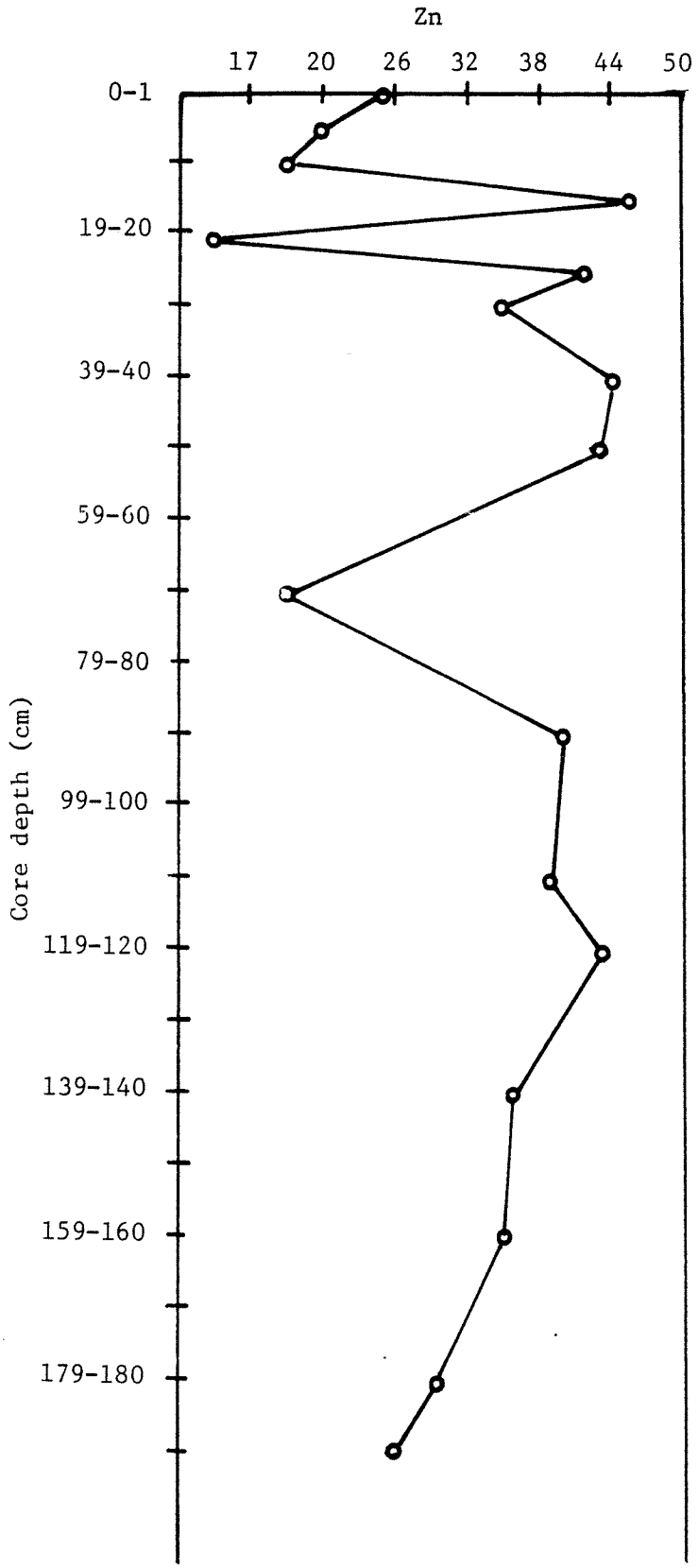



Fig. 13.21. Concentrations of Zn in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

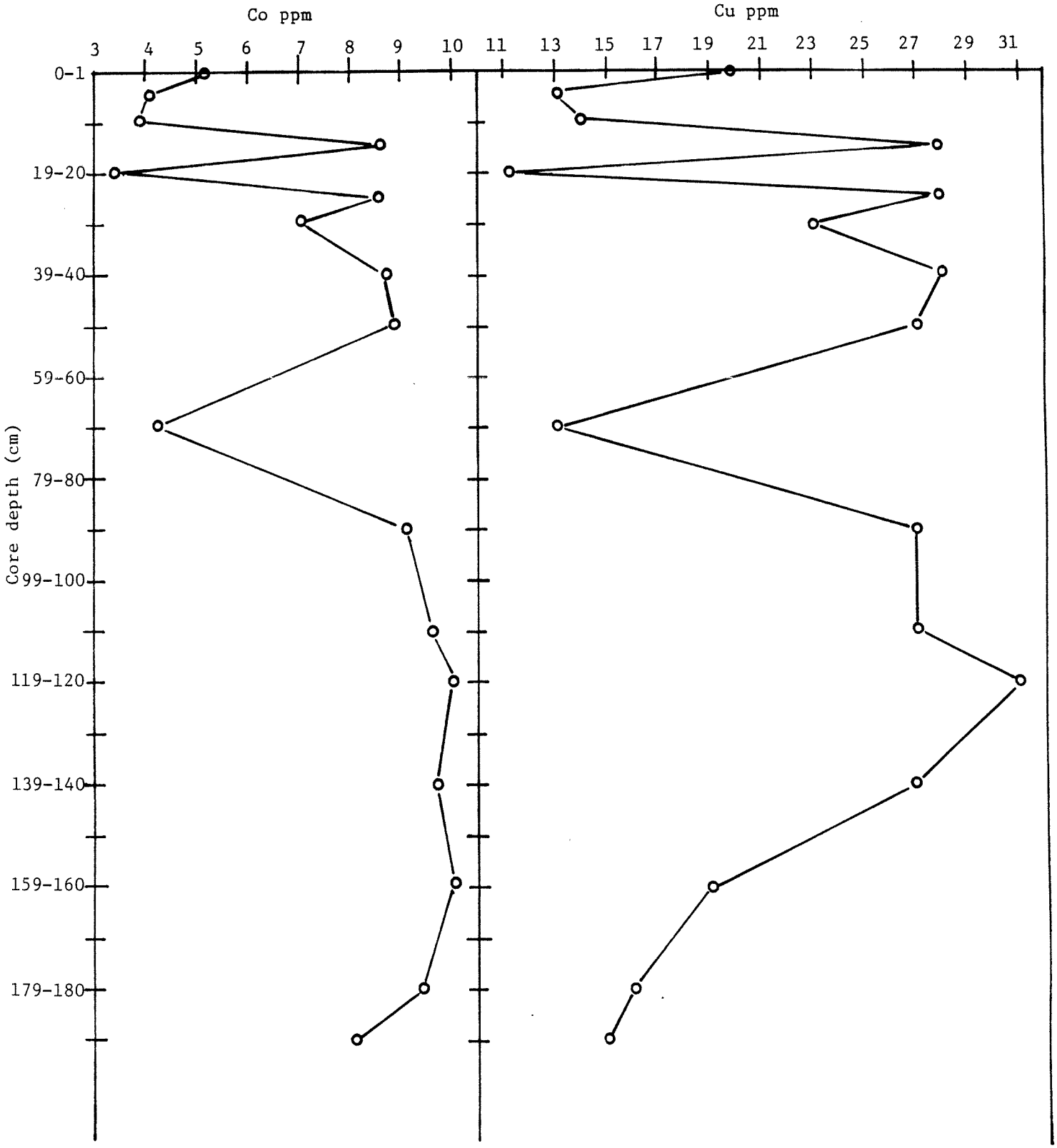



Fig. 13.22. Concentrations of Co and Cu in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

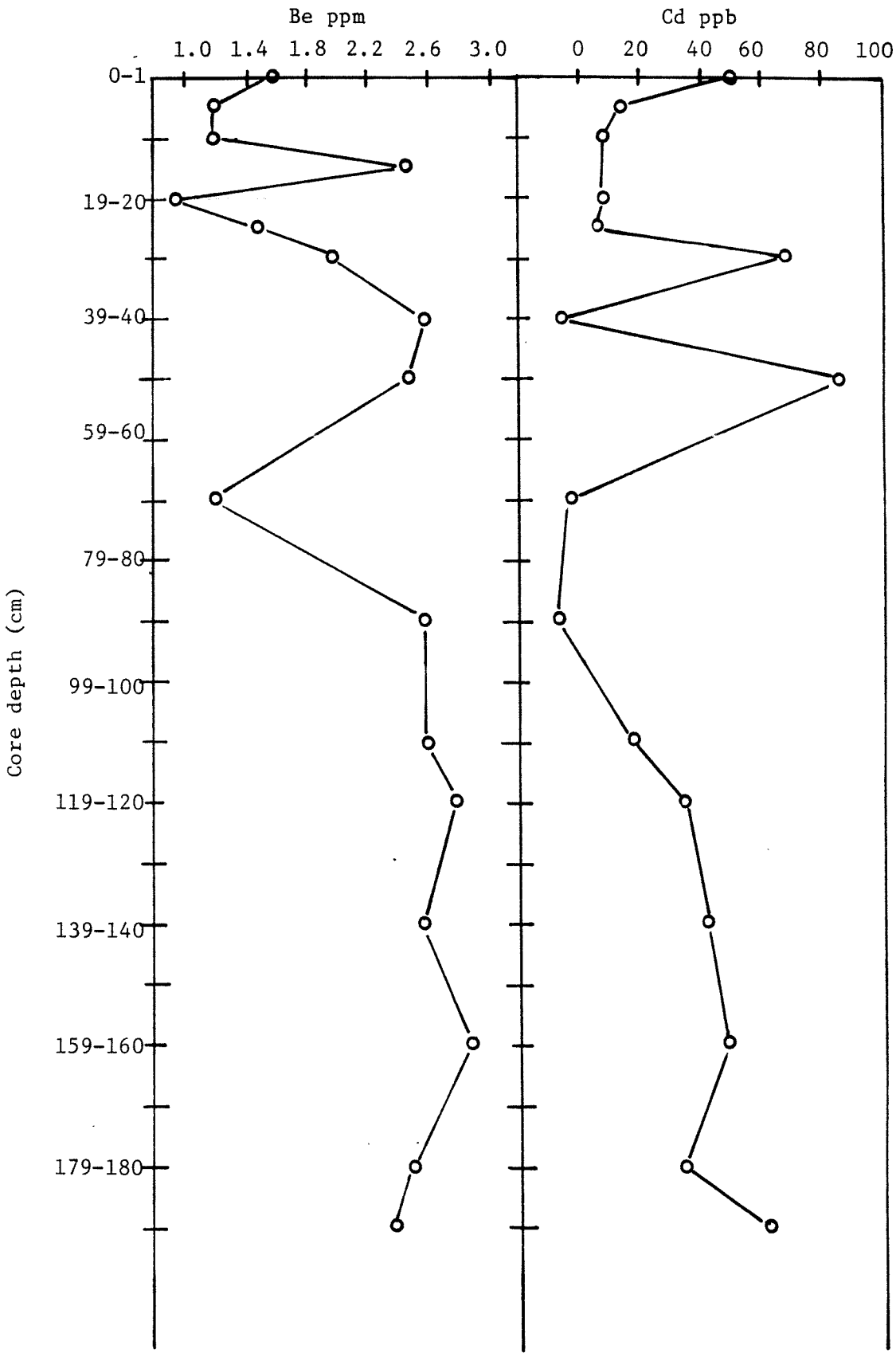



Fig. 13.23. Concentrations of Be and Cd in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

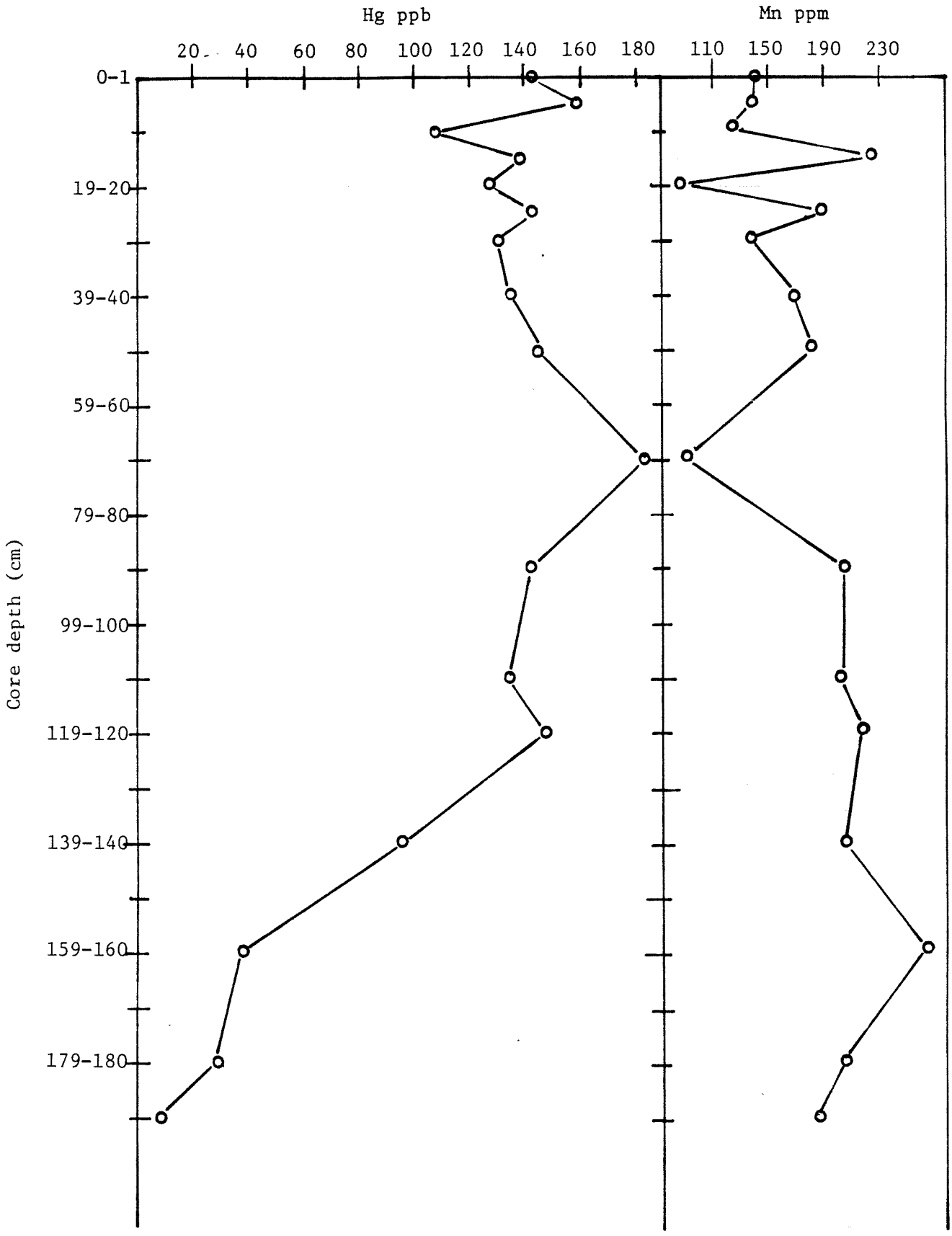



Fig. 13.24. Concentrations of Hg and Mn in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

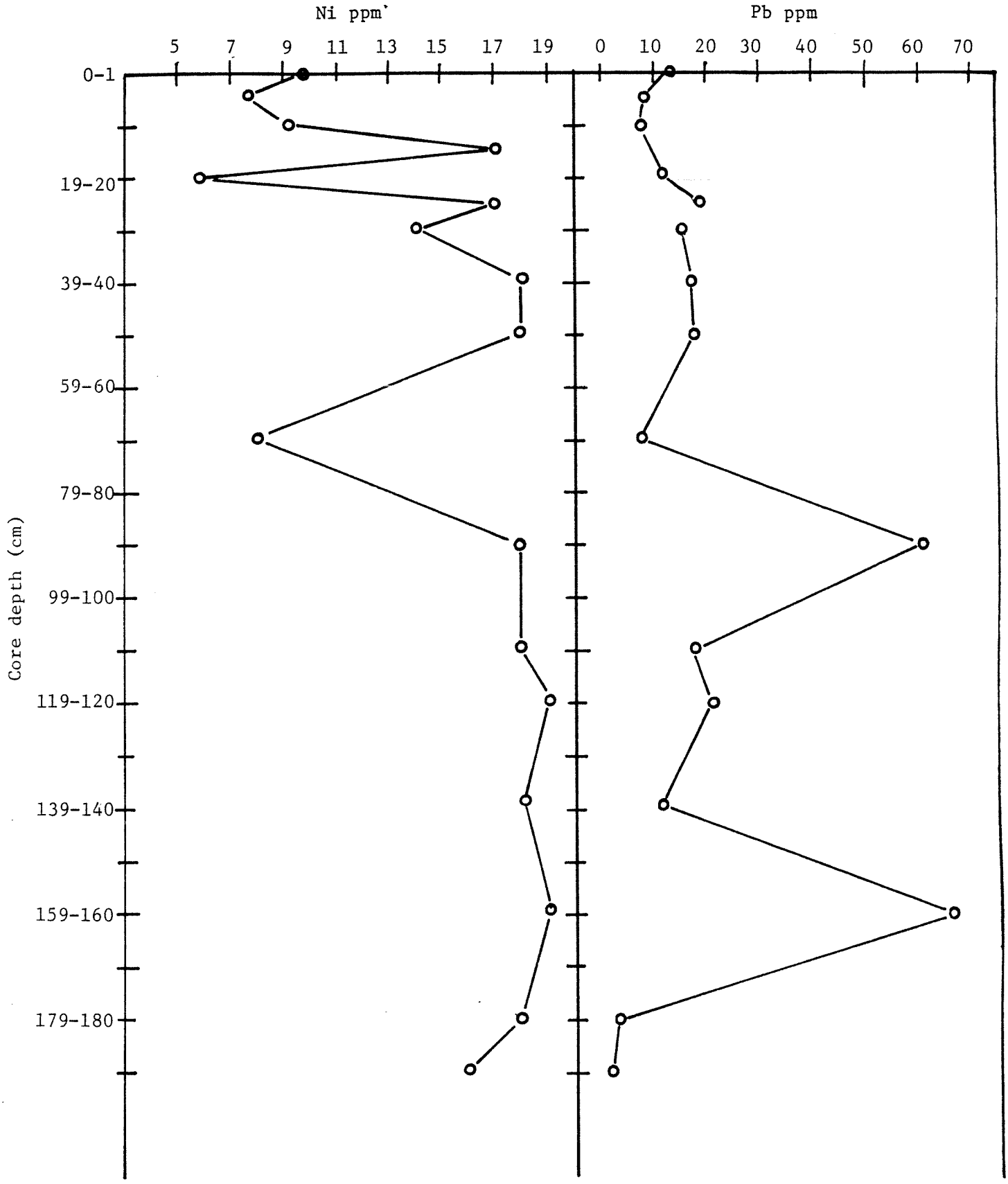



Fig. 13.25. Concentrations of Ni and Pb in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

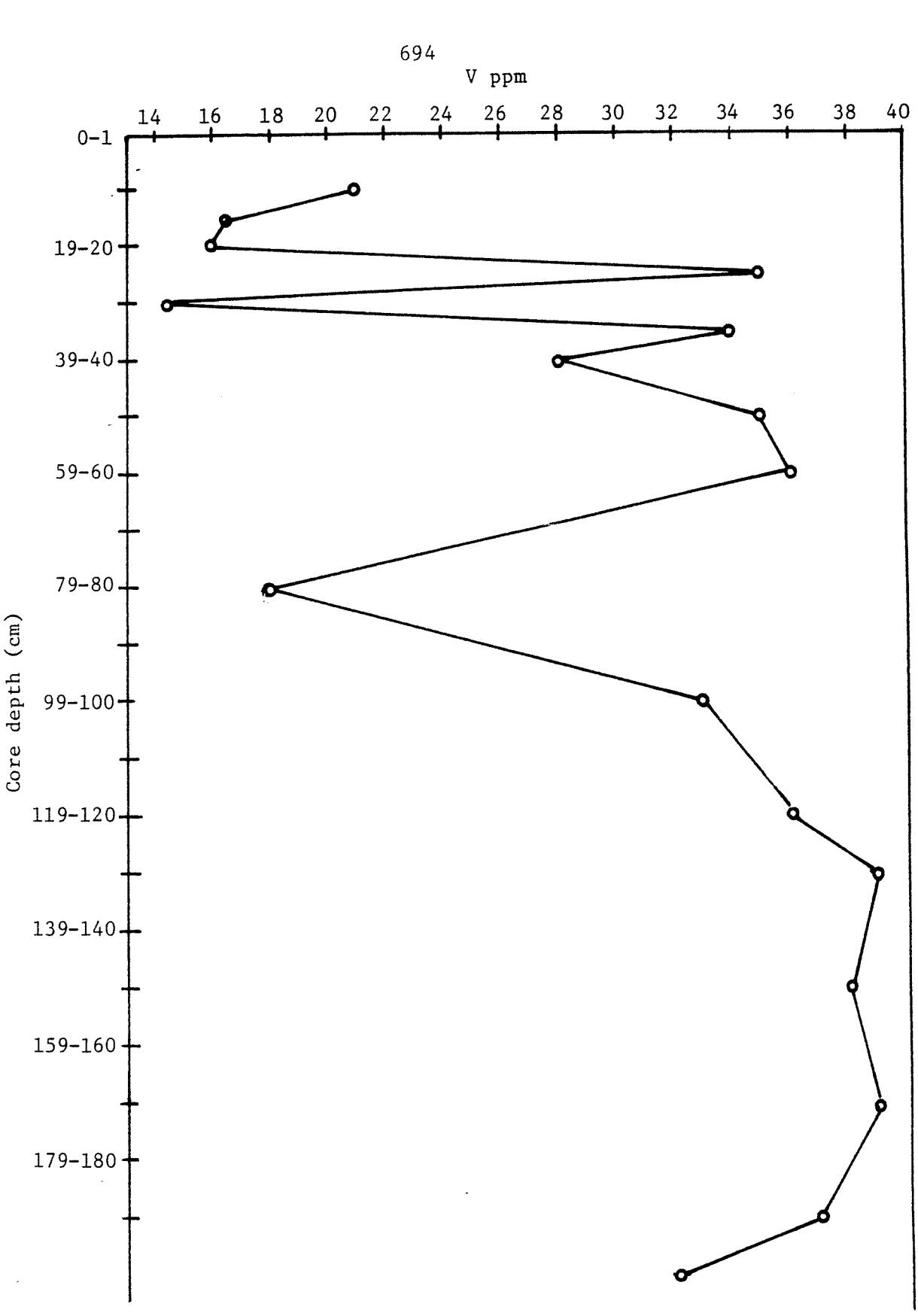



Fig. 13.26. Concentrations of V in sediment core K-3. Profiles are for wet sediment; to obtain similar profiles for dry sediment, the values for dry sediment should be used.

results will be undertaken as soon as the remaining data become available.

### 13.2.4 Trace Metals in Biota

The biological samples collected for trace metal analysis included plankton, benthic worms, clams, and fish. The number of samples, date of collection, and other information about these samples are given in Table 13.8.

For trace metal analysis of fish and shellfish samples, two different approaches can be taken: (1) careful handling of the samples and analysis of metals in each specimen in a clean laboratory environment to avoid any possible contamination; and (2) measurement of trace metals in parts of the sample that the general public usually use for consumption, and handling of the samples similarly as the public does. The second approach was taken for the baseline studies. For the same reason, for example, only the muscle of fish was used for analysis, whereas the muscle plus gut of littleneck clams were used for trace metal measurements. The specifications of fish and shellfish samples used for analysis are shown in Tables 13.9 and 13.10, respectively.

All the samples have been dissected, dried, and digested, and are being analyzed. The results will be presented as soon as the analysis is completed.

## 13.3 Analytical Services

The chemical analysis of the samples for the duration of baseline study was scheduled for completion in the first two years of the program. Originally, it was anticipated that approximately half of the samples would be analyzed during Phase I and the remaining samples in Phase II. However, the number of samples analyzed during Phase I in most cases were more than half of the total number of anticipated samples.

Table 13.8. Date of collection, type, location, average wet/dry ratio and dry weight of samples used for measurement of trace metals in biota.

| Sample ID | Date | Location/type | Ave. wet/dry | Sample dry weight (g) |
|---|---|---|---|---|
| Plankton | | | | |
| P1 | 9/22/82 | Westport St. #1 | 35.6 | 0.25 |
| P2 | 9/22/82 | Colvos Pass St. #2 | 25 | 0.4 |
| P3 | 9/22/82 | Comm. Bay St. #3 | 24.4 | 0.5 |
| P4 | 9/21/82 | St. #4 | 25 | 0.1 |
| P5 | 9/21/82 | St. #5 | 42 | 0.1 |
| P6 | 9/21/82 | St. #6 | 20 | 0.2 |
| P7 | 9/21/82 | St. #7 | 21 | 0.1 |
| P8 | 9/21/82 | St. #8 | 78 | 0.05 |
| P9 | 9/21/82 | St. #9 | 64 | 0.05 |
| 9 Total Samples | | | | |
| Animal - Worm | | | | |
| A1 | 10/7/82 | #199 | 13.6 | 4.0 |
| A2 | 10/8/82 | #202 | 47 | 0.1 |
| A3 | 10/8/82 | #204 | 7.75 | 0.4 |
| A4 | 10/8/82 | #205 | 35 | 0.1 |
| A5 | 10/8/82 | #206 | 1.36 | 3.9 |
| 5 Total Animal Samples | | | | |
| Clam | | | | |
| C1 | 11/18/82 | Seahurst N-Low Little Neck muscle & gut | 5.98 | 1.045 |
| C2 | 11/18/82 | Seahurst N-Low Butter Clam muscle | 6.0 | 1.675 |
| C3 | 11/18/82 | Seahurst N-High Little Neck muscle & gut | 7.12 | 1.271 |
| C4 | 11/17/82 | Seahurst S-Low Basket Cockle muscle | 3.18 | 1.768 |
| C5 | 11/17/82 | Seahurst S-High Polluted Macoma muscle & gut | 6.6 | 1.31 |
| C6 | 11/17/82 | Jefferson Head-Low Basket Cockle muscle | 6.04 | 1.534 |
| C7 | 11/17/82 | Jefferson Head-Low Little Neck muscle & gut | 6.64 | 1.588 |
| C8 | 11/17/82 | Des Moines - Low Horse Clam muscle | 6.47 | 1.446 |

Table 13.8 (cont'd)

| Sample ID | Date | Location/type | Ave. wet/dry | Sample dry weight (g) |
|---|---|---|---|---|
| Clam, cont'd | | | | |
| C9 | 11/17/82 | Des Moines - Low<br>Little Neck muscle & gut | 7.02 | 1.753 |
| C10 | 11/17/82 | Normandy Low<br>Little Neck muscle & gut | 9.11 | 0.718 |
| C11 | 8/4/82 | Lincoln Park Low<br>Little Neck muscle & gut | 6.63 | 1.179 |
| C12 | 11/17/82 | Jefferson Head - High<br>Little Neck muscle & gut | 8.34 | 1.176 |
| C13 | 11/17/82 | Des Moines High<br>Little Neck muscle & gut | 10.3 | 1.246 |
| C14 | 11/17/82 | Normandy High<br>Little Neck muscle & gut | 8.5 | 0.790 |
| C15 | 8/4/82 | Lincoln High<br>Butter Clam muscle | 5.19 | 1.460 |
| C16 | 9/14/82 | Normandy Low<br>Butter Clam muscle | 4.6 | 2.002 |
| C17 | 8/23/82 | Jefferson Head-Low<br>Basket Cockle muscle | 5.07 | 2.001 |
| C18 | 8/23/82 | Jefferson Head-High<br>Butter Clam muscle | 6.3 | 2.00 |
| C19 | 9/16/82 | Des Moines Low<br>Butter Clam muscle | 2.9 | 2.003 |
| C20 | 11/17/82 | Lincoln Park Low<br>Little Neck muscle & gut | 7.05 | 2.000 |
| C21 | 9/14/82 | Normandy High<br>Little Neck muscle & gut | 8.28 | 2.005 |
| C22 | 11/17/82 | Lincoln Park High<br>Little Neck muscle & gut | 8.19 | 1.497 |
| 22 Total Clam Samples | | | | |

Table 13.8 (cont'd)

| Sample ID | Date | Location/type | Ave. wet/dry | Sample dry weight (g) |
|---|---|---|---|---|
| Fish (muscle only) | | | | |
| F1 | 8/20/82 | Dolphin Pt. Night Smolt | 4.38 | 2.003 |
| F2 | 8/20/82 | Dolphin Pt. Rock Sole | 5.2 | 2.003 |
| F3 | 8/20/82 | Dolphin Pt. Striped Seaperch | 5.48 | 2.001 |
| F4 | 8/17/82 | Pt. Pully Striped Seaperch | 6.92 | 2.000 |
| F5 | 8/18/82 | Seahurst Rock Sole | 5.49 | 2.001 |
| F6 | 8/18/82 | Seahurst Striped Seaperch | 5.88 | 2.000 |
| F7 | 8/19/82 | Vashon Is. Rock Sole | 3.65 | 2.000 |
| F8 | 8/19/82 | Vashon Is. Striped Seaperch | 6.09 | 2.002 |
| F9 | 8/18/82 | Seahurst Striped Seaperch, juv | 5.97 | 1.159 |
| F10 | 8/20/82 | Dolphin Pt. Striped Seaperch, juv | 5.39 | 1.680 |
| F11 | 8/20/82 | Dolphin Pt. Rock Sole, juv | 5.1 | 1.869 |
| F12 | 8/19/82 | Vashon Is. Striped Seaperch, juv | 5.81 | 1.695 |
| F13 | 8/17/82 | Pt. Pully Rock Sole, juv | 4.89 | 1.494 |
| F14 | 8/17/82 | Pt. Pully Striped Seaperch, juv | 5.52 | 1.037 |
| 14 Total Fish Samples | | | | |

Table 13.9. Specification of fish samples analyzed for trace metals.

| Fish type | | Tissue | Fork length (cm) | Total length (cm) | Sample dry weight (g) | Wet/dry |
|---|---|---|---|---|---|---|
| F-1a | Night smelt | Muscle | 11.7 | 12.9 | 1.6 | 4.19 |
| b | Night smelt | Muscle | 16.5 | 17.9 | 1.9 | 4.58 |
| F-2a | Rock sole | Muscle | | 24 | 4.1 | 5.07 |
| b | Rock sole | Muscle | | 30.7 | 7 | 5.33 |
| F-3 | Striped seaperch | Muscle | 26.6 | 29.7 | 9.9 | 5.48 |
| F-4 | Striped seaperch | Muscle | 24 | 26.6 | 6.1 | 6.92 |
| F-5a | Rock sole | Muscle | | 23.9 | 4.9 | 5.5 |
| b | Rock sole | Muscle | | 20.7 | 3.1 | 5.49 |
| F-6 | Striped seaperch | Muscle | 22.5 | 24.8 | 7.2 | 5.88 |
| F-7 | Rock sole | Muscle | | 29.7 | 6.3 | 3.65 |
| F-8 | Striped seaperch | Muscle | 21.2 | 23.1 | 7.5 | 6.09 |
| F-9a | Striped seaperch, juv. | Muscle | 7.7 | 8.1 | 0.174 | 6.05 |
| b | Striped seaperch, juv. | Muscle | 7.8 | 8.4 | 0.159 | 6.33 |
| c | Striped seaperch, juv. | Muscle | 9.1 | 9.7 | 0.563 | 5.56 |
| d | Striped seaperch, juv. | Muscle | 8.0 | 8.5 | 0.275 | 5.95 |
| F-10a | Striped seaperch, juv. | Muscle | 8.6 | 9.0 | 0.477 | 5.5 |
| b | Striped seaperch, juv. | Muscle | 8.8 | 9.4 | 0.443 | 5.48 |
| c | Striped seaperch, juv. | Muscle | 8.8 | 9.6 | 0.779 | 5.19 |
| F-11a | Rock sole, juv. | Muscle | | 13 | 1.292 | 4.8 |
| b | Rock sole, juv. | Muscle | | 10.5 | 0.653 | 5.41 |
| F-12a | Striped seaperch, juv. | Muscle | 8.5 | 9 | 0.530 | 5.78 |
| b | Striped seaperch, juv. | Muscle | 9.6 | 10.1 | 0.743 | 6.09 |
| c | Striped seaperch, juv. | Muscle | 8 | 8.5 | 0.429 | 5.55 |
| F-13a | Rock sole, juv. | Muscle | | 10.7 | 0.448 | 4.83 |
| b | Rock sole, juv. | Muscle | | 11.2 | 0.440 | 4.87 |
| c | Rock sole, juv. | Muscle | | 9.6 | 0.254 | 5.04 |
| d | Rock sole, juv. | Muscle | | 10.5 | 0.394 | 4.75 |

Table 13.10. Specifications of shellfish samples analyzed for trace metals.

| Clam type | Tissue | Length (cm) | Height (cm) | Total dry weight, g | Wet/dry |
|---|---|---|---|---|---|
| C-1a Little Neck | Muscle & gut | 4.8 | 3.5 | 1.1 | 6.36 |
| b Little Neck | Muscle & gut | 5 | 3.5 | 1.7 | 5.59 |
| C-2 Butter Clam | Muscle | 9 | 6.5 | 4.2 | 6 |
| C-3a Little Neck | Muscle & gut | 4.6 | 3.7 | 1.55 | 6.6 |
| b Little Neck | Muscle & gut | 4.3 | 3.5 | 1.25 | 6.08 |
| c Little Neck | Muscle & gut | 4.2 | 3.2 | 0.6 | 8.67 |
| C-4 Basket Cockle | Muscle | 9.2 | 9 | 8.4 | 3.18 |
| C-5a Polluted Macoma | Muscle & gut | 5.3 | 4.3 | 0.7 | 6.43 |
| b Polluted Macoma | Muscle & gut | 4.5 | 3.4 | 0.6 | 6.5 |
| c Polluted Macoma | Muscle & gut | 5 | 4 | 0.8 | 6 |
| d Polluted Macoma | Muscle & gut | 4 | 3 | 0.4 | 7.5 |
| C-6 Basket Cockle | Muscle | 9 | 7.5 | 2.4 | 6.04 |
| C-7a Little Neck | Muscle & gut | 5.5 | 4.3 | 1.4 | 7.2 |
| b Little Neck | Muscle & gut | 6.5 | 5.8 | 2.9 | 6.07 |
| C-8 Horse Clam | Muscle | 8 | 7.5 | 3.0 | 6.47 |
| C-9a Little Neck | Muscle & gut | 5.8 | 5.2 | 2.6 | 6.46 |
| b Little Neck | Muscle & gut | 5.5 | 4.7 | 1.4 | 7.57 |
| C-10 Little Neck | Muscle & gut | 4.6 | 4 | 0.9 | 9.11 |
| C-11a Little Neck | Muscle & gut | 5 | 4.5 | 1.1 | 7.36 |
| b Little Neck | Muscle & gut | 4.1 | 3.8 | 1.1 | 5.9 |
| C-12a Little Neck | Muscle & gut | 5.4 | 5 | 1.7 | 7.6 |
| b Little Neck | Muscle & gut | 5.5 | 4.7 | 1.4 | 9.07 |
| C-13a Little Neck | Muscle & gut | 5.2 | 4.1 | 0.9 | 11.1 |
| b Little Neck | Muscle & gut | 5.1 | 4.1 | 1.1 | 9.5 |
| C-14a Little Neck | Muscle & gut | 4.7 | 3.6 | 0.8 | 7.75 |
| b Little Neck | Muscle & gut | 4 | 3.2 | 0.4 | 9.25 |
| C-15 Butter Clam | Muscle | 7.2 | 5.6 | 2.1 | 5.19 |
| C-16 Butter Clam | Muscle | 9.2 | 6.4 | 4.3 | 4.6 |
| C-17 Basket Cockle | Muscle | 7.5 | 7.2 | 3.0 | 5.07 |

Table 13.10 (cont'd)

| Clam type | Tissue | Length (cm) | Height (cm) | Total dry weight, g | Wet/dry |
|---|---|---|---|---|---|
| C-18 Butter Clam | Muscle | 7 | 6.2 | 2.7 | 6.3 |
| C-19 Butter Clam | Muscle | 9 | 6.8 | 10.1 | 2.9 |
| C-20a Little Neck | Muscle & gut | 6.1 | 5.5 | 2.0 | 6.5 |
| b Little Neck | Muscle & gut | 5.3 | 4.8 | 1.05 | 7.62 |
| C-21a Little Neck | Muscle & gut | 6.0 | 4.8 | 2.3 | 6.96 |
| b Little Neck | Muscle & gut | 5.5 | 4.3 | 1.3 | 9.6 |
| C-22a Little Neck | Muscle & gut | 4.5 | 3.3 | 0.7 | 7.7 |
| b Little Neck | Muscle & gut | 3.6 | 3.2 | 0.6 | 9.67 |
| c Little Neck | Muscle & gut | 4.3 | 3.7 | 0.5 | 7.8 |

The analytical work was carried out in the Oceanography laboratory, the Water Quality laboratory and the Laboratory of Radiation Ecology. The chemical analysis included development of methodology, quality control, quality assurance, and interlaboratory calibration. The number of analyses performed as of 1 January 1983, together with the names of participating labs and the analysts, are presented in Table 13.11. the procedures used for chemical analysis, together with the quality control and quality assurance, are described below.

13.3.1 Sediment Grain Size

The stepwise procedure for the sediment grain size determination was based on the U.S. Geological Survey Procedure (Guy 1969) and the University of Washington's "General Oceanography Laboratory Manual" (Krumbein and Pettijohn 1938).

Sediment samples were initially dried and the water content measured. Then particles larger than 62 m were measured by dry sieving, whereas particles smaller than 62 m were measured by wet pipetting technique. The results were classified in percentage: Cobble (156-64 mm), gravel (64-2 mm), coarse sand (2-0.5 mm), fine sand (0.5-0.062 mm), silt (0.062-0.004 mm), and clay (less than 0.004 mm). Metric standard sieve designations and size classes according to Lang et al. (1947), were used throughout the study. The sediment size classes and limits of particle diameter in metric and English units are given in Table 13.12. As a measure of reproducibility, the results of three replicate analyses are shown in Table 13.13.

13.3.2 Total Sulfide in Sediment

Sulfide is present in sediment as a result of decomposition of organic matter and bacterial reduction of sulfate. Total sulfide, i.e., the sum of dissolved $H_2S$, $HS^-$, as well as acid-soluble metallic sulfides present in the

Table 13.11. Number and type of analysis projected for the entire project and number of analyses performed as of 1 January 1983, together with the names of the labs and analysts.

| Laboratory | Type of analysis | Projected total analysis for two years | Number of analyses performed as of 1 January 1983 | Analyst |
|---|---|---|---|---|
| Oceanography Lab | Nutrients | 4,250 | 1,213 | K. Krugslund |
| | Salinity | 1,400 | 335 | K. Krugslund |
| Water Quality Lab | Oxygen | 1,400 | 451 | R. McClain |
| | BOD | 400 | 219 | D. DiJulio, R. McClain |
| | Sulfide | 200 | 176 | D. Bark, S. Felton |
| | % Volatile solids | 400 | 264 | D. DiJulio, R. McClain |
| | Carbon & nitrogen | 400 | 211 | R. McClain |
| Laboratory of Radiation Ecology | Grain size | 400 | 315 | V. Lance, B. Winslow |
| | Trace metals in sediments | 80 | 106 | J. Sung |
| | Lead-210 | 30 | 55 | G. Shott |

Table 13.12. SEDIMENT SIZE CLASSES

Limits of Particle Diameter

| CLASS NAME[1] | | METRIC UNITS MM | ENGLISH UNITS IN | MICRONS | ϕ UNITS | CLASS NAME[2] |
|---|---|---|---|---|---|---|
| BOULDERS | Very Large | 4096-2048 | 160-80 | | -11 | BOULDER |
| | Large | 2048-1024 | 80-40 | | -10 | |
| | Medium | 1024-512 | 40-20 | | - 9 | |
| | Small | 512-256 | 20-10 | | - 8 | |
| COBBLES | Large | 256-128 | 10-5 | | - 7 | COBBLE |
| | Small | 128-64 | 5-2.5 | | - 6 | |
| GRAVEL | Very Coarse | 64-32 | 2.5-1.25 | | - 5 | PEBBLE |
| | Coarse | 32-16 | 1.25-0.625 | | - 4 | |
| | Medium | 16-8 | 0.625-0.31 | | - 3 | |
| | Fine | 8-4 | 0.31-0.16 | | - 2 | |
| | Very Fine | 4-2 | 0.16-0.08 | | - 1 | GRANULE |
| SAND | Very Coarse | 2.00-1.00 | | 2000-1000 | 0 | SAND |
| | Coarse | 1.000-0.500 | | 1000-500 | 1 | |
| | Medium | 0.500-0.250 | | 500-250 | 2 | |
| | Fine | 0.250-0.125 | | 250-125 | 3 | |
| | Very Fine | 0.125-0.062 | | 125-62 | 4 | |
| SILT | Coarse | 0.062-0.031 | | 62-31 | 5 | SILT |
| | Medium | 0.031-0.016 | | 31-16 | 6 | |
| | Fine | 0.016-0.008 | | 16-8 | 7 | |
| | Very Fine | 0.008-0.004 | | 8-4 | 8 | |
| CLAY | Coarse | 0.004-0.002 | | 4-2 | 9 | CLAY |
| | Medium | 0.002-0.001 | | 2-1 | 10 | |
| | Fine | 0.0010-0.0005 | | 1-0.5 | 11 | |
| | Very Fine | 0.0005-0.00024 | | 0.5-0.24 | 12 | |

1. Lang, E.W. and others, 1947, Report of the sub-committee on Sediment Terminology, Trans. Am. Geophys. Union, Vol. 28, pp 936-938.

2. Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments; Journal Geology, Vol. 30, pp 377-392.

Table 13.13. Replicate analysis of sediment grain size.

| Sample No. | % Gravel | % Coarse sand | % Fine sand | % Silt | % Clay | % Water |
|---|---|---|---|---|---|---|
| 5007 A | 23 | 23.3 | 50.3 | 2.5 | 1.1 | 17.1 |
| 5007 B | 31 | 21.3 | 43.5 | 3.2 | 0.6 | 16.1 |
| 5026 A | 28.3 | 35.1 | 34.0 | 1.2 | 1.4 | 15.8 |
| 5026 B | 23.9 | 37.0 | 36.7 | 1.4 | 1.1 | 17.5 |
| 5027 A | 34.2 | 30.7 | 32.1 | 1.5 | 1.2 | 14.6 |
| 5027 B | 36.7 | 33.3 | 26.8 | 2.1 | 1.0 | 14.9 |

Table 13.14. Replicate analysis of sediment samples.

| Sample No. | Measurement 1 (ppm) | Measurement 2 (ppm) |
|---|---|---|
| 12 | 0.482 | 0.540 |
| 42 | 11.542 | 12.750 |
| 56 | 1.093 | 0.951 |
| 82 | 4.437 | 4.054 |
| 170 | 0.025 | 0.025 |
| 222 | 16.848 | 17.050 |
| 5044 | 0.697 | 0.697 |
| 5048 | 0.972 | 0.972 |

sediment were measured.

Hydrogen sulfide was volatilized from sediment samples by treating known quantities of each sample with concentrated hydrochloric acid. The sample was continuously stirred at 85 C while nitrogen gas was bubbled through the mixture to ensure complete removal of hydrogen sulfide from the sample. The hydrogen sulfide gas was then trapped in three collection flasks in tandem containing zinc acetate and sodium hydroxide. The trap contents were kept refrigerated until sulfide analysis was performed. Sulfide was determined in the combined trap contents using the methylene blue procedure (Standard Methods 1980). After the color development, the light absorption was measured at 6700 A on a Gilford 300-N photospectrometer. Laboratory sulfide standards were made using sodium sulfide, and the standards were calibrated by iodometric method. The overall precision and accuracy of the measurements were evaluated by performing replicate measurements in several samples (Table 13.14), spike recovery from sediment (Table 13.15), and measurement of standards (Table 13.16).

13.3.3 Sediment Biochemical Oxygen Demand and Percent Volatile Solids

The biochemical oxygen demand (BOD) measures the amount of oxygen required for the biochemical degradation of organic material and oxidation of inorganic materials present in the sediment. The 5-day BOD was determined following procedures of Standard Methods for the Examination of Water and Wastewater (1980) with the following modifications.

13.3.3.1 Preparation of Dilution Water

Seawater was collected off West Point and filtered through gravel, sand, and charcoal filters at the West Point toxicology lab. The water was then stored in 50-gallon container in the dark for quality improvement. The 5-day demand of the seawater dilution blank was greater than the recommended value

Table 13.15. Recovery data of sulfide standard addition.

| Sample # | Conc. added (ppm) | Conc. recovered (ppm) | % Recovery |
|---|---|---|---|
| 131* | 0.021 | 0.017 | 81 |
| 185* | 0.213 | 0.210 | 99.8 |
| 5056** | 7.040 | 4.857 | 70 |
| 5061** | 7.040 | 5.550 | 75 |

*$S^{=}$ added as ZnS.

**$S^{=}$ added as $Na_2S$.

Table 13.16. Instrument reading of sulfide standard on different dates.

| Date | Conc. (ppm) | Standard instrument reading |
|---|---|---|
| 1/18/83 | 7.04 | 769 |
| 1/19/83 | 7.04 | 771 |
| 1/20/83 | 7.04 | 762 |
| 1/17/83 | 7.04 | 769 |
| 11/30/82 | 7.04 | 768 |

Table 13.17. Five-day dissolved oxygen demand of dilution sea water collected 21 July 1982 (dilution water blank without seed).

| Date of analysis | Week | West Point mg/L, SD/(range) | n |
|---|---|---|---|
| 22 Jul 82 | 0 | 0.54 | 1 |
| 9 Aug 82 | 2 | 0.28 ± 0.08 | 4 |
| 12 Aug 82 | 2 | 0.30 ± 0.13 | 4 |
| 19 Aug 82 | 4 | 0.43 ± 0.02 | 4 |
| 25 Aug 82 | 5 | 0.30 ± 0.08 | 4 |
| 31 Aug 82 | 5 | 0.39 (0.38-0.40) | 2 |

($\leq$ 0.20 mg/L) for freshwater (Table 13.17).

The dilution water demand was added to the DO concentration of diluted sample after five days incubation to correct for high dilution seawater blanks. BOD values for standard solutions of glutamic acid/glucose mixtures were consistently higher than theoretical without correction for dilution seawater demand. With correction for dilution seawater demand, the data compare favorably with theoretical (Table 13.18) and with other laboratories (Table 13.19) values.

13.3.3.2 Seeding

Seed was developed in the laboratory by continuously aerating a three-liter culture medium composed initially of one liter of aquarium sand collected from the School of Fisheries' salt water aquarium gravity filter beds and two liters of the supernatant of equal parts sand and salt water which had been violently stirred. For the duration of the study the culture received 100 ml of salinity-adjusted West Point unchlorinated sewage effluent and about 10 mg of tetra-min baby fish food daily. As needed, the seed was violently stirred and a portion was transferred to a one-liter glass jar, the particulates were allowed to settle, and the supernatant was used for analysis. A seed concentration of 1 ml per 0.3 liters of diluted sample was used.

13.3.3.3 Dilution Technique

The frozen samples were thawed at room temperature and homogenized by stirring. Two representative aliquots of a sediment sample were weighed within 10 mg of each other and transferred quantitatively into incubation bottles. One milliliter of seed was introduced to each bottle. The bottles were then filled with dilution water. One bottle was fixed for DO determination immediately upon dilutoin of the sediment; the other bottle was

Table 13.18. Mean and standard deviation of triplicate BOD determinations of demand standard solutions of glutamic acid and glucose mixture for four sets of analyses.

| Identification date of analysis | Water Quality Laboratory standard, 300 mg/L glucose/glutamic[a] acid mixture (1:1) (mg/L) | U.S. Environmental Protection Agency standard concentration #6 (WP 678)[b] (mg/L) |
|---|---|---|
| 9 Aug 82 | 218 ± 5.7 | 91.0 ± 1.8 |
| 12 Aug 82 | 194 ± 1.2 | 85.9 ± 2.4 |
| 19 Aug 82 | 195 ± 5.7 | 84.2 ± 0.3 |
| 25 Aug 82 | 198 ± 11.8 | 82.8 ± 9.2 |
| | 194 ± 3.1[c] | 79.6 ± 5.9[c] |
| Grand mean ± SD | 200 ± 11 | 84.7 ± 5.8 |
| No. of determinations | 15 | 15 |
| Theoretical oxygen demand | 194 | 83.9 |

[a]Demand solution prepared 9 June 1982.

[b]Demand solution prepared 10 June 1982.

[c]Demand solution prepared 24 August 1982.

incubated for five days in the dark at 20 ± 1 C.

The quality of the dilution water, the effectiveness of the seed, and the technique of the analyst were checked for each set of BOD analyses by (1) preparing dilution water controls (Table 13.17); (2) using mixtures of glucose and flutamic acid with theoretical oxygen demand values of 83.9 and 194 mg/L (Tables 13.18 and 13.19); and (3) determining the BOD of two sediment samples with low and high organic load (Table 13.20).

Duplicate determinations of ratio of dry to wet weight of sediment, percent volatile solids, and BOD for selected samples and for different days are given in Table 13.21. Precision data for the ratio of dry to wet weight and percent volatile solids are reported in Table 13.22.

No marked differences in BOD values were observed when a sample was diluted over an optimum oxygen demand range of 2-5 mg/L (Table 13.23). The results of dilution water correction, seed correction and BOD for glucose/glutamic acid are shown in Table 13.24; precision of percent volatile solids measurements are demonstrated in Table 13.25.

13.3.4 Organic Carbon and Nitrogen Analysis

The frozen sediment sample was thawed, mixed in the laboratory, and a subsample was removed for drying at 60° C for 48 hours. Then, about 100 mg of dried sediment was weighed on a CAHN electrobalance for analysis. The weighed sample was placed on a precombusted square of aluminum foil and 50 µl of concentrated phosphoric acid was added for removal of inorganic carbon (Froelich 1980). The sample was then heated on a 60 C hotplate for a minimum of four hours. This allowed time for the phosphoric acid to react with the carbonate present in the sample and evaporation of most of the acid. Then the sample was combusted at 950 C and the combustion products, $N_2$ and $CO_2$, were analyzed by thermal conductivity detectors.

Table 13.19. Comparison of Water Quality Laboratory performance evaluation results for biochemical oxygen demand (BOD) with published results of two other studies.

| BOD quality assurance standard, theoretical value in mg/liter | Performance evaluation study[a] | | |
|---|---|---|---|
| | Water Quality Laboratory (present study) | Standard methods, interlaboratory study | U.S. EPA monitoring and support lab, method study 3 |
| 83.9 | 84.7 | -- | 83.9 |
| | (73.1 - 96.3) | -- | (57.8 - 110) |
| | + 1% | -- | 0% |
| 194 | 199 | 200 | -- |
| | (178 - 222) | (125 - 273) | -- |
| | + 3% | + 3% | -- |

[a]Mean recovery in mg/L, 95% confidence intervals (in parentheses), and percent relative error. The 95% confidence interval represents the mean recovery plus or minus two standard deviations.

Table 13.20. Individual determinations of the biochemical oxygen demand (BOD) in mg/kg dry wt of two samples of subtidal Puget Sound sediment for four sets of analyses.

| Identification date of analyses | ID number | |
|---|---|---|
| | 12 | 15 |
| 9 Aug 82 | 299 | 2286 |
| 12 Aug 82 | 304 | 2696 |
| 19 Aug 82 | 300 | 2747 |
| 25 Aug 82 | 312 | 2650 |
| Mean ± SD | 304 ± 6 | 2595 ± 210 |
| Coefficient of variation | 2.0% | 8.1% |
| Number of determinations | 4 | 4 |

Table 13.21. Duplicate determinations of dry to wet weight ratio, percent volatile solids, and 5-day BOD.

| Sample ID No. | Dry/wet weight | % Volatile solids on ignition | BOD (mg/kg dry sediment) |
|---|---|---|---|
| 1 | 0.745 | -- | -- |
| 1 | 0.768 | 2.2 | 606 |
| 14 | 0.665 | 1.44 | 741 |
| 14 | -- | -- | 829 |
| 18 | 0.737 | -- | -- |
| 18 | 0.734 | 3.46 | 504 |
| 50 | 0.694 | -- | -- |
| 50 | 0.710 | 2.92 | 273 |
| 55 | 0.723 | -- | -- |
| 55 | 0.693 | 1.88 | 432 |
| 58 | 0.452 | 4.71 | 956 |
| 58 | -- | -- | 1,098 |
| 86 | 0.433 | 5.42 | 2,320 |
| 86 | -- | -- | 2,340 |

Table 13.22. Triplicate determinations of the ratio of dry to wet weight of sediment and percent volatile solids of Puget Sound subtidal sediment samples 12 and 15, analyzed on 12 August 1982.

| | ID Number 12 | | ID Number 15 | |
|---|---|---|---|---|
| | Ratio dry/wet | % VS | Ratio dry/wet | % VS |
| | 0.744 | 0.82 | 0.300 | 8.52 |
| | 0.746 | 0.78 | 0.300 | 8.48 |
| | 0.745 | 0.81 | 0.299 | 8.26 |
| Mean ± SD | 0.745 ± 0.001 | 0.81 ± 0.023 | 0.300 ± 0.001 | 8.42 ± 0.14 |
| Coefficient of variation | 0.1% | 2.8% | 0.3% | 1.7% |

Table 13.23. The effect of sediment dilution on the determination of biochemical oxygen demand (BOD) of Puget Sound subtidal sample 15.

| Wet wt of sediment (g) | Sediment dilution % (W/V) | 5-day dissolved oxygen demand (mg/L) | BOD (mg/kg dry wt sediment) |
|---|---|---|---|
| 0.812 | 0.27 | 2.11 | 2600 |
| 1.207 | 0.40 | 2.86 | 2290 |
| 1.202 | 0.40 | 3.36 | 2700 |
| 1.205 | 0.40 | 3.31 | 2750 |
| 1.200 | 0.40 | 3.18 | 2650 |
| 1.404 | 0.47 | 3.39 | 2410 |
| 2.003 | 0.66 | 4.81 | 2400 |
| | | Mean $\pm$ SD | 2540 $\pm$ 175 |
| | | Coefficient of determination | 6.9% |

Table 13.24. Correction values for dilution water, seed, and the BOD for glucose/glutamic acid standard.

| Dilution water (mg/L) | Seed correction (mg/L) | Glucose/glutamic acid standard (mg/L) |
|---|---|---|
| 0.10 | 0.014 | 192 |
| 0.09 | 0.014 | 184 |
| 0.37 | 0.043 | 179 |
| 0.51 | 0.050 | 195 |
| 0.43 | 0.026 | 192 |
| 0.35 | 0.026 | 192 |
| 0.13 | 0.025 | 198 |
| 0.26 | 0.018 | 198 |
| 0.20 | 0.028 | 192 |
| 0.01 | 0.034 | 200 |
| | | 200 |
| | | 191 |
| | | 198 |
| | | 202 |
| | | 200 |
| | | 194 |
| | | 180 |
| | | 196 |
| $\bar{X}$ 0.25 | $\bar{X}$ 0.028 | $\bar{X}$ 193.5 |
| S 0.17 | S 0.012 | S 6.71 |
| N=10 | N=10 | N=18 |

Table 13.25. Precision of percent volatile solids measurement in sample No. 30.

| Subsample ID | % Volatile solid |
|---|---|
| 1 | 2.29 |
| 2 | 2.32 |
| 3 | 2.27 |
| 4 | 2.35 |
| 5 | 2.34 |
| | $\overline{X}$ 2.31 |
| | S 0.03 |
| | N=5 |

The instrument was calibrated daily with ascetanelide which containes 10.36% nitrogen and 71.09% carbon. Some of the results of instrument calibration together with the effect of phosphoric acid on the calibrations are shown in Table 13.26. The results show that the instrument is stable and the addition of phosphoric acid has no significant effect on the standard results. The effectiveness of phosphoric acid on removal of carbonate from sediment samples was tested by adding $CaCO_3$ to sediment sample and then treating the sediment with $H_3PO_4$. The results of these measurements are shown in Table 27.

The combustion and carrier gas used for the measurements was cylinder oxygen. The gas contains some nitrogen and $CO_2$ as impurities. However, the background values are constant because the same cylinder of oxygen has been used for the past five years. Some of the results of blank measurements are presented in Table 13.28. The blank values were measured daily prior to and during analysis of the samples.

To establish the detection limits of instrument, a number of blanks were run and the results are presented in Table 13.29. If the detection limit is defined as the concentration that produces signal equivalent to twice or thrice the magnitude of the background fluctuation, then the values in Table 13.29 should be used as a benchmark. However, from a practical standpoint, the detection limit should be set at least two to three times higher than the limits in Table 13.29 and samples having carbon and nitrogen near these values should be considered as the detection limit.

The precision and reproducibility of measurements for samples with relatively high carbon and nitrogen are very good. The result of precision measurements is shown in Table 13.30.

In addition, inter-laboratory calibrations were performed with the School

Table 13.26. Calibration of carbon-nitrogen analyzer with ascetanelide and the effect of phosphoric acid on the calibration performed during August 1982.

| Ascetanelide Standard No. | $K_N$* | $K_C$* | Comments |
|---|---|---|---|
| 1 | 7.02 | 19.51 | |
| 2 | 6.99 | 19.42 | |
| 3 | 7.16 | 19.74 | |
| 4 | 7.11 | 19.60 | |
| 5 | 8.12 | 20.54 | |
| 6 | 6.97 | 19.65 | |
| 7 | 6.80 | 19.70 | |
| $\overline{X}$ | 7.17 | 19.74 | |
| S | 0.44 | 0.37 | |
| 3.362 mg | 6.92 | 19.32 | No $H_3PO_4$ |
| 2.019 mg | 6.83 | 18.98 | Plus 50 µl $H_3PO_4$ |
| 1.626 mg | 6.87 | 19.47 | Plus 50 µl $H_3PO_4$ |

*$K_N$ = µv/µg - N

$K_c$ = µv/µg - C

Table 13.27. Effectiveness of phosphoric acid on removal of carbonate from sediment sample No. 25.

| Sample No. | N (mg/g) | C (mg/g) | Remarks |
|---|---|---|---|
| 1 | 0.28 | 1.45 | Sample treated with $H_3PO_4$ |
| 2 | 0.26 | 1.41 | " " " |
| 3 | 0.27 | 1.32 | 20 mg $CaCO_3$ added to sample, then treated with $H_3PO_4$ |
| 4 | 0.33 | 1.50 | " " " |

Table 13.28. Carbon and nitrogen blanks.

| | N, µg | C, µg |
|---|---|---|
| | 30.0 | 5.44 |
| | 29.4 | 1.09 |
| | 32.5 | < 0.10 |
| | 32.3 | < 0.10 |
| | 33.1 | 2.18 |
| | 30.9 | < 0.10 |
| | 30.2 | < 0.10 |
| | 33.4 | < 0.10 |
| | 34.5 | 5.44 |
| | 33.0 | 0.54 |
| | 27.6 | 4.35 |
| | 30.0 | 2.72 |
| | 29.3 | 7.62 |
| | 30.5 | 4.90 |
| | 32.2 | < 0.10 |
| $\overline{X}$ | 31.3 | 2.29 |
| S | 1.90 | 2.61 |
| C.V. | 6.08% | 114% |

Table 13.29. Detection limit calculation, carbon-nitrogen, 1-28-83.

| | N blanks (μv) | C blanks (μv) | $K_N$ (μv/μg) | $K_C$ (μv/μg) |
|---|---|---|---|---|
| 1 | 196 | 100 | 6.18 | 17.92 |
| 2 | 192 | 20 | 7.29 | 18.29 |
| 3 | 212 | 000 | 6.32 | 18.20 |
| 4 | 211 | 000 | 6.22 | 18.00 |
| 5 | 216 | 40 | 6.37 | 18.50 |
| 6 | 202 | 000 | 6.54 | 18.38 |
| 7 | 197 | 000 | 6.18 | 18.36 |
| 8 | 218 | 000 | 6.40 | 18.23 |
| 9 | 225 | 100 | 7.30 | 19.43 |
| 10 | 213 | 10 | | |
| 11 | 180 | 80 | | |
| 12 | 196 | 50 | | |
| 13 | 191 | 140 | | |
| 14 | 199 | 90 | | |
| 15 | 210 | 000 | | |
| | $\bar{X}$ 204 | $\bar{X}$ 42 | $\bar{X}$ 6.53 | $\bar{X}$ 18.37 |
| | S 12.26 | S 48.0 | S 0.45 | S 0.44 |
| | C.V. 6.01% | C.V. 114% | C.V. 6.84% | C.V. 2.38% |

of Oceanography and the College of Forest Resources. The results of these intercalibrations are shown in Tables 13.31 and 13.32.

13.3.5 Dissolved Oxygen Determination

For dissolved oxygen determination, Carpenter's (1965) modification of the Winkler (1888) method was used to reduce the error in measurments. Loss of iodine produced after a sample has been acidified has been shown to be one of the most significant errors in other techniques. Carpenter's method reduces this error by eliminating sample transfers which could contribute to iodine losses. This is done by using the entire sample for titration in the original collection bottle.

Oxygen measurements for the Tunnel Project were carried out at the Oceanography Lab, and for the Baseline Studies at the Water Quality Lab. Both labs are using Carpenter's method with exactly the same kind of setup for titration and the same concentrations of reagents. Initially, there was concern that measurements by one analyst might differ considerably from measurements by another because of differences in reading of volumes, endpoint of titration, etc. However, intercalibration of the labs, without the prior knowledge of the analysts, proved that there is no ground for any concern. The results of this intercalibration are presented in Table 13.33.

Table 13.30. Carbon-nitrogen precision test for sample No. 202.*

| N mg/g | C mg/g |
|---|---|
| 1.60 | 17.4 |
| 1.40 | 16.7 |
| 2.01 | 18.4 |
| 1.92 | 16.4 |
| 1.88 | 16.2 |
| 1.80 | 17.4 |
| 1.88 | 18.3 |
| 1.68 | 17.7 |

*Two analyses a day on four days.

Table 13.31. Sediment carbon and nitrogen comparison with an analytical lab in Oceanography (results in mg/g). N.D. = none detected.

| | Fisheries* | | Oceanography** | |
|---|---|---|---|---|
| Sample | N | C | N | C |
| 1 | 0.57 | 2.7 | 0.19 | N.D. |
| 3 | 1.16 | 14.4 | 1.00 | 13.6 |
| 16 | 3.32 | 27.0 | 2.69 | 23.0 |
| 22 | 1.40 | 9.9 | 0.94 | 7.8 |
| 31 | 3.00 | 25.5 | Lost | 41.0 |
| 54 | 0.40 | 0.8 | 0.53 | N.D. |

*Perkin Elmer elemental analyzer.
**Carlo Erba elemental analyzer.

Table 13.32. Sediment carbon and nitrogen comparison with an analytical lab in Forestry (results in mg/g).

| | Fisheries* | | Forestry** | |
|---|---|---|---|---|
| Sample | N | C | N | C |
| 131 | 0.35 | 1.8 | 0.24 | 1.4 |
| 170 | 0.24 | 1.4 | 0.20 | 1.3 |
| 185 | 0.31 | 2.2 | 0.25 | 1.1 |
| 275 | 3.22 | 27.4 | 1.08 | 4.2 |
| 277 | 0.20 | 1.0 | 0.14 | 0.7 |
| 289 | 0.31 | 5.8 | 0.35 | 2.4 |
| 291 | 0.32 | 1.1 | 0.12 | 0.6 |
| 313 | 0.14 | 0.5 | 0.16 | 0.8 |
| 5062 | 0.29 | 1.4 | 0.19 | 0.9 |
| 5065 | 0.43 | 2.7 | 0.26 | 1.1 |

*Perkin Elmer elemental analyzer.

**Carbon: Walkley A. and I.A. Black. Chromic Acid Titration. Nitrogen: Parkinson J.A. and I.A. Allen. A Wet Oxidation Procedure and Auto Analyzer Method.

Table 13.33. Intercalibration of oxygen measurements in water column between Water Quality Lab and Oceanography Lab.

| | Duplicate Oxygen Data | | | |
|---|---|---|---|---|
| | Sample | | Analyst | |
| Date | St. | Z(m) | Ray $O_2$ (ml/L) | Kathy $O_2$ (ml/L) |
| 8/23/82 | 7 | 25 | 4.81 | 4.81 |
| | 7 | 75 | 4.23 | 4.18 |
| | 8 | 50 | 4.59 | 4.57 |
| 8/24/82 | 1 | 20 | 4.34 | 5.28 |
| | 1 | 200 | 4.28 | 4.20 |
| | 2 | 95 | 4.74 | 4.81 |
| | 3 | 20 | 4.94 | 4.87 |
| 8/30/82 | 4 | 150 | 4.22 | 4.26 |
| | 5 | 100 | 3.99 | 4.06 |
| | 6 | 100 | 4.01 | 4.02 |
| | 7 | 100 | 4.02 | 4.00 |
| | 8 | 50 | 4.31 | 4.37 |
| | 9 | 20 | 4.72 | 4.93 |
| | 10 | 10 | 8.21 | 8.38 |

13.3.6 Salinity Measurement

Salinity was determined by measuring the electrical conductivity of sea water using a Wheatstone bridge. The instrument is believed to be an improvement over the Bradshaw and Schleicher bridge. Details of construction, operation, and maintenance of this equipment are given in Paquette (1958). The bridge was calibrated with Copenhagen water and a second standard. Implicit in this method, and in the whole procedure for the use of the bridge, is the assumption that the conductivity-chlorinity relation for Copenhagen water is the same as in waters of Puget Sound. Comparisons with many titrations at the School of Oceanography have shown this assumption to be true, at least on the average, to 0.003 o/oo salinity or less. The details of procedure are given in Paquette (1958). Detailed logs on the standardization and calibration of the instrument have been kept at the School of Oceanography since 1960.

13.3.7 Nutrient Measurement

An autoanalyzer procedure, outlined by Pavlou (1972) was utilized for nutrient measurements. Methods of determining ammonia, nitrate, nitrite, silicate, and phosphate, together with the corresponding references and the detection ranges, are given in Table 13.34. For each analysis a secondary combined standard using 10 ml of each of the primary standards was run for baseline calibration on all channels. Running standard for each day of operation was made by diluting an aliquot of the secondary standard. A seawater blank was used for correction of dilution waters. The blank and all the standards were run at least once a day, and the blank and one of the standards were run with every set of samples to check the calibration. The recorder strip charts were read to the nearest 0.1% transmittance and the readings were then converted to absorbance. The data were punched on cards

Table 13.34. Range of measurement, primary standards, and method references for measurement of nutrients.

| Nutrient | Optimum range of concentration (μM) | Primary standard (g/L) | References |
|---|---|---|---|
| Ammonia | 0-20 | 0.1070 $NH_4Cl$ | Koroleff 1970; Slawyk and MacIsaac 1972 |
| Nitrate | 0-50 | 1.0110 $KNO_3$ | Armstrong, et al., 1967 |
| Nitrite | 0-50 | 1.0110 $KNO_3$ | Armstrong, et al., 1967 |
| Phosphate | 0-20 | 0.2770 $KH_2PO_4$ | Murphy & Riley 1962; Hager, et al., 1968 |
| Silicate | 0-30 | 0.7522 $Na_2SiF_6$ | Armstrong, et al., 1967 |

and the concentrations of nutrients were calculated by computer. Detailed logs on the calibration of the instrument are kept at the School of Oceanography.

13.3.8 Measurement of Trace Metals in Sediments

The weight of the sample required for trace metal analysis is 0.3 to 1 g dry sediment. Since sediments are intrinsically heterogeneous, a small fraction taken from an inhomogeneous mixture, even from a well-mixed sample, may not constitute a representative sample. For example, the NBS Standard Reference Material 1645 (River Sediment) is freeze-dried, homogenized, sieved to pass a No. 80 (180 m) screen, and thoroughly mixed in a V-blender. Still the total uncertainties, both measurement and material variability, for the elements range from ±2% to ±45% (Table 13.35). With this in mind an attempt was made to use the best possible approach in analyzing trace metals in the sediment samples.

Sediment samples were dried, mixed well, and then digested using $HNO_3/HClO_4$ mixture. To make sure that digestion was adequate, NBS Standard Reference Material 1645 was also digested using $HNO_3/HClO_4$ in one digestion and $HF/HNO_3$ in another digestion. Each digestion was carried out in duplicate. The results of these digestions together with the NBS certified values and the ratio of average value of each digestion over the NBS value are presented in Table 13.35. The ratios of average HF digestion/NBS values ranged from 0.91 to 1.14. Similar values were obtained from the average ratio of $HNO_3/HClO_4$ digestion/NBS values except for Al (0.33), Na (0.3), and Co (1.26). The low ratios showed that digestion with $HNO_3/HClO_4$ was recovering only 33% of Al and 30% of Na; the rest remained in the crystal lattice of the mineral. High recovery of Co (1.26) was probably due to interference or contamination.

Table 13.35. Analysis of NBS Standard Reference Material 1645 river sediment. All values are in ppm unless otherwise specified.*

| Element | Method | $HNO_3/HClO_4$ digestion | | Ave. 1&2 | HF Digestion | | Ave. 3&4 | NBS values |
|---|---|---|---|---|---|---|---|---|
| | | Digestion 1 | Digestion 2 | NBS value | Digestion 3 | Digestion 4 | NBS value | |
| Ag | ICP | ND | ND | -- | ND | ND | -- | NR |
| Al% | ICP | 0.49% | 0.50% | 0.33 | 2.10% | 2.18% | 0.95 | (2.26±0.04)% |
| Ba | ICP | 50.5 | 52.8 | -- | 313 | 321 | -- | NR |
| Be | AA | 0.05 | -- | -- | 0.075 | -- | -- | NR |
| Ca | ICP | 2.78% | 2.83% | 0.97 | 2.98% | 3.1% | 1.05 | 2.9%** |
| Co | ICP | 18.5 | 19.5 | -- | 13.6 | 15.8 | -- | -- |
| Co | AA | 12.5 | 13.0 | 12.6 | 10.5 | 11.2 | 10.7 | 10.1±0.6 |
| Cr% | ICP | 2.8% | 2.84% | 0.95 | 2.8% | 2.9% | 0.96 | (2.96±0.28)% |
| Cu | ICP | 120 | 119 | -- | 155 | 141 | -- | -- |
| Cu | AA | 105 | 105 | 0.96 | 113 | 110 | 1.02 | 109±19 |
| Fe% | ICP | 10.1% | 10.6% | 0.92 | 10.1% | 10.5% | 0.91 | (11.3±1.2)% |
| Mg% | ICP | 0.8% | 0.84% | 1.11 | 0.84% | 0.85% | 1.14 | (0.74±0.02)% |
| Mn | ICP | 815 | 860 | 1.07 | 848 | 890 | 1.11 | 785±97 |
| Na% | ICP | 0.14% | 0.18% | 0.3 | 0.51% | 0.53% | 0.96 | (0.54±0.01)% |
| Ni | ICP | 62 | 61 | -- | 59 | 63 | -- | -- |
| Ni | AA | 52 | 52 | 1.14 | 50.2 | 55 | 1.15 | 45.8±2.9 |
| V | ICP | 29.3 | 25.5 | 1.17 | 22.5 | 25.4 | 1.02 | 23.5±0.9 |
| Zn% | ICP | 0.176% | 0.177% | 1.03 | 0.174% | 0.170% | 1.00 | (0.172±0.017)% |
| K% | ICP | 0.145% | 0.145% | 0.12 | 1.2% | 1.25% | 0.97 | (1.26±0.05)% |
| Cd | AA | 9.5 | 9.5 | 0.93 | 10.0 | 10.0 | 0.98 | 10.2±1.5 |
| Pb | AA | 750 | 725 | 1.03 | 725 | 800 | 1.07 | 714±28 |
| Hg | AA | 0.98 | 1.17 | 0.98 | -- | -- | -- | 1.1±0.5 |

*AA = Atomic absorption spectroscopy.
ICP = Inductively coupled plasma emission.
ND = Not detected.
NR = Not reported.

**No certified value.

Although there is no NBS value for Ba, comparison of the two digestion methods shows that the recovery of Ba was only 16%. The overall results in Table 13.35 show that the $HNO_3/HClO_4$ digestion was adequate for most trace metals, assuming Puget Sound sediments behave physically and chemically the same as NBS River Sediment 1645.

Similar digestions were made to leach trace metals from Puget Sound sediment samples (Table 13.36). To make sure that leaching was complete, or that leachable metals were recovered completely, the $HNO_3/HClO_4$ digestion was carried out in two steps. After the first step, the solution was filtered and the residue was redigested and trace metals in steps 1 and 2 were measured separately. The results show that Cr, Ba, Be, Cu, Zn, Cd, and Pb were completely recovered in step 1, and that more than 94% of leachable A1, Co, Ni, Mn, V, Ca, Mg, Na, and K was recovered during step 1. However, comparison with HF digestions of the same sample shows that for all metals except Pb the recovery was less than the corresponding values obtained for NBS standard (Table 13.36). One reason for these discrepancies was the difference in grain sizes of both samples; grain size of the NBS standard was less than 180 m, whereas 95.3% of smaple 63G was composed of fine sand (250-125 m). It is obvious that smaller particles are more soluble or leachable than larger particles. Another factor may be that differences in the morphology and crystallography of the samples make one more soluble than another. Additional replicate analyses of the two digestion techniques for samples 5001G and 58G are shown in Tables 13.37 and 13.38. It is interesting to note that sometimes the discrepancies between the replicate analyses by the same technique are much larger than between the different digestion procedures.

In view of the above results and the limitations of the available resources, the $HNO_3/HClO_4$ leaching procedure was used for sediment analysis.

Table 13.36. Replicate analysis of sample 63G (values in ppm).* Dashes mean not detectable.

| Digestion method: | $HNO_3/HClO_4$ | | | | | | $HNO_3/HF$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | A | | | B | | |
| Duplicate: | Digestion 1 | | | Digestion 2 | | | | | A ave. |
| Element | Step 1 | 2 | 1 + 2 | Step 1 | 2 | 1 + 2 | Dig. 1 | Dig. 2 | B ave. |
| Ag | <blank | | | <blank | | | 2.11 | 2.25 | -- |
| Al | 9110 | 390 | 9500 | 9900 | 268 | 10200 | 44000 | 44300 | 0.22 |
| Cr | 21.6 | -- | 21.6 | 22.2 | -- | 22.2 | 51.3 | 52.3 | 0.43 |
| Ba | 20.2 | -- | 20.2 | 20.4 | -- | 20.4 | 244 | 236 | 0.085 |
| Be | 2.54 | -- | 2.54 | 2.73 | -- | 2.73 | 4.61 | 4.92 | 0.55 |
| Co | 8.7 | 0.18 | 8.88 | 9.9 | 0.13 | 10.0 | 22.0 | 24.8 | 0.40 |
| Cu | 31.5 | -- | 31.5 | 32.0 | -- | 32.0 | 37.9 | 37.2 | 0.85 |
| Fe | 12500 | 133 | 12600 | 13200 | 101 | 13300 | 25900 | 27200 | 0.49 |
| Ni | 17.3 | 0.13 | 17.4 | 19.1 | 0.15 | 19.2 | 22.6 | 29.7 | 0.70 |
| Mn | 165 | 1.8 | 167 | 177 | 1.1 | 178 | 378 | 399 | 0.44 |
| Zn | 41 | -- | 41 | 44 | -- | 44 | 65.3 | 63.8 | 0.69 |
| V | 29.5 | 1.6 | 31.1 | 31.5 | 1.4 | 32.9 | 67.7 | 72.1 | 0.46 |
| Ca | 3500 | 275 | 3800 | 4010 | 180 | 4200 | 20000 | 21200 | 0.19 |
| Mg | 4750 | 43 | 4790 | 5200 | 27 | 5230 | 11000 | 10700 | 0.46 |
| Na | 5750 | 68 | 5820 | 6000 | 38 | 6040 | 17700 | 17900 | 0.33 |
| K | 1200 | 75 | 1280 | 1250 | 75 | 1280 | 7000 | 6800 | 0.18 |
| Cd | 0.040 | -- | 0.040 | 0.038 | -- | 0.038 | 0.045 | 0.043 | 0.89 |
| Pb | 14.8 | -- | 14.8 | 14.1 | -- | 14.1 | 13.4 | 13.3 | 1.1 |

*Grain size:
% Gravel = 0.057
% Coarse sand = 2.674
% Fine sand = 95.283
% Silt = 0.685
% Clay = 1.37

Table 13.37. Replicate analysis of sample 5001G.*

| | $HNO_3/HClO_4$ | | | | $HNO_3/HF$ | | | |
|---|---|---|---|---|---|---|---|---|
| | A | | | B | C | | | A+B ave. |
| Element | 1 | 2 | Ave. | 1 | 1 | 2 | Ave. | C ave. |
| Ag | < | < | -- | | 2.34 | 2.21 | 2.28 | -- |
| Al | 10300 | 10400 | 10400 | 9800 | 47400 | 44000 | 45700 | 0.22 |
| Cr | 39.9 | 40.8 | 40.4 | 43.6 | 94.4 | 85.6 | 90.0 | 0.47 |
| Ba | 24.8 | 23.2 | 24 | 42.7 | 309 | 286 | 298 | 0.11 |
| Be | 2.5 | 2.68 | 2.59 | 3.17 | 4.72 | 4.72 | 4.72 | 0.61 |
| Co | 12.5 | 14.7 | 13.6 | 12 | 26.5 | 29.3 | 27.9 | 0.46 |
| Cu | 16.8 | 18.3 | 17.6 | 14 | 23.7 | 21.8 | 22.8 | 0.69 |
| Fe | 12400 | 13400 | 12900 | 12200 | 25500 | 25100 | 25300 | 0.50 |
| Ni | 45.8 | 56.3 | 51.1 | 42.7 | 65.8 | 69.9 | 67.9 | 0.69 |
| Mn | 185 | 197 | 191 | 199 | 390 | 365 | 378 | 0.77 |
| Zn | 34 | 41.2 | 37.6 | 33.7 | 50.7 | 49.3 | 50.5 | 0.71 |
| V | 36.6 | 36.9 | 36.8 | 38.0 | 79.5 | 80 | 80 | 0.47 |
| Ca | 4560 | 4020 | 4290 | 3850 | 23200 | 22900 | 23100 | 0.18 |
| Mg | 5500 | 5980 | 5740 | 4890 | 8320 | 6540 | 7430 | 0.72 |
| Na | 2750 | 2880 | 2820 | 2720 | 19600 | 18100 | 18900 | 0.15 |
| K | 955 | 1130 | 1040 | 1250 | 5750 | 6500 | 6130 | 0.19 |
| Cd | 0.038 | 0.040 | 0.039 | 0.045 | 0.045 | 0.043 | 0.044 | 0.95 |
| Pb | 1.5 | 1.5 | 1.5 | 1.3 | 5.0 | 5.0 | 5.0 | 0.30 |

*Grain size:
% Gravel = 13.55
% Coarse sand = 10.58
% Fine sand = 66.15
% Silt = 8.8
% Clay = 0.86

Table 13.38. Replicate analysis of sample 58G (values in ppm).*

| | $HNO_3/HClO_4$ | | | | $HNO_3/HF$ | | | Ave. $HNO_3/HClO_4$ / Ave. $HNO_3/HF$ |
|---|---|---|---|---|---|---|---|---|
| | A | | Ave. | B | C | | Ave. | |
| Element | Dig. 1 | Dig. 2 | 1&2 | Dig. 3 | Dig. 4 | Dig. 5 | 4&5 | |
| Ag | <blank | <blank | -- | | 0.53 | 0.43 | 0.048 | -- |
| Al | 946 | 9830 | 9650 | 6780 | 20900 | 21500 | 21200 | 0.45 |
| Cr | 26.3 | 27.0 | 26.7 | 29.4 | 37.7 | 38.9 | 38.3 | 0.70 |
| Ba | 24.4 | 25.4 | 24.9 | 23.9 | 28 | 35 | 31.5 | 0.76 |
| Be | 2.52 | 2.55 | 2.54 | 2.86 | 2.84 | 2.99 | 2.92 | 0.87 |
| Co | 8.62 | 8.76 | 8.69 | 8.53 | 13.1 | 14.2 | 13.7 | 0.63 |
| Cu | 29.3 | 27.8 | 28.6 | 18.6 | 26.0 | 25.9 | 25.5 | 1.12 |
| Fe | 12400 | 12600 | 12500 | 10500 | 16600 | 17100 | 16900 | 0.74 |
| Ni | 19.8 | 20.0 | 19.9 | 17.4 | 21.8 | 21.5 | 21.7 | 0.92 |
| Mn | 320 | 358 | 339 | 239 | 340 | 368 | 354 | 0.96 |
| Zn | 50.9 | 51.3 | 51.1 | 41 | 53.1 | 51.5 | 52.3 | 0.98 |
| V | 26.8 | 27.6 | 27.2 | 26.9 | 43.6 | 45.9 | 44.8 | 0.61 |
| Ca | 2630 | 2760 | 2700 | 1940 | 6620 | 6770 | 6690 | 0.40 |
| Mg | 5300 | 5500 | 5400 | 3670 | 7240 | 7470 | 7350 | 0.74 |
| Na | 8130 | 8750 | 8440 | 5300 | 10200 | 11000 | 10700 | 0.79 |
| K | 1350 | 1380 | 1360 | 940 | 3000 | 3380 | 3190 | 0.43 |
| Cd | 0.063 | 0.058 | 0.060 | 0.075 | 0.050 | 0.063 | 0.057 | 1.05 |
| Pb | 17.8 | 17.8 | 17.8 | 12.7 | 17.0 | 16.5 | 16.8 | 1.06 |

*Grain size:
% Gravel = 1.58
% Coarse sand = 5.34
% Fine sand = 38.53
% Silt = 22.16
% Clay = 32.3

Because of low recoveries for Al, Na, K, Ba, and Ca, these values are not included in most of the results. The quality control and quality assurance of the measurements are considered neither complete nor convincing at this point. Currently, three other sediment standard reference materials are being investigated using both digestion techniques. After these measurements, a recovery factor for individual metals that may be used to correct the analytical results will be sought.

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14.4 SUMMARY

14.2 INTRODUCTION

14.3 PROJECT MANAGEMENT

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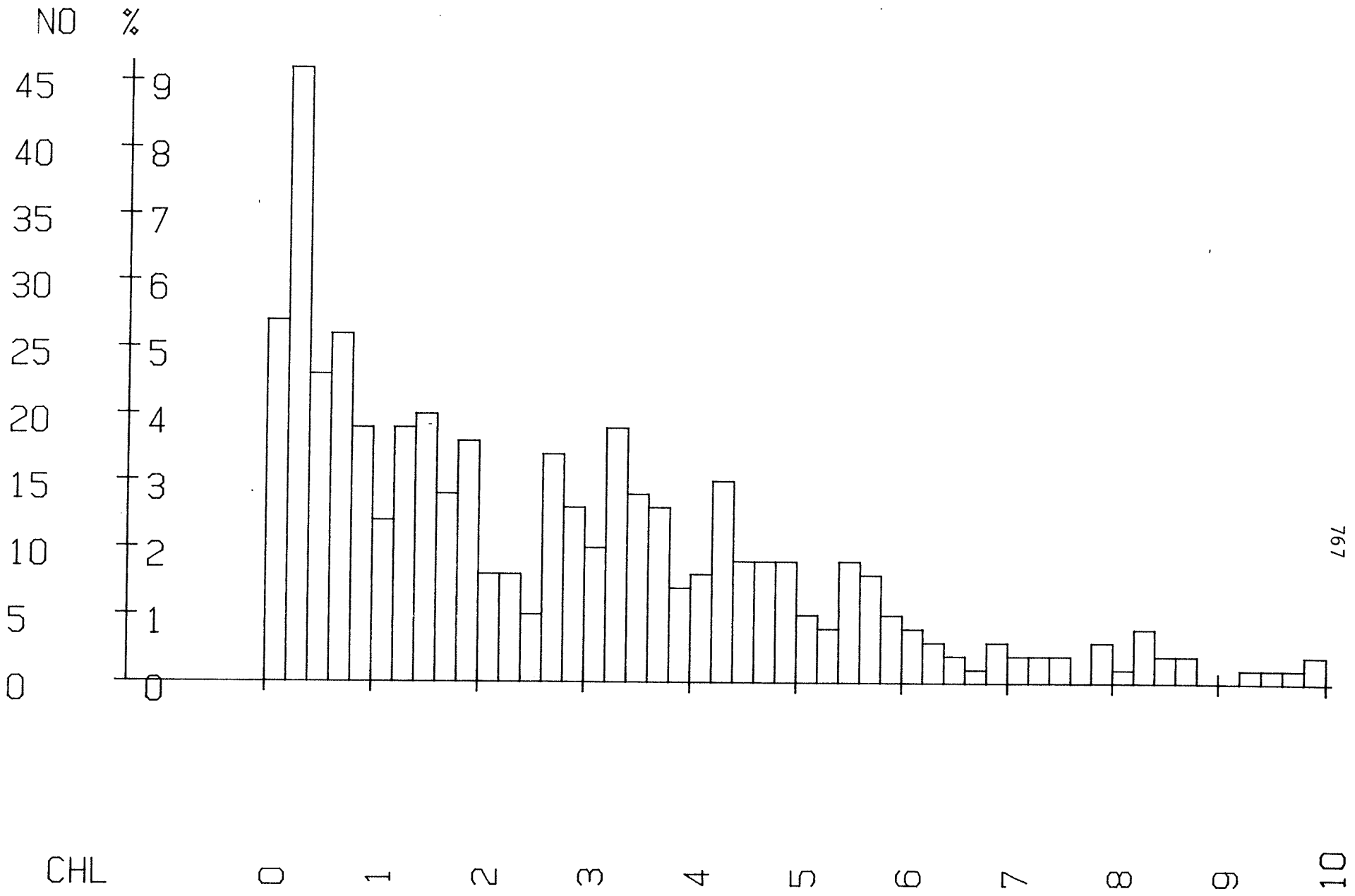
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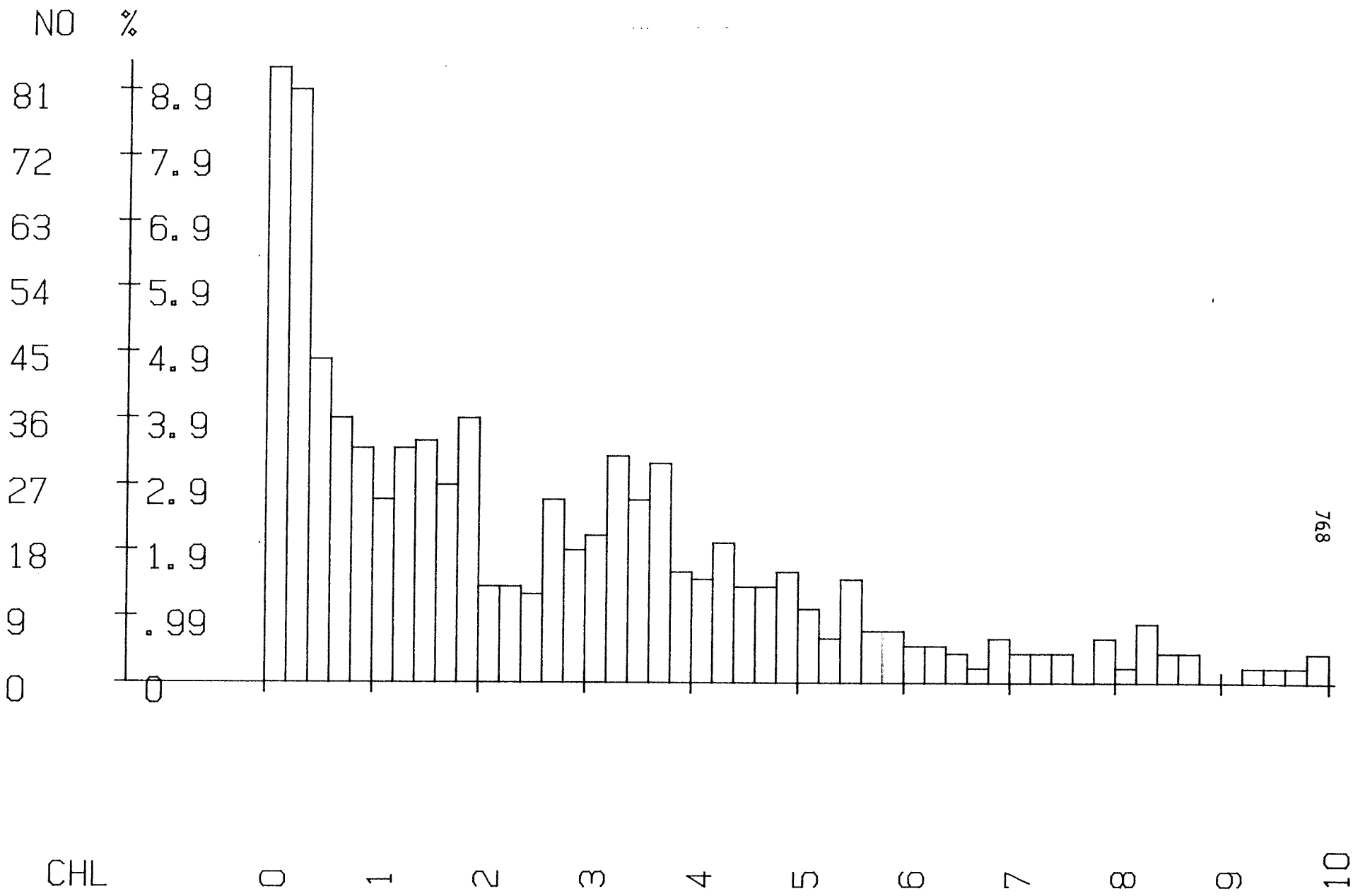
# 15.0 APPENDICES

# APPENDIX 4A

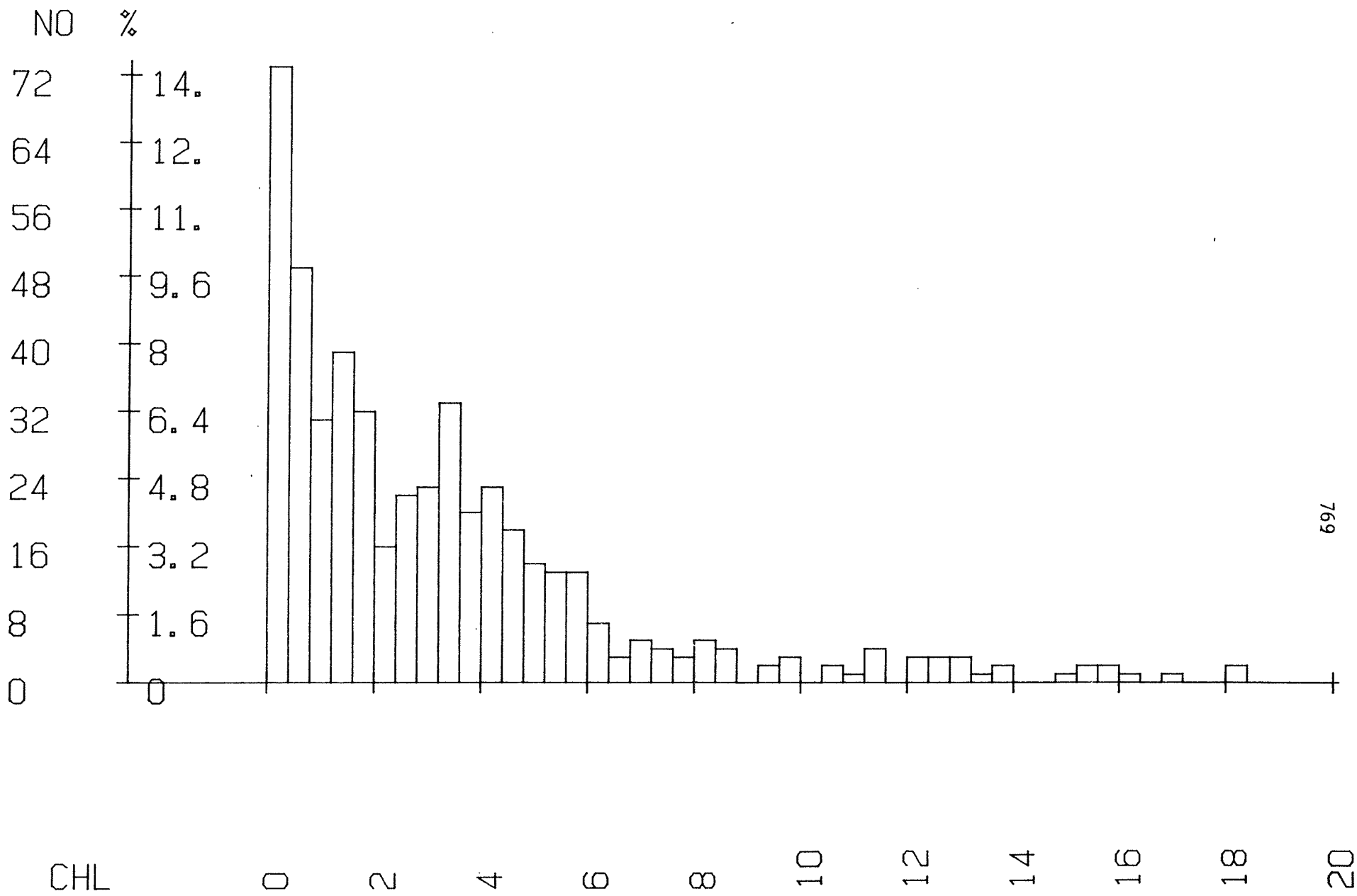
## PROBABILITY DISTRIBUTIONS OF CHLOROPHYLL AT NEARSHORE STATIONS




Appendix 4A.1. Probability distribution of chlorophyll in the upper 10 meters at nearshore stations (4-10) for the time October, 1982-January 1983. Chlorophyll is in µg/1.



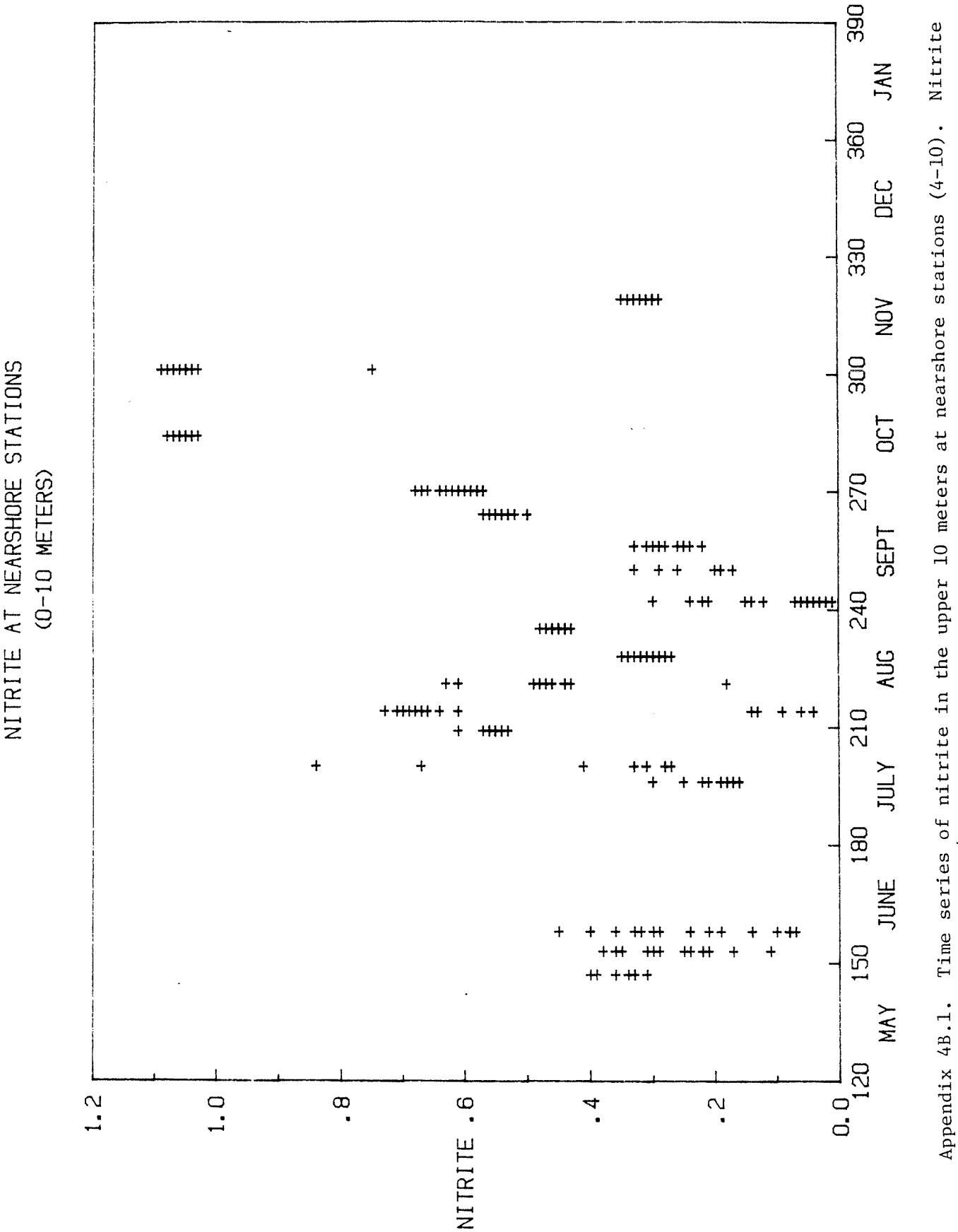

Appendix 4A.2. Probability distribution of chlorophyll in the upper 10 meters at nearshore stations (4-10) for the time period May - September, 1982. Chlorophyll is in µg/l.



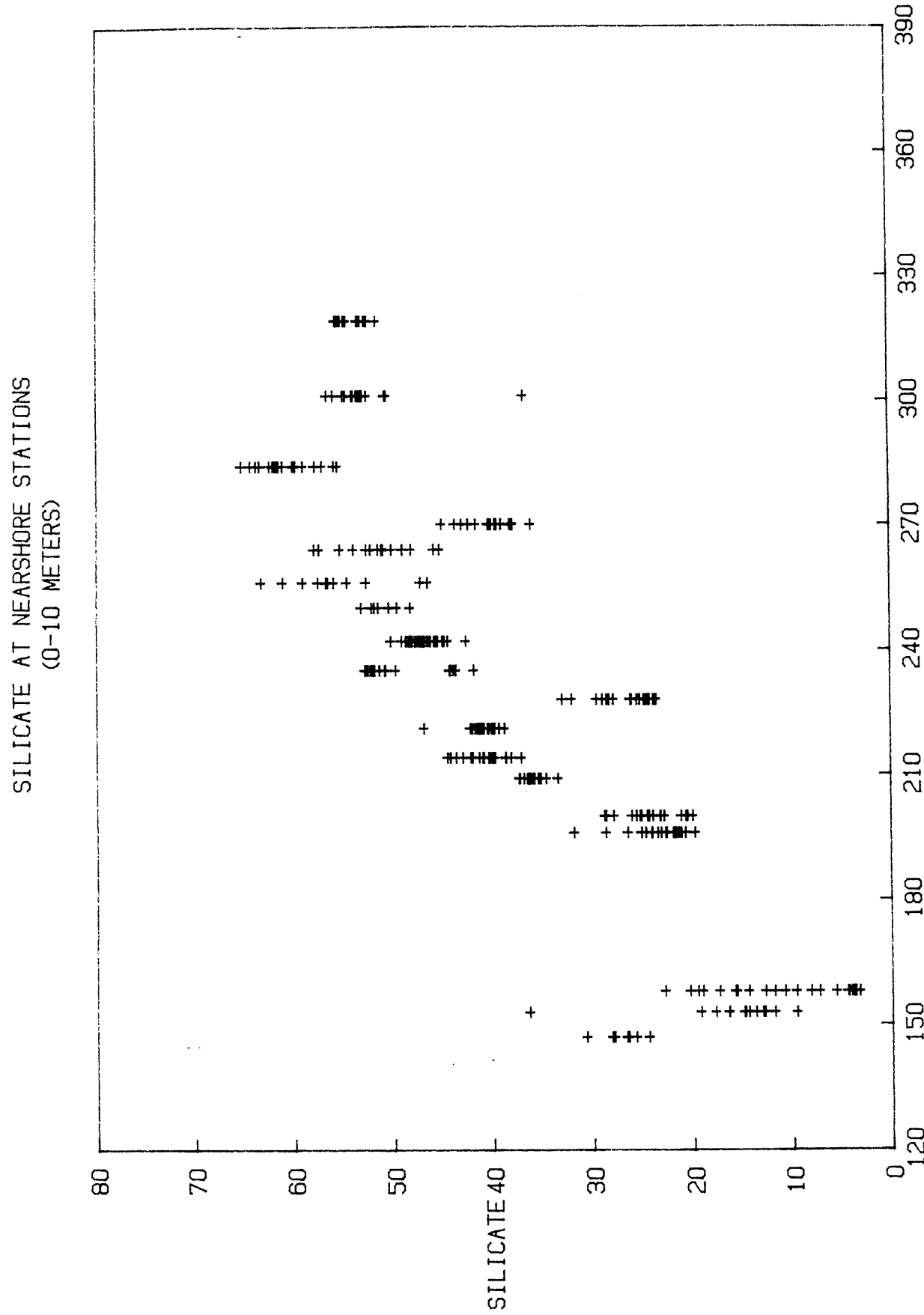

Appendix 4A.3. Probability distribution of chlorophyll at nearshore stations.

# APPENDIX 4B

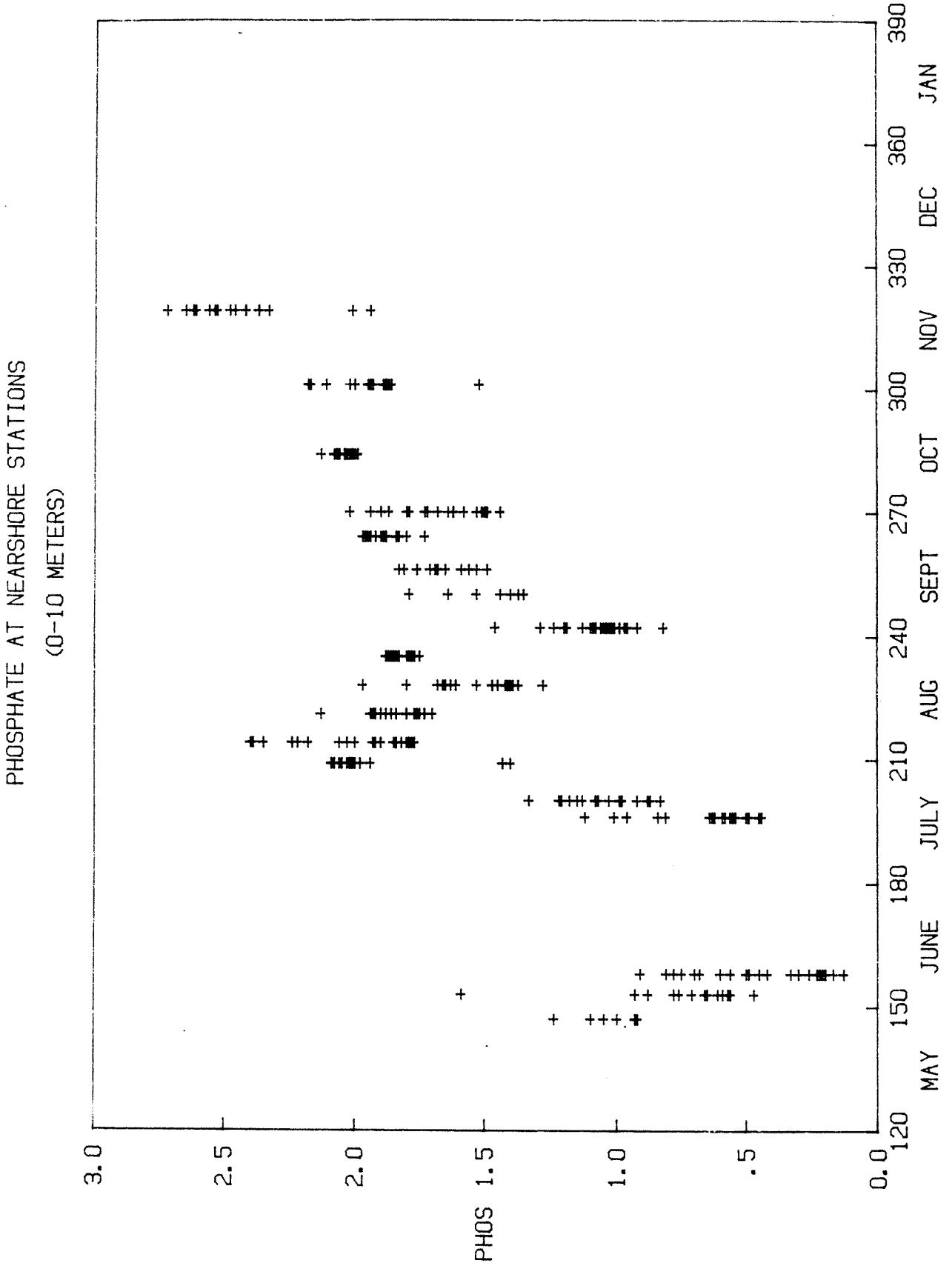
## TIME SERIES OF DISSOLVED NUTRIENTS, NEARSHORE STATIONS




Appendix 4B.1. Time series of nitrite in the upper 10 meters at nearshore stations (4-10). Nitrite is in µg-at/l.




Appendix 4B.2. Time series of silicate in the upper 10 meters at nearshore stations (4-10). Silicate is in µg-at/l.




Appendix 4B.3. Time series of phosphate in the upper 10 meters at nearshore stations (4-10). Phosphate is in µg-at/l.

# APPENDIX 4C

## NUTRIENT LIMITATION STUDY

Appendix

# 4C NUTRIENT LIMITATION STUDY

E. B. Welch and H. Ehlers

## 4C.1 Introduction

Phytoplankton production in coastal waters is known to be dependent, among other factors, upon the relative abundance of the limiting nutrient. In marine systems, nitrogen is generally considered the most limiting nutrient to algal growth (Dugdale 1967), as indicated by a number of experimental bioassays (Ryther and Dunstan 1971; Yentsch et al. 1977). Nitrogen is also the most limiting nutrient in Puget Sound. However, whether an increase in phytoplankton biomass would result from adding more N to Puget Sound via the Seahurst discharge depends upon the length of time that growth rate limiting levels exist and the rates of other losses.

Light, rather than nutrients, is generally recognized to be the controlling factor for phytoplankton productivity in Puget Sound. Vertical mixing carries phytoplankton cells deep in the water column limiting their available light. Net productivity is inversely proportional to the depth of mixing. Under conditions of low vertical mixing, which often occur during neap tides and in embayments, the mixing depth decreases and light availability increases, to the point that productivity may decrease the N concentration to growth-rate limiting levels. Experimental results indicate that N concentration less than 200 ug/1 would reduce the growth rate of some nearshore marine phytoplankton species (Eppley et al. 1974). Using that criterion, potentially growth rate limiting conditions have existed in Puget Sound for as long as a week in the past. By observing nutrient concentrations in situ and conducting bioassays during and after blooms, when nutrient depletion is likely to occur, the actual existence of nutrient limitation can

be documented and the potential for increased growth rate and biomass with added nutrient can be estimated.

The following were the objectives for the first year's bioassays:

1. Determine if N is the nutrient likely to be limiting phytoplankton growth, when nutrients are controlling biomass production.
2. Determine the amount of biomass increase that is theoretically possible from increases in nutrients when nutrients are controlling growth rate.
3. Determine if nutrient enhancement will have more effect inshore than offshore. That is, does greater water detention time and less turbulence inshore result in denser blooms, lower nutrient concentrations, and thus more opportunity for nutrients to control growth?

4C.2 Materials and Methods

Mixed, naturally occurring algal populations were used for performing the bioassays. After initial sample collections, it was determined that the use of integrated surface samples was not appropriate for assessment since they tended to obscure localized conditions. Additionally, the spray pump aboard the R/V Liberty proved to cause considerable damage to phytoplankton cells, producing an unsuitable sample. The sampling scheme was subsequently modified to allow collection of discrete surface samples from station 4 (mid-channel, East Passage) and 10 (nearshore, Seahurst Park). It was felt that such a comparison would provide a more realistic approach to assessment, focusing upon the area of potential impact.

The use of natural populations presented some difficulties in measuring algal growth, largely due to the low levels achieved in the lab. Optical

density proved to be an inappropriate measure of growth, prompting the use of carbon-14 uptake, via inoculation with radioactive carbon-14 and monitoring its accumulation during algal growth by recording activity of filtered material with a liquid scintillation counter, as an indicator of algal growth. Chlorophyll (chl a) measurements and microscopic assessment were utilized to quantify the effects of enhancement.

Five nutrient bioassays were conducted during the period July through September, 1982. The results of these experiments will be discussed in the following sections, as well as the overall conclusions which might be drawn from them. Physiochemical data collected within the water column program is also presented for evaluating the observed biological response to assay conditions.

After collection in the field, water samples were returned to the labor - atory, transferred to 500 ml Erlenmeyer flasks, and enriched as follows to yield five treatments:

(1) Control (no additions)

(2) 3.57 ug/l $NO_3$-N + 1.61 ug-at/l $PO_4$-P

(3) 7.14 ug/l $NO_3$-N + 1.61 ug-at/l $PO_4$-P

(4) 10.7 ug-at/l $NO_3$-N + 1.61 ug-at/l $PO_4$-P

(5) 14.3 ug-at/l $NO_3$-N + 1.61 ug-at/l $PO_4$-P

Nutrient enrichments of these static bioassays were made utilizing nitrate as a nitrogen source in order to minimize treatment complexity. The levels of $NO_3$-N addition were selected to represent dilutions of about 30, 15, 10, and 7.5 fold dilution of Renton Treatment Plant effluent. Phosphorus additions were also made to ensure that P was non-limiting.

Initial nutrient conditions for each assay series are shown in Table 4C.1, which were obtained from samples analyzed in conjunction with the water

Table 4C.1. Initial nutrient concentrations of surface waters utilized in algal bioassays during the period of June through September 1982 (units are μg at $\ell^{-1}$).

| Cruise Date | Station | $NO_3$-N | $NO_2$-N | $NH_3$-N | $PO_4$-P | $S_1O_4$ |
|---|---|---|---|---|---|---|
| 820715 | (4) | 3.46 | 0.25 | 0.86 | 0.81 | 24.68 |
| | (10) | 2.16 | 0.17 | 0.97 | 0.56 | 22.65 |
| 820728 | (4) | 15.60 | 0.55 | 1.34 | 1.40 | 36.05 |
| | (10) | 16.25 | 0.55 | 1.36 | 2.02 | 36.27 |
| 820802 | (4) | 14.74 | 0.69 | 0.42 | 1.84 | 35.63 |
| | (10) | 12.76 | 0.64 | 0.42 | 1.82 | 40.83 |
| 820816 | (4) | 9.08 | 0.32 | 0.93 | 1.40 | 24.79 |
| | (10) | 7.09 | 0.27 | 0.11 | 1.28 | 23.63 |
| 820830 | (4) | 0.30 | 0.10 | 0.14 | 1.06 | 42.62 |
| | (10) | 0.13 | 0.03 | 0.09 | 0.99 | 45.86 |

column studies. In addition, surface concentrations of $NO_3$ + $NO_2$ - N and $NH_3$-N for stations 4 and 10 are noted in Figure 4C.1, showing measured nutrient levels in surface waters during the period June through September, 1982. It is notable that extremely low concentrations of nitrogen were only observed on two of twelve cruises, both occurring on dates when samples were collected for use in the bioassays. Based upon vertical nutrient profiles obtained by cruises during this period, it is apparent that Station 10 remained relatively well-mixed throughout the summer due to its shallow depth. Station 4 also was relatively mixed during some of this period.

4C.3 Results and Discussion

The data obtained during the course of the five bioassays will be reviewd individually, allowing a more detailed comparison between the two stations. As a reference, field measurements of surface chl *a* levels and the maximum levels measured within the water column at each station are shown in Figure 4C.2 for June through September. Although no data are available for the four weeks prior to June 15 (no cruises were conducted), it appears that the remains of an earlier bloom were encountered, after which maximum chl *a* levels remained below about 6 µg chl *a*/l until the end of August. On August 30, the occurrence of a fall bloom is noted at both Stations 4 and 10, but the algal populations have effectively crashed by September 13th.

4C.3.1 Cruise (July 15, 1982) No. 820715

At Station 4, initial nutrient concentrations of 3.71 ug-at/l $NO_3$+$NO_2$-N, 0.83 ug-at/l $NH_3$-N, and 0.81 ug-at/l $PO_4$-P were measured in surface waters Table 4C.1), yielding a N:P ratio of 5.6:1. Because the optimal N:P ratio is generally about 16:1 the existing ratio suggests that nitrogen would limit first. In actuality, the observed concentrations are quite low and would not

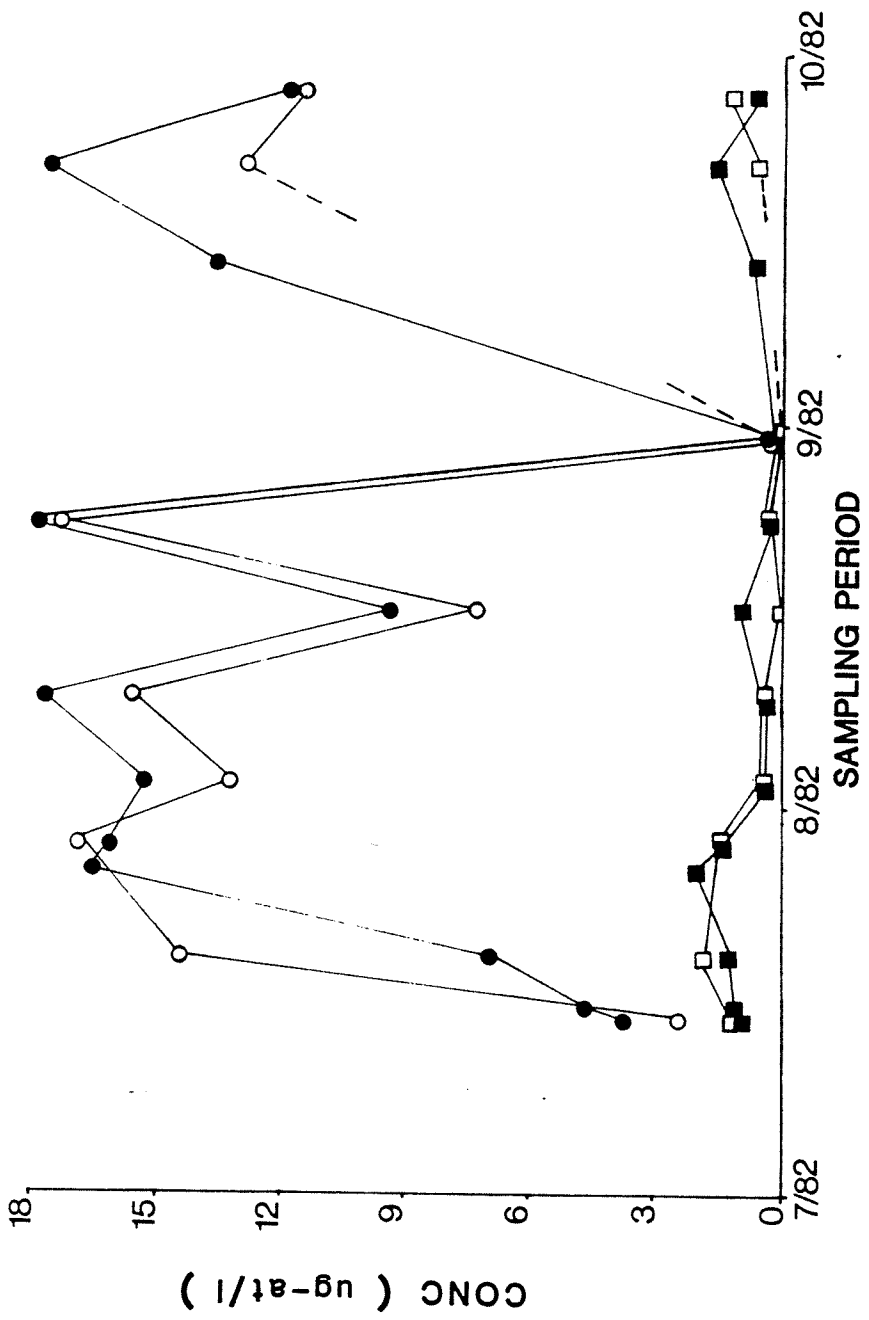



Figure 4C.1. Nitrogen content in surface waters at Stations 4 (closed symbols) and 10 (open symbols) during the period July through September 1982. Circles (O) represent Nitrate+Nitrate-N (µg - at/ℓ) and square symbols (□) denote Ammonia-N (µg - at/ℓ).

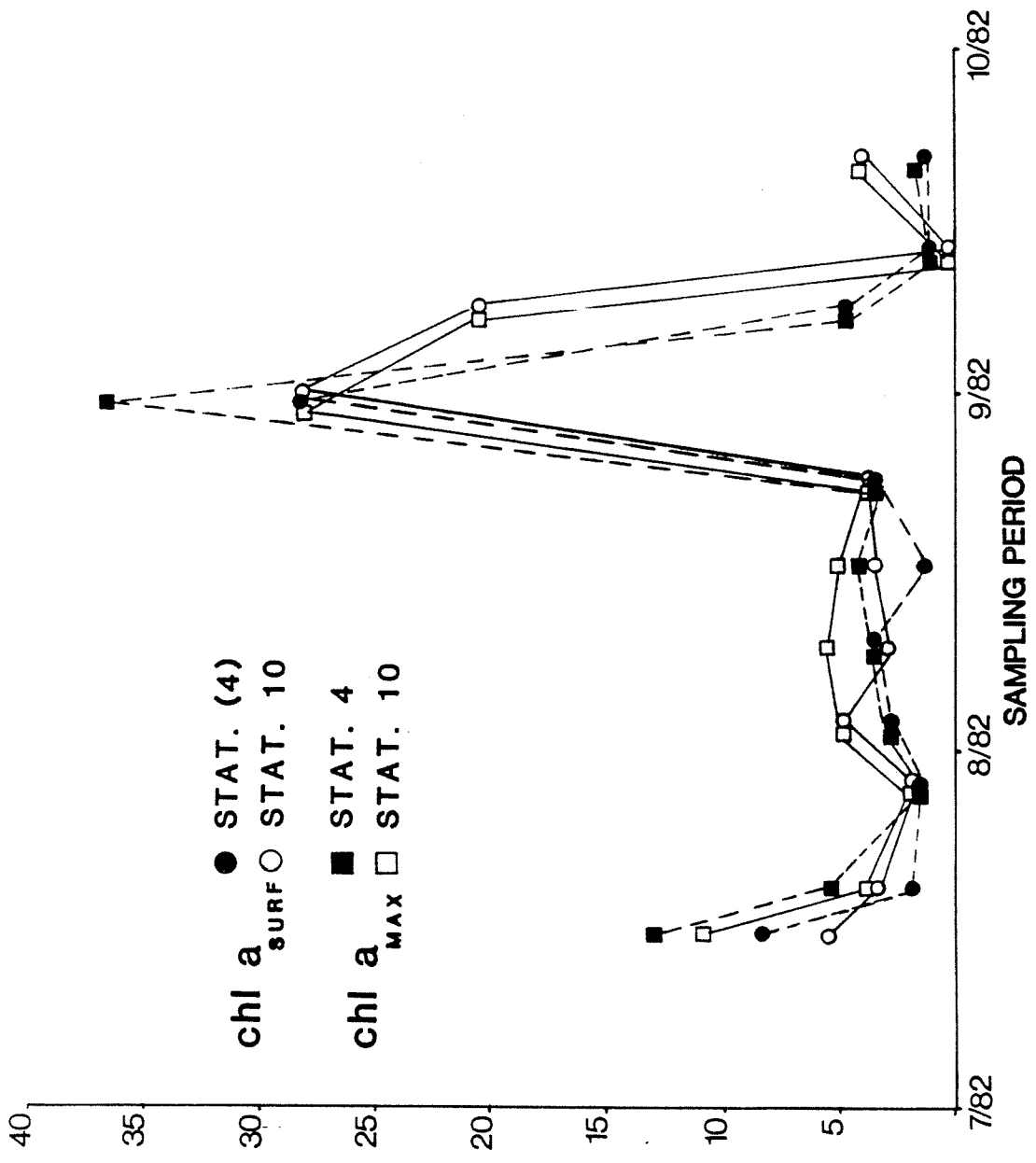



Figure 4C.2. Surface Chlorophyll a (O) and maximum Chlorophyll Content (□) observed throughout the water column during June through September 1982.

likely support much biomass increase, yet initial chl a levels of 8.3 ug/l and 10.4 ug/l were measured in the field and at the beginning of the bioassays. As shown in Figure 4C.3, from chlorophyll level versus time, nitrogen enrichment did stimulate some growth as a function of the amount of nitrogen added. The maximum chlorophyll level reached in the assay occurred in the 200 g N/l treatment, yielding 26.1 ug/l chl a. This value represents an increase of about 130% over the maximum achieved in the control (11.3 ± 1.8 ug/l), occurring during the second day of the assay. The population crashed during the following days.

Station 10 also showed relatively low nitrogen concentrations initially (Table 4C.1), yielding a N:P ratio of 5.9:1. Initial chl a levels were measured in the field as 5.5 ug/l at the surface and a maximum of 10.9 ug/l in the water column. At the time at which the assays were begun, the chl a level was 14.7 ± 1.1. ug/l. Nitrogen enrichment yielded a maximum chl a level of 16.0 ± 4.3 ug/l by the second day, but all other treatments were decreasing from the initial, effectively crashing by the sixth day. Clearly, nitrogen enrichment did not stimulate growth, in populations from either Station 10 or 4, nor did chl a increase to a level expected if the populations were healthy and the available N were utilized.

In contrast, carbon-14 uptake by both assays was relatively rapid, as indicated by the high counts per minute (cpm) measured within the first 48 hours (Figure 4C.4). It is notable that increasing nitrogen level generally reflected higher carbon uptake in both assays, although the maximum uptake by the control for station 10 reached only 60% of that reached in Station 4's control. Beyond day three, uptake leveled out.

Although nitrogen enrichment proved somewhat stimulatory for Station 4, it would appear that other factors are limiting (inhibiting) the populations.

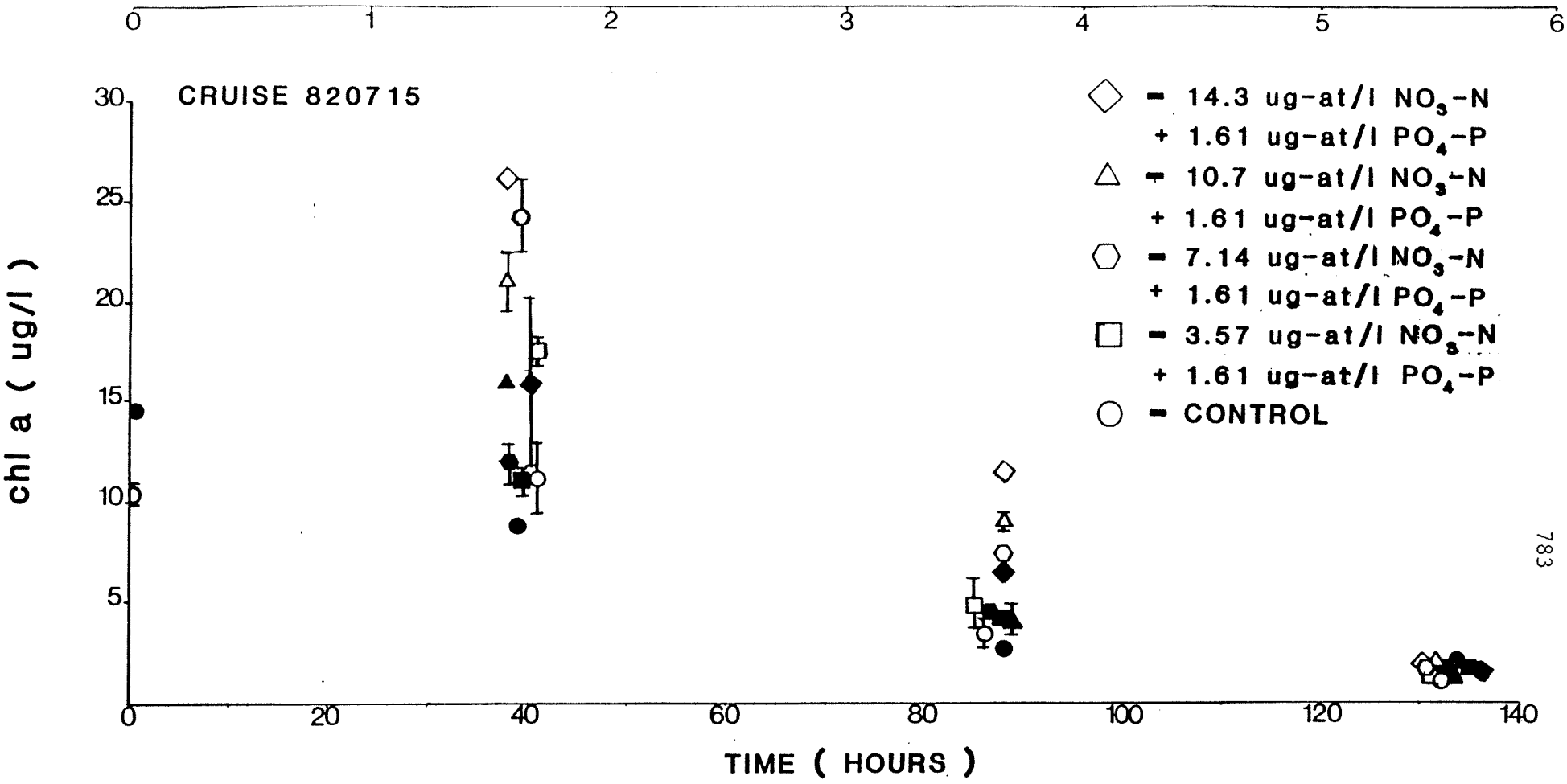



Figure 4C.3. Change in Chlorophyll a concentration with time in the nutrient enrichment bioassay for samples collected July 15, 1982 at Stations 4 (open symbols) and 10 (closed symbols).

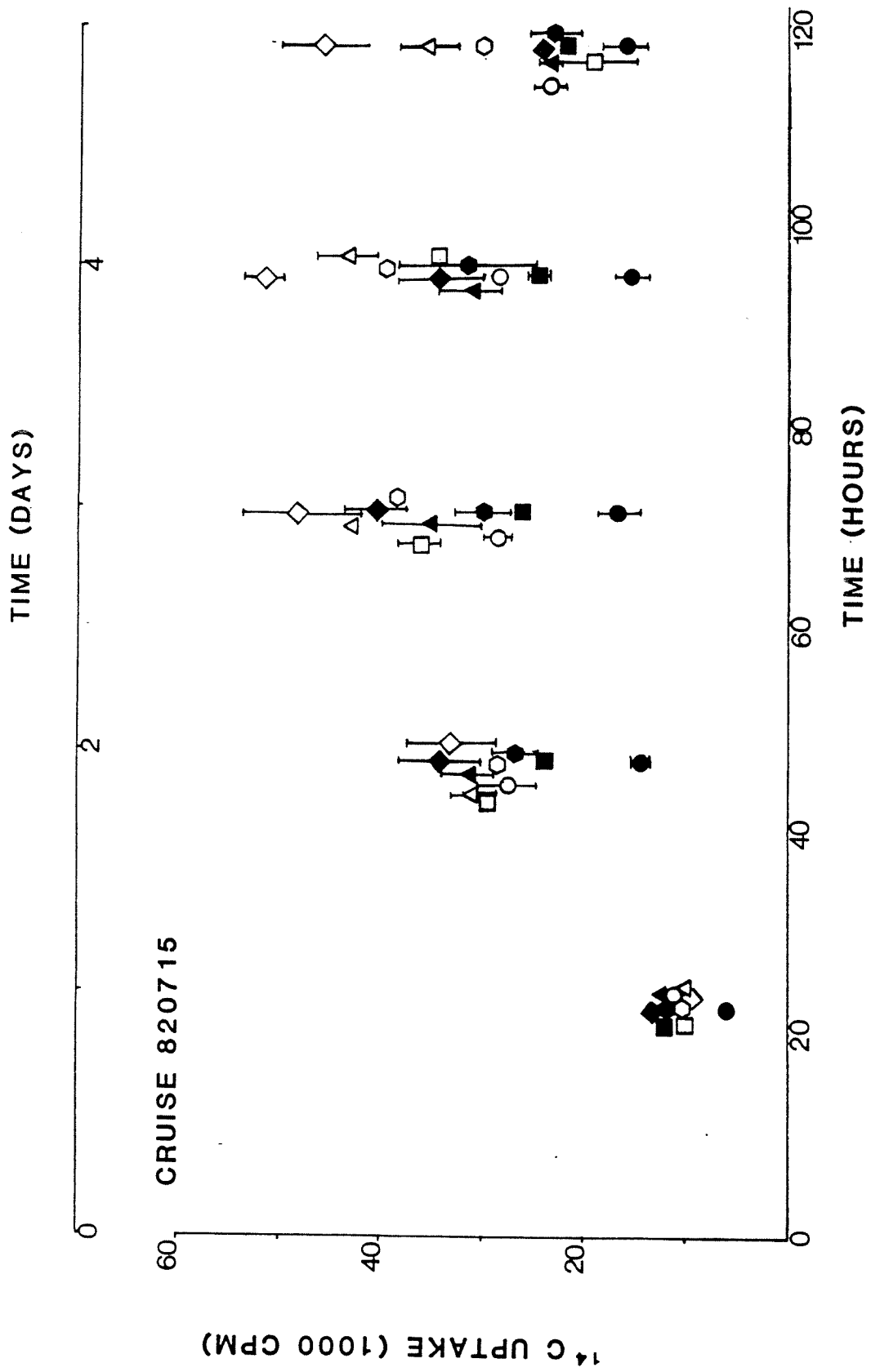



Figure 4C.4. Change in Carbon-14 uptake with time in the nutrient enrichment bioassay for water samples collected July 15, 1982, at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

Nutrient concentrations within the water column at Station 4 indicated stratification, and nutrients had been depleted in the upper layers. Station 10 was well-mixed but nutrients were largely depleted. Low nitrogen content along with stimulation of carbon-14 assimilation indicates that a portion of the endemic assemblage responded while another portion reflected the decline of an earlier bloom. It would appear that growth may have been limited by nitrogen at this time, but results were obscured by an apparent unhealthy fraction of the population which had declined too far to respond to nutrient availability.

4C.3.2 Cruise (July 28, 1982) No. 820728

Initial nutrient concentrations at station 4 were relatively high in nitrogen (16.16 ug-at/l $NO_3$+$NO_2$-N, 1.34 ug-at/l $NH_3$-N) and phosphorus (1.4 ug-at/l $PO_4$-P), yielding a N:P ratio of about 12.5:1 (Table 4C.1). Vertical distribution of nutrient concentrations indicated extensive mixing of the water column, an important factor considering the low chl *a* levels observed. Field determinations of chl *a* yielded a surface level of 1.6 ug/l, which was also the highest value measured in the water column. In the bioassay, all five treatments showed increased growth over initial values and differentiation among the higher enrichment levels as opposed to the controls (Figure 4C.5). The assay was ended early, however, in order to conform to a revision in cruise scheduling. Since the treatments with lower enrichment were beginning to decline in chl *a* similar to the control, it was decided that a comparison between treatments was still valid. The maximum chl *a* level reached in the assay was 16.7 $\pm$ 1.1 ug/l, an increase of only 70% above the maximum attained in the control. The control, however, showed an increase of 240% over its initial value in response to laboratory growth conditions. Although nitrogen enrichment did promote some growth, the bioassay was

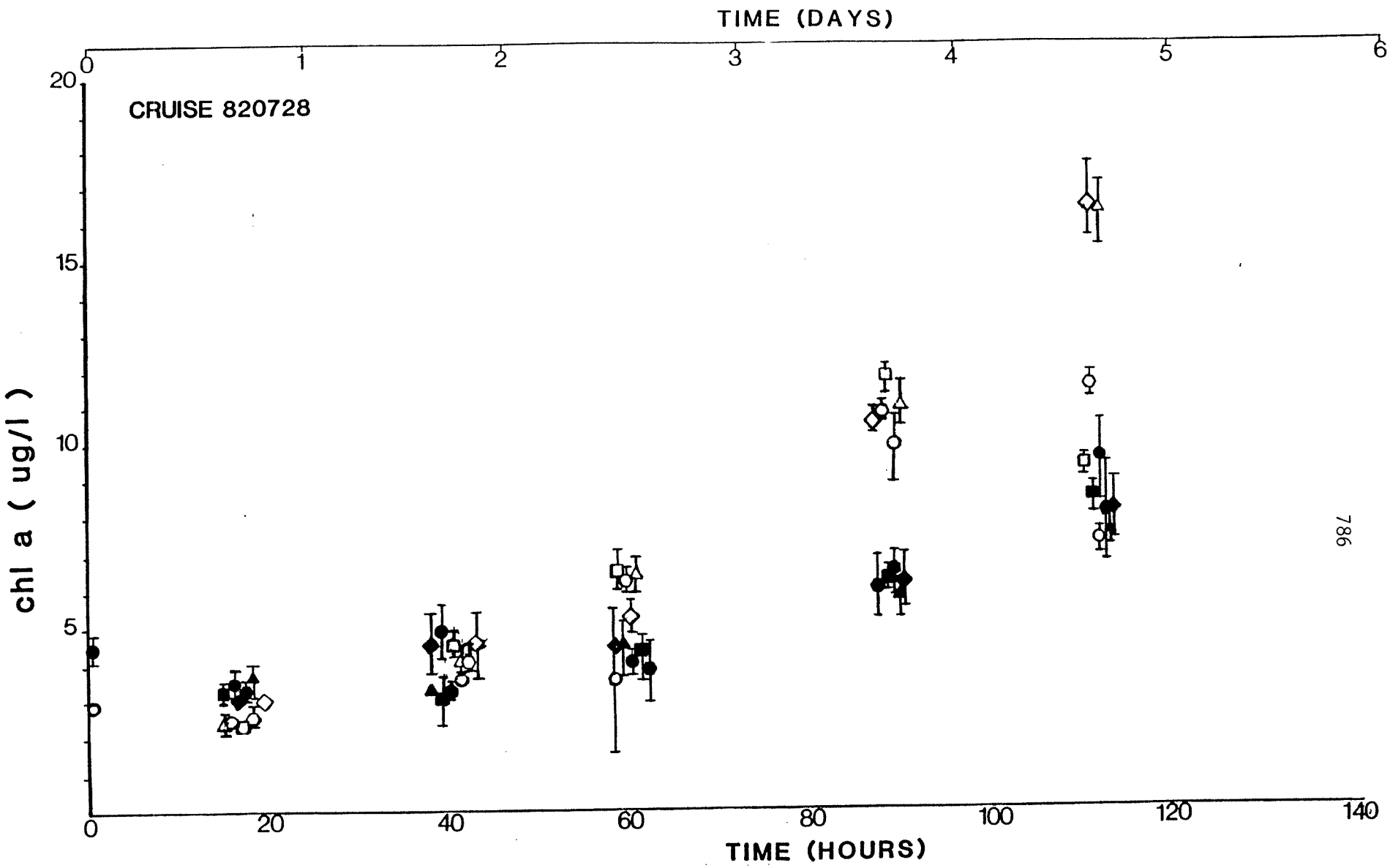





Figure 4C.5. Change in Chlorophyll a concentration with time in the nutrient enrichment bioassay for samples collected July 28, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

terminated too soon to determine if the response would have been proportional to N added.

Station 10 surface samples also contained relatively high nutrient concentrations (Table 4C.1), and data from the vertical profile showed a well-mixed condition. A ratio of N:P of 9:1 could suggest nitrogen limitation, yet nutrient enhancement had no significant impact upon chl a levels (Figure 4C.5), producing no differential growth from that of the controls. Because initial nutrient and chl a levels were similar at both stations, the lack of response at station 10 suggests the presence of inhibitory substances.

Carbon-14 uptake was very slow in water from both stations. By the third day, however, nitrogen enrichment had resulted in an increase in excess of the control in samples from station 4 (Figure 4C.6). As with chl a, no increase over control occurred at Station 10. Again, growth was far lower in these assays than available nutrients (nitrogen and phosphorus) should have produced. No major shifts in species composition appeared to occur. Chaetoceros spp. and Skeletonema costatum remained the dominant alga throughout the assay.

4.C.3.3 Cruise (August 2, 1982) No. 820802

As noted in Table 4C.1 and Figure 4C.1, nutrient concentrations suggest sufficient quantities to support growth at Station 4, yet chl a values were relatively low. The maximum concentrations measured in the water column were 2.8 ug/l chl a (at the surface), and 3.7 ug/l at the beginning of the assay. The maximum biomass achieved in the assay (Figure 4C.7) occurred in the 14.3 ug-at N/l treatment (20.1 $\pm$ 0.2 ug/l chl a), reflecting a 126% increase over the maximum attained in the control (8.9 $\pm$0.9 ug/l). There is also a clear differentiation in chl a between sucessive levels of nitrogen addition at day three. Maximum biomass was nearly proportional to the relative availability

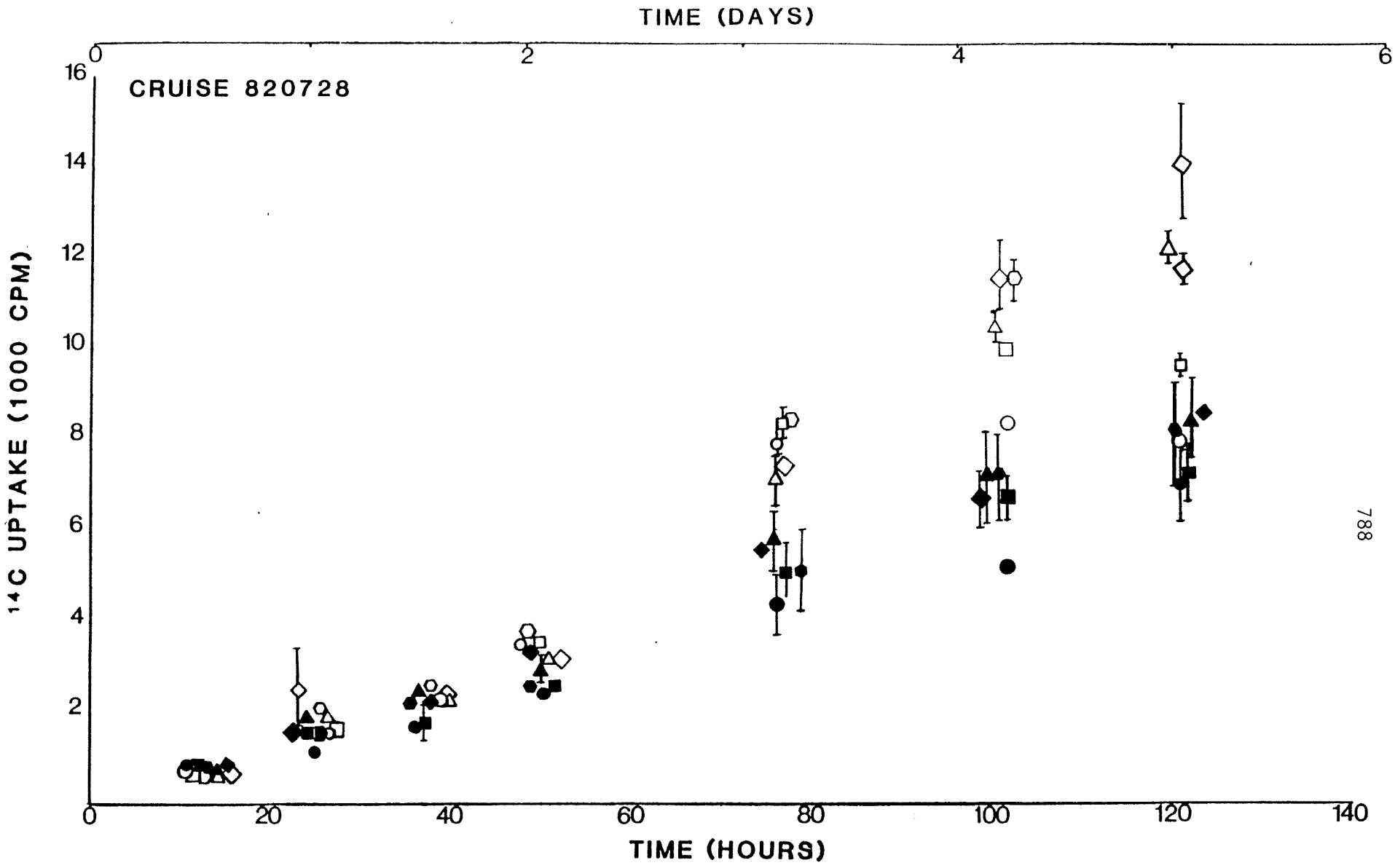



Figure 4C.6. Change in Carbon-14 uptake with time in the nutrient enrichment bioassay for water samples collected July 28, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

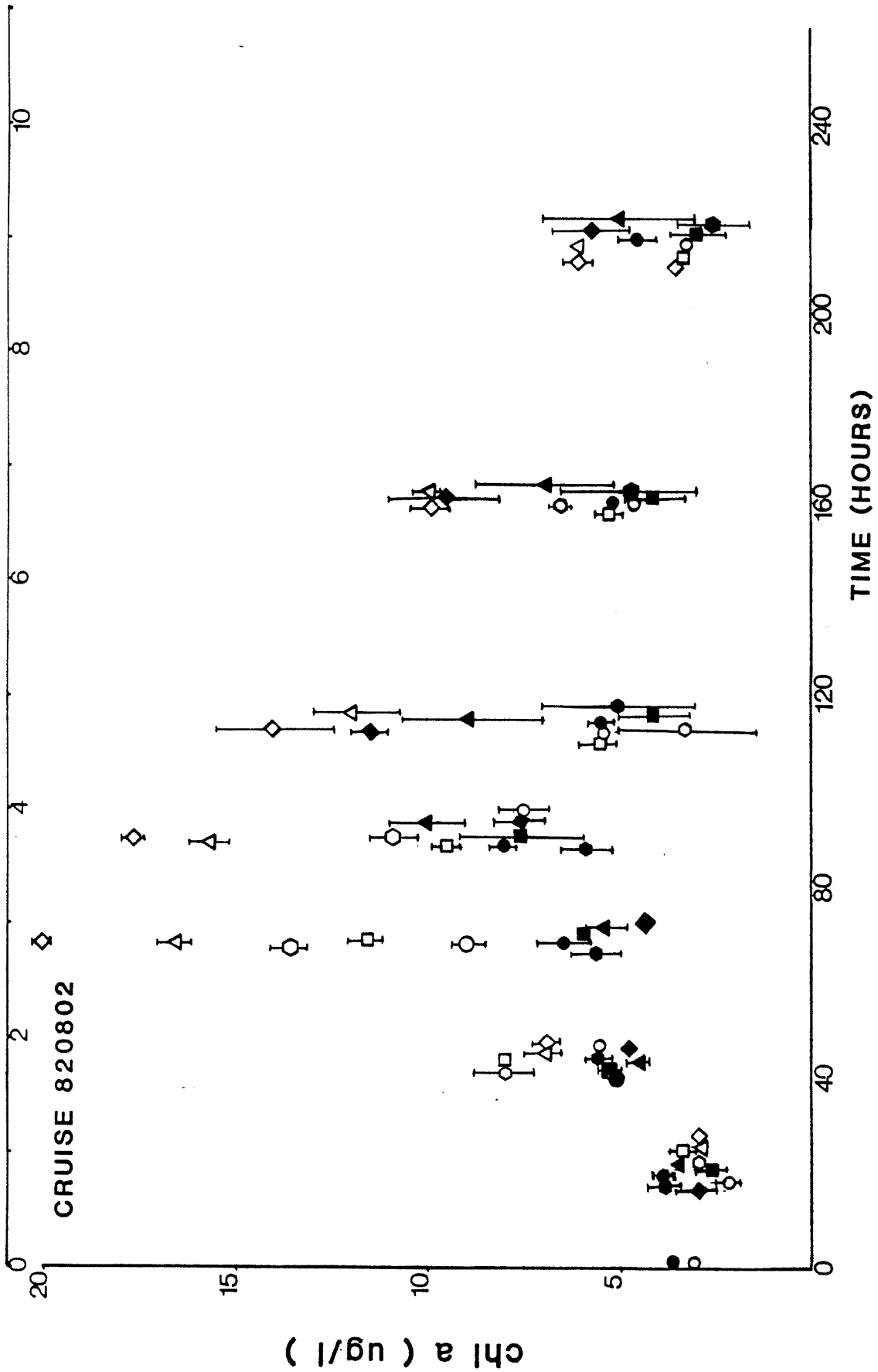



Figure 4C.7. Change in Chlorophyll a concentration with time in the nutrient enrichment bioassay for samples collected August 2, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

of nutrients provided. Beyond the third day, the algal population became more variable and crashed to pre-enrichment levels. N addition, at the highest level, approximately doubled available N and the maximum biomass reflected that doubling.

The water column at station 10 was again well-mixed and nutrients were rather abundant. Yet chl a levels were low (4.8 ug/l surface, 4.8 ug/l maximum in water column) due to the extensive mixing occurring in East Passage at that time. The maximum chl a levels produced in the algal assay occurred in the 14.3 ug-at/l addition, yielding 11.4 + 0.6 ug/l. The maximum attained by the control (8.0 $\pm$ 0.5 ug/l) is about 70% of that produced by the largest nitrogen addition. It is also notable that a considerable amount of variability occurred in this set of samples. As with results from earlier cruises, Station 10 water produced less than Station 4 at similar initial and added nutrient levels, suggesting inhibition in the nearshore area.

Considering Figure 4C.8, carbon-14 uptake increased rather rapidly by the second day in both assays, although consistent with chl a, Station 10 water produced less than at Station 4. Increasing nitrogen addition produced proportionately more response, especially at station 4. Carbon-14 uptake was also much greater in Station 4 samples, which exhibited more growth than those from Station 10. Overall, Station 4 water responded far more than Station 10 samples. N enrichment clearly stimulated growth over and above that in the control, as indicated by both chl a and $C^{14}$, with Station 4 water showing less inhibition than Station 10 water. Again, some species shifts were observed, but Chaetoceros spp. and Skeletonema costatum continued to be most prevalent.

4C.3.4 Cruise (August 16, 1982) No. 820816

Similar to previous cruises, initial nutrient concentrations at Stations 4 and 10 were available in N:P ratios of 6-7:1, indicating that nitrogen would

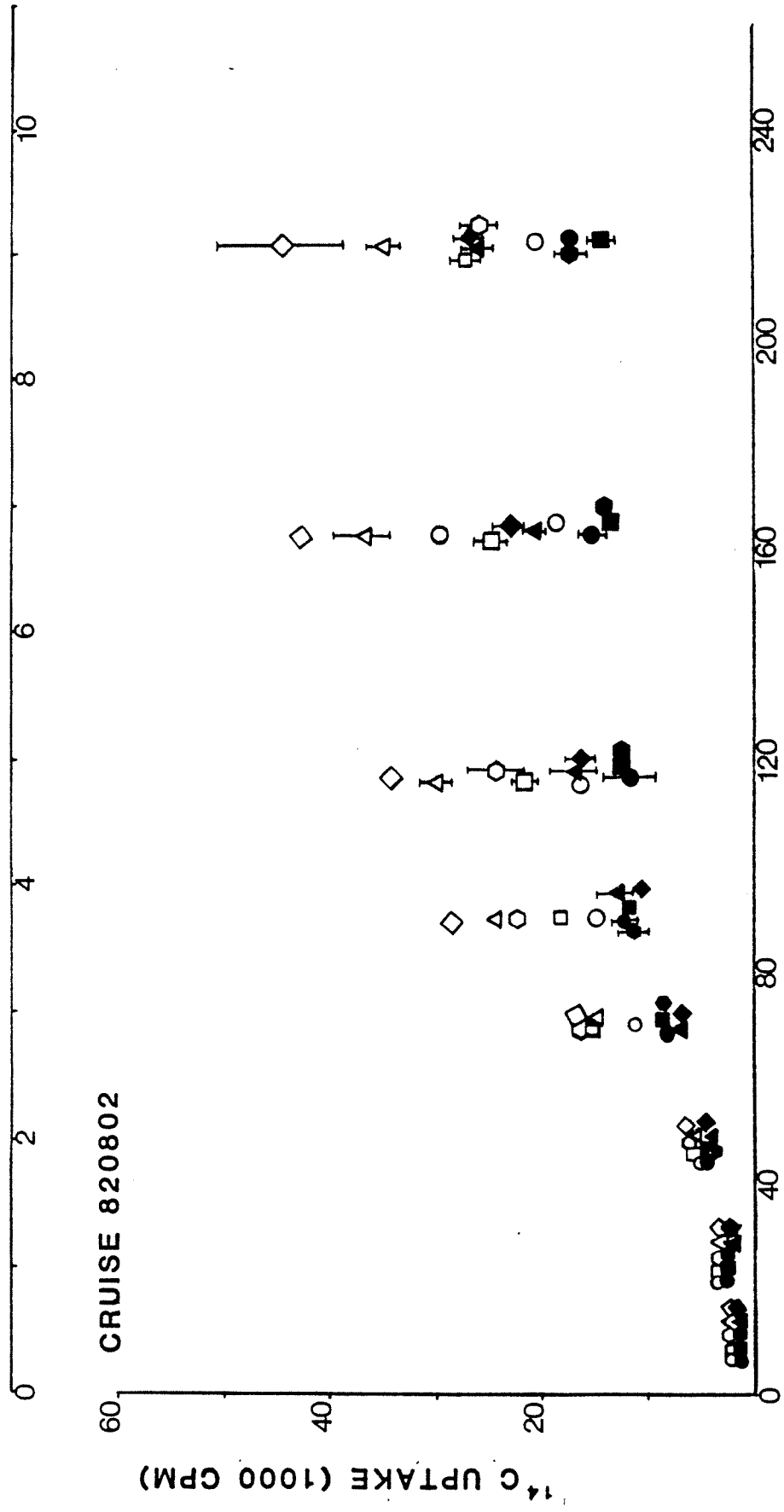



Figure 4C.8. Change in Carbon-14 uptake with time in the nutrient enrichment bioassay for water samples collected August 2, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

limit first. Nitrogen enrichment did result in differential chl a levels during both assays (Figure 4C.9), and response was in proportion to added N. Relative changes of 113% and 125% increases over control maximums were obtained for Stations 10 and 4, respectively. Maximum chl a levels were measured during the 6th day of the assay, beyond which the cultures ultimately crashed to low levels. It is also notable that introduction of the samples to laboratory conditions significantly increased the concentration of chl a in the controls from their initial levels. A rather radical shift from initial domination by dinoflagellates to final predominance of Chaetoceros spp. and Skeletonema costatum was observed during this assay.

Carbon-14 uptake was quite slow during the first four days of the assays, then increased rapidly during the fifth day (Figure 4C.10). Uptake rate again tended to differentiate between increasing nitrogen enrichment and suggested higher uptake rates at Station 4.

4C.3.5 Cruise (August 30, 1982) No. 820830

As noted in Table 4C.1 and Figure 4C.1, nutrient conditions at both Stations 4 and 10 reflect near exhaustion of surface nutrients. In considering vertical nutrient profiles in the water column, Station 4 showed a vertical stratification of nutrients, with low nutrient concentrations existing in the upper 3 m of water, while station 10 had very low values throughout its depth. Field measurements showed surface values of 28.3 ug/l and 28.2 ug/l chl a for Stations 4 and 10, respectively, with maximum levels of 36.6 ug/l and 28.2 ug/l occurring within the water column. These sites were clearly experiencing a fall bloom, and by the response to laboratory conditions (Figure 4C.11), probably in the declining stages of the bloom. Samples utilized to start this series of assays contained intitial chl a concentrations of 48.7 $\pm$ 1.9 ug/l (Station 4) and 15.7 $\pm$ 0.0 (Station 10).

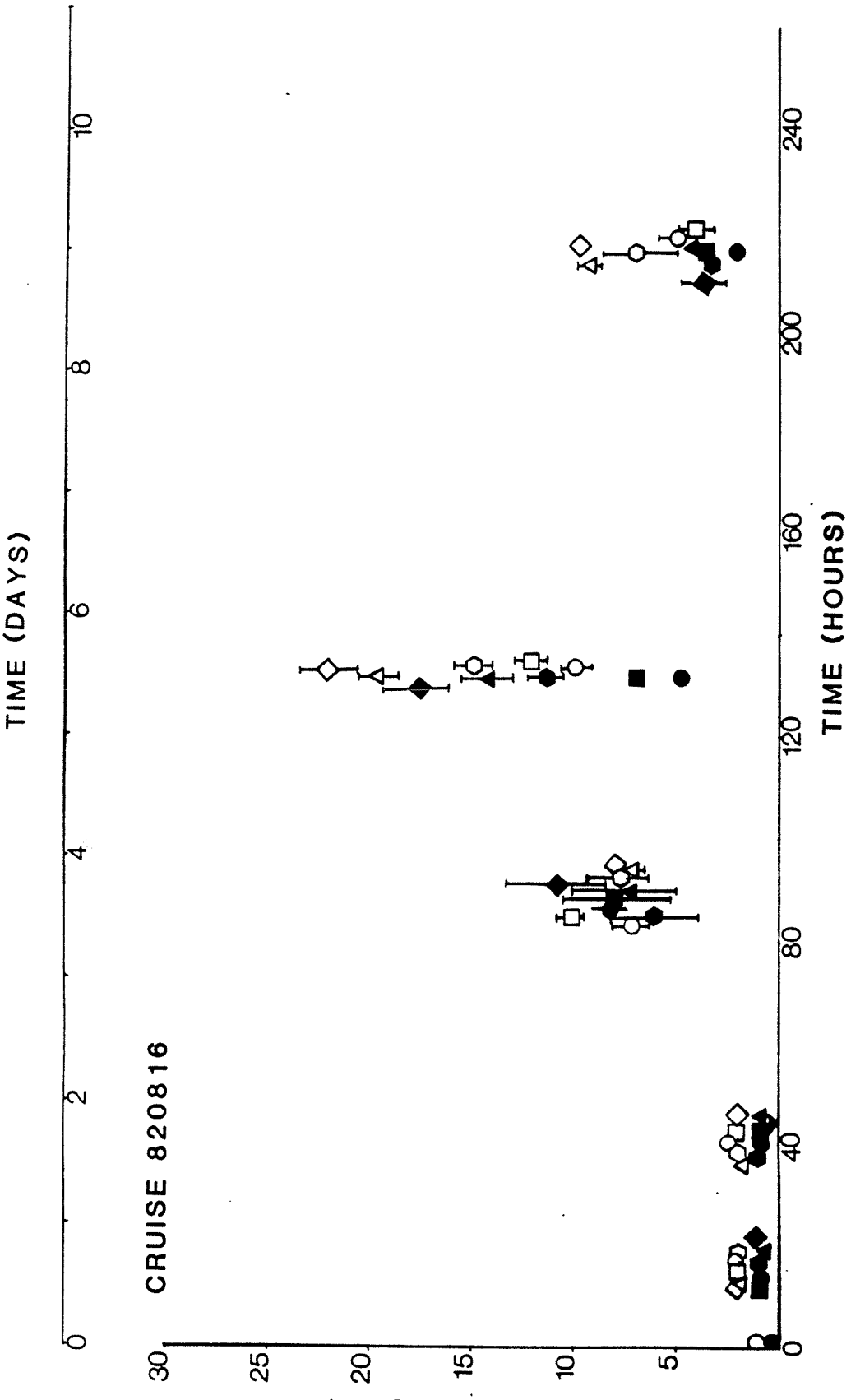



Figure 4C.9. Change in Chlorophyll a concentration with time in the nutrient enrichment bioassay for samples collected August 16, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

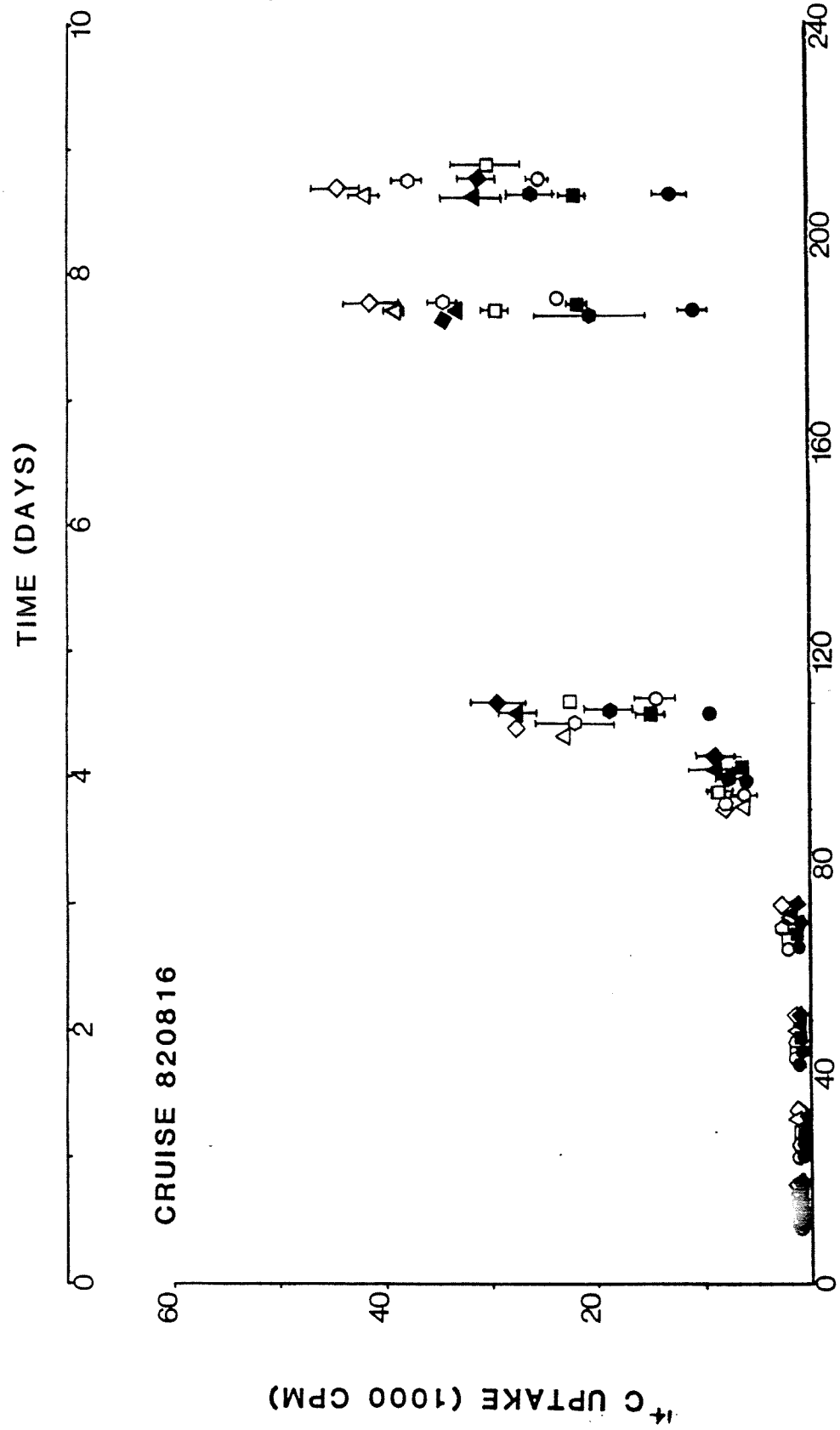



Figure 4C.10. Change in Carbon-14 uptake with time in the nutrient enrichment bioassay for water samples collected August 16, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

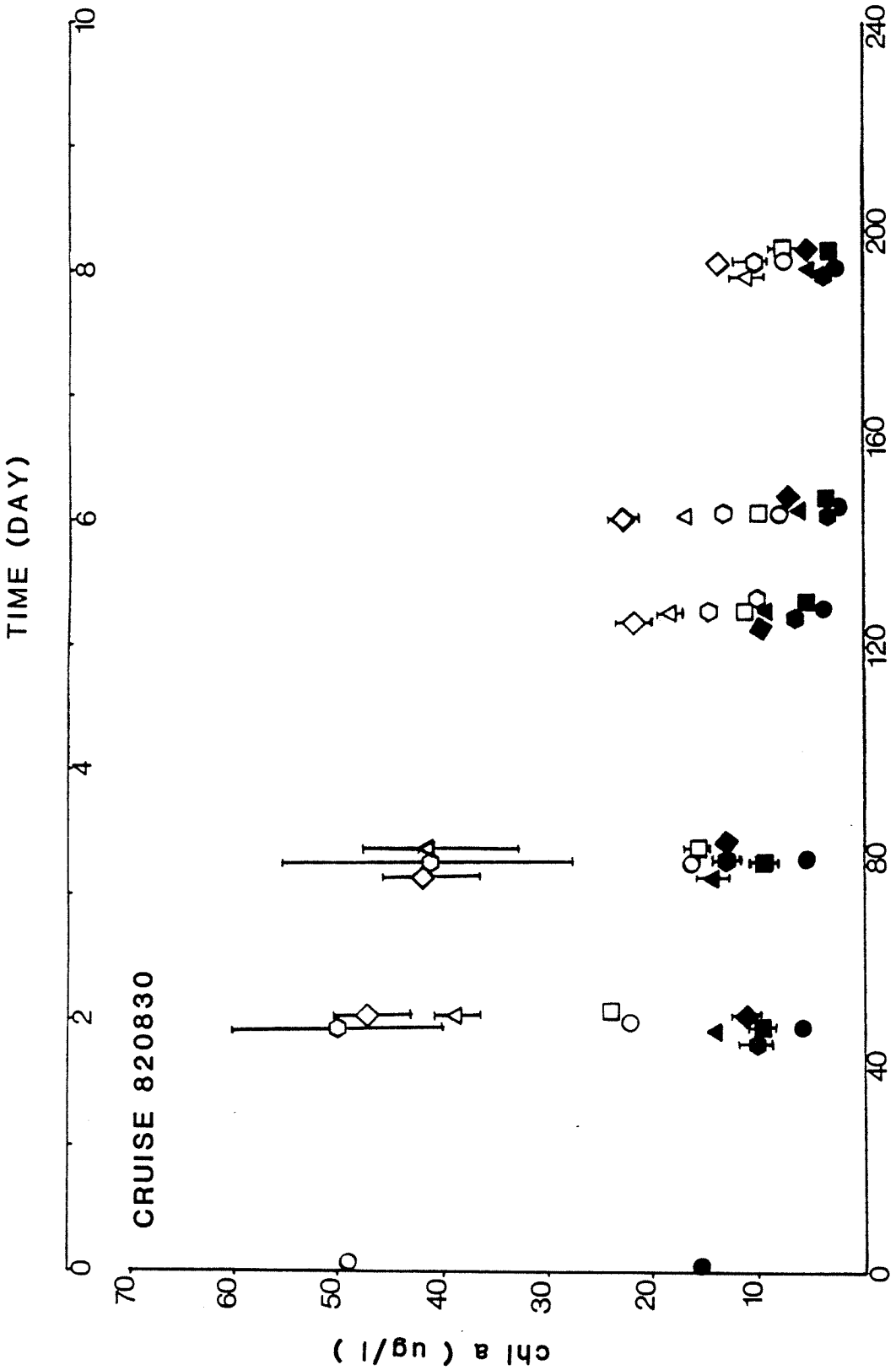



Figure 4C.11. Change in Chlorophyll a concentration with time in the nutrient enrichment bioassay for samples collected August 30, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

Nitrogen additions largely delayed the collapse of the algal population from Station 4, but only temporarily, indicating that the populations were probably senescing. At Station 10, nitrogen additions had no significant impact upon chl a levels, though they may have also slightly delayed the collapse of the algal culture.

Carbon-14 uptake proved to be quite rapid for Station 4 samples, (Figure 4C.12) and reflected high rates of uptake at both sites. By day 6, distinct differentiation of response to nutrients was apparent in both assays, with uptake by Station 4 samples exceeding levels observed in most of the previous assessments. As indicated by C-14 levels, Station 4's populations were maintaining a higher growth/assimilation rate than those at Station 10, again indicating that inhibition may be present nearshore.

## 4C.4 Conclusions

Results of these five assays have indicated several effects. To varying degrees, nitrogen enrichment increased chl a above initial levels existing at the time of sample collection. This is particularily notable in samples from Station 4, in which maximum chl a concentrations increased an average of about 10 g/l chl a over those in controls. Samples collected from Station 10 (nearshore) were less influenced by nitrogen addition even though initial N levels were similar to Station 4 suggesting possible inhibition in nearshore waters. Maximum chlorophyll levels obtained in these assays were usually about proportional to the available N provided, assuming a ratio of 7 N:1 Chl. However, if a large biomass of senescent populations existed at time of collection a positive response was not as obvious. $C^{14}$ uptake results usually paralleled those with chlorophyll and in most instances showed more consistent responses with time.

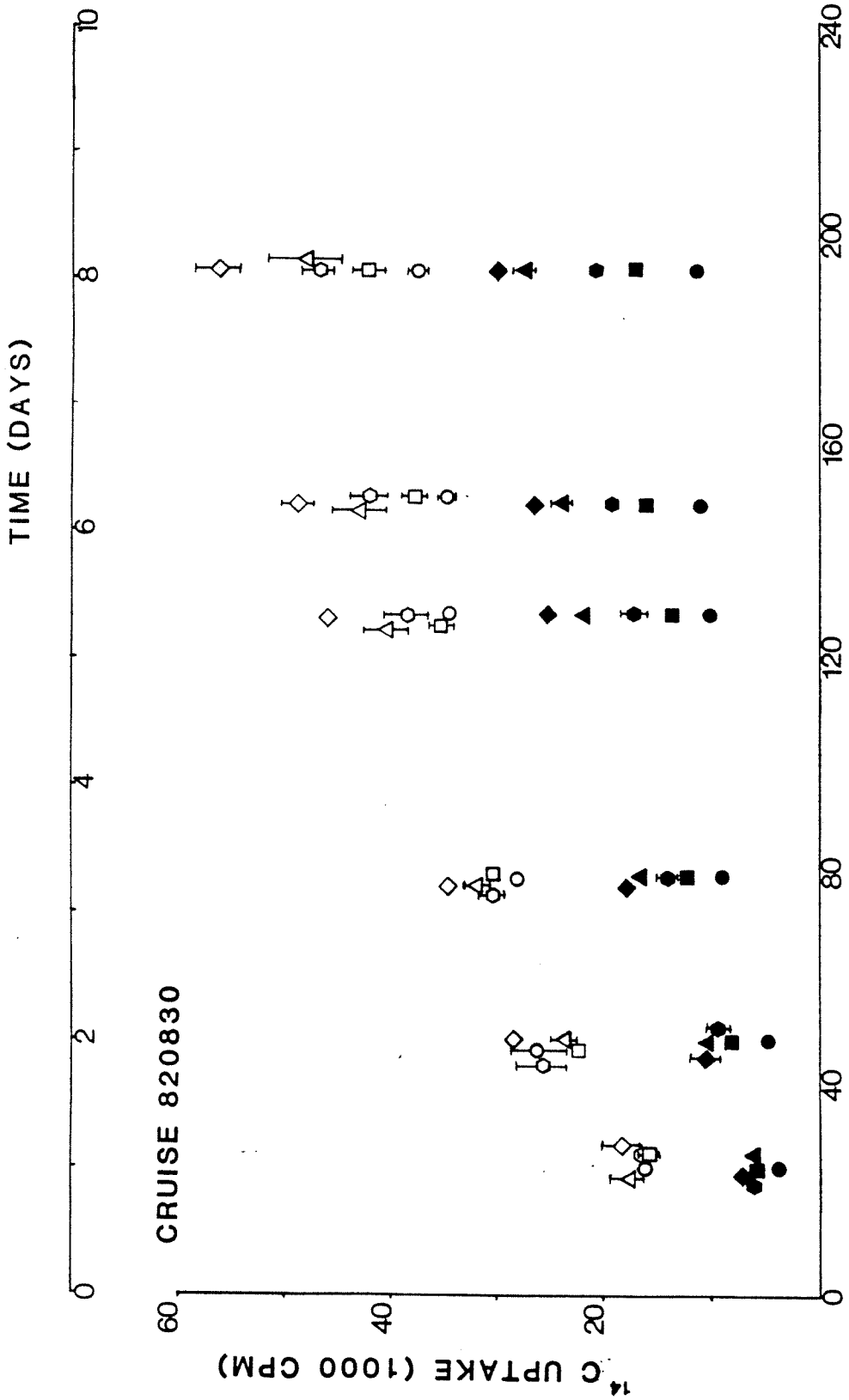



Figure 4C.12. Change in Carbon-14 uptake with time in the nutrient enrichment bioassay for water samples collected August 30, 1982 at Stations 4 (open symbols) and 10 (closed symbols). Enrichments were as noted in Figure 3.

With one exception, the response of endemic phytoplankton populations at Station 4, in open water, was positive to the addition of N, which indicates that of the two nutrients, N would become limiting first in the water column. However, it does not follow that N addition *in situ* would necessarily increase chl *a*. In fact, there was often enough N existing initially (controls) to stimulate additional growth apparently as a result of favorable physical conditions, probably light. On two occasions, when high concentrations of chl *a* and low concentrations of N did occur in the water column, further increases in biomass in the field could have been limited by N availability *in situ*. However, endemic populations at those times were apparently senescent and declined rather quickly after the assays were begun, whether N was added or not, which complicated the interpretation of response to nutrients. To better illucidate growth limiting potential under such conditions, bioassays with a low initial cell concentration (preferably a unispecies culture) would provide more easily interpretable results.

## References

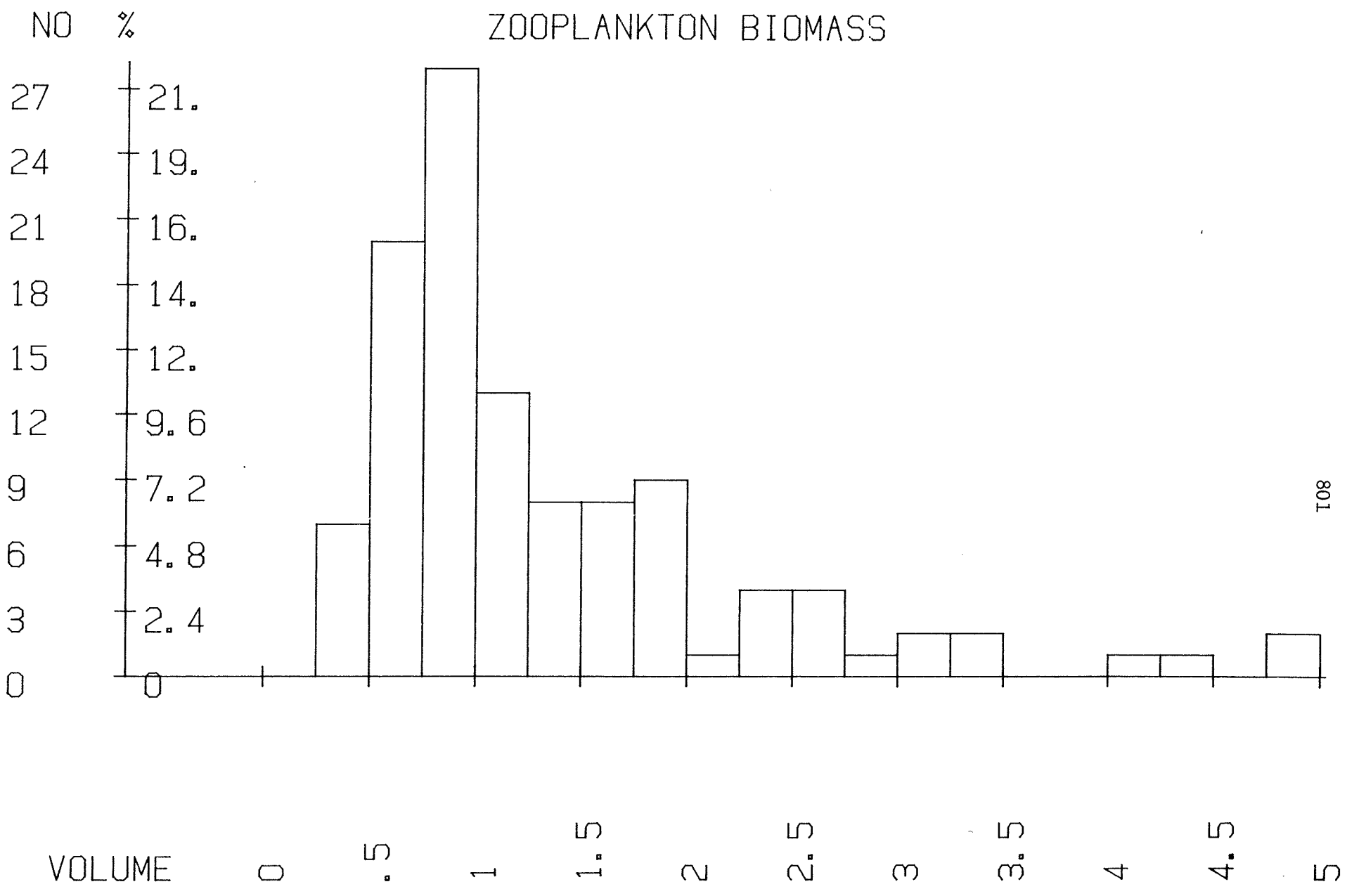
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Ryther, J. H. and W. M. Dunstan. 1971. "Nitrogen, phosphorus, and eutrophication in the coastal marine environment." Science 171 (1008-1013).

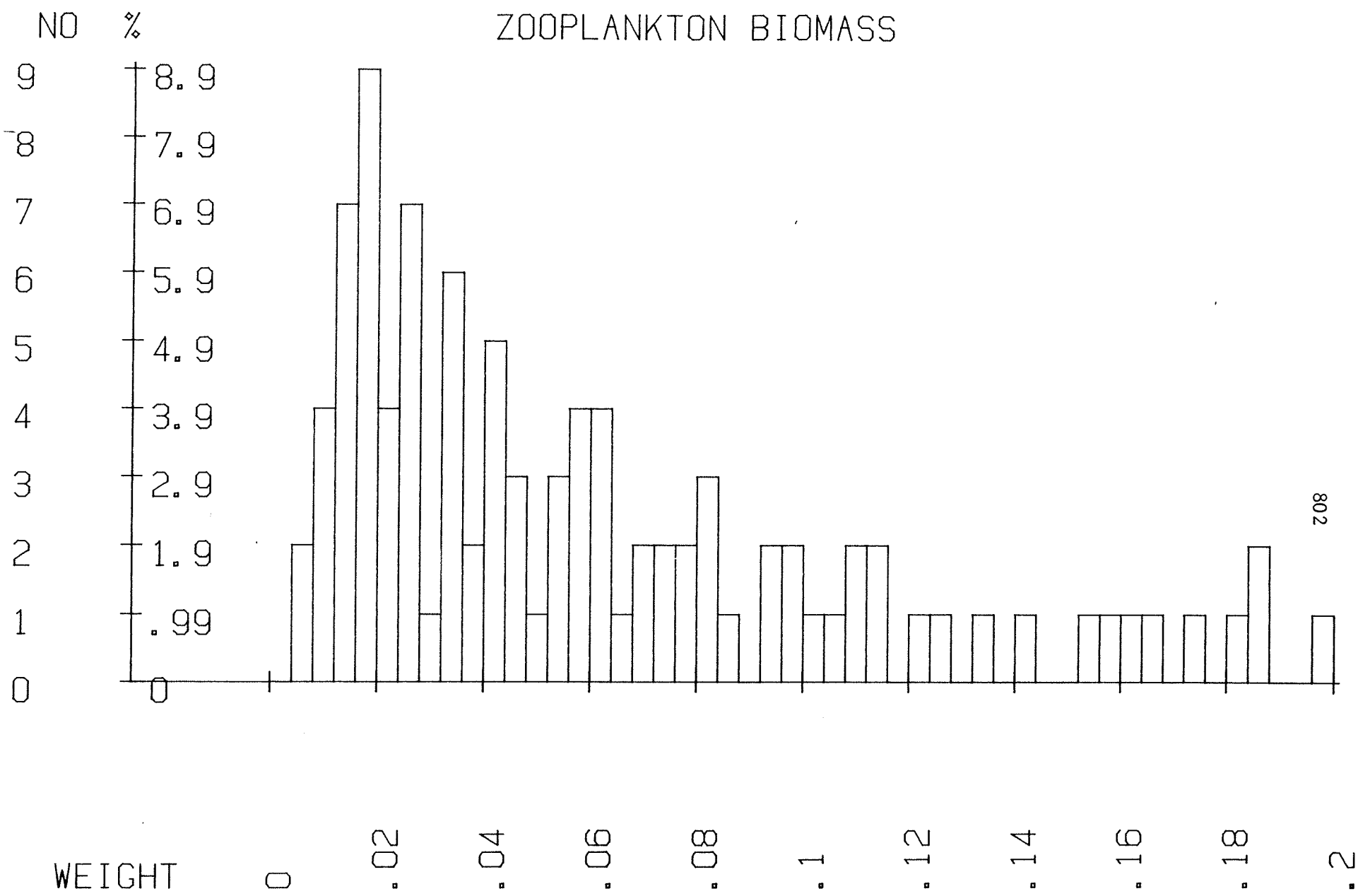
Yentsch, C. M., C. S. Yentsch, and L. R. Strube. 1977. "Variations in ammonium enhancement, an indication of nitrogen deficiency in New England coastal phytoplankton populations." Journal of Marine Research 35(3) (537-555).

# APPENDIX 4D

## PROBABILITY DISTRIBUTIONS OF ZOOPLANKTON BIOMASS, NEARSHORE STATIONS



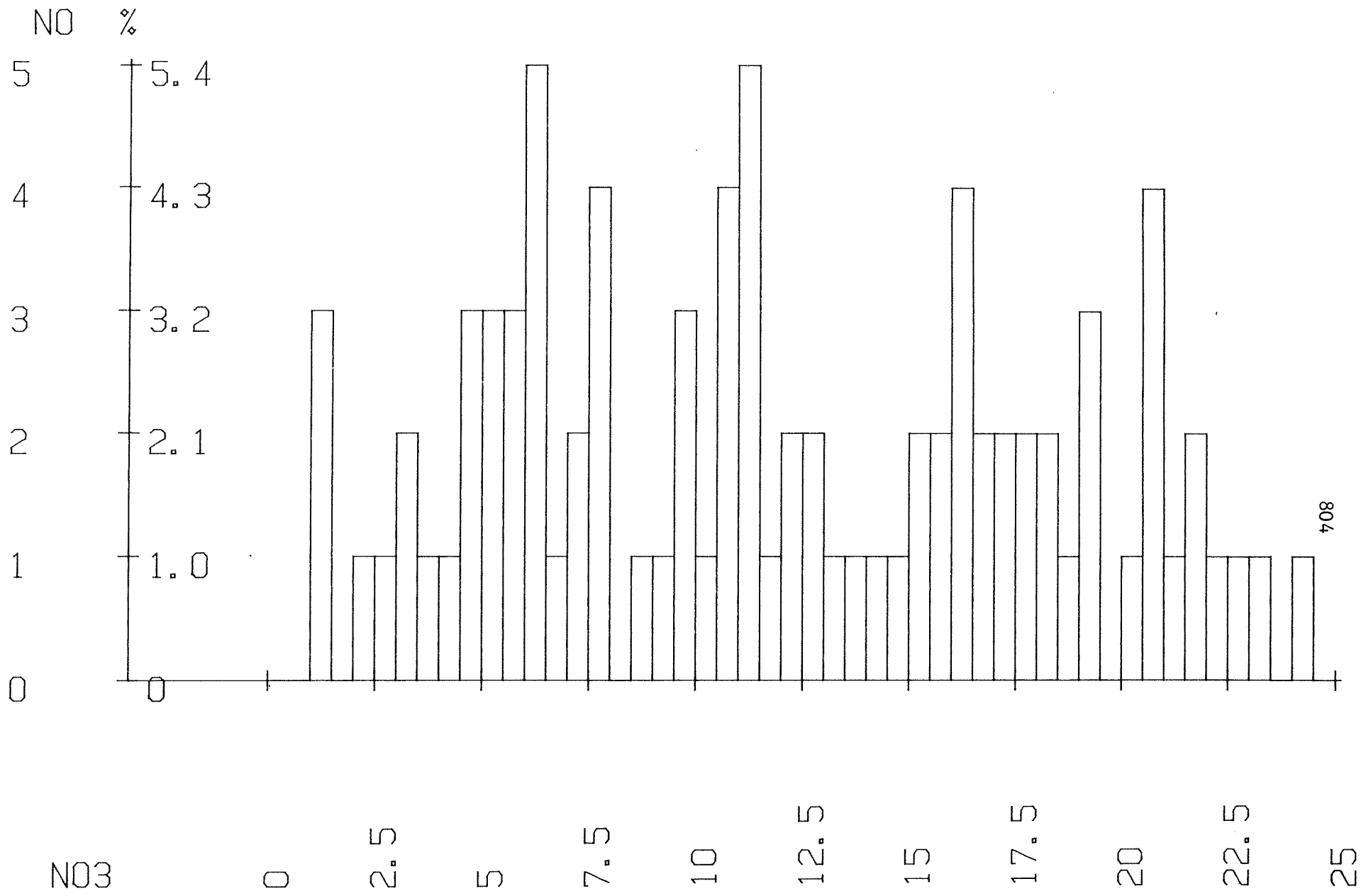

Appendix 4D.1. Probability distribution of zooplankton biomass (measured as wet volume) at nearshore stations (4-10) for the time period June, 1982 - January 1983. Zooplankton wet volume is in $ml/m^3$.



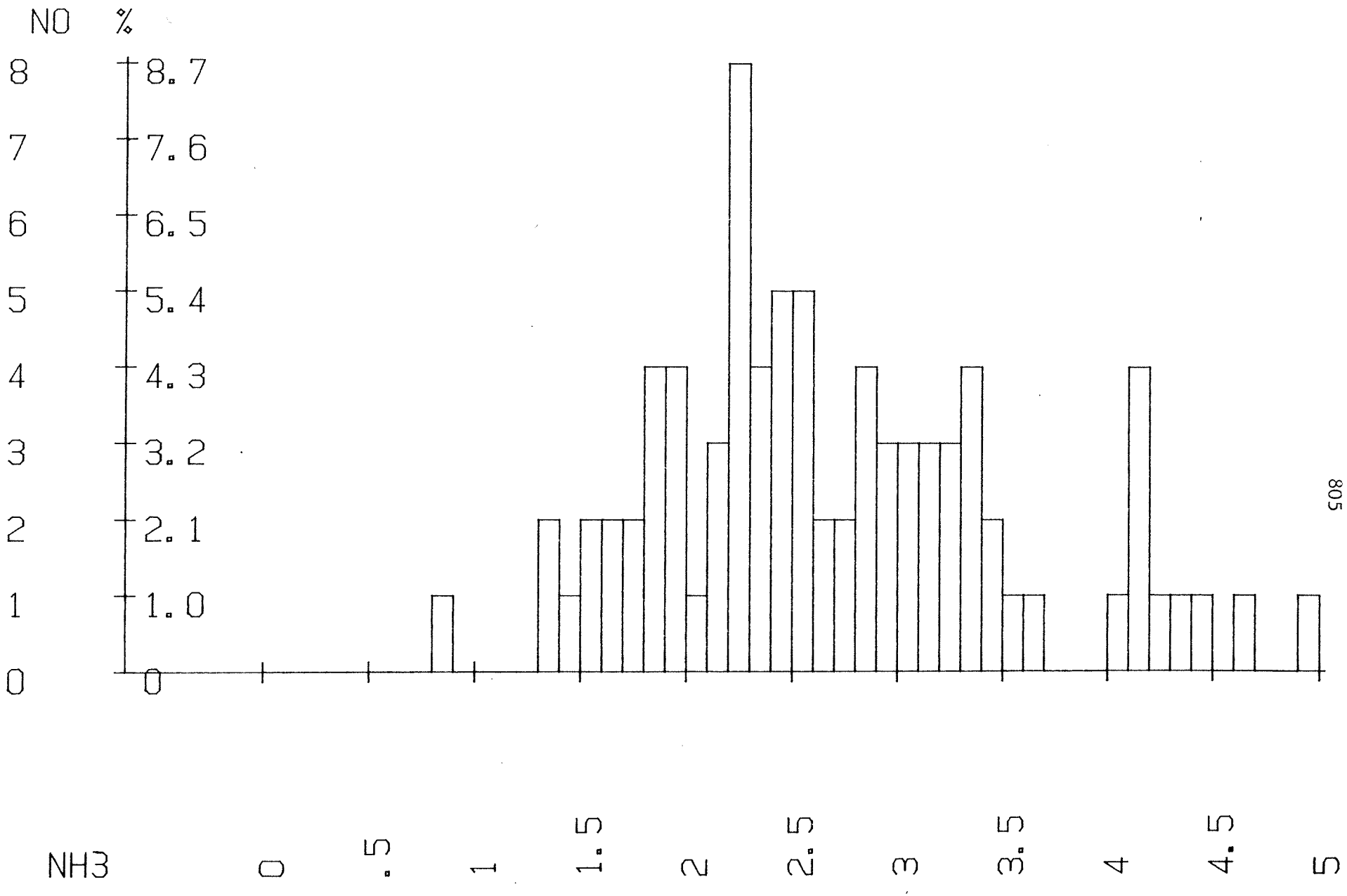

Appendix 4D.2. Probability distribution of zooplankton biomass (measured as dry weight) at nearshore stations (4-10) for the time period June, 1982 - January, 1983. Zooplankton dry weight is in $g/m^3$.

# APPENDIX 4E

## PROBABILITY DISTRIBUTIONS OF DISSOLVED NUTRIENTS, SEAHURST INSHORE STATIONS




Appendix 4E.1. Probability distribution of nitrate at Seahurst Park (surface) for the time period May, 1982 - January, 1983. Nitrate is in µg-at/l.






Appendix 4E.2. Probability distribution of ammonia at Seahurst Park (surface) for the time period May, 1982 - January, 1983. Ammonia is in µg-at/l.

# APPENDIX 4F

## SPECIES COUNTS OF PHYTOPLANKTON SPECIES ANALYSIS

PHYTOPLANKTON SPECIES ANALYSIS-1

(CELLS/LITER) 50% LIGHT DEPTH

| JDAY | 147 | 147 | 153 | 153 | 153 | 158 | 158 | 158 | 159 | 159 | 196 | 196 | 196 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATION | 7 | 10 | 4 | 7 | 10 | 4 | 7 | 10 | 1 | 3 | 4 | 7 | 10 |
| ATOMS | | | | | | | | | | | | | |
| letonema costatum | 514200 | 1.52E6 | 4800 | 3400 | 2800 | 1400 | 2200 | 8000 | 12600 | 1600 | 8.76E6 | 8.07E6 | 7.05E6 |
| ætoceros debilis | 29200 | 16400 | 1.03E6 | 1.45E6 | 955500 | 2.13E6 | 2.78E6 | 3.22E6 | 1.69E6 | 2.18E6 | 348500 | 36600 | 580785 |
| ær Chaetoceros spp. | 116600 | 93600 | 1.66E6 | 1.60E6 | 1.13E6 | 2.63E6 | 3.28E6 | 3.40E6 | 3.19E6 | 3.49E6 | 363500 | 126600 | 116846 |
| ilassiosira spp. | 143400 | 19500 | 473600 | 981000 | 702700 | 52000 | 69000 | 61200 | 84200 | 49400 | 32000 | 15600 | 33400 |
| ddulphia longicruris | 1200 | 400 | 5600 | 3400 | 2400 | 1800 | 2800 | 8000 | 4200 | 4200 | 0 | 0 | 0 |
| tzschia spp. | 134000 | 293266 | 34800 | 53600 | 49600 | 49800 | 42200 | 68800 | 92200 | 77600 | 303878 | 247302 | 288519 |
| tal Diatoms | 989000 | 2.14E6 | 3.34E6 | 4.14E6 | 2.94E6 | 4.91E6 | 6.21E6 | 6.80E6 | 5.11E6 | 5.85E6 | 9.84E6 | 8.55E7 | 8.12E6 |
| INOFLAGELLATES | | | | | | | | | | | | | |
| yaulax catenella | 0 | 0 | 0 | 0 | 1800 | 0 | 1400 | 6400 | 0 | 0 | 600 | 0 | 400 |
| sc. Peridinium sp. | 14600 | 10600 | 3400 | 17400 | 20200 | 3600 | 38800 | 56200 | 16400 | 1200 | 26200 | 18000 | 10400 |
| phidinium spp. | 1000 | 200 | 2000 | 3400 | 2200 | 13800 | 224820 | 134892 | 33800 | 82434 | 400 | 5600 | 4400 |
| tal Dinoflagellates | 37800 | 26600 | 73600 | 41200 | 42800 | 39200 | 293620 | 224292 | 75000 | 97034 | 99800 | 89800 | 84800 |
| NOANOFLAGELLATES | 0 | 0 | 0 | 0 | 0 | 63529 | 27227 | 63529 | 117892 | 45378 | 81680 | 27227 | 63529 |
| ICROFLAGELLATES | | | | | | | | | | | | | |
| ss than 10 micron | 834946 | 834946 | 952928 | 1.02E6 | 1.59E6 | 1.18E6 | 1.46E6 | 2.79E6 | 1.67E6 | 1.02E6 | 1.36E6 | 1.75E6 | 1.97E6 |
| 10 TO 20 micron | 744191 | 308567 | 453775 | 535455 | 671587 | 317643 | 626210 | 471926 | 426549 | 199661 | 426549 | 481002 | 707889 |
| eater than 20 micron | 136133 | 99831 | 117982 | 145208 | 145208 | 81680 | 90755 | 99831 | 45378 | 27227 | 99831 | 145208 | 226888 |
| CILIATES | 10200 | 9000 | 17600 | 7200 | 8800 | 12200 | 10400 | 15400 | 18200 | 6200 | 14200 | 13000 | 14600 |

PHYTOPLANKTON SPECIES ANALYSIS-2

CELLS PER LITER 50% LIGHT DEPTH

| JDAY | 196 | 196 | 197 | 200 | 200 | 200 | 207 | 209 | 209 | 209 | 209 | 214 | 214 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATION | 10 | 10 | 1 | 4 | 7 | 10 | 1 | 4 | 7 | 10 | 4 | 7 | 10 |
| DIATOMS | | | | | | | | | | | | | |
| Skeletonema costatum | 8.22E6 | 6.42E6 | 1.22E6 | 86181 | 10400 | 15000 | 4000 | 200 | 2200 | 1300 | 15600 | 106400 | 633243 |
| Chaetoceros debilis | 97422 | 168615 | 487110 | 528327 | 96400 | 247302 | 7600 | 1200 | 0 | 0 | 4200 | 3200 | 10400 |
| Other Chaetoceros spp. | 99000 | 130217 | 114200 | 153800 | 191800 | 208000 | 7600 | 1000 | 1000 | 400 | 1000 | 600 | 0 |
| Thalassiosira spp. | 14800 | 25400 | 5800 | 19200 | 7800 | 10800 | 0 | 0 | 400 | 0 | 200 | 7600 | 4800 |
| Biddulphia longicruris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitzschia spp. | 359712 | 368406 | 173162 | 27800 | 37200 | 37000 | 4000 | 2100 | 400 | 1200 | 800 | 1200 | 2600 |
| Total Diatoms | 9.26E6 | 7.21E6 | 2.03E6 | 861908 | 373400 | 567702 | 43800 | 12700 | 11100 | 7900 | 25000 | 122800 | 659843 |
| DINOFLAGELLATES | | | | | | | | | | | | | |
| Gonyaulax catenella | 1800 | 400 | 400 | 400 | 400 | 600 | 0 | 0 | 500 | 400 | 0 | 2000 | 3000 |
| Misc. Peridinium sp. | 10400 | 14200 | 125251 | 5600 | 6200 | 4400 | 11000 | 8100 | 6800 | 6500 | 5600 | 18000 | 27535 |
| Amphidinium spp. | 2200 | 1600 | 1800 | 400 | 400 | 400 | 400 | 500 | 400 | 100 | 200 | 600 | 400 |
| Total Dinoflagellates | 77100 | 98800 | 815752 | 30200 | 26800 | 26200 | 35600 | 32400 | 47400 | 45300 | 37400 | 114200 | 279114 |
| CHOANOFLAGELLATES | 9076 | 54453 | 0 | 27226 | 18151 | 18151 | 36302 | 13613 | 0 | 0 | 0 | 400 | 18152 |
| MICROFLAGELLATES | | | | | | | | | | | | | |
| less than 10 micron | 1.47E6 | 1.74E6 | 1.10E6 | 1.24E6 | 889399 | 744191 | 1.42E6 | 567219 | 1.12E6 | 1.46E6 | 1.33E6 | 2.53E6 | 2.41E6 |
| 10 TO 20 micron | 435624 | 526379 | 444700 | 235963 | 163359 | 127057 | 671587 | 149746 | 176982 | 422034 | 317660 | 481028 | 533636 |
| greater than 20 micron | 172435 | 181510 | 54453 | 63528 | 18151 | 36302 | 117892 | 45378 | 63532 | 54456 | 27228 | 45380 | 54456 |
| CILIATES | 13000 | 7600 | 11600 | 6000 | 6000 | 7000 | 8000 | 5600 | 8200 | 6600 | 9600 | 16400 | 14400 |

Appendix 4F.1. Phytoplankton species analysis. Phytoplankton counts are in cells/l.

| | JDAY | 221 | 221 | 221 | 223 | 223 | 228 | 228 | 228 | 235 | 235 | 235 | 236 | 236 | 236 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | STATION | 4 | 7 | 10 | 1 | 3 | 4 | 7 | 10 | 4 | 7 | 10 | 1 | 2 | 3 |
| TOMS | | | | | | | | | | | | | | | |
| etonema costatum | | 1.57E6 | 741906 | 2.29E6 | 370593 | 7.87E6 | 7000 | 800 | 4800 | 2200 | 1500 | 4500 | | 4400 | 10600 |
| toceros debilis | | 157374 | 87800 | 775629 | 543315 | 26000 | 12400 | 0 | 10400 | 5400 | 8300 | 2700 | 2400 | 112410 | 0 |
| r Chaetoceros spp. | | 29400 | 17400 | 10200 | 31600 | 7600 | 3200 | 800 | 1800 | 13600 | 16900 | 15400 | 6400 | 163110 | 1200 |
| assiosira spp. | | 65200 | 74800 | 83800 | 27200 | 88000 | 0 | 600 | 0 | 1000 | 500 | 0 | 200 | 500 | 500 |
| ulphia longicruri | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| schia spp. | | 6800 | 3000 | 800 | 3600 | 5200 | 1600 | 400 | 0 | 1600 | 800 | 600 | 500 | 2400 | 800 |
| l Diatoms | | 1.85E6 | 943506 | 3.16E6 | 986648 | 8.00E6 | 30200 | 9200 | 19800 | 33800 | 33000 | 26700 | 11600 | 185210 | 16900 |
| NOFLAGELLATES | | | | | | | | | | | | | | | |
| aulax catenella | | 0 | 0 | 0 | 0 | 0 | 600 | 1400 | 800 | 0 | 0 | 0 | 800 | 1800 | 1600 |
| . Peridinium sp. | | 4400 | 2400 | 3200 | 4600 | 2200 | 2600 | 1400 | 2200 | 400 | 200 | 100 | 2800 | 800 | 2200 |
| idinium spp. | | 0 | 0 | 0 | 600 | 0 | 0 | 0 | 200 | 0 | 100 | 0 | 200 | 200 | 100 |
| l Dinoflagellates | | 14200 | 22200 | 23200 | 29400 | 29000 | 35600 | 27400 | 56800 | 16200 | 14500 | 10000 | 26900 | 64105 | 162180 |
| ANOFLAGELLATES | | 27228 | 18152 | 0 | 18152 | 0 | 27228 | 9076 | 9076 | 0 | 4538 | 4538 | 0 | 4538 | 0 |
| CROFLAGELLATES | | | | | | | | | | | | | | | |
| s than 10 micron | | 962056 | 1.16E6 | 898524 | 1.31E6 | 1.5E12 | 889448 | 871296 | 825916 | 853144 | 490104 | 857682 | 1.62E6 | 816840 | 984746 |
| 10 TO 20 micron | | 90760 | 145216 | 127064 | 163368 | 72608 | 90760 | 63532 | 18152 | 72608 | 27228 | 36304 | 36304 | 31766 | 54456 |
| ater than 20 micron | | 36304 | 18152 | 9076 | 45380 | 0 | 18152 | 18152 | 0 | 9076 | 4538 | 4538 | 4538 | 0 | 0 |
| LIATES | | 1000 | 4200 | 3800 | 7000 | 9800 | 3400 | 2600 | 6000 | 1000 | 900 | 600 | 3900 | 700 | 600 |

| | JDAY | 242 | 242 | 242 |
|---|---|---|---|---|
| | STATION | 4 | 7 | 10 |
| DIATOMS | | | | |
| Skeletonema costatum | | 0 | 0 | 0 |
| Chaetoceros debilis | | 0 | 0 | 0 |
| Other Chaetoceros spp. | | 0 | 0 | 0 |
| Thalassiosira spp. | | 0 | 1200 | 1200 |
| Biddulphia longicruri | | 0 | 0 | 0 |
| Nitzschia spp. | | 1800 | 200 | 800 |
| Total Diatoms | | 4400 | 2600 | 5600 |
| DINOFLAGELLATES | | | | |
| Gonyaulax catenella | | 4800 | 3400 | 6000 |
| Misc. Peridinium sp. | | 800 | 1600 | 1800 |
| Amphidinium spp. | | 0 | 0 | 0 |
| Total Dinoflagellates | | 993420 | 410741 | 741277 |
| CHOANOFLAGELLATES | | 0 | 0 | 0 |
| MICROFLAGELLATES | | | | |
| less than 10 micron | | 1.52E6 | 1.35E6 | 1.19E6 |
| 10 TO 20 micron | | 99836 | 45380 | 45380 |
| greater than 20 micron | | 0 | 0 | 90766 |
| CILIATES | | 400 | 1400 | 1000 |

Appendix 4F.1. (continued).

# APPENDIX 4G

## SPECIES COUNTS FOR ZOOPLANKTON SPECIES ANALYSIS

ZOOPLANKTON SPECIES ANALYSIS-O

(IN NUMBERS PER METER CUBED)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 147 | 147 | 153 | 153 | 153 | 158 | 158 | 158 | 158 | 159 | 159 | 196 | 196 | 196 | 196 |
| STATION | 7 | 7 | 4 | 7 | 10 | 4 | 6 | 7 | 10 | 2 | 3 | 4 | 5 | 6 | 7 |
| CALANOIDS | | | | | | | | | | | | | | | |
| alanus marshallae | | 68 | | | | | | | | | | | | | |
| . pacificus | | 489 | 102 | 70 | | 150 | 282 | 502 | | 565 | 213 | | | | |
| . plumchrus | | | | | | | | | | | | | | | |
| icrocalanus sp. | | | | | | | | | | | | 306 | 357 | 336 | 340 |
| aracalanus sp. | | | | | | | | | | | | | | | 340 |
| seudocalanus sp. | 896 | 910 | 209 | 423 | 318 | 219 | 503 | 422 | | 410 | 235 | 74 | 117 | 204 | 119 |
| etidius divergens | | | | | | | | | | | | | | | |
| etridia lucens | | | | | | | | | | | 72 | | | | |
| entropages abdominalis | | | | | | | | | | | | | | | |
| andacia columbiae | | | | | | | | | | | | | | | |
| pilabidocera longipedata | | | | | | | | | | | | | | | |
| ortanus discaudatus | | | | | | | | | | | | | | | |
| cartia clausii | | | | | 701 | | | | | | | | | | |
| . longiremus | | | | | | | | | | | | | | | |
| CYCLOPOIDS | | | | | | | | | | | | | | | |
| Oithona similis | 421 | 394 | | | | 109 | 114 | 189 | | 118 | 177 | 232 | 265 | 112 | 204 |
| O. spinirostris | | | | | | | | | | | | | | | |
| Corycaeus anglicus | 584 | 584 | 693 | 1110 | 9873 | 390 | 653 | 986 | 12296 | 478 | 545 | 922 | 815 | 1284 | 1240 |
| AMPHIPODS | | | | | | | | | | | | | | | |
| Calliopus laeviusculus | | | | | | | | | | | | | | | |
| Cyphocaris challengeri | | | | | | | | | | | | | | | |
| Parathemisto pacifica | | | | | | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | | | | | | |
| CHORDATES | | | | | | | | | | | | | | | |
| Fritillaria borealis | | | | | | | | | | | | | | | 187 |
| Oikopleura dioica | 557 | 394 | | 59 | 318 | 55 | | 58 | 102 | | | 555 | 540 | 1141 | 2463 |
| O. labradoriensis | | | | | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | | | | | | |
| EGGS | 41 | | 21 | | | | | | | | | | | | |
| JUV/ADULTS | 489 | 448 | | 113 | 764 | 72 | 48 | 109 | 1020 | | | | | | |
| LARVAE | | | | | | | | | | | | | | | |
| Bivalves | | 109 | 40 | 32 | | 20 | 48 | | | | 47 | | | | |
| Gastropods | 285 | 231 | 102 | 70 | | 89 | 84 | | | | 61 | | | | |
| Polychaetes | | | | | | | | | 255 | | | | | | |
| Cirripedia nauplii | 122 | 95 | | | | | | | 204 | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | | | | |
| Copepod nauplii | 1697 | 842 | 119 | 488 | 5669 | 75 | 258 | 342 | 1428 | 410 | 72 | | | 295 | 730 |
| Euphausiacae eggs | | | | | | | | | | | | | | | |
| Euphausiacae nauplii | 163 | 122 | | | | | | | | | | | | | |



Appendix 4G.1. Zooplankton species analysis. Zooplankton counts are in numbers/$m^3$.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 196 | 196 | 196 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| STATION | 8 | 9 | 10 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| CALANOIDS | | | | | | | | | | |
| Calanus marshallae | | | | | | | | | | |
| C. pacificus | | | | | 316 | | | | | |
| C. plumchrus | | | | | | | | | | |
| Microcalanus sp. | 51 | | | 195 | 71 | | | | | |
| Paracalanus sp. | 349 | 570 | 459 | 280 | 407 | | 435 | | 1751 | 4439 |
| Pseudocalanus sp. | 229 | | | 102 | 30 | | | | | 204 |
| Metidius divergens | | | | | | | | | | |
| Metridia lucens | | | | | | | | | | |
| Centropages abdominalis | | | | | | | | | | |
| Candacia columbiae | | | | | | | | | | |
| Epilabidocera longipedata | | | | | | | | | | |
| Tortanus discaudatus | | | | | | | | | | |
| Acartia clausii | | | | | | | | | | |
| A. longiremus | | | | | | | | | | |
| CYCLOPOIDS | | | | | | | | | | |
| Oithona similis | 254 | 204 | | | 193 | | 258 | | | |
| O. spinirostris | | | | | | | | | | |
| Corycaeus anglicus | 993 | 1344 | 1428 | 1002 | 1100 | 1875 | 1861 | 1405 | 2037 | 1837 |
| AMPHIPODS | | | | | | | | | | |
| Calliopes laeviusculus | | | | | | | | | | |
| Cyphocaris challengeri | | | | | | | | | | |
| Parathemisto pacifica | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | |
| CHORDATES | | | | | | | | | | |
| Fritillaria borealis | 369 | 1263 | 1837 | | 204 | 275 | 312 | 214 | 1181 | |
| Oikopleura dioica | 2979 | 7047 | 12091 | 857 | 856 | 1202 | 2010 | 1303 | 5132 | 5969 |
| O. labradoriensis | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | |
| EGGS | | | | | | | | | | |
| JUV/ADULTS | | | | | | | | | | |
| LARVAE | | | | | | | | | | |
| Bivalves | | | | 170 | | | | | | |
| Gastropods | | | | | | | | | | 1377 |
| Polychaetes | | | | | | | | | | 204 |
| Cirripedia nauplii | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | |
| Copepod nauplii | 980 | 896 | 2857 | 390 | 285 | 733 | 258 | 387 | 2159 | 6990 |
| Euphausiacae eggs | | | | | 754 | 458 | 747 | 988 | 2077 | |
| Euphausiacae nauplii | | | | | | 61 | 122 | 142 | 285 | |

Appendix 4G.1. (continued).

ZOOPLANKTON SPECIES ANALYSIS-I

(IN NUMBERS PER METER CUBED)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 207 | 207 | 207 | 207 | 209 | 209 | 209 | 209 | 209 | 209 | 209 |
| STATION | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| LANOIDS | | | | | | | | | | | |
| unus marshallae | 5 | | | | | | | | | | |
| pacificus | 180 | 150 | 99 | 179 | 215 | 161 | 194 | 173 | 247 | 25 | 34 |
| pluschrus | | | | | | | | | | | |
| rocalanus sp. | 355 | 64 | 247 | 222 | 283 | 849 | 621 | 509 | 466 | 8 | |
| acalanus sp. | 436 | 472 | 235 | 370 | 515 | 569 | 611 | 530 | 1499 | 255 | 476 |
| udocalanus sp. | | | 74 | 747 | | | | | | | |
| idius divergens | | | | | | | | | | | |
| ridia lucens | | | 86 | 111 | 68 | 569 | 92 | 61 | 44 | | |
| tropages abdominal | | | | | | | | | | | |
| dacia columbiae | | | | | | | | | | | |
| labidocera longipe | | | | | | | | | | | |
| tanus discaudatus | | | | | | | | | | | |
| rtia clausii | | | | | | | | | | | |
| longiremus | | | | | | | | | | | |
| ICLOPOIDS | | | | | | | | | | | |
| hona similis | 460 | 279 | 401 | 364 | 555 | 569 | 387 | 367 | 611 | 289 | 510 |
| spinirostris | | | | | | | | | | | |
| ycaeus anglicus | 1199 | 2102 | 850 | 1247 | 1602 | 1452 | 1202 | 1274 | 2139 | 1324 | 3741 |
| AMPHIPODS | | | | | | | | | | | |
| Calliopus laeviusculus | | | | | | | | | | | |
| Cyphocaris challenger | 14 | | | | | | | | | | |
| Paratheanisto pacifica | 90 | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | | |
| CHORDATES | | | | | | | | | | | |
| Fritillaria borealis | | | | | | | | | | | |
| Oikopleura dioica | | 172 | | | | | | | | 42 | |
| O. labradoriensis | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | | |
| EGGS | 66 | | | | | | | | | | |
| JUV/ADULTS | | 75 | | | | | | | | | |
| LARVAE | | | | | | | | | | | |
| Bivalves | | | | | | | | | 20 | | 25 34 |
| Gastropods | 156 | 139 | 321 | 321 | 136 | 263 | 295 | 122 | 320 | 25 | 272 |
| Polychaetes | | | | | | | | | | | 34 |
| Cirripedia nauplii | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | |
| Copepod nauplii | | 64 | | | | | | | | 25 | |
| Euphausiacae eggs | | | | | | | | | | | |
| Euphausiacae nauplii | | | | | | | | | | | |



Appendix 4G.1. (continued).

ZOOPLANKTON SPECIES ANALYSIS-2

(IN NUMBERS PER METER CUBED)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 221 | 221 | 221 | 221 | 221 | 221 | 221 | 221 |
| STATION | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 4 | 5 | 6 | 7 | 7 | 8 | 9 | 10 |
| CALANOIDS | | | | | | | | | | | | | | | |
| ilanus marshallae | | | | | | | | | | | | | | | |
| pacificus | 181 | 190 | 296 | 280 | 115 | | | 35 | 117 | 53 | 58 | 74 | | | |
| plumchrus | | | | | | | | | | | | | | | |
| crocalanus sp. | 323 | 301 | 1223 | 560 | 95 | | 44 | 320 | 631 | 939 | 495 | 407 | | | |
| racalanus sp. | 572 | 347 | 361 | 416 | 476 | 416 | 305 | 338 | 577 | 354 | 543 | 611 | 365 | | 102 |
| eudocalanus sp. | | | | | | 59 | 38 | | | | | | | | |
| ltidius divergens | | | | | | | | | | | | | | | |
| tridia lucens | 62 | | | | | | | | | | | | | | |
| ntropages abdominalis | | | | | | | | | | | | | | | |
| edacia columbiae | | | | | | | | | | | | | | | |
| ilabidocera longipedata | | | | | | | | | | | | | | | |
| rtanus discaudatus | | | | | | | | | | | | | | | |
| artia clausii | | | | | | | | | | | | | | | |
| longirenus | | | 18 | | 6 | | | | | | | | | | |
| | | | 9 | | | | | | | | | | | | |
| CYCLOPOIDS | | | 18 | | 6 | | | | | | | | | | |
| ithona similis | 226 | 236 | 296 | 246 | 439 | 170 | | 390 | 568 | 487 | | 852 | 647 | 764 | 617 |
| . spinirostris | | | | | | | | | | | | | | | |
| rycaeus anglicus | 843 | 1107 | 1426 | 840 | 1261 | 1137 | 770 | 547 | 875 | 815 | 961 | 760 | 863 | 326 | 490 |
| AMPHIPODS | | | | | | | | | | | | | | | |
| Calliopus laeviusculus | | | | | | | | | | | | | | | |
| Cyphocaris challengeri | | | | | | | | 55 | | | | | | | |
| Paratheraisto pacifica | | | | | | | | 93 | | | | | | | |
| CLADOCERANS | | | | | | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | | | | | | |
| CHORDATES | | | | | | | | | | | | | | | |
| Fritillaria borealis | 34 | | | | 48 | 42 | 25 | | | 54 | 44 | 39 | | 114 | | 312 |
| Oikopleura dioica | 79 | | | 42 | 29 | 68 | 121 | 81 | 63 | 71 | 68 | 65 | 863 | 279 | 203 |
| O. labradoriensis | | | | | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | | | | | | |
| EGGS | | | | | | | | | | | | | | | |
| JUV/ADULTS | | | | 85 | | | 19 | | | | | | | | |
| LARVAE | | | | | | | | | | | | | | | |
| Bivalves | | | | | | | | | | | | | 48 | | |
| Gastropods | 96 | 111 | | | 172 | | | 163 | 189 | 62 | 145 | 167 | 335 | | 102 |
| Polychaetes | | | | | | | | | | | | | | | |
| Cirripedia nauplii | | | | | | | | | | | | | | | 133 |
| Cirripedia cyprid | | | | | | | | | | | | | | | |
| Copepod nauplii | | | | | | | | | | | | | | 127 | 108 |
| Euphausiacae eggs | | | | | | | 59 | | | | | | | 183 | 44 |
| Euphausiacae nauplii | | | | | | | | | | | | | | 56 | 32 |

Appendix 4G.1. (continued).

ZOOPLANKTON SPECIES ANALYSIS-3

(IN NUMBERS PER METER CUBED)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 223 | 223 | 223 | 228 | 228 | 228 | 228 | 228 | 228 | 228 | 235 | 235 | 235 | 235 | 235 |
| STATION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 4 | 5 | 6 | 7 | 8 |
| CALANOIDS | | | | | | | | | | | | | | | |
| Calanus marshallae | | | | | | | | | | | | | | | |
| C. pacificus | | 74 | | 23 | 93 | 70 | 93 | 133 | 143 | | 23 | 51 | | | |
| C. plumchrus | | | | | | | | | | | | | | | |
| Microcalanus sp. | 319 | 463 | 106 | 240 | 111 | 228 | 130 | | | | 104 | 346 | 526 | 183 | 46 |
| Paracalanus sp. | 908 | 201 | 345 | 1500 | 2168 | 1704 | 2297 | 694 | 881 | 2184 | 1301 | 2659 | 1630 | 2466 | 1703 |
| Pseudocalanus sp. | | | | | | | | | | | | 244 | 102 | 61 | 15 |
| Aetidius divergens | | | | | | | | | | | | | | | |
| Metridia lucens | | 37 | | | | | | | | | | | | | |
| Centropages abdominalis | | | | | | | | | | | | | | | |
| Candacia columbiae | | | | | | | | | | | | | | | |
| Epilabidocera longipedata | | | | | | | | | | | | | | | |
| Tortanus discaudatus | | | | | | | | | | | | | | | |
| Acartia clausii | | | | | | | | | | | | | | | |
| A. longiremus | | | | | | | | | | | | | | | |
| CYCLOPOIDS | | 18 | | 6 | | | | | | | | | | | |
| Oithona similis | 398 | 593 | 748 | 583 | 667 | 457 | 463 | 1063 | 253 | | 714 | 1029 | 883 | 978 | 654 |
| O. spinirostris | | | | | | | | | | | | | | | |
| Corycaeus anglicus | 796 | 519 | 578 | 630 | 908 | 703 | 945 | 1727 | 1157 | 1061 | 967 | 1049 | 764 | 1345 | 1019 |
| AMPHIPODS | | | | | | | | | | | | | | | |
| Calliopus laeviusculus | | | | | | | | | | | | | | | |
| Cyphocaris challengeri | | 55 | | | | | | | | | | | | | |
| Parathemisto pacifica | | 93 | | | | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | | | | | | |
| CHORDATES | | | | | | | | | | | | | | | |
| Fritillaria borealis | 227 | 37 | 249 | 80 | 93 | 193 | 93 | 753 | 540 | 714 | | 51 | | | |
| Oikopleura dioica | 148 | 25 | 255 | 103 | 296 | 457 | 333 | 1284 | 771 | 633 | 196 | 224 | 136 | 326 | 198 |
| O. labradoriensis | | | | | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | | |
| Sagitta elegans | | | | | | | | | | | | | | | |
| EGGS | | | | | | | | | | 204 | | | | | |
| JUV/ADULTS | | | | | | | | | | | | | | | |
| LARVAE | | | | | | | | | | | | | | | |
| Bivalves | | 55 | 85 | 46 | 148 | | | | | | 23 | | 51 | 61 | |
| Gastropods | 111 | 167 | 44 | 11 | 222 | 158 | 204 | 399 | 88 | | 92 | 224 | 238 | 143 | 122 |
| Polychaetes | | | | | | | | | | | | | | | |
| Cirripedia nauplii | | | | | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | | | | |
| Copepod nauplii | | | | 34 | 93 | 263 | 111 | 266 | 231 | 143 | | | | | |
| Euphausiacae eggs | | | | | | | | | | | | 183 | 339 | 102 | 167 |
| Euphausiacae nauplii | | | | 80 | | 53 | | | | | | 92 | 34 | 61 | |



Appendix 4G.1. (continued).

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 235 | 235 | 236 | 236 | 236 | 242 | 242 | 242 | 242 | 242 | 242 | 242 |
| | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **NLANOIDS** | | | | | | | | | | | | |
| lanus marshallae | | | | | | | | | | | | |
| pacificus | | | 139 | | 61 | 34 | 38 | 145 | 75 | | | |
| pluschrus | | | | | | | | | | | | |
| crocalanus sp. | | | 343 | 50 | 190 | 80 | 197 | 446 | 226 | 222 | 15 | |
| racalanus sp. | 245 | 1095 | 2500 | 729 | 877 | 1750 | 379 | 1310 | 1019 | 989 | 424 | 1592 |
| eudocalanus sp. | | | 213 | | | | | | | | | |
| tidius divergens | | | | | | | | | | | | |
| tridia lucens | | | | | 24 | 11 | | 58 | | | | |
| ntropages abdominalis | | | | | | | | | | | | |
| ndacia columbiae | | | | | | | | | | | | |
| ilabidocera longipedata | | | | | | | | | | | | |
| rtanus discaudatus | | | | | | | | | | | | |
| artia clausii | | | | | | | | | | | | |
| longirenus | | | | | | | | | | | | |
| **YCLOPOIDS** | | | | | | | | | | | | |
| thona similis | 170 | 942 | 741 | 509 | 319 | 403 | 293 | 786 | 462 | 462 | 154 | 318 |
| spinirostris | | | | | | | | | | | | |
| rycaeus anglicus | 896 | 2445 | 1121 | 1468 | 632 | 794 | 516 | 883 | 915 | 843 | 779 | 10700 |
| **MPHIPODS** | | | | | | | | | | | | |
| illiopus laeviusculus | | | | | | | | | | | | |
| yphocaris challengeri | | | | | | | | | | | | |
| rathemisto pacifica | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CLADOCERANS** | | | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | | | |
| **CHORDATES** | | | | | | | | | | | | |
| Fritillaria borealis | 19 | 280 | | 210 | | 34 | | | | | | |
| Oikopleura dioica | 292 | 891 | 93 | 400 | 86 | 92 | 60 | 136 | 104 | 47 | 54 | 2229 |
| O. labradoriensis | | | | | | | | | | | | |
| **CHAETOGNATHS** | | | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | | | |
| EGGS | | | | | | | | | | | | |
| JUV/ADULTS | | | | | | | | | | | | |
| **LARVAE** | | | | | | | | | | | | |
| Bivalves | | | | | 67 | 34 | 25 | 87 | 28 | | | |
| Gastropods | | 204 | 178 | | 215 | 34 | 29 | 116 | 28 | 164 | 31 | 382 |
| Polychaetes | | | | | | | | | | | | |
| Cirripedia nauplii | 47 | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | |
| Copepod nauplii | | | | | | | | | | | 23 | |
| Euphausiacae eggs | 198 | | 241 | | | | | | | | | |
| Euphausiacae nauplii | | | 65 | | | | | | | | | |

Appendix 4G.1. (continued).

ZOOPLANKTON SPECIES ANALYSIS-4

(IN NUMBERS PER METER CUBED)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 252 | 252 | 252 | 256 | 256 | 256 | 256 | 256 |
| STATION | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| LANOIDS | | | | | | | | | | | | | | | |
| anus marshallae | | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | | |
| pacificus | | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | 132 | | | 6 | | | | |
| MALES | | | | | | | | 10 | | | 17 | | | | |
| COPEPODIDS | | | | | | 34 | | 469 | | | 51 | 75 | | | 652 |
| pluschrus | | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | | |
| rocalanus sp. | | | | | | | | | | | | | | | |
| FEMALES | 74 | 198 | 26 | 120 | 123 | | | 244 | 8 | 36 | 85 | 54 | 163 | 58 | 35 |
| MALES | 6 | 27 | 6 | 20 | | | | 41 | | 12 | | | | | |
| COPEPODIDS | 29 | 81 | 20 | 90 | 24 | | | 71 | 2 | 18 | 17 | 61 | 51 | 14 | |
| acalanus sp. | | | | | | | | | | | | | | | |
| FEMALES | 217 | 370 | 243 | 469 | 417 | 17 | 222 | 520 | 123 | 224 | 413 | 211 | 285 | 422 | 244 |
| MALES | 29 | 45 | 52 | 120 | 12 | | 18 | 112 | 10 | 54 | 90 | 27 | 42 | | |
| COPEPODIDS | 532 | 667 | 506 | 1169 | 86 | 289 | 176 | 988 | 255 | 649 | 498 | 530 | 601 | 786 | 1071 |
| Pseudocalanus sp. | | | | | | | | | | | | | | | |
| FEMALES | 40 | 45 | 20 | 10 | | | | 10 | | 18 | 17 | 20 | 10 | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | | 18 | 6 | | 24 | | | 10 | | 12 | 51 | 61 | 30 | 29 | |
| Aetidius divergens | | | | | | | | | | | | | | | |
| Metridia lucens | | | | | | | | | | | | | | | |
| Centropages abdominalis | | | | | | | | | | | | | | | |
| Candacia columbiae | | | | | | | | | | | | | | | |
| Epilabidocera longipedata | | | | | | | | | | | | | | | |
| Tortanus discaudatus | | | | | | | | | | | | | | | |
| Acartia clausii | | | | | | | | | | | | | | | |
| A. longiremus | | | | | | | | | | | | | | | |
| CYCLOPOIDS | | | | | | | | | | | | | | | |
| Oithona similis | | | | | | | | | | | | | | | |
| FEMALES | 189 | 225 | 138 | 250 | 295 | 34 | | 520 | 163 | 176 | 130 | 176 | 255 | 422 | 384 |
| MALES | 6 | 9 | | 10 | 12 | | | 41 | 8 | 12 | 11 | 20 | 10 | | |
| COPEPODIDS | 86 | 99 | 59 | 170 | 86 | 51 | 9 | 255 | 61 | 150 | 62 | 81 | 92 | 29 | 23 |
| O. spinirostris | | | | | | | | | | | | | | | |
| FEMALES | 6 | | 6 | 10 | 12 | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | 17 | | | | 12 | | | | | | | | | | |
| Corycaeus anglicus | | | | | | | | | | | | | | | |
| FEMALES | 269 | 352 | 223 | 210 | 172 | 17 | 18 | 224 | 122 | 218 | 266 | 190 | 428 | 320 | 70 |
| MALES | 235 | 496 | 98 | 340 | 184 | | | 876 | 61 | 200 | 272 | 170 | 520 | 131 | 58 |
| COPEPODIDS | 97 | 126 | 85 | 110 | 209 | 679 | 46 | 346 | 181 | 54 | 153 | 530 | 601 | 1164 | 931 |
| AMPHIPODS | | | | | | | | | | | | | | | |
| Calliopus laeviusculu | | | | | | | | | | | | | | | |
| Cyphocaris challenger | | | | | | | | | | | | | | | |
| Parathemisto pacifica | | | | | | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | | | | | | |

Appendix 4G.1. (continued).

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evadne nordmanni | | | | | | | 176 | | | | | | | | |
| Podon leukarti | | | | | | | 74 | | | | | | | | |
| CHORDATES | | | | | | | | | | | | | | | |
| Fritillaria borealis | 212 | 354 | 131 | 360 | 552 | 1053 | 65 | 112 | 244 | 121 | 266 | 278 | 295 | 233 | 1514 |
| Oikopleura dioica | 395 | 2373 | 381 | 839 | 1007 | 1783 | 935 | 102 | 359 | 400 | 632 | 897 | 1049 | 1616 | 2795 |
| O. labradoriensis | | | | | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | | |
| Sagitta elegans | | | | | | | | | | | | | | | |
| EGGS | | | | | | | | | | | | | | | |
| JUV/ADULTS | | | | | | | | | | | | | | | |
| LARVAE | | | | | | | | | | | | | | | |
| Bivalves | 46 | 54 | 46 | 20 | 49 | 34 | | | | 54 | | | | | |
| Gastropods | 80 | 153 | 20 | 110 | 141 | | | 92 | 8 | 48 | | | | 73 | |
| Polychaetes | | | | | | | | | | | | | | | |
| Cirripedia nauplii | | | | | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | | | | |
| Copepod nauplii | | 63 | 33 | 250 | 98 | 322 | 185 | 10 | 59 | 30 | | 143 | 81 | 189 | 885 |
| Euphausiacae eggs | | | | | | | | | | | | | 173 | 204 | |
| Euphausiacae nauplii | | | | | | | | | | 73 | | 54 | 92 | 189 | 81 |



Appendix 4 G.1. (continued).

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 256 | 264 | 264 | 264 | 264 | 264 | 264 | 264 | 265 | 265 | 265 | 270 | 270 | 270 | 270 |
| STATION | 10 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| CALANOIDS | | | | | | | | | | | | | | | |
| ılanus marshallae | | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | | |
| . pacificus | | | | | | | | | | | | | | | |
| FEMALES | | | | 7 | | | | | 51 | | 10 | 11 | 9 | | |
| MALES | | 6 | | 7 | | | | | 5 | | 265 | | | | |
| COPEPODIDS | 89 | 63 | 71 | 87 | 77 | 72 | | | 143 | 49 | | 69 | 95 | 58 | |
| . pluschrus | | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | | |
| icrocalanus sp. | | | | | | | | | | | | | | | |
| FEMALES | | 6 | 20 | 43 | 55 | 84 | | | 51 | | 51 | | 34 | | |
| MALES | | | 10 | | | | | | | | | | | | |
| COPEPODIDS | | | 10 | 7 | 11 | 24 | | | 9 | | 20 | | | | |
| aracalanus sp. | | | | | | | | | | | | | | | |
| FEMALES | 153 | 149 | 214 | 173 | 321 | 180 | 233 | 272 | 218 | 105 | 835 | 378 | 216 | 116 | 225 |
| MALES | 38 | 23 | 20 | 50 | 66 | 36 | | | 65 | 6 | 132 | 17 | 17 | 10 | 29 |
| COPEPODIDS | 828 | 687 | 988 | 773 | 1417 | 1138 | 582 | 493 | 625 | 537 | 2302 | 973 | 725 | 825 | 1028 |
| eudocalanus sp. | | | | | | | | | | | | | | | |
| FEMALES | | 6 | | | | | | | 18 | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | 255 | 6 | | | | 12 | | | | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metridia lucens | | | | | | | | | | | | | | | |
| Centropages abdominalis | | | | | | | | | | | | | | | |
| Candacia columbiae | | | | | | | | | | | | | | | |
| Epilabidocera longipedata | | | | | | | | | | | | | | | |
| Tortanus discaudatus | | | | | | | | | | | | | | | |
| Acartia clausii | | | | | | | | | | | | | | | |
| A. longiremus | | | | | | | | | | | | | | | |
| CYCLOPOIDS | | | | | | | | | | | | | | | |
| Oithona similis | | | | | | | | | | | | | | | |
| FEMALES | 298 | 346 | 224 | 543 | 264 | 80 | 85 | 194 | 136 | 1223 | 183 | 250 | 213 | 245 | |
| MALES | 29 | 41 | 14 | 55 | 24 | 22 | | 9 | | | | | | 8 | |
| COPEPODIDS | 223 | 163 | 260 | 376 | 299 | 29 | 68 | 79 | 68 | 886 | 137 | 129 | 223 | 147 | |
| O. spinirostris | | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | | |
| Corycaeus anglicus | | | | | | | | | | | | | | | |
| FEMALES | 51 | 401 | 244 | 238 | 321 | 192 | 58 | 272 | 356 | 130 | 458 | 223 | 199 | 184 | 215 |
| MALES | | 137 | 407 | 159 | 421 | 383 | 65 | 459 | 523 | 123 | 509 | 132 | 95 | 126 | 196 |
| COPEPOD | 650 | 160 | 316 | 166 | 244 | 204 | 349 | 1088 | 83 | 222 | 173 | 195 | 173 | 204 | 548 |
| AMPHIPODS | | | | | | | | | | | | | | | |
| Calliopus laeviusculu | | | | | | | | | | | | | | | |
| Cyphocaris challenger | | | | | | | | | | | | | | | |
| Parathemisto pacifica | | | | | | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | | | | | | |
| CHORDATES | | | | | | | | | | | | | | | |



Appendix 4G.1. (continued).

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fritillaria borealis | 1822 | 17 | 30 | 22 | 133 | 168 | 407 | 680 | | 25 | 132 | | 78 | 48 | 186 |
| Oikopleura dioica | 5070 | 29 | 112 | 72 | 88 | 180 | 95 | 221 | | 74 | 295 | 109 | 302 | 155 | 470 |
| O. labradoriensis | | | | | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | | | | | | |
| EGGS | | | | | | | | | | | | | | | |
| JUV/ADULTS | | 17 | 30 | | | | | | | | | | | | |
| LARVAE | | | | | | | | | | | | | | | |
| Bivalves | | 46 | | 22 | 55 | | | | 14 | 6 | | 11 | 9 | 39 | |
| Gastropods | | 29 | | 58 | 66 | 36 | | | 46 | 18 | | 29 | 84 | 68 | |
| Polychaetes | | 11 | | | | | | | | | | | | | |
| Cirripedia nauplii | | | | | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | | | | |
| Copepod nauplii | 1566 | 23 | 224 | 36 | 88 | 84 | 619 | 901 | | | | 40 | | | |
| Euphausiacae eggs | | 23 | | | | | | | | | | | | | |
| Euphausiacae nauplii | 25 | 51 | 41 | 29 | 33 | | | | | 25 | 183 | 23 | 43 | 29 | |



Appendix 4G.1. (continued).

ZOOPLANKTON SPECIES ANALYSIS-5

(IN NUMBERS PER METER CUBED)

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JDAY | 270 | 270 | 270 | 279 | 279 | 279 | 279 | 284 | 284 | 284 | 284 | 284 | 284 | 284 |
| STATION | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| AMOIDS | | | | | | | | | | | | | | |
| aus marshallae | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | |
| acificus | | | | | | | | | | | | | | |
| FEMALES | | | | 37 | | | | | | | 10 | | | |
| MALES | | | | | | 6 | | | | | | | | |
| COPEPODIDS | | | | 185 | 54 | 104 | 36 | 23 | 81 | 23 | 24 | | | |
| luanchrus | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | |
| rocalanus sp. | | | | | | | | | | | | | | |
| FEMALES | | | | 18 | | 6 | | | | | | | | |
| MALES | | | | 9 | | | | | | | | | | |
| COPEPODIDS | | | | 18 | | 6 | | | | | | | | |
| acalanus sp. | | | | | | | | | | | | | | |
| FEMALES | 251 | 347 | 408 | 278 | 300 | 117 | 47 | 116 | 113 | 158 | 147 | 193 | 127 | 137 |
| MALES | 24 | | | 111 | 75 | 6 | 22 | 6 | 40 | 45 | 10 | | | |
| COPEPODIDS | 1018 | 493 | 272 | 667 | 761 | 712 | 253 | 693 | 577 | 536 | 446 | 460 | 415 | 387 |
| Pseudocalanus sp. | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | |
| Aetidius divergens | | | | | | | | | | | | | | |
| Metridia lucens | | | | | | | | | | | | | | |
| Centropages abdominal | | | | | | | | | | | | | | |
| Candacia columbiae | | | | | | | | | | | | | | |
| Epilabidocera longipe | | | | | | | | | | | | | | |
| Tortanus discaudatus | | | | | | | | | | | | | | |
| Acartia clausii | | | | | | | | | | | | | | |
| A. longiremus | | | | | | | | | | | | | | |
| CYCLOPOIDS | | | | | | | | | | | | | | |
| Oithona similis | | | | | | | | | | | | | | |
| FEMALES | 304 | 201 | | 278 | 150 | 110 | 22 | 151 | 162 | 241 | 157 | 160 | 141 | 168 |
| MALES | 13 | | | | 11 | 6 | | | | 23 | | 4 | | |
| COPEPODIDS | 159 | 73 | | 130 | 193 | 147 | 42 | 169 | 275 | 98 | 117 | 115 | 146 | 127 |
| O. spinirostris | | | | | | | | | | | | | | |
| FEMALES | | | | | | | | | | | | | | |
| MALES | | | | | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | | | | | |
| Corycaeus anglicus | | | | | | | | | | | | | | |
| FEMALES | 92 | 274 | 119 | 176 | 84 | 159 | 89 | 41 | 54 | 53 | 93 | 53 | 99 | 25 |
| MALES | 132 | 347 | 272 | 704 | 118 | 184 | 136 | 163 | 198 | 173 | 142 | 127 | 165 | 102 |
| COPEPODIDS | 159 | 1113 | 1615 | 148 | 214 | 196 | 78 | 122 | 104 | 128 | 88 | 214 | 340 | 260 |
| AMPHIPODS | | | | | | | | | | | | | | |
| Calliopus laeviusculu | | | | | | | | | | | | | | |
| Cyphocaris challenger | | | | | | | | | | | | | | |
| Parathemisto pacifica | | | | | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | | | | | |



Appendix 4G.1 (continued).

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evadne nordmanni | | | | | | | | | | | | | | |
| Podon leuckarti | | | | | | | | | | | | | | |
| CHORDATES | | | | | | | | | | | | | | |
| Fritillaria borealis | 212 | 785 | 1156 | | | | | | | | | | | |
| Oikopleura dioica | 489 | 1861 | 2381 | 28 | 289 | 74 | 11 | 64 | 140 | 83 | 127 | 111 | 90 | 229 |
| O. labradoriensis | | | | | | | | | | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | |
| Sagitta elegans | | | | | | | | | | | | | | |
| EGGS | | | | | | | | | | | | | | |
| JUV/ADULTS | | | | | | | | | | | | | | |
| LARVAE | | | | | | | | | | | | | | |
| Bivalves | | | | 37 | 86 | 12 | 5 | | 86 | | | | | |
| Gastropods | | | | 83 | 96 | 43 | 19 | 111 | 81 | | 64 | | 94 | 76 |
| Polychaetes | | | | | | | | | | | | | | |
| Cirripedia nauplii | | | | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | | | |
| Copepod nauplii | | 876 | 1497 | | | | | | | | | | | |
| Euphausiacae eggs | 185 | | | | | | | | | | | | | |
| Euphausiacae nauplii | 159 | | | | | | | | | | | | | |



Appendix 4G.1. (continued).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| JBAY | 300 | 300 | 300 | 301 | 301 | 301 | 301 | 301 | 301 | 301 |
| STATION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| AMOIDS | | | | | | | | | | |
| nus marshallae | | | | | | | | | | |
| FEMALES | | | | | | | | | | |
| MALES | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | |
| acificus | | | | | | | | | | |
| FEMALES | | | | 3 | | | | | | |
| MALES | | | | | | | | | | |
| COPEPODIDS | 62 | | | 25 | | | | | | |
| luschrus | | | | | | | | | | |
| FEMALES | | | | | | | | | | |
| MALES | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | |
| ocalanus sp. | | | | | | | | | | |
| FEMALES | 18 | | | | | | | | | |
| MALES | | | | | | | | | | |
| COPEPODIDS | 9 | | | | | | | | | |
| calanus sp. | | | | | | | | | | |
| FEMALES | 106 | 123 | 153 | 59 | 136 | 104 | 164 | 180 | 166 | 187 |
| MALES | 13 | 27 | 13 | 11 | 4 | 16 | 31 | 18 | | |
| COPEPODIDS | 195 | 375 | 411 | 306 | 301 | 365 | 408 | 491 | 379 | 425 |
| idocalanus sp. | | | | | | | | | | |
| FEMALES | | | | | | | | | | |
| MALES | 4 | | | | | | | | | |
| Aetidius divergens | 18 | | | | | | | | | |
| Metridia lucens | | | | | | | | | | |
| Centropages abdominalis | | | | | | | | | | |
| Candacia columbiae | | | | | | | | | | |
| Epilabidocera longipedata | | | | | | | | | | |
| Tortanus discaudatus | | | | | | | | | | |
| Acartia clausii | | | | | | | | | | |
| A. longiremus | | | | | | | | | | |
| CYCLOPOIDS | | | | | | | | | | |
| Oithona similis | | | | | | | | | | |
| FEMALES | 49 | 198 | 140 | 96 | 59 | 148 | 93 | 132 | 86 | 68 |
| MALES | | 27 | | | 4 | 8 | | | | |
| COPEPODIDS | 44 | 107 | 153 | 71 | 119 | 52 | 111 | 126 | 64 | 34 |
| O. spinirostris | | | | | | | | | | |
| FEMALES | | | | | | | | | | |
| MALES | | | | | | | | | | |
| COPEPODIDS | | | | | | | | | | |
| Corycaeus anglicus | | | | | | | | | | |
| FEMALES | 93 | 70 | 60 | 62 | 114 | 116 | 44 | 96 | 80 | 119 |
| MALES | 275 | 75 | 19 | 201 | 153 | 112 | 89 | 102 | 130 | 221 |
| COPEPODIDS | 142 | 102 | 35 | 110 | 199 | 100 | 137 | 228 | 166 | 289 |
| AMPHIPODS | | | | | | | | | | |
| Calliopus laeviusculus | | | | | | | | | | |
| Cyphocaris challengeri | | | | | | | | | | |
| Paratheraisto pacifica | | | | | | | | | | |
| CLADOCERANS | | | | | | | | | | |
| Evadne nordmanni | | | | | | | | | | |
| Podon leukarti | | | | | | | | | | |

Appendix 4G.1. (continued).

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHORDATES | | | | | | | | | | | | | | | |
| Fritillaria borealis | | | | | | | | 31 | | | 57 | | 78 | 48 | 186 |
| Oikopleura dioica | 22 | 107 | 140 | 175 | 250 | 156 | 279 | 353 | 443 | 300 | 109 | 302 | 155 | 470 | |
| O. labradoriensis | | | | | | 32 | 71 | | 76 | 142 | | | | | |
| CHAETOGNATHS | | | | | | | | | | | | | | | |
| Sagitta elegens | | | | | | | | | | | | | | | |
| EGGS | | | | | | | | | | | | | | | |
| JUV/ADULTS | | | | | | | | | | | | | | | |
| LARVAE | | | | | | | | | | | | | | | |
| Bivalves | | 32 | | | | | | | | | | | | | |
| Gastropods | | 54 | | | | 36 | | 36 | | | | | | | |
| Polychaetes | | | | | | | | | | | | | | | |
| Cirripedia nauplii | | | | | | | | | | | | | | | |
| Cirripedia cyprid | | | | | | | | | | | | | | | |
| Copepod nauplii | | | | | | | | | | | | | | | |
| Euphausiacae eggs | | | | | | | | | | | | | | | |
| Euphausiacae nauplii | | | | | | | | | | | | | | | |



Appendix 4G.1. (continued).

# APPENDIX 4H

## ADDITIONAL UNDERWAY MAPPING TRANSECTS

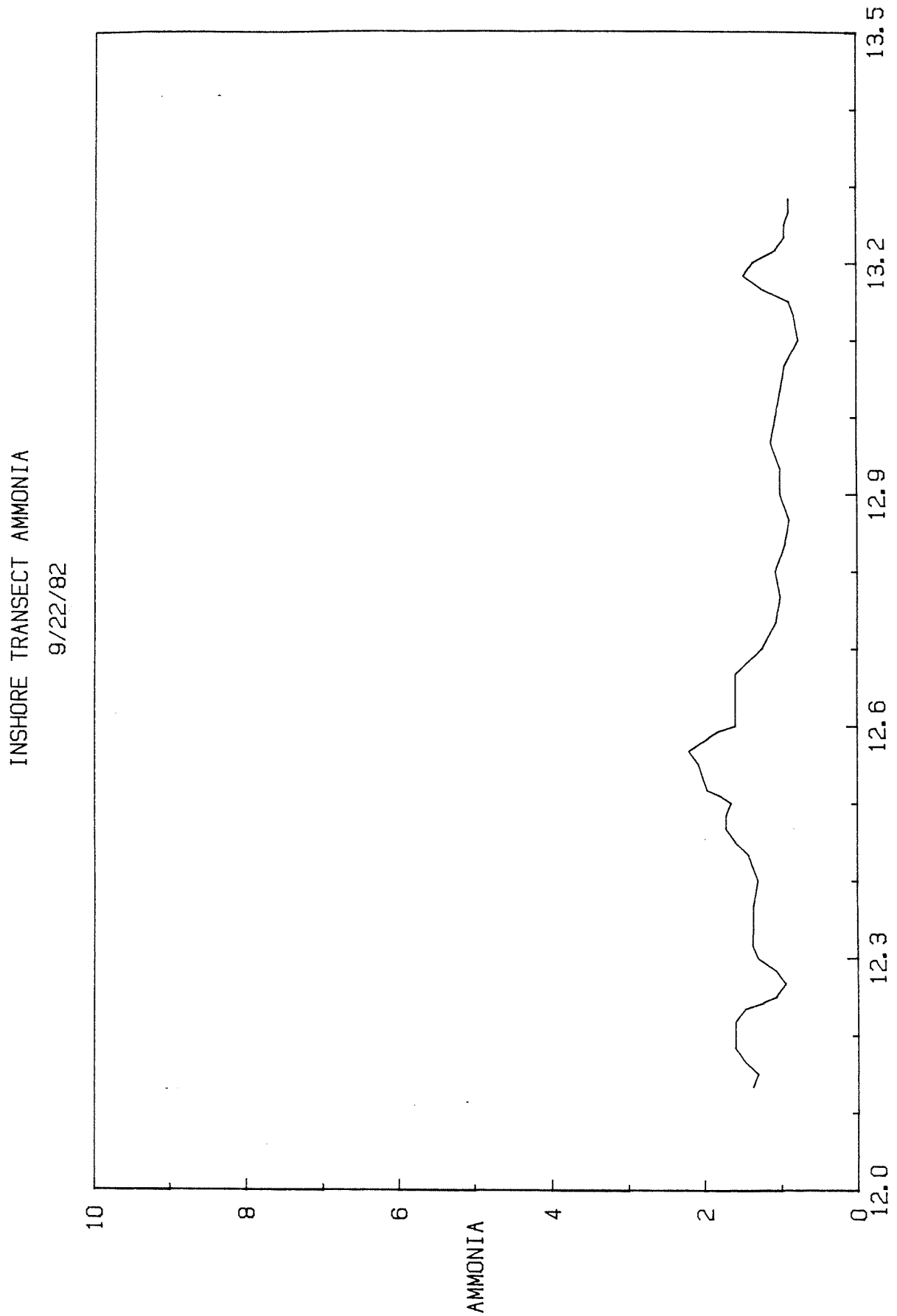
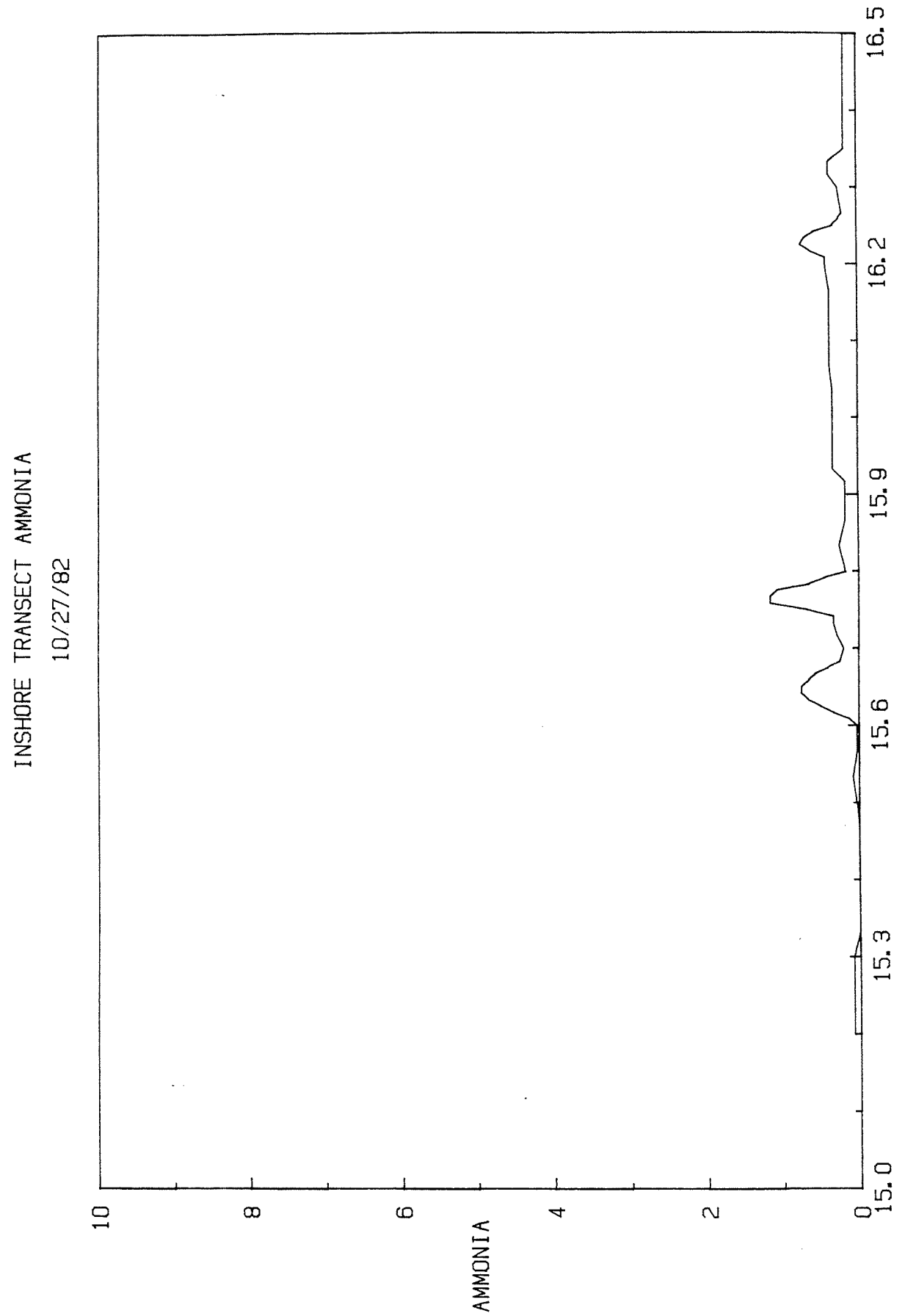



Figure 4.H.1. Time series of ammonia in surface waters for the inshore transect on August 22, 1982. Ammonia is in µg-at/l.




Appendix 4.H2. Time series of ammonia in surface waters for the inshore transect on August 22, 1982. Ammonia is in µg-at/l.

# APPENDIX 5A

## Data Tabulations

The following tables contain calibrated temperature ($^{o}C$), dissolved oxygen (mg/l), salinity ($^{o}/oo$), and density (sigma-t units) for all ten CTD stations at 10m depth intervals.

Station #1
Temperature (°C)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 13.426 | 13.200 | 13.226 | 12.190 | 12.162 | 11.113 | 10.756 | 10.671 | 10.624 | 10.607 | 10.577 | 10.593 | 10.588 |
| 7/26 | 13.446 | 12.900 | 12.539 | 12.347 | 12.038 | 11.767 | 11.340 | 11.152 | 11.072 | 11.018 | 10.970 | 10.918 | 10.905 |
| 8/24 | 12.980 | 12.765 | 12.745 | 12.517 | 12.186 | 12.073 | 11.913 | 11.826 | 11.717 | 11.463 | 11.452 | 11.411 | 11.352 |
| 9/9 | 12.638 | 12.631 | 12.428 | 12.295 | 11.863 | 11.735 | 11.673 | 11.650 | 11.649 | 11.600 | 11.542 | 11.524 | 11.506 |
| 9/22 | 12.577 | 12.371 | 12.370 | 12.295 | 12.277 | 12.152 | 11.980 | 11.895 | 11.818 | 11.720 | 11.628 | 11.547 | 11.522 |
| 10/6 | 11.977 | 11.973 | 11.960 | 11.901 | 11.886 | 11.864 | 11.705 | 11.585 | 11.451 | 11.400 | 11.367 | 11.329 | 11.311 |
| 10/27 | 11.440 | 11.444 | 11.451 | 11.462 | 11.464 | 11.313 | 11.041 | 11.006 | 10.929 | 10.906 | 10.863 | 10.835 | 10.782 |

| Depth, m: Date | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|
| 7/16/82 | 10.519 | 10.564 | 10.571 | 10.574 | 10.583 | 10.586 | 10.586 |
| 7/26 | 10.864 | 10.820 | 10.798 | 10.777 | 10.772 | 10.749 | 10.716 |
| 8/24 | 11.349 | 11.313 | 11.310 | 11.294 | 11.284 | 11.280 | 11.272 |
| 9/9 | 11.438 | 11.430 | 11.385 | 11.342 | 11.331 | 11.314 | 11.256 |
| 9/22 | 11.500 | 11.485 | 11.479 | 11.459 | 11.455 | 11.465 | 11.448 |
| 10/6 | 11.308 | 11.291 | 11.285 | 11.266 | 11.222 | 11.121 | 11.084 |
| 10/27 | 10.760 | 10.739 | 10.722 | 10.650 | 10.643 | 10.547 | 10.447 |

STATION #1
Oxygen (mg/l)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 8.172 | 8.230 | 8.442 | 8.428 | 7.913 | 7.660 | 6.945 | 6.585 | 6.503 | 6.477 |
| 7/26 | 7.530 | 7.677 | 7.624 | 7.387 | 7.212 | 7.057 | 6.882 | 6.653 | 6.507 | 6.492 |
| 8/24 | 7.259 | 7.575 | 7.828 | 7.582 | 6.581 | 6.223 | 6.079 | 6.003 | 5.991 | 5.867 |
| 9/9 | 8.787 | 8.937 | 8.979 | 8.695 | 8.561 | 7.959 | 7.674 | 7.592 | 7.585 | 7.575 |
| 9/22 | 6.393 | 6.587 | 6.473 | 6.392 | 6.329 | 6.336 | 6.249 | 6.148 | 6.057 | 6.032 |
| 10/6 | 6.290 | 6.508 | 6.605 | 6.522 | 6.287 | 6.107 | 6.082 | 5.892 | 5.830 | 5.868 |
| 10/27 | 5.255 | 5.416 | 5.482 | 6.105 | 6.429 | 5.308 | 4.959 | 4.740 | 5.253 | 5.493 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 6.518 | 6.600 | 6.701 | 6.732 | 6.797 | 6.873 | 6.924 | 6.999 | 7.048 | 7.063 |
| 7/26 | 6.493 | 6.501 | 6.524 | 6.545 | 6.529 | 6.516 | 6.491 | 6.485 | 6.473 | 6.429 |
| 8/24 | 5.773 | 5.771 | 5.874 | 5.992 | 6.061 | 6.114 | 6.144 | 6.153 | 6.186 | 6.223 |
| 9/9 | 7.535 | 7.538 | 7.599 | 7.586 | 7.604 | 7.613 | 7.506 | 7.462 | 7.394 | 7.264 |
| 9/22 | 6.063 | 6.105 | 6.119 | 6.159 | 6.200 | 6.235 | 6.201 | 6.144 | 6.136 | 6.149 |
| 10/6 | 5.958 | 5.974 | 5.949 | 5.929 | 5.940 | 5.947 | 5.930 | 5.885 | 5.835 | 5.743 |
| 10/27 | 5.263 | 5.324 | 5.214 | 5.275 | 5.131 | 5.523 | 5.403 | 5.301 | 5.263 | 5.419 |

STATION #1
Salinity (°/₀₀)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 28.164 | 28.422 | 28.452 | 28.944 | 28.937 | 29.391 | 29.556 | 29.624 | 29.718 | 29.733 |
| 7/26 | 28.690 | 29.095 | 29.179 | 29.194 | 29.252 | 29.336 | 29.467 | 29.566 | 29.625 | 29.664 |
| 8/24 | 29.332 | 29.505 | 29.547 | 29.600 | 29.671 | 29.689 | 29.753 | 29.780 | 29.817 | 29.928 |
| 9/9 | 29.277 | 29.297 | 29.467 | 29.519 | 29.656 | 29.695 | 29.715 | 29.729 | 29.727 | 29.769 |
| 9/22 | 29.880 | 29.920 | 29.923 | 29.947 | 29.955 | 30.053 | 30.136 | 30.159 | 30.190 | 30.239 |
| 10/6 | 30.033 | 30.069 | 30.103 | 30.152 | 30.153 | 30.160 | 30.227 | 30.301 | 30.367 | 30.396 |
| 10/27 | 30.121 | 30.122 | 30.121 | 30.128 | 30.131 | 30.256 | 30.391 | 30.425 | 30.425 | 30.427 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 29.795 | 29.859 | 29.834 | 29.918 | 29.952 | 29.963 | 29.972 | 29.985 | 30.007 | 30.025 |
| 7/26 | 29.700 | 29.741 | 29.751 | 29.780 | 29.804 | 29.816 | 29.830 | 29.837 | 29.853 | 29.876 |
| 8/24 | 29.942 | 29.970 | 30.053 | 30.066 | 30.107 | 30.108 | 30.125 | 30.126 | 30.121 | 30.131 |
| 9/9 | 29.810 | 29.873 | 29.916 | 29.962 | 29.969 | 29.988 | 29.998 | 29.991 | 30.011 | 30.048 |
| 9/22 | 30.281 | 30.321 | 30.341 | 30.348 | 30.352 | 30.373 | 30.388 | 30.395 | 30.408 | 30.424 |
| 10/6 | 30.418 | 30.447 | 30.454 | 30.461 | 30.474 | 30.478 | 30.491 | 30.535 | 30.608 | 30.639 |
| 10/27 | 30.427 | 30.438 | 30.451 | 30.453 | 30.460 | 30.476 | 30.516 | 30.530 | 30.622 | 30.720 |

STATION #1
Density ($\sigma_t$)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 21.056 | 21.298 | 21.316 | 21.888 | 21.887 | 22.423 | 22.611 | 22.678 | 22.759 | 22.773 |
| 7/26 | 21.457 | 21.873 | 22.005 | 22.052 | 22.153 | 22.266 | 22.442 | 22.551 | 22.611 | 22.650 |
| 8/24 | 22.041 | 22.214 | 22.251 | 22.334 | 22.450 | 22.484 | 22.562 | 22.599 | 22.647 | 22.778 |
| 9/9 | 22.062 | 22.079 | 22.248 | 22.312 | 22.496 | 22.549 | 22.576 | 22.591 | 22.589 | 22.631 |
| 9/22 | 22.539 | 22.608 | 22.611 | 22.643 | 22.652 | 22.751 | 22.846 | 22.880 | 22.917 | 22.973 |
| 10/6 | 22.767 | 22.796 | 22.825 | 22.873 | 22.877 | 22.886 | 22.966 | 23.045 | 23.120 | 23.151 |
| 10/27 | 22.931 | 22.931 | 22.929 | 22.933 | 22.935 | 23.058 | 23.210 | 23.242 | 23.255 | 23.261 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 22.826 | 22.873 | 22.886 | 22.931 | 22.950 | 22.957 | 22.964 | 22.972 | 22.990 | 23.003 |
| 7/26 | 22.626 | 22.727 | 22.737 | 22.766 | 22.792 | 22.805 | 22.820 | 22.826 | 22.842 | 22.866 |
| 8/24 | 22.791 | 22.819 | 22.894 | 22.905 | 22.943 | 22.944 | 22.960 | 22.962 | 22.959 | 22.968 |
| 9/9 | 22.673 | 22.724 | 22.761 | 22.808 | 22.815 | 22.838 | 22.843 | 22.850 | 22.868 | 22.907 |
| 9/22 | 23.022 | 23.067 | 23.087 | 23.096 | 23.102 | 23.119 | 23.135 | 23.141 | 23.149 | 23.164 |
| 10/6 | 23.181 | 23.203 | 23.212 | 23.218 | 23.231 | 23.235 | 23.248 | 23.290 | 23.364 | 23.395 |
| 10/27 | 23.268 | 23.281 | 23.301 | 23.306 | 23.315 | 23.330 | 23.373 | 23.385 | 23.473 | 23.566 |

STATION #2
Temperature (°C)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 12.824 | 12.114 | 12.006 | 11.817 | 11.665 | 11.575 | 11.394 | 11.379 | 11.252 | 11.148 | 11.102 | 11.083 |
| 7/26 | 12.920 | 12.812 | 12.321 | 12.137 | 12.063 | 12.024 | 11.953 | 11.928 | 11.883 | 11.840 | 11.839 | |
| 8/11 | 12.367 | 12.334 | 12.283 | 12.035 | 11.997 | 11.910 | 11.873 | 11.863 | 11.828 | 11.797 | 11.778 | 11.672 |
| 8/24 | 12.637 | 12.539 | 12.328 | 12.306 | 12.287 | 12.217 | 12.196 | 12.181 | 12.167 | 12.087 | 12.072 | |
| 9/9 | 12.629 | 12.516 | 12.443 | 12.344 | 12.293 | 12.271 | 12.262 | 12.267 | 12.247 | 12.209 | 11.973 | 11.930 |
| 9/22 | 12.721 | 12.699 | 12.388 | 12.296 | 12.274 | 12.248 | 12.213 | 12.185 | 12.187 | 12.199 | 12.186 | |
| 10/6 | 12.111 | 12.105 | 12.108 | 12.033 | 12.003 | 11.997 | 11.993 | 11.965 | 11.944 | 11.904 | 11.879 | 11.866 |
| 10/27 | 11.395 | 11.393 | 11.390 | 11.395 | 11.382 | 11.384 | 11.347 | 11.352 | 11.360 | 11.361 | 11.356 | 11.347 |



STATION #2
Oxygen (mg/1)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 7.527 | 7.883 | 7.708 | 7.484 | 7.330 | 7.213 | 7.147 | 7.129 | 7.195 | 7.122 | 7.115 | 7.150 |
| 7/26 | 7.093 | 7.188 | 7.213 | 7.107 | 7.035 | 7.027 | 7.047 | 7.021 | 7.006 | 7.025 | 7.033 | |
| 8/11 | 6.950 | 7.104 | 7.104 | 7.023 | 6.850 | 6.903 | 6.939 | 7.001 | 7.075 | 7.157 | 7.241 | 7.294 |
| 8/24 | 6.234 | 6.324 | 6.305 | 6.176 | 6.205 | 6.228 | 6.252 | 6.321 | 6.390 | 6.442 | 6.458 | |
| 9/9 | 5.581 | 5.671 | 5.949 | 6.154 | 6.098 | 5.979 | 5.921 | 5.990 | 6.091 | 6.193 | 6.196 | 6.124 |
| 9/22 | 6.909 | 6.684 | 6.658 | 6.364 | 6.190 | 6.185 | 6.231 | 6.294 | 6.359 | 6.444 | 6.535 | |
| 10/6 | 6.051 | 6.124 | 6.102 | 6.076 | 6.013 | 5.965 | 6.004 | 6.058 | 6.091 | 6.092 | 6.127 | 6.129 |
| 10/27 | 5.717 | 5.763 | 6.201 | 6.196 | 6.049 | 6.270 | 5.838 | 5.859 | 5.993 | 6.079 | 6.468 | 6.176 |

STATION #2
Salinity (°/₀₀)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 28.802 | 29.042 | 29.061 | 29.105 | 29.166 | 29.204 | 29.273 | 29.280 | 29.336 | 29.379 | 29.397 | 29.407 |
| 7/26 | 29.214 | 29.135 | 29.237 | 29.232 | 29.235 | 29.237 | 29.257 | 29.268 | 29.285 | 29.300 | 29.297 | |
| 8/11 | 29.415 | 29.413 | 29.407 | 29.482 | 29.440 | 29.476 | 29.489 | 29.488 | 29.504 | 29.517 | 29.521 | 29.563 |
| 8/24 | 29.619 | 29.606 | 29.644 | 29.642 | 29.638 | 29.671 | 29.678 | 29.679 | 29.688 | 29.717 | 29.717 | |
| 9/9 | 29.738 | 29.763 | 29.788 | 29.818 | 29.831 | 29.842 | 29.843 | 29.842 | 29.855 | 29.868 | 29.953 | 29.962 |
| 9/22 | 29.905 | 29.899 | 29.945 | 29.974 | 29.970 | 29.984 | 30.006 | 30.016 | 30.016 | 30.012 | 30.020 | |
| 10/6 | 30.023 | 30.028 | 30.025 | 30.060 | 30.074 | 30.076 | 30.084 | 30.100 | 30.109 | 30.131 | 30.141 | 30.149 |
| 10/27 | 30.191 | 30.192 | 30.195 | 30.192 | 30.210 | 30.212 | 30.242 | 30.239 | 30.232 | 30.237 | 30.236 | 30.258 |

STATION #2
Density (sigma-t)

| Depth, m: Date | 1 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 21.662 | 21.977 | 22.011 | 22.079 | 22.153 | 22.198 | 22.283 | 22.291 | 22.356 | 22.407 | 22.429 | 22.440 |
| 7/26 | 21.961 | 21.920 | 22.090 | 22.120 | 22.135 | 22.144 | 22.172 | 22.185 | 22.206 | 22.225 | 22.223 | |
| 8/11 | 22.219 | 22.223 | 22.228 | 22.331 | 22.306 | 22.349 | 22.366 | 22.367 | 22.385 | 22.401 | 22.407 | 22.459 |
| 8/24 | 22.326 | 22.335 | 22.403 | 22.405 | 22.406 | 22.444 | 22.453 | 22.457 | 22.466 | 22.503 | 22.506 | |
| 9/9 | 22.420 | 22.460 | 22.493 | 22.534 | 22.554 | 22.566 | 22.569 | 22.567 | 22.581 | 22.598 | 22.706 | 22.721 |
| 9/22 | 22.531 | 22.531 | 22.624 | 22.664 | 22.665 | 22.680 | 22.704 | 22.716 | 22.716 | 22.711 | 22.719 | |
| 10/6 | 22.735 | 22.740 | 22.737 | 22.778 | 22.794 | 22.797 | 22.804 | 22.821 | 22.832 | 22.856 | 22.869 | 22.877 |
| 10/27 | 22.993 | 22.994 | 22.997 | 22.994 | 23.010 | 23.011 | 23.041 | 23.038 | 23.031 | 23.035 | 23.035 | 23.054 |

STATION #3
Temperature (°C)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 13.230 | 12.775 | 12.373 | 11.650 | 11.396 | 11.286 | 11.077 | 10.713 | 10.507 | 10.367 |
| 7/26 | 14.162 | 12.823 | 12.426 | 12.014 | 11.873 | 11.815 | 11.597 | 11.406 | 11.323 | 11.235 |
| 8/11 | 14.057 | 12.450 | 12.130 | 11.831 | 11.659 | 11.547 | 11.383 | 10.967 | 10.964 | 10.869 |
| 8/24 | 13.965 | 13.405 | 12.637 | 12.285 | 12.140 | 12.049 | 11.951 | 11.796 | 11.506 | 11.294 |
| 9/9 | 13.106 | 13.098 | 12.704 | 12.155 | 12.064 | 11.988 | 11.759 | 11.584 | 11.490 | 11.409 |
| 9/22 | 13.148 | 12.794 | 12.589 | 12.228 | 12.189 | 12.120 | 12.079 | 11.911 | 11.819 | 11.671 |
| 10/6 | 12.289 | 12.195 | 12.042 | 11.931 | 11.889 | 11.827 | 11.814 | 11.657 | 11.529 | 11.282 |
| 10/27 | 11.464 | 11.464 | 11.419 | 11.296 | 11.177 | 11.119 | 11.090 | 11.058 | 11.050 | 11.022 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 |
|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 10.325 | 10.310 | 10.349 | 10.352 | 10.310 | 10.269 | 10.235 | | |
| 7/26 | 11.005 | 10.764 | 10.686 | 10.653 | 10.613 | 10.551 | 10.542 | 10.527 | |
| 8/11 | 10.849 | 10.815 | 10.811 | 10.808 | 10.814 | 10.814 | 10.810 | 10.807 | |
| 8/24 | 11.237 | 11.244 | 11.216 | 11.173 | 11.139 | 11.126 | 11.117 | 11.108 | 11.089 |
| 9/9 | 11.414 | 11.332 | 11.282 | 11.258 | 11.240 | 11.234 | 11.204 | 11.197 | |
| 9/22 | 11.613 | 11.595 | 11.585 | 11.554 | 11.564 | 11.562 | 11.555 | 11.538 | |
| 10/6 | 11.270 | 11.234 | 11.179 | 11.114 | 11.091 | 11.077 | 11.065 | 11.047 | |
| 10/27 | 11.029 | 10.979 | 10.959 | 10.942 | 10.938 | 10.918 | 10.887 | 10.833 | 10.773 |

STATION #3
Oxygen (mg/l)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 9.210 | 9.247 | 9.169 | 7.756 | 7.145 | 6.935 | 6.818 | 6.685 | 6.542 | 6.462 |
| 7/26 | 7.491 | 7.651 | 7.599 | 7.281 | 7.085 | 7.006 | 6.963 | 6.852 | 6.726 | 6.662 |
| 8/11 | 10.925 | 11.150 | 8.901 | 6.234 | 5.485 | 5.295 | 5.283 | 5.275 | 5.169 | 5.227 |
| 8/24 | 8.988 | 9.707 | 10.426 | 8.279 | 6.835 | 6.304 | 6.058 | 5.929 | 5.809 | 5.582 |
| 9/9 | 7.486 | 7.673 | 7.980 | 7.128 | 6.178 | 5.850 | 5.555 | 5.313 | 5.211 | 5.152 |
| 9/22 | 8.447 | 8.410 | 7.888 | 7.020 | 6.421 | 6.198 | 6.104 | 6.092 | 6.000 | 5.874 |
| 10/6 | 6.845 | 6.920 | 6.796 | 6.362 | 6.076 | 5.963 | 5.882 | 5.847 | 5.767 | 5.697 |
| 10/27 | 7.188 | 6.771 | 6.363 | 5.808 | 5.360 | 5.202 | 5.337 | 5.292 | 5.131 | 5.234 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 |
|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 6.424 | 6.464 | 6.501 | 6.571 | 6.627 | 6.684 | 6.719 | | |
| 7/26 | 6.578 | 6.458 | 6.345 | 6.318 | 6.326 | 6.320 | 6.316 | 6.303 | |
| 8/11 | 5.287 | 5.376 | 5.461 | 5.545 | 5.653 | 5.711 | 5.785 | 5.838 | |
| 8/24 | 5.525 | 5.569 | 5.654 | 5.711 | 5.785 | 5.784 | 5.802 | 5.792 | 5.828 |
| 9/9 | 5.162 | 5.286 | 5.360 | 5.440 | 5.519 | 5.591 | 5.657 | 5.714 | |
| 9/22 | 5.895 | 5.915 | 5.973 | 6.025 | 6.074 | 6.123 | 6.159 | 6.207 | |
| 10/6 | 5.554 | 5.515 | 5.544 | 5.576 | 5.477 | 5.427 | 5.387 | 5.355 | |
| 10/27 | 5.284 | 5.240 | 5.723 | 5.505 | 5.781 | 5.696 | 5.857 | 5.775 | 5.557 |

STATION #3
Salinity (°/₀₀)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 27.164 | 28.082 | 28.644 | 29.099 | 29.172 | 29.212 | 29.291 | 29.458 | 29.596 | 29.737 |
| 7/26 | 27.536 | 29.216 | 29.250 | 29.241 | 29.260 | 29.274 | 29.325 | 29.378 | 29.426 | 29.464 |
| 8/11 | 27.207 | 29.238 | 29.371 | 29.440 | 29.474 | 29.498 | 29.549 | 29.764 | 29.784 | 29.839 |
| 8/24 | 28.918 | 29.324 | 29.589 | 29.604 | 29.616 | 29.625 | 29.636 | 29.712 | 29.844 | 29.974 |
| 9/9 | 29.357 | 29.426 | 29.721 | 29.815 | 29.822 | 29.852 | 29.925 | 29.992 | 30.066 | 30.094 |
| 9/22 | 29.057 | 29.688 | 29.892 | 29.975 | 29.978 | 29.989 | 30.012 | 30.073 | 30.110 | 30.226 |
| 10/6 | 29.504 | 29.821 | 30.064 | 30.121 | 30.151 | 30.179 | 30.187 | 30.264 | 30.329 | 30.469 |
| 10/27 | 29.560 | 29.381 | 30.159 | 30.333 | 30.404 | 30.436 | 30.438 | 30.444 | 30.446 | 30.449 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 |
|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 29.779 | 29.796 | 29.866 | 29.903 | 29.911 | 29.911 | 29.913 | | |
| 7/26 | 29.609 | 29.764 | 29.808 | 29.825 | 29.841 | 29.864 | 29.869 | 29.871 | |
| 8/11 | 29.867 | 29.913 | 29.926 | 29.942 | 29.960 | 29.975 | 29.985 | 30.000 | |
| 8/24 | 30.010 | 30.007 | 30.027 | 30.052 | 30.067 | 30.074 | 30.088 | 30.102 | 30.117 |
| 9/9 | 30.105 | 30.196 | 30.269 | 30.283 | 30.304 | 30.306 | 30.332 | 30.347 | |
| 9/22 | 30.269 | 30.286 | 30.304 | 30.327 | 30.328 | 30.326 | 30.329 | 30.345 | |
| 10/6 | 30.477 | 30.496 | 30.534 | 30.578 | 30.597 | 30.610 | 30.614 | 30.627 | |
| 10/27 | 30.444 | 30.448 | 30.459 | 30.462 | 30.464 | 30.466 | 30.471 | 30.475 | 30.481 |

STATION #3
Density ($\sigma_t$)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 20.324 | 21.116 | 21.623 | 22.104 | 22.204 | 22.254 | 22.351 | 22.542 | 22.683 | 22.816 |
| 7/26 | 20.431 | 21.981 | 22.081 | 22.149 | 22.189 | 22.210 | 22.288 | 22.362 | 22.414 | 22.458 |
| 8/11 | 20.199 | 22.067 | 22.228 | 22.335 | 22.392 | 22.430 | 22.498 | 22.736 | 22.752 | 22.811 |
| 8/24 | 21.531 | 21.953 | 22.303 | 22.380 | 22.416 | 22.439 | 22.465 | 22.552 | 22.705 | 22.843 |
| 9/9 | 22.036 | 22.091 | 22.392 | 22.567 | 22.589 | 22.625 | 22.723 | 22.806 | 22.880 | 22.916 |
| 9/22 | 21.797 | 22.350 | 22.546 | 22.677 | 22.686 | 22.707 | 22.733 | 22.810 | 22.855 | 22.972 |
| 10/6 | 22.302 | 22.564 | 22.780 | 22.844 | 22.874 | 22.907 | 22.916 | 23.003 | 23.076 | 23.228 |
| 10/27 | 22.493 | 22.354 | 22.964 | 23.121 | 23.196 | 23.231 | 23.238 | 23.248 | 23.251 | 23.258 |

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 |
|---|---|---|---|---|---|---|---|---|---|
| 7/16/82 | 22.855 | 22.871 | 22.919 | 22.947 | 22.960 | 22.967 | 22.974 | | |
| 7/26 | 22.610 | 22.771 | 22.818 | 22.837 | 22.856 | 22.884 | 22.889 | 22.893 | |
| 8/11 | 22.836 | 22.878 | 22.888 | 22.901 | 22.914 | 22.926 | 22.934 | 22.947 | |
| 8/24 | 22.881 | 22.877 | 22.897 | 22.924 | 22.942 | 22.949 | 22.962 | 22.974 | 22.989 |
| 9/9 | 22.923 | 23.008 | 23.073 | 23.088 | 23.108 | 23.110 | 23.136 | 23.149 | |
| 9/22 | 23.015 | 23.032 | 23.047 | 23.071 | 23.070 | 23.068 | 23.072 | 23.087 | |
| 10/6 | 23.237 | 23.258 | 23.297 | 23.342 | 23.361 | 23.373 | 23.378 | 23.392 | |
| 10/27 | 23.253 | 23.265 | 23.277 | 23.282 | 23.284 | 23.289 | 23.298 | 23.310 | 23.325 |

STATION #4
Temperature (°C)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 13.256 | 13.200 | 12.437 | 11.757 | 11.633 | 11.536 | 11.388 | 10.995 | 10.584 | 10.465 |
| 7/16 | 13.302 | 12.944 | 12.639 | 11.895 | 11.485 | 11.260 | 11.181 | 11.097 | 10.733 | 10.558 |
| 7/19 | 13.254 | 12.728 | 12.590 | 11.890 | 11.515 | 11.400 | 11.190 | 10.969 | 10.608 | 10.495 |
| 7/26 | 12.524 | 12.107 | 11.949 | 11.892 | 11.881 | 11.832 | 11.798 | 11.403 | 11.246 | 11.157 |
| 7/28 | 13.116 | 12.859 | 12.484 | 12.352 | 12.184 | 12.145 | 11.935 | 11.804 | 11.737 | 11.369 |
| 8/2 | 13.623 | 12.882 | 12.552 | 12.265 | 11.867 | 11.718 | 11.504 | 11.191 | 10.992 | 10.807 |
| 8/9 | 12.270 | 12.167 | 12.092 | 12.035 | 11.938 | 11.922 | 11.837 | 11.493 | 11.006 | 10.955 |
| 8/16 | 13.428 | 12.954 | 12.579 | 12.164 | 12.054 | 11.816 | 11.649 | 11.374 | 11.307 | 11.184 |
| 9/23 | 12.303 | 12.253 | 12.205 | 12.155 | 12.138 | 12.086 | 12.033 | 11.893 | 11.638 | 11.570 |
| 9/7 | 12.484 | 12.342 | 12.199 | 12.167 | 12.144 | 12.126 | 12.084 | 11.922 | 11.663 | 11.519 |
| 9/13 | 13.038 | 12.652 | 12.612 | 12.494 | 12.373 | 12.127 | 12.002 | 11.761 | 11.701 | 11.626 |
| 9/21 | 12.242 | 12.231 | 12.208 | 12.163 | 12.140 | 12.129 | 12.126 | 12.126 | 11.911 | 11.642 |
| 9/27 | 12.720 | 12.720 | 12.552 | 12.417 | 12.221 | 12.037 | 11.949 | 11.793 | 11.626 | 11.472 |
| 10/6 | 12.125 | 12.104 | 12.035 | 11.985 | 11.862 | 11.812 | 11.761 | 11.616 | 11.479 | 11.447 |
| 10/11 | 11.899 | 11.898 | 11.893 | 11.894 | 11.899 | 11.903 | 11.886 | 11.810 | 11.767 | 11.676 |
| 10/28 | 11.338 | 11.376 | 11.412 | 11.369 | 11.324 | 11.271 | 11.160 | 10.950 | 10.444 | 10.913 |

STATION #4
Temperature (°C), cont'd

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 10.445 | 10.414 | 10.443 | 10.413 | 10.408 | 10.411 | 10.401 | 10.398 | 10.399 | 10.378 |
| 7/16 | 10.503 | 10.463 | 10.484 | 10.475 | 10.467 | 10.453 | 10.315 | 10.372 | 10.381 | 10.415 |
| 7/19 | 10.419 | 10.436 | 10.459 | 10.455 | 10.449 | 10.447 | 10.433 | | | |
| 7/26 | 11.036 | 10.945 | 10.858 | 10.756 | 10.715 | 10.649 | 10.621 | 10.583 | 10.572 | |
| 7/28 | 11.119 | 10.883 | 10.816 | 10.737 | 10.726 | 10.698 | 10.624 | 10.593 | 10.568 | 10.506 |
| 8/2 | 10.762 | 10.741 | 10.730 | 10.708 | 10.745 | 10.743 | 10.758 | 10.761 | 10.771 | 10.839 |
| 8/9 | 10.938 | 10.931 | 10.908 | 10.886 | 10.863 | 10.866 | 10.861 | 10.859 | 10.856 | 10.849 |
| 8/16 | 11.114 | 11.114 | 11.133 | 11.056 | 11.036 | 11.054 | 11.060 | 11.124 | 11.127 | 11.121 |
| 8/23 | 11.399 | 11.341 | 11.237 | 11.233 | 11.185 | 11.168 | 11.153 | 11.131 | 11.115 | 11.101 |
| 9/7 | 11.445 | 11.367 | 11.344 | 11.273 | 11.261 | 11.226 | 11.204 | 11.187 | 11.168 | 11.145 |
| 9/13 | 11.538 | 11.459 | 11.420 | 11.398 | 11.377 | 11.364 | 11.364 | 11.351 | 11.341 | 11.334 |
| 9/21 | 11.580 | 11.534 | 11.538 | 11.510 | 11.503 | 11.491 | 11.463 | 11.441 | 11.448 | 11.423 |
| 9/27 | 11.445 | 11.432 | 11.395 | 11.376 | 11.347 | 11.342 | 11.282 | 11.258 | 11.256 | 11.179 |
| 10/6 | 11.418 | 11.272 | 11.192 | 11.165 | 11.146 | 11.148 | 11.139 | 11.137 | 11.119 | 11.084 |
| 10/11 | 11.564 | 11.499 | 11.454 | 11.319 | 11.248 | 11.210 | 11.196 | 11.181 | 11.174 | 11.139 |
| 10/28 | 10.868 | 10.819 | 10.742 | 10.729 | 10.664 | 10.604 | 10.551 | 10.525 | 10.425 | 10.421 |

STATION #4
Oxygen (mg/l)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 8.893 | 8.943 | 9.093 | 8.240 | 7.515 | 7.370 | 7.296 | 7.190 | 6.977 | 6.780 |
| 7/16 | 8.701 | 8.914 | 8.890 | 8.254 | 7.487 | 7.150 | 6.917 | 6.848 | 6.814 | 6.615 |
| 7/19 | 8.926 | 9.044 | 9.436 | 9.122 | 8.416 | 7.837 | 7.488 | 7.237 | 7.012 | 6.810 |
| 7/26 | 7.367 | 7.549 | 7.792 | 7.785 | 7.660 | 7.516 | 7.356 | 7.263 | 7.078 | 6.964 |
| 7/28 | 7.785 | 7.951 | 8.263 | 8.015 | 7.556 | 7.413 | 7.326 | 7.201 | 7.147 | 7.098 |
| 8/2 | 7.786 | 8.036 | 7.761 | 7.330 | 6.931 | 6.685 | 6.594 | 6.533 | 6.378 | 6.271 |
| 8/9 | 7.312 | 7.454 | 7.712 | 7.522 | 7.484 | 7.461 | 7.454 | 7.200 | 6.919 | 6.547 |
| 8/16 | 8.319 | 8.658 | 8.619 | 7.221 | 6.690 | 6.484 | 6.252 | 6.099 | 5.912 | 5.889 |
| 8/23 | 6.645 | 6.894 | 7.144 | 7.142 | 6.821 | 6.774 | 6.763 | 6.745 | 6.510 | 6.411 |
| 9/7 | 7.653 | 7.855 | 8.056 | 7.798 | 7.531 | 7.386 | 7.362 | 7.379 | 7.209 | 6.960 |
| 9/13 | 6.636 | 6.774 | 6.617 | 6.473 | 6.332 | 6.249 | 6.171 | 6.112 | 6.042 | 6.006 |
| 9/21 | 6.160 | 6.334 | 6.558 | 6.798 | 6.582 | 6.377 | 6.333 | 6.369 | 6.413 | 6.315 |
| 9/27 | 7.907 | 8.220 | 8.547 | 7.655 | 6.809 | 6.290 | 6.008 | 5.935 | 5.867 | 5.843 |
| 10/6 | 6.537 | 6.669 | 6.515 | 6.258 | 6.026 | 5.892 | 5.852 | 5.857 | 5.742 | 5.678 |
| 10/11 | 6.509 | 6.476 | 6.430 | 6.410 | 6.443 | 6.518 | 6.468 | 6.386 | 6.270 | 6.144 |
| 10/28 | 8.243 | 8.227 | 8.075 | 7.588 | 7.281 | 6.788 | 6.485 | 6.549 | 6.484 | 6.417 |

STATION #4
Oxygen (mg/l) Cont.)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 6.700 | 6.680 | 6.707 | 6.752 | 6.791 | 6.853 | 6.902 | 6.958 | 6.952 | 6.997 |
| 7/16 | 6.497 | 6.498 | 6.511 | 6.574 | 6.635 | 6.708 | 6.770 | 6.786 | 6.802 | 6.823 |
| 7/19 | 6.731 | 6.744 | 6.799 | 6.854 | 6.881 | 6.907 | 6.914 | | | |
| 7/26 | 6.869 | 6.821 | 6.781 | 6.750 | 6.712 | 6.667 | 6.590 | 6.513 | 6.453 | |
| 7/28 | 6.931 | 6.755 | 6.641 | 6.553 | 6.507 | 6.495 | 6.457 | 6.394 | 6.322 | 6.248 |
| 8/2 | 6.232 | 6.233 | 6.225 | 6.262 | 6.276 | 6.303 | 6.383 | 6.387 | 6.400 | 6.443 |
| 8/9 | 6.442 | 6.505 | 6.569 | 6.621 | 6.666 | 6.714 | 6.725 | 6.712 | 6.703 | 6.672 |
| 8/16 | 5.885 | 5.962 | 6.045 | 6.162 | 6.164 | 6.146 | 6.174 | 6.291 | 6.489 | 6.529 |
| 8/23 | 6.367 | 6.360 | 6.362 | 6.399 | 6.428 | 6.460 | 6.516 | 6.558 | 6.563 | 6.539 |
| 9/7 | 6.833 | 6.740 | 6.730 | 6.696 | 6.701 | 6.704 | 6.729 | 6.753 | 6.758 | 6.735 |
| 9/13 | 5.993 | 5.973 | 5.991 | 6.024 | 6.055 | 6.069 | 6.103 | 6.108 | 6.083 | 6.064 |
| 9/21 | 6.182 | 6.190 | 6.228 | 6.255 | 6.282 | 6.314 | 6.325 | 6.340 | 6.364 | 6.356 |
| 9/27 | 5.855 | 5.910 | 6.007 | 6.060 | 6.107 | 6.186 | 6.259 | 6.320 | 6.396 | 6.484 |
| 10/6 | 5.672 | 5.672 | 5.616 | 5.611 | 5.635 | 5.635 | 5.636 | 5.628 | 5.593 | 5.555 |
| 10/11 | 6.083 | 5.985 | 5.888 | 5.799 | 5.720 | 5.624 | 5.562 | 5.472 | 5.384 | 5.321 |
| 10/28 | 6.473 | 6.510 | 6.357 | 6.483 | 6.529 | 6.565 | 6.629 | 6.634 | 6.576 | 6.670 |

STATION #4
Salinity (°/₀₀)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | | | 28.852 | 29.107 | 29.147 | 29.200 | 29.291 | 29.381 | 29.607 | 29.754 |
| 7/16 | | 28.692 | 28.844 | 29.113 | 29.278 | 29.373 | 29.395 | 29.410 | 29.638 | 29.670 |
| 7/19 | | | | 29.205 | 29.311 | 29.352 | 29.431 | 29.534 | 29.792 | 29.856 |
| 7/26 | 29.330 | 29.262 | 29.278 | 29.282 | 29.282 | 29.295 | 29.312 | 29.468 | 29.527 | 29.578 |
| 7/28 | 29.173 | 29.221 | 29.306 | 29.275 | 29.282 | 29.288 | 29.332 | 29.352 | 29.385 | 29.503 |
| 8/2 | 28.124 | 29.148 | 29.206 | 29.242 | 29.394 | 29.422 | 29.494 | 29.638 | 29.771 | 29.798 |
| 8/9 | 29.411 | 29.406 | 29.433 | 29.429 | 29.438 | 29.443 | 29.483 | 29.573 | 29.792 | 29.841 |
| 8/16 | 29.246 | 29.394 | 29.454 | 29.562 | 29.585 | 29.662 | 29.716 | 29.801 | 29.815 | 29.915 |
| 8/23 | 29.615 | 29.640 | 29.645 | 29.666 | 29.680 | 29.692 | 29.702 | 29.729 | 29.838 | 29.856 |
| 8/30 | 29.259 | 29.460 | 29.664 | 29.676 | 29.798 | 29.896 | 29.916 | 29.959 | 30.001 | 30.045 |
| 9/ 7 | 29.800 | 29.812 | 29.838 | 29.855 | 29.862 | 29.857 | 29.882 | 29.938 | 30.030 | 30.111 |
| 9/13 | 29.597 | 29.764 | 29.777 | 29.809 | 29.857 | 29.940 | 29.985 | 30.101 | 20.120 | 30.169 |
| 9/21 | 29.971 | 29.973 | 29.976 | 29.998 | 30.015 | 30.032 | 30.013 | 30.025 | 30.132 | 30.287 |
| 9/27 | 29.692 | 29.738 | 29.927 | 29.968 | 30.001 | 30.069 | 30.101 | 30.179 | 30.258 | 30.346 |
| 10/6 | 29.988 | 30.029 | 30.078 | 30.104 | 30.156 | 30.177 | 30.208 | 30.293 | 30.366 | 30.382 |
| 10/11 | 30.122 | 30.114 | 30.125 | 30.130 | 30.130 | 30.139 | 30.143 | 30.158 | 30.186 | 30.252 |
| 10/28 | 29.998 | 30.053 | 30.131 | 30.204 | 30.260 | 30.337 | 30.381 | 30.462 | 30.472 | 30.484 |

STATION #4
Salinity (°/₀₀)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 29.806 | 29.873 | 29.906 | 29.922 | 29.941 | 29.953 | 29.971 | 29.994 | 29.994 | 30.102 |
| 7/16 | 29.813 | 29.884 | 29.912 | 29.929 | 29.935 | 29.951 | 29.955 | 29.957 | 29.982 | 29.970 |
| 7/19 | 29.912 | 29.946 | 29.966 | 29.972 | 29.982 | 29.980 | 29.986 | | | |
| 7/26 | 29.636 | 29.680 | 29.732 | 29.806 | 29.814 | 29.861 | 29.859 | 29.879 | 29.878 | |
| 7/28 | 29.621 | 29.755 | 29.794 | 29.837 | 29.844 | 29.853 | 29.875 | 29.901 | 29.902 | 29.929 |
| 8/2 | 29.842 | 29.825 | 29.872 | 29.913 | 29.911 | 29.943 | 29.926 | 29.930 | 29.947 | 30.022 |
| 8/9 | 29.882 | 29.910 | 29.933 | 29.966 | 30.006 | 30.052 | 30.069 | 30.067 | 30.074 | 30.079 |
| 8/16 | 29.978 | 30.010 | 30.017 | 30.075 | 30.085 | 30.105 | 30.132 | 30.180 | 30.186 | 30.187 |
| 8/23 | 29.957 | 29.985 | 30.054 | 30.058 | 30.115 | 30.132 | 30.136 | 30.153 | 30.171 | 30.172 |
| 8/30 | 30.111 | 30.102 | 30.121 | 30.146 | 30.145 | 30.160 | 30.164 | 30.202 | 30.262 | 30.305 |
| 9/7 | 30.130 | 30.185 | 30.196 | 30.248 | 30.297 | 30.352 | 30.372 | 30.390 | 30.414 | 30.432 |
| 9/13 | 30.245 | 30.307 | 30.353 | 30.370 | 30.383 | 30.386 | 30.382 | 30.387 | 30.399 | 30.409 |
| 9/21 | 30.317 | 30.350 | 30.356 | 30.383 | 30.385 | 30.399 | 30.439 | 30.443 | 30.443 | 30.461 |
| 9/27 | 30.349 | 30.365 | 30.393 | 30.406 | 30.411 | 30.418 | 30.433 | 30.451 | 30.449 | 30.490 |
| 10/6 | 30.405 | 30.484 | 30.542 | 30.564 | 30.574 | 30.570 | 30.586 | 30.585 | 30.602 | 30.616 |
| 10/11 | 30.301 | 30.339 | 30.360 | 30.447 | 30.483 | 30.511 | 30.522 | 30.541 | 30.542 | 30.572 |
| 10/28 | 30.490 | 30.496 | 30.514 | 30.521 | 30.564 | 30.585 | 30.626 | 30.670 | 30.774 | 30.791 |

STATION #4
Density ($\sigma_t$)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | | | 21.772 | 22.091 | 22.144 | 22.202 | 22.307 | 22.435 | 22.679 | 22.813 |
| 7/16 | | 21.554 | 21.728 | 22.071 | 22.271 | 22.383 | 22.414 | 22.440 | 22.678 | 22.802 |
| 7/19 | | | | 22.143 | 22.291 | 22.343 | 22.440 | 22.558 | 22.819 | 22.887 |
| 7/26 | 22.124 | 22.148 | 22.189 | 22.202 | 22.204 | 22.223 | 22.242 | 22.432 | 22.505 | 22.560 |
| 7/28 | 21.892 | 21.978 | 22.113 | 22.114 | 22.150 | 22.161 | 22.233 | 22.272 | 22.309 | 22.465 |
| 8/2 | 20.988 | 21.917 | 22.024 | 22.104 | 22.293 | 22.341 | 22.435 | 22.601 | 22.750 | 22.790 |
| 8/9 | 22.234 | 22.249 | 22.283 | 22.290 | 22.315 | 22.321 | 22.367 | 22.498 | 22.752 | 22.798 |
| 8/16 | 21.888 | 22.093 | 22.210 | 22.370 | 22.407 | 22.510 | 22.581 | 22.695 | 22.718 | 22.816 |
| 8/23 | 22.385 | 22.414 | 22.426 | 22.452 | 22.465 | 22.484 | 22.501 | 22.548 | 22.677 | 22.703 |
| 8/30 | 21.738 | 22.056 | 22.385 | 22.432 | 22.579 | 22.678 | 22.700 | 22.764 | 22.828 | 22.893 |
| 9/7 | 22.494 | 22.530 | 22.576 | 22.595 | 22.605 | 22.604 | 22.631 | 22.704 | 22.821 | 22.910 |
| 9/13 | 22.234 | 22.435 | 22.453 | 22.500 | 22.559 | 22.668 | 22.726 | 22.8 9 | 22.884 | 22.935 |
| 9/21 | 22.671 | 22.675 | 22.681 | 22.706 | 22.724 | 22.739 | 22.725 | 22.734 | 22.856 | 23.024 |
| 9/27 | 22.367 | 22.403 | 22.580 | 22.637 | 22.698 | 22.784 | 22.825 | 22.913 | 23.004 | 23.100 |
| 10/6 | 22.702 | 22.741 | 22.792 | 22.821 | 22.883 | 22.908 | 22.942 | 23.033 | 23.114 | 23.132 |
| 10/11 | 22.850 | 22.844 | 22.854 | 22.857 | 22.856 | 22.863 | 22.869 | 22.894 | 22.923 | 22.991 |
| 10/28 | 22.854 | 22.890 | 22.944 | 23.008 | 23.059 | 23.128 | 23.181 | 23.280 | 23.290 | 23.298 |

STATION #4
Density ($\sigma_t$)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 22.856 | 22.914 | 22.934 | 22.967 | 22.967 | 22.976 | 22.992 | 23.010 | 23.100 | 23.027 |
| 7/16 | 22.852 | 22.914 | 22.932 | 22.953 | 22.953 | 22.968 | 22.993 | 22.986 | 23.004 | 22.989 |
| 7/19 | 22.943 | 22.967 | 22.978 | 22.992 | 22.992 | 22.991 | 22.998 | | | |
| 7/26 | 22.626 | 22.675 | 22.730 | 22.818 | 22.818 | 22.865 | 22,868 | 22.890 | 22.891 | |
| 7/28 | 22.600 | 22.744 | 22.785 | 22.839 | 22.839 | 22.851 | 22.880 | 22.906 | 22.911 | 22.942 |
| 8/2 | 22.832 | 22.822 | 22.860 | 22.888 | 22.888 | 22.913 | 22.897 | 22.900 | 22.912 | 22.958 |
| 8/9 | 22.833 | 22.856 | 22.877 | 22.942 | 22.942 | 22.977 | 22.991 | 22.990 | 22.996 | 23.001 |
| 8/16 | 22.877 | 22.902 | 22.904 | 22.973 | 22.973 | 22.986 | 23.006 | 23.032 | 23.036 | 23.038 |
| 8/23 | 22.811 | 22.843 | 22.915 | 22.971 | 22.971 | 22.987 | 22.993 | 23.010 | 23.026 | 23.030 |
| 8/30 | 22.955 | 22.948 | 22.964 | 22.981 | 22.981 | 22.996 | 23.999 | 23.033 | 23.076 | 23,112 |
| 9/7 | 22.937 | 22.994 | 23,006 | 23,099 | 23,099 | 23,147 | 23,167 | 23.184 | 23.206 | 23.224 |
| 9/13 | 23.010 | 23.072 | 23.114 | 23.145 | 23,145 | 23.150 | 23.147 | 23,153 | 23.164 | 23.173 |
| 9/21 | 23.058 | 23:092 | 23.096 | 23.124 | 23,124 | 23.137 | 23.173 | 23,180 | 23.179 | 23.197 |
| 9/27 | 23.107 | 23.121 | 23.150 | 23.172 | 23.172 | 23.178 | 23.200 | 23.219 | 23.217 | 23.263 |
| 10/6 | 23.155 | 23.242 | 23.301 | 23.333 | 23.333 | 23.329 | 23.344 | 23.343 | 23.360 | 23.377 |
| 10/11 | 23.049 | 23.090 | 23.114 | 23.245 | 23.245 | 23.273 | 23.284 | 23.302 | 23.304 | 23.333 |
| 10/28 | 23.316 | 23.329 | 23.356 | 23.408 | 23.408 | 23.435 | 23.475 | 23.514 | 23.611 | 23.625 |

STATION #5
Temperature (°C)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 13.557 | 13.488 | 12.998 | 12.040 | 11.585 | 11.002 | 10.554 | 10.291 | 10.286 | 10.268 |
| 7/19 | 12.973 | 12.870 | 12.686 | 12.346 | 12.016 | 11.555 | 11.385 | 10.952 | 10.588 | 10.455 |
| 7/28 | 13.766 | 13.512 | 13.200 | 12.192 | 11.990 | 11.814 | 11.714 | 11.488 | 11.157 | 11.017 |
| 8/2 | 13.764 | 13.502 | 12.827 | 12.044 | 11.633 | 11.553 | 11.416 | 11.224 | 11.029 | 10.848 |
| 8/9 | 12.385 | 12.233 | 12.049 | 11.794 | 11.667 | 11.643 | 11.576 | 11.331 | 11.057 | 10.958 |
| 8/16 | 13.947 | 13.548 | 13.178 | 12.914 | 12.276 | 11.847 | 11.794 | 11.518 | 11.477 | 11.352 |
| 8/23 | 12.842 | 12.293 | 12.268 | 12.168 | 12.141 | 12.103 | 11.994 | 11.557 | 11.435 | 11.292 |
| 8/30 | 14.095 | 13.417 | 13.238 | 12.416 | 11.945 | 11.952 | 11.761 | 11.491 | 11.383 | 11.293 |
| 9/7 | 12.990 | 12.832 | 12.581 | 12.478 | 12.292 | 12.126 | 11.838 | 11.553 | 11.464 | 11.401 |
| 9/13 | 13.259 | 13.119 | 12.668 | 12.352 | 12.070 | 11.904 | 11.851 | 11.714 | 11.579 | 11.526 |
| 9/21 | 12.386 | 12.292 | 12.261 | 12.237 | 12.223 | 12.169 | 12.129 | 12.132 | 12.112 | 12.038 |
| 9/27 | 12.789 | 12.731 | 12.374 | 12.279 | 12.191 | 12.033 | 11.953 | 11.631 | 11.501 | 11.459 |
| 10/11 | 12.202 | 12.022 | 11.961 | 11.896 | 11.882 | 11.863 | 11.807 | 11.769 | 11.745 | 11.705 |
| 10/28 | 11.374 | 11.401 | 11.422 | 11.421 | 11.345 | 11.295 | 11.054 | 10.978 | 10.868 | 10.863 |

STATION #5
Temperature (°C)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 10.347 | 10.315 | 10.277 | 10.269 | 10.269 | |
| 7/19 | 10.443 | 10.392 | | | | |
| 7/28 | 10.904 | 10.803 | 10.713 | 10.667 | 10.621 | 10.604 |
| 8/2 | 10.780 | 10.747 | | | | |
| 8/9 | 10.733 | 10.705 | 10.744 | | | |
| 8/16 | 11.250 | 11.158 | | | | |
| 8/23 | 11.255 | 11.178 | 11.118 | | | |
| 8/30 | 11.235 | 11.202 | 11.173 | 11.169 | | |
| 9/7 | 11.334 | 11.238 | 11.190 | | | |
| 9/13 | 11.442 | 11.335* | | | | |
| 9/21 | 11.768 | 11.570 | 11.579 | | | |
| 9/27 | 11.442 | 11.428 | 11.427 | | | |
| 10/11 | 11.673 | 11.633 | | | | |
| 10/28 | 10.829 | 10.772 | 10.752 | 10.750 | 10.731 | |

* value at 98 m

STATION #5
Oxygen (mg/l)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 8.939 | 9.146 | 9.191 | 8.699 | 7.858 | 7.321 | 6.875 | 6.593 | 6.440 | 6.424 |
| 7/19 | 8.149 | 8.213 | 8.311 | 7.973 | 7.691 | 7.446 | 7.138 | 6.987 | 6.702 | 6.501 |
| 7/28 | 7.395 | 7.765 | 7.540 | 7.232 | 6.923 | 6.809 | 6.703 | 6.624 | 6.538 | 6.348 |
| 8/2 | 7.703 | 7.995 | 7.786 | 7.021 | 6.426 | 6.248 | 6.207 | 6.143 | 6.078 | 6.020 |
| 8/9 | 7.435 | 7.728 | 7.517 | 6.771 | 6.438 | 6.307 | 6.303 | 6.269 | 6.085 | 5.931 |
| 8/16 | 8.597 | 8.877 | 9.014 | 8.325 | 7.664 | 6.592 | 6.134 | 5.948 | 5.800 | 5.785 |
| 8/23 | 6.643 | 6.772 | 6.654 | 6.531 | 6.472 | 6.452 | 6.480 | 6.244 | 5.964 | 5.856 |
| 8/30 | 11.315 | 12.025 | 10.606 | 7.962 | 6.533 | 5.813 | 5.742 | 5.596 | 5.545 | 5.546 |
| 9/7 | 8.886 | 8.950 | 8.751 | 7.860 | 7.295 | 6.718 | 6.247 | 5.784 | 5.464 | 5.352 |
| 9/13 | 7.228 | 7.293 | 7.190 | 6.769 | 6.460 | 6.160 | 6.067 | 6.036 | 5.926 | 5.907 |
| 9/21 | 6.873 | 6.811 | 6.523 | 6.277 | 6.183 | 6.231 | 6.225 | 6.262 | 6.297 | 6.358 |
| 9/27 | 8.309 | 8.433 | 8.207 | 6.904 | 6.301 | 5.976 | 5.827 | 5.752 | 5.610 | 5.579 |
| 10/11 | 7.649 | 7.255 | 7.029 | 6.563 | 6.392 | 6.269 | 6.138 | 6.055 | 5.987 | 5.948 |
| 10/28 | 8.781 | 8.212 | 8.051 | 7.502 | 6.624 | 6.327 | 5.773 | 5.752 | 5.796 | 5.807 |

STATION #5
Oxygen (mg/l)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 6.435 | 6.500 | 6.566 | 6.623 | 6.673 | |
| 7/19 | 6.439 | 6.446 | | | | |
| 7/28 | 6.265 | 6.225 | 6.173 | 6.139 | 6.135 | 6.138 |
| 8/2 | 5.984 | 5.979 | | | | |
| 8/9 | 5.881 | 5.854 | 5.924 | | | |
| 8/16 | 5.707 | 5.713 | | | | |
| 8/23 | 5.854 | 5.884 | 5.854 | | | |
| 8/30 | 5.625 | 5.733 | 5.782 | 5.861 | | |
| 9/7 | 5.364 | 5.356 | 5.358 | | | |
| 9/13 | 5.901 | 5.850* | | | | |
| 9/21 | 6.353 | 6.147 | 6.145 | | | |
| 9/27 | 5.650 | 5.725 | 5.835 | | | |
| 10/11 | 5.904 | 5.883 | | | | |
| 10/28 | 6.166 | 6.055 | 5.183 | 6.384 | 6.066 | |

*value at 98 m

STATION #5
Salinity (°/₀₀)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 28.245 | 28.295 | 28.651 | 29.034 | 29.157 | 29.375 | 29.597 | 29.787 | 29.796 | 29.819 |
| 7/19 | 28.687 | 28.765 | 28.906 | 29.110 | 29.198 | 29.320 | 29.366 | 29.559 | 29.757 | 29.844 |
| 7/28 | 29.135 | 29.129 | 29.147 | 29.309 | 29.345 | 29.370 | 29.401 | 29.474 | 29.595 | 29.670 |
| 8/2 | 28.362 | 28.468 | 29.126 | 29.376 | 29.489 | 29.507 | 29.546 | 29.627 | 29.715 | 29.799 |
| 8/9 | 29.383 | 29.420 | 29.436 | 29.493 | 29.529 | 29.534 | 29.552 | 29.631 | 29.749 | 29.785 |
| 8/16 | 29.165 | 29.245 | 29.326 | 29.403 | 29.565 | 29.665 | 29.689 | 29.807 | 29.819 | 29.847 |
| 8/23 | 29.651 | 29.689 | 29.693 | 29.698 | 29.700 | 29.716 | 29.725 | 29.859 | 29.927 | 30.003 |
| 8/30 | 29.324 | 29.508 | 29.479 | 29.679 | 29.783 | 29.779 | 29.825 | 29.938 | 29.985 | 30.040 |
| 9/7 | 29.731 | 29.734 | 29.799 | 29.816 | 29.846 | 29.872 | 29.970 | 30.086 | 30.119 | 30.161 |
| 9/13 | 29.493 | 29.584 | 29.758 | 29.855 | 29.949 | 30 024 | 30.043 | 30.103 | 30.197 | 30.217 |
| 9/21 | 29.975 | 29.995 | 29.993 | 29.996 | 30.007 | 30.016 | 30.036 | 30.038 | 30.044 | 30.082 |
| 9/27 | 29.669 | 29.735 | 29.972 | 29.992 | 30.015 | 30.076 | 30.101 | 30.269 | 30.334 | 30.362 |
| 10/11 | 29.116 | 30.105 | 30.140 | 30.137 | 30.141 | 30.154 | 30.165 | 30.190 | 30.206 | 30.230 |
| 10/28 | 29.838 | 29.863 | 29.874 | 30.121 | 30.266 | 30.316 | 30.448 | 30.477 | 30.489 | 30.486 |

STATION #5
Salinity (°/₀₀)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 29.878 | 28.898 | 29.901 | 29.909 | 29.919 | |
| 7/19 | 29.850 | 29.911 | | | | |
| 7/28 | 29.724 | 29.781 | 29.835 | 29.856 | 29.879 | 29.890 |
| 8/2 | 29.828 | 29.846 | | | | |
| 8/9 | 29.894 | 29.926 | 29.957 | | | |
| 8/16 | 29.895 | 29.947 | | | | |
| 8/23 | 30.010 | 30.060 | 0.107 | | | |
| 8/30 | 30.067 | 30.083 | 30.116 | 30.096 | | |
| 9/7 | 30.196 | 30.253 | 30.332 | | | |
| 9/13 | 30.259 | 30.331* | | | | |
| 9/21 | 30.213 | 30.325 | 30.320 | | | |
| 9/27 | 30.368 | 30.381 | 30.388 | | | |
| 10/11 | 30.247 | 30.269 | | | | |
| 10/28 | 30.487 | 30.508 | 30.511 | 30.516 | 30.526 | |

*value at 98 m

STATION #5
Density ($\sigma_t$)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 21.093 | 21.145 | 21.513 | 21.984 | 22.160 | 22.429 | 22.676 | 22.867 | 22.875 | 22.896 |
| 7/19 | 21.545 | 21.624 | 21.767 | 21.987 | 22.115 | 22.291 | 22.356 | 22.580 | 22.795 | 22.884 |
| 7/28 | 21.737 | 21.782 | 21.856 | 22.169 | 22.233 | 22.284 | 22.326 | 22.422 | 22.573 | 22.655 |
| 8/2 | 21.143 | 21.276 | 21.911 | 22.248 | 22.408 | 22.436 | 22.490 | 22.586 | 22.688 | 22.784 |
| 8/9 | 22.191 | 22.247 | 22.293 | 22.383 | 22.433 | 22.441 | 22.467 | 22.571 | 22.710 | 22.754 |
| 8/16 | 21.724 | 21.864 | 21.998 | 22.108 | 22.351 | 22.506 | 22.534 | 22.674 | 22.691 | 22.734 |
| 8/23 | 22.313 | 22.444 | 22.452 | 22.474 | 22.480 | 22.500 | 22.526 | 22.708 | 22.782 | 22.866 |
| 8/30 | 21.817 | 22.092 | 22.105 | 22.414 | 22.580 | 22.576 | 22.645 | 22.781 | 22.836 | 22.894 |
| 9/7 | 22.346 | 22.378 | 22.476 | 22.508 | 22.565 | 22.616 | 22.744 | 22.884 | 22.925 | 22.969 |
| 9/13 | 22.111 | 22.208 | 22.428 | 22.561 | 22.686 | 22.774 | 22.798 | 22.869 | 22.965 | 22.990 |
| 9/21 | 22.648 | 22.681 | 22.685 | 22.691 | 22.702 | 22.719 | 22.742 | 22.743 | 22.751 | 22.794 |
| 9/27 | 22.336 | 22.398 | 22.648 | 22.681 | 22.714 | 22.790 | 22.824 | 23.012 | 23.085 | 23.114 |
| 10/11 | 22.790 | 22.815 | 22.853 | 22.862 | 22.868 | 22.881 | 22.900 | 22.926 | 22.943 | 22.969 |
| 10/28 | 22.724 | 22.738 | 22.743 | 22.935 | 23.060 | 23.108 | 23.252 | 23.278 | 23.315 | 23.314 |

STATION #5
Density ($\sigma_t$)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 22.928 | 22.949 | 22.958 | 22.965 | 22.973 | |
| 7/19 | 22.891 | 22.947 | | | | |
| 7/28 | 22.716 | 22.777 | 22.834 | 22.858 | 22.884 | 22.895 |
| 8/2 | 22.818 | 22.837 | | | | |
| 8/9 | 22.877 | 22.906 | 22.924 | | | |
| 8/16 | 22.789 | 22.846 | | | | |
| 8/23 | 22.878 | 22.930 | 22.976 | | | |
| 8/30 | 22.925 | 22.942 | 22.974 | 22.959 | | |
| 9/7 | 23.008 | 23.069 | 23.138 | | | |
| 9/13 | 23.038 | 23.112* | | | | |
| 9/21 | 22.944 | 23.066 | 23.061 | | | |
| 9/27 | 23.122 | 23.135 | 23.141 | | | |
| 10/11 | 22.987 | 23.012 | | | | |
| 10/28 | 23.320 | 23.346 | 23.352 | 23.356 | 23.367 | |

*value at 98 m

STATION #6
Temperature (°C)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 13.509 | 13.490 | 13.481 | 11.550 | 11.502 | 10.767 | 10.508 | 10.374 | 10.244 | 10.094 |
| 7/19 | 13.112 | 12.959 | 12.732 | 12.587 | 12.130 | 11.672 | 11.535 | 11.228 | 11.043 | 10.720 |
| 7/28 | 13.960 | 13.417 | 12.583 | 11.879 | 11.776 | 11.632 | 11.455 | 11.300 | 11.128 | 11.014 |
| 8/2 | 14.212 | 13.530 | 13.077 | 12.225 | 11.899 | 11.700 | 11.438 | 11.228 | 11.051 | 10.980 |
| 8/9 | 12.432 | 12.330 | 12.035 | 11.966 | 11.787 | 11.619 | 11.414 | 11.048 | 10.934 | 10.767 |
| 8/16 | 13.822 | 13.222 | 13.004 | 12.427 | 12.308 | 12.065 | 11.527 | 11.404 | 11.326 | 11.253 |
| 8/23 | 12.779 | 12.457 | 12.204 | 12.119 | 11.973 | 11.633 | 11.515 | 11.367 | 11.313 | 11.171 |
| 8/30 | 14.260 | 13.867 | 13.840 | 12.549 | 12.163 | 12.005 | 11.840 | 11.599 | 11.415 | 11.289 |
| 9/7 | 13.579 | 13.251 | 12.911 | 12.793 | 12.393 | 12.070 | 11.863 | 11.659 | 11.451 | 11.359 |
| 9/13 | 13.550 | 12.985 | 12.703 | 12.484 | 12.111 | 12.059 | 11.964 | 11.897 | 11.712 | 11.604 |
| 9/21 | 12.344 | 12.301 | 12.274 | 12.229 | 12.135 | 12.004 | 11.712 | 11.650 | 11.621 | 11.542 |
| 9/27 | 12.748 | 12.577 | 12.450 | 12.216 | 12.133 | 12.016 | 11.834 | 11.608 | 11.522 | 11.487 |
| 10/11 | 12.067 | 11.878 | 11.873 | 11.816 | 11.814 | 11.785 | 11.770 | 11.750 | 11.691 | 11.659 |
| 10/28 | 11.413 | 11.414 | 11.421 | 11.404 | 11.365 | 11.266 | 11.112 | 11.024 | 10.981 | 10.964 |

STATION #6
Temperature (°C)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 10.099 | 10.135 | 10.152 | | | |
| 7/19 | 10.508 | 10.345 | | | | |
| 7/28 | 10.890 | 10.738 | | | | |
| 8/2 | 10.840 | 10.753 | 10.701 | 10.678 | | |
| 8/9 | 10.736 | 10.724 | | | | |
| 8/16 | 11.094 | 10.990 | 10.987 | 10.976 | | |
| 8/23 | | | | | | |
| 8/30 | 11.169 | 11.168 | 11.169 | 11.148 | 11.151 | |
| 9/7 | 11.203 | 11.186 | 11.152 | 11.139 | 11.126 | 11.128 |
| 9/13 | 11.542 | 11.433 | 11.358 | 11.309 | | |
| 9/21 | 11.500 | 11.429 | 11.411 | 11.410 | 11.410 | |
| 9/27 | 11.443 | 11.407 | 11.406 | 11.405 | | |
| 10/11 | 11.630 | 11.552 | 11.479 | | | |
| 10/28 | 10.882 | 10.857 | 10.832 | 10.796 | 10.754 | |

STATION #6
Oxygen (mg/l)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 8.733 | 8.911 | 9.014 | 9.088 | 7.564 | 7.019 | 6.693 | 6.556 | 6.471 | 6.433 |
| 7/19 | 8.358 | 8.411 | 8.527 | 8.178 | 7.930 | 7.657 | 7.317 | 7.162 | 6.988 | 6.811 |
| 7/28 | 7.679 | 7.776 | 7.713 | 7.214 | 6.834 | 6.688 | 6.608 | 6.510 | 6.399 | 6.291 |
| 8/2 | 7.820 | 8.130 | 7.957 | 7.451 | 6.664 | 6.357 | 6.238 | 6.136 | 6.023 | 5.954 |
| 8/9 | 7.653 | 8.138 | 7.786 | 7.008 | 6.815 | 6.550 | 6.332 | 6.113 | 5.890 | 5.812 |
| 8/16 | 8.424 | 8.742 | 8.449 | 7.672 | 6.874 | 6.584 | 5.943 | 5.624 | 5.543 | 5.531 |
| 8/23 | 6.745 | 6.856 | 6.804 | 6.386 | 6.243 | 6.094 | 5.860 | 5.763 | 5.762 | 5.709 |
| 8/30 | 11.556 | 11.948 | 11.585 | 10.158 | 6.961 | 6.063 | 5.958 | 5.881 | 5.778 | 5.760 |
| 9/7 | 8.489 | 8.794 | 9.052 | 8.634 | 8.136 | 7.158 | 6.347 | 5.744 | 5.424 | 5.170 |
| 9/13 | 7.334 | 7.341 | 6.973 | 6.619 | 6.374 | 6.159 | 6.094 | 6.132 | 6.100 | 6.019 |
| 9/21 | 6.271 | 6.213 | 6.206 | 6.207 | 6.119 | 6.058 | 5.930 | 5.784 | 5.763 | 5.774 |
| 9/27 | 8.003 | 8.145 | 7.657 | 6.734 | 6.123 | 5.912 | 5.754 | 5.621 | 5.559 | 5.536 |
| 10/11 | 7.347 | 6.786 | 6.755 | 6.519 | 6.235 | 6.060 | 5.976 | 5.946 | 5.928 | 5.860 |
| 10/28 | 8.136 | 7.944 | 7.873 | 7.581 | 6.788 | 6.243 | 5.778 | 5.760 | 5.613 | 5.616 |

STATION #6
Oxygen (mg/l)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 6.451 | 6.488 | 6.501 | | | |
| 7/19 | 6.649 | 6.534 | | | | |
| 7/28 | 6.261 | 6.239 | | | | |
| 8/2 | 5.922 | 5.919 | 5.928 | 5.931 | | |
| 8/9 | 5.772 | 5.839 | | | | |
| 8/16 | 5.512 | 5.455 | 5.515 | 5.597 | | |
| 8/23 | | | | | | |
| 8/30 | 5.771 | 5.844 | 5.884 | 5.958 | 6.066 | |
| 9/7 | 5.093 | 5.059 | 5.159 | 5.215 | 5.288 | 5.361 |
| 9/13 | 5.997 | 5.969 | 5.925 | 5.878 | | |
| 9/21 | 5.803 | 5.817 | 5.818 | 5.855 | 5.899 | |
| 9/27 | 5.616 | 5.721 | 5.799 | 5.864 | | |
| 10/11 | 5.839 | 5.801 | 5.751 | | | |
| 10/28 | 5.710 | 5.776 | 5.798 | 5.934 | 5.833 | |

STATION #6
Salinity (°/₀₀)

| Depth, m: Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 28.281 | 28.294 | 28.299 | 29.212 | 29.365 | 29.488 | 29.624 | 29.703 | 29.771 | 29.833 |
| 7/19 | 28.581 | 28.696 | 28.870 | 28.979 | 29.140 | 29.271 | 29.320 | 29.435 | 29.513 | 29.673 |
| 7/28 | 29.108 | 29.195 | 29.312 | 29.384 | 29.384 | 29.421 | 29.484 | 29.558 | 29.607 | 29.659 |
| 8/2 | 28.115 | 28.504 | 28.951 | 29.321 | 29.397 | 29.459 | 29.557 | 29.628 | 29.704 | 29.736 |
| 8/9 | 29.408 | 29.408 | 29.451 | 29.463 | 29.503 | 29.538 | 29.608 | 29.745 | 29.771 | 29.851 |
| 8/16 | 29.069 | 29.316 | 29.404 | 29.526 | 29.508 | 29.536 | 29.774 | 29.833 | 29.848 | 29.888 |
| 8/23 | 29.694 | 29.679 | 29.695 | 29.712 | 29.748 | 29.839 | 29.889 | 29.932 | 29.964 | 30.023 |
| 8/30 | 29.337 | 29.366 | 29.364 | 29.666 | 29.740 | 29.768 | 29.806 | 29.896 | 29.967 | 30.026 |
| 9/7 | 29.699 | 29.774 | 29.790 | 29.774 | 29.827 | 29.901 | 29.943 | 30.030 | 30.101 | 30.165 |
| 9/13 | 29.483 | 29.644 | 29.735 | 29.809 | 29.931 | 29.947 | 29.982 | 30.011 | 30.095 | 30.151 |
| 9/21 | 29.987 | 29.981 | 29.983 | 29.992 | 30.030 | 30.080 | 30.220 | 30.267 | 30.278 | 30.310 |
| 9/27 | 29.696 | 29.914 | 29.947 | 30.010 | 30.034 | 30.079 | 30.154 | 30.270 | 30.333 | 30.346 |
| 10/11 | 30.122 | 30.128 | 30.139 | 30.143 | 30.169 | 30.184 | 30.193 | 30.204 | 30.241 | 30.249 |
| 10/28 | 29.898 | 29.904 | 30.094 | 30.206 | 30.325 | 30.418 | 30.452 | 30.473 | 30.482 | 30.483 |

STATION #6
Salinity (°/₀₀)

| Depth, m: Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 29.877 | 29.889 | 29.901 | - | - | - |
| 7/19 | 29.787 | 29.903 | - | - | - | - |
| 7/28 | 29.727 | 20.806 | - | - | - | - |
| 8/2 | 29.803 | 29.845 | 29.868 | 29.881 | - | - |
| 8/9 | 29.870 | 29.882 | - | - | - | - |
| 8/16 | 29.949 | 29.989 | 29.998 | 30.017 | - | - |
| 8/23 | - | - | - | - | - | - |
| 8/30 | 30.107 | 30.113 | 30.106 | 30.114 | 30.053 | - |
| 9/7 | 30.261 | 30.332 | 30.388 | 30.422 | 30.437 | 30.432 |
| 9/13 | 30.188 | 30.242 | 30.290 | 30.315 | - | - |
| 9/21 | 30.318 | 30.374 | 30.394 | 30.415 | 30.421 | - |
| 9/27 | 30.377 | 30.404 | 30.396 | 30.404 | - | - |
| 10/11 | 30.272 | 30.317 | 30.360 | - | - | - |
| 10/28 | 30.485 | 30.495 | 30.505 | 30.524 | - | - |

STATION #6
Density ($\sigma_t$)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 21.130 | 21.144 | 21.150 | 22.209 | 22.413 | 22.556 | 22.705 | 22.788 | 22.862 | 22.935 |
| 7/19 | 21.437 | 21.555 | 21.731 | 21.842 | 22.050 | 22.233 | 22.295 | 22.437 | 22.529 | 22.708 |
| 7/28 | 21.678 | 21.851 | 22.100 | 22.283 | 22.302 | 22.356 | 22.436 | 22.520 | 22.587 | 22.647 |
| 8/2 | 20.865 | 21.298 | 21.729 | 22.172 | 22.290 | 22.373 | 22.495 | 22.586 | 22.676 | 22.713 |
| 8/9 | 22.202 | 22.220 | 22.309 | 22.329 | 22.392 | 22.449 | 22.539 | 22.708 | 22.748 | 22.838 |
| 8/16 | 21.675 | 21.982 | 22.091 | 22.294 | 22.302 | 22.367 | 22.647 | 22.715 | 22.740 | 22.783 |
| 8/23 | 22.358 | 22.406 | 22.465 | 22.494 | 22.548 | 22.679 | 22.738 | 22.798 | 22.832 | 22.902 |
| 8/30 | 21.794 | 21.895 | 21.899 | 22.379 | 22.507 | 22.557 | 22.617 | 22.729 | 22.816 | 22.884 |
| 9/7 | 22.208 | 22.329 | 22.407 | 22.417 | 22.532 | 22.648 | 22.718 | 22.822 | 22.914 | 22.979 |
| 9/13 | 22.047 | 22.280 | 22.403 | 22.501 | 22.664 | 22.686 | 22.730 | 22.765 | 22.863 | 22.925 |
| 9/21 | 22.665 | 22.668 | 22.675 | 22.690 | 22.736 | 22.799 | 22.960 | 23.007 | 23.021 | 23.059 |
| 9/27 | 22.365 | 22.565 | 22.614 | 22.706 | 22.740 | 22.796 | 22.887 | 23.017 | 23.081 | 23.097 |
| 10/11 | 22.820 | 22.859 | 22.868 | 22.881 | 22.902 | 22.919 | 22.928 | 22.940 | 22.980 | 22.991 |
| 10/28 | 22.748 | 22.763 | 22.767 | 22.917 | 23.010 | 23.120 | 23.218 | 23.260 | 23.284 | 23.294 |

STATION #6
Density ($\sigma_t$)

| Depth, m<br>Date | 90 | 100 | 110 | 120 | 130 | 140 |
|---|---|---|---|---|---|---|
| 7/15/82 | 22.968 | 22.971 | 22.978 | - | - | - |
| 7/19 | 22.831 | 22.948 | - | - | - | - |
| 7/28 | 22.721 | 22.808 | - | - | - | - |
| 8/2 | 22.788 | 22.835 | 22.862 | 22.876 | - | - |
| 8/9 | 22.858 | 22.869 | - | - | - | - |
| 8/16 | 22.858 | 22.907 | 22.914 | 22.931 | - | - |
| 8/23 | - | - | - | - | - | - |
| 8/30 | 22.968 | 22.972 | 22.967 | 22.977 | 22.929 | - |
| 9/7 | 23.081 | 23.139 | 23.188 | 23.217 | 23.231 | 23.226 |
| 9/13 | 22.965 | 23.026 | 23.076 | 23.104 | - | - |
| 9/21 | 23.073 | 23.129 | 23.148 | 23.164 | 23.169 | - |
| 9/27 | 23.129 | 23.156 | 23.150 | 23.156 | - | - |
| 10/11 | 23.014 | 23.063 | 23.109 | - | - | - |
| 10/28 | 23.308 | 23.314 | 23.326 | 23.340 | 23.362 | - |

STATION #7
Temperature (°C)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 13.384 | 13.386 | 13.383 | 11.976 | 11.481 | 11.294 | 11.001 | 10.773 | 10.638 | 10.426 |
| 7/19 | 12.876 | 12.695 | 12.636 | 12.169 | 11.914 | 11.399 | 11.128 | 10.630 | 10.591 | - |
| 7/28 | 13.474 | 13.305 | 13.227 | 13.106 | 12.028 | 11.820 | 11.751 | 11.727 | 11.551 | 11.334 |
| 8/2 | 13.548 | 13.488 | 13.403 | 12.494 | 11.787 | 11.660 | 11.308 | 11.144 | 10.941 | 10.873 |
| 8/9 | 12.670 | 12.510 | 12.173 | 11.909 | 11.642 | 11.552 | 11.260 | 11.015 | 10.917 | 10.825 |
| 8/16 | 13.858 | 13.650 | 13.157 | 12.794 | 12.035 | 11.576 | 11.308 | 11.179 | 11.084 | 11.078 |
| 8/23 | 12.917 | 12.249 | 12.212 | 12.165 | 12.114 | 12.016 | 11.768 | 11.666 | 11.368 | 11.353 |
| 8/30 | 13.969 | 13.784 | 13.572 | 12.450 | 12.055 | 11.914 | 11.653 | 11.467 | 11.331 | 11.220 |
| 9/7 | 13.474 | 13.372 | 13.115 | 12.744 | 12.290 | 11.913 | 11.601 | 11.472 | 11.406 | 11.338 |
| 9/13 | 13.243 | 13.195 | 12.841 | 12.569 | 12.082 | 11.951 | 11.878 | 11.770 | 11.582 | 11.569 |
| 9/21 | 12.553 | 12.349 | 12.271 | 12.235 | 12.213 | 12.188 | 12.126 | 12.101 | 12.051 | 11.779 |
| 9/27 | 12.739 | 12.615 | 12.483 | 12.293 | 12.121 | 12.053 | 11.947 | 11.897 | 11.588 | 11.494 |
| 10/11 | 11.938 | 11.911 | 11.862 | 11.852 | 11.823 | 11.774 | 11.748 | 11.720 | 11.624 | - |

STATION #7
Temperature (°C)

| Depth, m<br>Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 |
|---|---|---|---|---|---|---|---|
| 7/15/82 | 10.354 | 10,282 | 10.138 | - | - | - | - |
| 7/19 | - | - | - | - | - | - | - |
| 7/28 | 11.095 | - | - | - | - | - | - |
| 8/2 | 10.807 | 10.775 | - | - | - | - | - |
| 8/9 | 10.784 | 10.745 | - | - | - | - | - |
| 8/16 | 11.050 | 11.046 | 11.016 | - | - | - | - |
| 8/23 | 11.180 | 11.103 | - | - | - | - | - |
| 8/30 | 11.191 | 11.154 | 11.143 | 11.133 | 11.119 | 11.121 | 11.119 |
| 9/7 | 11.242 | 11.176 | 11.144 | - | - | - | - |
| 9/13 | 11.531 | 11.474 | - | - | - | - | - |
| 9/21 | 11.723 | 11.661 | - | - | - | - | - |
| 9/27 | 11.469 | 11.457 | - | - | - | - | - |
| 10/11 | | | - | - | - | - | - |

STATION #7
Oxygen (mg/l)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 8.680 | 8.782 | 8.927 | 8.408 | 7.722 | 7.084 | 6.906 | 6.771 | 6.671 | 6.625 |
| 7/19 | 7.791 | 7.887 | 8.047 | 7.978 | 7.717 | 7.521 | 7.108 | 6.810 | 6.536 | - |
| 7/28 | 7.425 | 7.422 | 7.426 | 7.315 | 7.243 | 6.910 | 6.765 | 6.758 | 6.716 | 6.595 |
| 8/2 | 7.720 | 8.087 | 7.817 | 7.397 | 6.808 | 6.482 | 6.329 | 6.214 | 6.049 | 6.011 |
| 8/9 | 8.020 | 8.418 | 8.386 | 7.549 | 6.882 | 6.460 | 6.234 | 6.013 | 5.801 | 5.697 |
| 8/16 | 8.738 | 9.013 | 8.999 | 8.188 | 7.328 | 6.200 | 5.645 | 5.401 | 5.326 | 5.338 |
| 8/23 | 6.797 | 7.211 | 7.232 | 6.774 | 6.503 | 6.434 | 6.297 | 6.079 | 5.998 | 5.815 |
| 8/30 | 10.709 | 11.249 | 10.951 | 8.649 | 6.662 | 5.883 | 5.606 | 5.512 | 5.465 | 5.496 |
| 9/7 | 10.278 | 10.669 | 10.974 | 9.756 | 8.142 | 6.862 | 5.855 | 5.453 | 5.260 | 5.187 |
| 9/13 | 7.421 | 7.452 | 7.244 | 6.850 | 6.492 | 6.123 | 6.019 | 5.995 | 5.918 | 5.839 |
| 9/21 | 7.085 | 7.047 | 6.726 | 6.302 | 6.234 | 6.206 | 6.237 | 6.238 | 6.267 | 6.274 |
| 9/27 | 8.390 | 8.511 | 8.108 | 6.983 | 6.316 | 5.977 | 5.849 | 5.775 | 5.733 | 5.658 |
| 10/11 | 6.764 | 6.721 | 6.653 | 6.222 | 6.057 | 5.976 | 5.913 | 5.863 | 5.806 | - |

STATION #7
Oxygen (mg/l)

| Depth, m<br>Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 |
|---|---|---|---|---|---|---|---|
| 7/15/82 | 6.586 | 6.583 | 6.626 | - | - | - | - |
| 7/19 | - | - | - | - | - | - | - |
| 7/28 | 6.472 | - | - | - | - | - | - |
| 8/2 | 5.981 | 6.030 | - | - | - | - | - |
| 8/9 | 5.650 | 5.704 | - | - | - | - | - |
| 8/16 | 5.427 | 5.557 | 5.642 | - | - | - | - |
| 8/23 | 5.849 | 5.838 | - | - | - | - | - |
| 8/30 | 5.573 | 5.662 | 5.773 | 5.842 | 5.899 | 6.000 | 5.969 |
| 9/7 | 5.136 | 5.133 | 5.219 | - | - | - | - |
| 9/13 | 5.871 | 5.882 | - | - | - | - | - |
| 9/21 | 6.140 | 6.110 | - | - | - | - | - |
| 9/27 | 5.669 | 5.745 | - | - | - | - | - |
| 10/11 | | | | | | | |

STATION #7
Salinity (°/₀₀)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | - | - | - | 29.025 | 29.193 | 29.243 | 29.362 | 29.466 | 29.538 | 29.660 |
| 7/19 | - | - | - | 29.157 | 29.216 | 29.375 | 29.465 | 29.722 | 29.745 | - |
| 7/28 | 29.082 | 29.183 | 29.198 | 29.227 | 29.350 | 29.361 | 29.379 | 29.385 | 29.432 | 29.512 |
| 8/2 | 28.431 | 28.451 | 28.528 | 29.216 | 29.434 | 29.467 | 29.593 | 29.656 | 29.756 | 29.778 |
| 8/9 | 29.389 | 29.389 | 29.428 | 29.450 | 29.532 | 29.559 | 29.656 | 29.759 | 29.776 | 29.822 |
| 8/16 | 29.189 | 29.241 | 29.358 | 29.397 | 29.632 | 29.751 | 29.854 | 29.923 | 29.974 | 29.996 |
| 8/23 | 29.592 | 29.692 | 29.687 | 29.685 | 29.693 | 29.715 | 29.781 | 29.811 | 29.928 | 29.916 |
| 8/30 | 20.303 | 29.367 | 29.395 | 29.677 | 29.759 | 29.782 | 29.876 | 29.944 | 30.024 | 30.068 |
| 9/7 | 29.738 | 29.707 | 29.724 | 29.785 | 29.848 | 29.956 | 30.050 | 30.107 | 30.141 | 30.185 |
| 9/13 | 29.409 | 29.549 | 29.699 | 29.789 | 29.954 | 29.999 | 30.022 | 30.064 | 30.161 | 30.153 |
| 9/21 | 29.940 | 29.974 | 29.993 | 29.997 | 30.003 | 30.016 | 30.037 | 30.052 | 30.071 | 30.197 |
| 9/27 | 29.667 | 29.835 | 29.945 | 29.997 | 30.039 | 30.055 | 30.102 | 30.133 | 30.297 | 30.342 |
| 10/11 | 30.104 | 30.118 | 30.146 | 30.146 | 30.152 | 30.186 | 30.200 | 30.218 | 30.288 | - |

STATION #7
Salinity (°/₀₀)

| Depth, m<br>Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 |
|---|---|---|---|---|---|---|---|
| 7/15/82 | 29.704 | 29.757 | 29.863 | - | - | - | - |
| 7/19 | - | - | - | - | - | - | - |
| 7/28 | 29.615 | - | - | - | - | - | - |
| 8/2 | 29.816 | 29.827 | - | - | - | - | - |
| 8/9 | 29.843 | 29.876 | - | - | - | - | - |
| 8/16 | 30.033 | 30.043 | 30.049 | - | - | - | - |
| 8/23 | 30.020 | 30.063 | - | - | - | - | - |
| 8/30 | 30.088 | 30.120 | 30.127 | 30.131 | 30.131 | 30.073 | 30.071 |
| 9/7 | 30.231 | 30.346 | 30.399 | - | - | - | - |
| 9/13 | 30.195 | 30.207 | - | - | - | - | - |
| 9/21 | 30.224 | 30.258 | - | - | - | - | - |
| 9/27 | 30.354 | 30.363 | - | - | - | - | - |
| 10/11 | - | - | - | - | - | - | - |

STATION #7
Density ($\sigma_t$)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | - | - | - | 21.989 | 22.206 | 22.277 | 22.419 | 22.538 | 22.617 | 22.746 |
| 7/19 | - | - | - | 22.056 | 22.147 | 22.361 | 22.477 | 22.761 | 22.785 | - |
| 7/28 | 21.753 | 21.864 | 21.890 | 21.936 | 22.230 | 22.276 | 22.302 | 22.311 | 22.379 | 22.478 |
| 8/2 | 21,238 | 21.265 | 21.341 | 22.042 | 22.338 | 22.386 | 22.545 | 22.623 | 22.735 | 22,763 |
| 8/9 | 22.143 | 22.173 | 22.264 | 22.329 | 22.440 | 22.477 | 22.603 | 22.724 | 22.754 | 22.805 |
| 8/16 | 21.760 | 21.841 | 22.027 | 22.126 | 22.447 | 22.621 | 22.748 | 22.823 | 22.879 | 22.897 |
| 8/23 | 22.253 | 22.454 | 22.457 | 22.464 | 22.480 | 22.515 | 22.610 | 22.651 | 22.794 | 22.788 |
| 8/30 | 21.826 | 21.912 | 21.975 | 22.406 | 22.541 | 22.585 | 22.704 | 22.789 | 22.875 | 22.929 |
| 9/7 | 22.258 | 22.254 | 22.317 | 22.434 | 22.567 | 22.719 | 22.848 | 22.915 | 22.953 | 22.999 |
| 9/13 | 22.050 | 22.167 | 22.350 | 22.470 | 22.687 | 22.746 | 22.777 | 22.829 | 22.937 | 22.933 |
| 9/21 | 22.590 | 22.654 | 22.683 | 22.693 | 22.701 | 22.716 | 22.743 | 22.760 | 22.783 | 22.930 |
| 9/27 | 22.344 | 22.497 | 22.607 | 22.682 | 22.746 | 22.771 | 22.826 | 22.859 | 23.041 | 23.093 |
| 10/11 | 22.829 | 22.845 | 22.875 | 22.877 | 22.887 | 22.922 | 22.938 | 22.957 | 23.028 | - |

STATION #7
Density ($\sigma_t$)

| Depth, m<br>Date | 90 | 100 | 110 | 120 | 130 | 140 | 150 |
|---|---|---|---|---|---|---|---|
| 7/15/82 | 22.792 | 22.845 | 22.951 | - | - | - | - |
| 7/19 | - | - | - | - | - | - | - |
| 7/28 | 22.599 | - | - | - | - | - | - |
| 8/2 | 22.804 | 22.818 | - | - | - | - | - |
| 8/9 | 22.829 | 22.861 | - | - | - | - | - |
| 8/16 | 22.931 | 22.939 | 22.949 | - | - | - | - |
| 8/23 | 22.898 | 22.945 | - | - | - | - | - |
| 8/30 | 22.949 | 22.980 | 22.988 | 22.992 | 22.995 | 22.950 | 22.948 |
| 9/7 | 23.051 | 23.152 | 23.198 | - | - | - | - |
| 9/13 | 22.972 | 22.992 | - | - | - | - | - |
| 9/21 | 22.961 | 22.998 | - | - | - | - | - |
| 9/27 | 23.106 | 23.116 | - | - | - | - | - |
| 10/11 | - | - | - | - | - | - | - |

STATION #8
Temperature (°C)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 13.564 | 13.541 | 13.517 | 12.013 | 11.465 | 11.231 | 10.929 | 10.720 | 10.483 | - | - | - |
| 7/19 | 12.784 | 12.660 | 12.626 | 12.126 | 11.889 | 11.507 | 11.169 | - | - | - | - | - |
| 7/28 | 13.530 | 13.356 | 13.228 | 12.321 | 12.058 | 11.930 | 11.793 | 11.758 | 11.416 | 11.232 | - | - |
| 8/2 | 13.573 | 13.528 | 13.359 | 12.314 | 11.787 | 11.691 | 11.363 | 11.138 | 10.936 | 10.839 | 10.781 | 10.742 |
| 8/9 | 12.695 | 12.328 | 12.143 | 11.972 | 11.731 | 11.513 | 11.428 | 11.208 | - | - | - | |
| 8/16 | 13.902 | 13.828 | 13.330 | 12.900 | 12.281 | 11.916 | 11.592 | 11.430 | 11.350 | - | - | - |
| 8/23 | 12.617 | 12.285 | 12.217 | 12.158 | 12.059 | 11.860 | 11.779 | 11.450 | 11.296 | - | - | - |
| 8/30 | 14.048 | 14.008 | 13.723 | 12.385 | 12.171 | 12.005 | 11.792 | 11.577 | 11.411 | 11.235 | - | - |
| 9/7 | 13.126 | 13.101 | 12.762 | 12.227 | 11.875 | 11.661 | 11.612 | 11.450 | - | - | - | - |
| 9/13 | 13.405 | 13.185 | 12.961 | 12.775 | 12.266 | 12.029 | 11.955 | 11.838 | 11.695 | - | - | - |
| 9/21 | 12.396 | 12.366 | 12.341 | 12.327 | 12.233 | 12.138 | 12.061 | 11.862 | 11.753 | - | - | - |
| 9/27 | 12.773 | 12.642 | 12.541 | 12.228 | 12.127 | 12.011 | 11.941 | 11.793 | 11.591 | 11.483 | - | - |
| 10/11 | 11.982 | 11.907 | 11.895 | 11.887 | 11.860 | 11.823 | 11.803 | 11.758 | 11.654 | 11.598 | 11.526 | - |
| 10/28 | 11.401 | 11.412 | 11.437 | 11.443 | 11.429 | 11.355 | 11.037 | 11.009 | 10.968 | 10.952 | 10.869 | 10.819 |

STATION #8
Oxygen (mg/1)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | 8.936 | 9.348 | 9.097 | 8.962 | 7.814 | 7.812 | 6.900 | 6.760 | 6.650 | – | – | – |
| 7/19 | 7.980 | 7.915 | 7.955 | 7.815 | 7.541 | 7.364 | 7.100 | – | – | – | – | – |
| 7/28 | 7.263 | 7.605 | 7.428 | 7.278 | 6.997 | 6.816 | 6.778 | 6.717 | 6.682 | 6.552 | – | – |
| 8/2 | 7.625 | 8.025 | 7.857 | 7.189 | 6.644 | 6.383 | 6.286 | 6.144 | 6.975 | 6.006 | 5.958 | 5.925 |
| 8/9 | 8.155 | 8.725 | 8.125 | 7.338 | 6.924 | 6.603 | 6.343 | 6.198 | – | – | – | – |
| 8/16 | 8.942 | 9.211 | 9.360 | 8.482 | 7.634 | 6.647 | 6.058 | 5.780 | 5.643 | – | – | – |
| 8/23 | 6.717 | 6.861 | 6.722 | 6.498 | 6.417 | 6.360 | 6.179 | 6.073 | 5.866 | – | – | – |
| 8/30 | 11.821 | 12.138 | 12.031 | 10.486 | 7.564 | 6.491 | 6.021 | 5.742 | 5.632 | 5.612 | – | – |
| 9/7 | 10.476 | 10.297 | 10.042 | 8.442 | 6.620 | 5.693 | 5.340 | 5.200 | – | – | – | – |
| 9/13 | 6.879 | 7.043 | 7.055 | 6.824 | 6.747 | 6.320 | 6.112 | 6.045 | 6.012 | – | – | – |
| 9/21 | 6.697 | 6.683 | 6.506 | 6.356 | 6.389 | 6.251 | 6.148 | 6.110 | 5.991 | – | – | – |
| 9/27 | 8.319 | 8.473 | 8.200 | 7.229 | 6.378 | 6.034 | 5.866 | 5.802 | 5.736 | 5.669 | – | – |
| 10/11 | 6.585 | 6.571 | 6.481 | 6.367 | 6.324 | 6.195 | 6.073 | 5.955 | 5.948 | 5.863 | 5.769 | – |
| 10/28 | 8.040 | 7.973 | 7.842 | 7.680 | 7.370 | 6.705 | 5.655 | 5.618 | 5.607 | 5.617 | 5.713 | 5.857 |

STATION #8
Salinity (°/₀₀)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | - | - | - | 29.043 | 29.197 | 29.267 | 29.400 | 29.505 | 29.634 | - | - | - |
| 7/19 | - | - | - | 29.165 | 29.203 | 29.331 | 29.462 | - | - | - | - | - |
| 7/28 | 29.073 | 29.150 | 29.187 | 29.313 | 29.318 | 29.330 | 29.370 | 29.378 | 29.479 | - | - | - |
| 8/2 | 28.297 | 28.361 | 28.543 | 29.278 | 29.434 | 29.461 | 29.578 | 29.661 | 29.755 | 29.795 | 29.830 | 29.847 |
| 8/9 | 29.386 | 29.412 | 29.445 | 29.440 | 29.518 | 29.578 | 29.603 | 29.679 | - | - | - | - |
| 8/16 | 29.246 | 29.191 | 29.275 | 29.400 | 29.527 | 29.606 | 29.735 | 29.792 | 29.823 | - | - | - |
| 8/23 | 29.458 | 29.682 | 29.687 | 29.680 | 29.727 | 29.759 | 29.781 | 29.904 | 29.965 | - | - | - |
| 8/30 | 29.295 | 29.347 | 29.369 | 29.719 | 29.732 | 29.773 | 29.816 | 29.909 | 29.981 | 30.074 | - | - |
| 9/7 | 29.729 | 29.725 | 29.776 | 29.857 | 29.954 | 30.032 | 30.044 | 30.126 | - | - | - | - |
| 9/13 | 29.416 | 29.477 | 29.665 | 29.713 | 29.889 | 29.974 | 29.986 | 30.049 | 30.105 | - | - | - |
| 9/21 | 29.994 | 29.969 | 29.973 | 29.974 | 30.000 | 30.033 | 30.068 | 30.153 | 30.199 | - | - | - |
| 9/27 | 29.656 | 29.764 | 29.922 | 30.010 | 30.035 | 30.082 | 30.111 | 30.177 | 30.287 | 30.349 | - | - |
| 10/11 | 30.105 | 30.127 | 30.119 | 30.133 | 30.148 | 30.162 | 30.169 | 30.198 | 30.257 | 30.295 | 30.339 | - |
| 10/28 | 29.837 | 29.866 | 29.885 | 29.899 | 30.042 | 30.261 | 30.451 | 30.456 | 30.477 | 30.484 | 30.489 | 30.499 |

STATION #8
Density ($\sigma_t$)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/15/82 | - | - | - | 21.996 | 22.212 | 22.306 | 22.461 | 22.577 | 22.717 | - | - | - |
| 7/19 | - | - | - | 22.070 | 22.142 | 22.308 | 22.468 | - | - | - | - | - |
| 7/28 | 21.736 | 21.829 | 21.882 | 22.149 | 22.200 | 22.233 | 22.288 | 22.300 | 22.439 | 22.511 | - | - |
| 8/2 | 21.130 | 21.188 | 21.361 | 22.123 | 22.338 | 22.376 | 22.524 | 22.627 | 22.735 | 22.782 | 22.819 | 22.839 |
| 8/9 | 22.136 | 22.224 | 22.283 | 22.310 | 22.413 | 22.498 | 22.532 | 22.629 | - | - | - | - |
| 8/16 | 21.796 | 21.768 | 21.930 | 22.108 | 22.321 | 22.448 | 22.606 | 22.678 | 22.716 | - | - | - |
| 8/23 | 22.206 | 22.440 | 22.456 | 22.462 | 22.516 | 22.577 | 22.608 | 22.761 | 22.836 | - | - | - |
| 8/30 | 21.804 | 21.852 | 21.925 | 22.450 | 22.500 | 22.561 | 22.633 | 22.743 | 22.828 | 22.931 | - | - |
| 9/7 | 22.319 | 22.320 | 22.424 | 22.586 | 22.725 | 22.823 | 22.841 | 22.933 | - | - | - | - |
| 9/13 | 22.024 | 22.113 | 22.301 | 22.373 | 22.603 | 22.712 | 22.735 | 22.805 | 22.874 | | | |
| 9/21 | 22.661 | 22.647 | 22.654 | 22.658 | 22.695 | 22.738 | 22.779 | 22.881 | 22.936 | - | - | - |
| 9/27 | 22.329 | 22.437 | 22.578 | 22.704 | 22.742 | 22.799 | 22.834 | 22.912 | 23.033 | 23.100 | - | - |
| 10/11 | 22.822 | 22.853 | 22.849 | 22.861 | 22.877 | 22.895 | 22.904 | 22.934 | 22.999 | 23.038 | 23.085 | - |
| 10/28 | 22.718 | 22.739 | 22.749 | 22.759 | 22.872 | 23.054 | 23.257 | 23.266 | 23.289 | 23.297 | 23.315 | 23.331 |

STATION #9
Temperature (°C)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|
| 7/15/82 | 13.589 | 13.584 | 13.481 | 11.861 | 11.621 | 11.122 |
| 7/19 | 12.734 | 12.702 | 12.696 | 12.015 | - | - |
| 7/28 | 13.578 | 13.495 | 13.420 | 12.144 | - | - |
| 8/2 | 13.742 | 13.547 | 12.666 | 12.161 | 11.825 | 11.733 |
| 8/9 | 13.021 | 12.401 | 12.261 | 12.114 | - | - |
| 8/16 | 13.799 | 13.480 | 13.320 | 12.878 | 12.385 | - |
| 8/23 | 12.714 | 12.298 | 12.211 | 12.138 | 12.041 | - |
| 8/30 | 14.089 | 13.937 | 13.691 | 12.287 | 12.091 | - |
| 9/7 | 13.564 | 13.186 | 12.958 | 12.573 | - | - |
| 9/13 | 13.578 | 13.191 | 12.928 | 12.750 | 12.346 | - |
| 9/21 | 12.353 | 12.294 | 12.267 | 12.213 | 12.183 | - |
| 9/27 | 12.614 | 12.520 | 12.392 | 12.138 | 12.105 | - |
| 10/11 | 12.190 | 11.903 | 11.856 | 11.856 | 11.844 | - |
| 10/28 | 11.408 | 11.399 | 11.421 | 11.449 | 11.423 | - |

STATION #9
Oxygen (mg/l)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|
| 7/15/82 | 8.955 | 9.184 | 9.141 | 8.798 | 7.645 | 7.154 |
| 7/19 | 7.872 | 7.863 | 7.985 | 7.914 | - | - |
| 7/28 | 7.332 | 7.509 | 7.399 | 7.276 | - | - |
| 8/2 | 7.866 | 8.158 | 8.021 | 7.194 | 6.595 | 6.342 |
| 8/9 | 7.975 | 8.366 | 8.047 | 7.460 | - | - |
| 8/16 | 8.526 | 8.897 | 9.018 | 8.412 | 7.610 | - |
| 8/23 | 7.025 | 6.990 | 6.765 | 6.385 | 6.213 | - |
| 8/30 | 11.993 | 12.272 | 11.915 | 10.317 | 7.004 | - |
| 9/7 | 10.787 | 11.049 | 10.973 | 9.319 | - | - |
| 9/13 | 7.566 | 7.535 | 7.242 | 6.880 | 6.773 | - |
| 9/21 | 7.064 | 6.980 | 6.620 | 6.268 | 6.124 | - |
| 9/27 | 8.286 | 8.352 | 7.844 | 6.609 | 5.982 | - |
| 10/11 | 7.063 | 6.906 | 6.650 | 6.224 | 6.092 | - |
| 10/28 | 8.327 | 8.085 | 8.025 | 7.819 | 7.363 | - |

STATION #9
Salinity (°/₀₀)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|
| 7/15/82 | - | - | - | 29.072 | 29.146 | 29.316 |
| 7/19 | - | - | - | 29.174 | - | - |
| 7/28 | 29.135 | 29.139 | 29.123 | 29.373 | - | - |
| 8/2 | 28.230 | 28.328 | 29.159 | 29.335 | 29.433 | 29.448 |
| 8/9 | 29.042 | 29.397 | 29.399 | 29.437 | - | - |
| 8/16 | 29.210 | 29.248 | 29.273 | 29.394 | 29.495 | - |
| 8/23 | 29.656 | 29.689 | 29.691 | 29.703 | 29.722 | - |
| 8/30 | 29.328 | 29.320 | 29.389 | 29.717 | 29.756 | - |
| 9/7 | 29.705 | 29.724 | 29.743 | 29.805 | - | - |
| 9/13 | 29.415 | 29.545 | 29.663 | 29.725 | 29.857 | - |
| 9/21 | 29.979 | 29.981 | 29.981 | 29.997 | 30.007 | - |
| 9/27 | 29.746 | 29.809 | 29.965 | 30.034 | 30.042 | - |
| 10/11 | 30.090 | 30.143 | 30.144 | 30.139 | 30.154 | - |
| 10/28 | 29.845 | 29.867 | 29.872 | 29.921 | 30.097 | - |

STATION #9
Density ($\sigma_t$)

| Depth, m<br>Date | 0 | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|
| 7/15/82 | - | - | - | 22.045 | 22.145 | 22.363 |
| 7/19 | - | - | - | 22.097 | - | - |
| 7/28 | 21.774 | 21.793 | 21.795 | 22.227 | - | - |
| 8/2 | 21.046 | 21.159 | 21.966 | 22.195 | 22.331 | 22.359 |
| 8/9 | 21.809 | 22.199 | 22.226 | 22.282 | - | - |
| 8/16 | 21.788 | 21.880 | 21.930 | 22.108 | 22.277 | - |
| 8/23 | 22.340 | 22.443 | 22.461 | 22.483 | 22.515 | - |
| 8/30 | 21.821 | 21.845 | 21.947 | 22.467 | 22.533 | - |
| 9/7 | 22.215 | 22.303 | 22.361 | 22.482 | - | - |
| 9/13 | 21.989 | 22.164 | 22.306 | 22.387 | 22.564 | - |
| 9/21 | 22.657 | 22.669 | 22.674 | 22.697 | 22.710 | - |
| 9/27 | 22.429 | 22.495 | 22.639 | 22.739 | 22.751 | - |
| 10/11 | 22.773 | 22.866 | 22.875 | 22.871 | 22.885 | - |
| 10/28 | 22.723 | 22.742 | 22.742 | 22.775 | 22.916 | - |

STATION #10
Temperature (°C)

| Depth, m<br>Date | 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| 7/15/82 | 13.581 | 13.579 | 13.560 | - |
| 7/19 | 12.842 | 12.802 | 12.624 | - |
| 7/28 | 13.593 | 13.503 | 13.148 | - |
| 8/2 | 13.624 | 13.555 | 12.596 | 12.215 |
| 8/9 | 12.766 | 12.422 | 12.387 | - |
| 8/16 | 13.739 | 13.578 | 13.453 | - |
| 8/23 | 12.595 | 12.277 | 12.177 | - |
| 8/30 | 13.959 | 13.817 | 13.743 | - |
| 9/7 | - | - | - | - |
| 9/13 | 13.530 | 13.147 | 12.873 | - |
| 9/21 | 12.722 | 12.481 | 12.359 | 12.261 |
| 9/27 | 12.749 | 12.569 | 12.420 | - |
| 10/11 | 11.922 | 12.002 | 11.872 | 11.843 |
| 10/28 | 11.445 | 11.446 | 11.442 | - |

STATION #10
Oxygen (mg/l)

| Depth, m<br>Date | 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| 7/15/82 | 8.585 | 8.901 | 9.052 | - |
| 7/19 | 7.912 | 7.907 | 8.059 | - |
| 7/28 | 7.698 | 7.735 | 7.626 | - |
| 8/2 | 7.852 | 7.971 | 7.769 | 6.920 |
| 8/9 | 8.336 | 8.752 | 8.291 | - |
| 8/16 | 8.739 | 8.999 | 9.124 | - |
| 8/23 | 7.029 | 6.936 | 6.600 | - |
| 8/30 | 11.082 | 11.356 | 11.211 | - |
| 9/7 | - | - | - | - |
| 9/13 | 7.514 | 7.542 | 7.206 | - |
| 9/21 | 7.339 | 7.286 | 7.123 | 6.432 |
| 9/27 | 8.178 | 8.411 | 8.300 | - |
| 10/11 | 7.209 | 6.274 | 6.353 | 6.224 |
| 10/28 | 7.732 | 7.705 | 7.699 | - |

STATION #10
Salinity (°/₀₀)

| Depth, m / Date | 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| 7/15/82 | - | - | - | - |
| 7/19 | - | - | - | - |
| 7/28 | 29.127 | 29.150 | 29.233 | - |
| 8/2 | 28.236 | 28.308 | 29.191 | 29.304 |
| 8/9 | 29.342 | 29.408 | 29.400 | - |
| 8/16 | 29.191 | 29.201 | 29.260 | - |
| 8/23 | 29.665 | 29.681 | 29.695 | - |
| 8/30 | 29.310 | 29.330 | 29.377 | - |
| 9/7 | - | - | - | - |
| 9/13 | 29.413 | 29.570 | 29.684 | - |
| 9/21 | 29.896 | 29.943 | 29.967 | 29.987 |
| 9/27 | 29.657 | 29.751 | 29.942 | - |
| 10/11 | 30.136 | 30.113 | 30.146 | 30.154 |
| 10/28 | 29.859 | 29.873 | 29.882 | - |

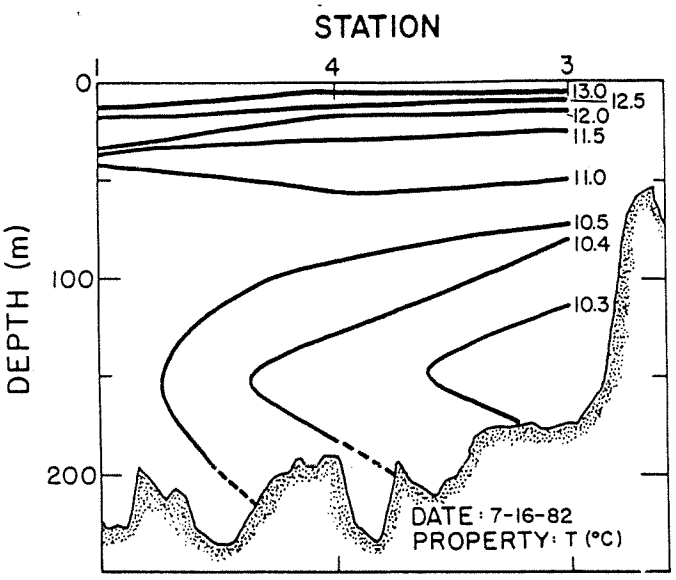
STATION #10
Density ($\sigma_t$)

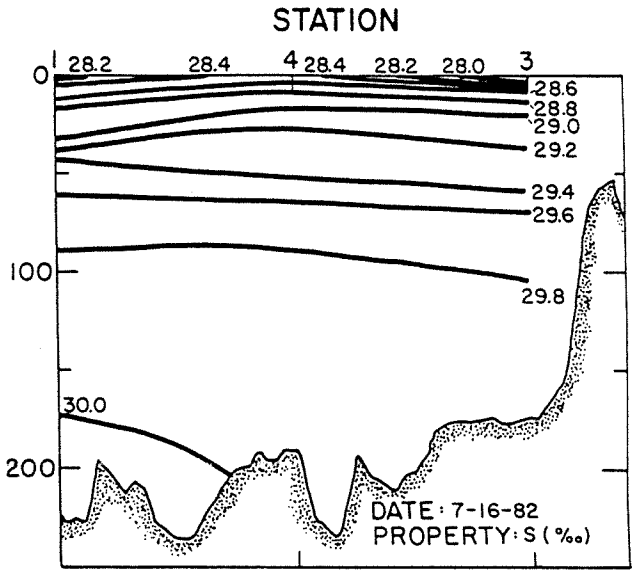
| Depth, m / Date | 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| 7/15/82 | - | - | - | - |
| 7/19 | - | - | - | - |
| 7/28 | 21.765 | 21.800 | 21.932 | - |
| 8/2 | 21.074 | 21.142 | 22.004 | 22.161 |
| 8/9 | 22.089 | 22.203 | 22.204 | - |
| 8/16 | 21.785 | 21.825 | 21.894 | - |
| 8/23 | 22.370 | 22.441 | 22.470 | - |
| 8/30 | 21.833 | 21.877 | 21.928 | - |
| 9/7 | - | - | - | - |
| 9/13 | 21.997 | 22.192 | 22.332 | - |
| 9/21 | 22.524 | 22.605 | 22.647 | 22.680 |
| 9/27 | 22.335 | 22.441 | 22.616 | - |
| 10/11 | 22.857 | 22.825 | 22.874 | 22.885 |
| 10/28 | 22.728 | 22.738 | 22.746 | - |

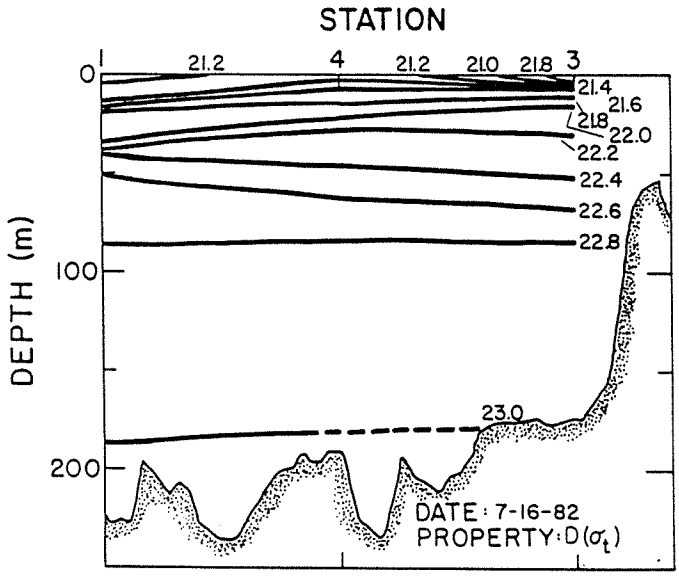
# APPENDIX 5B

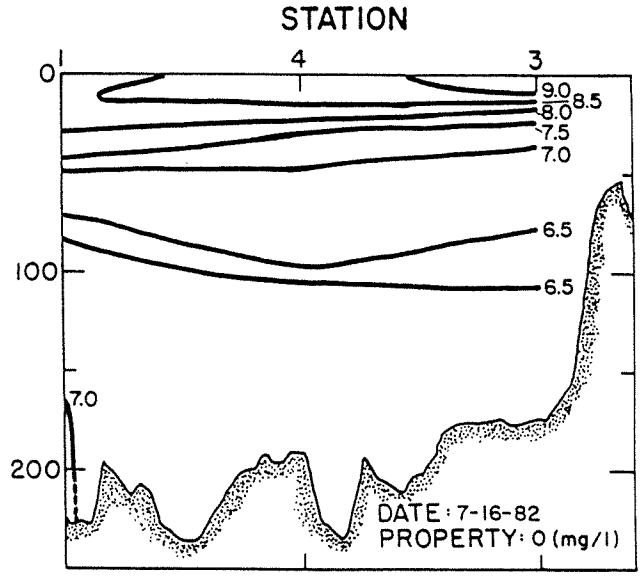
## Contours of the Observations

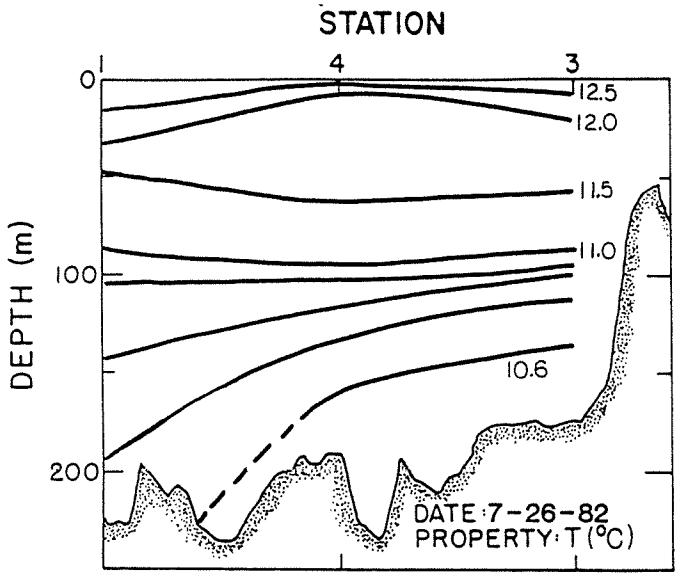
The following vertical contours are arranged by transect : Mid-channel (stations 1, 4, 3); Seahurst (stations 4, 7, 8, 9, 10); and the Bay (stations 6, 7, 5). Within each set of transects the contours are arranged chronologically by date. Each page contains contours of temperature (°C), salinity (°/oo), density (sigma-t units), and dissolved oxygen (mg/l) on the date given in each panel at the lower right corner.

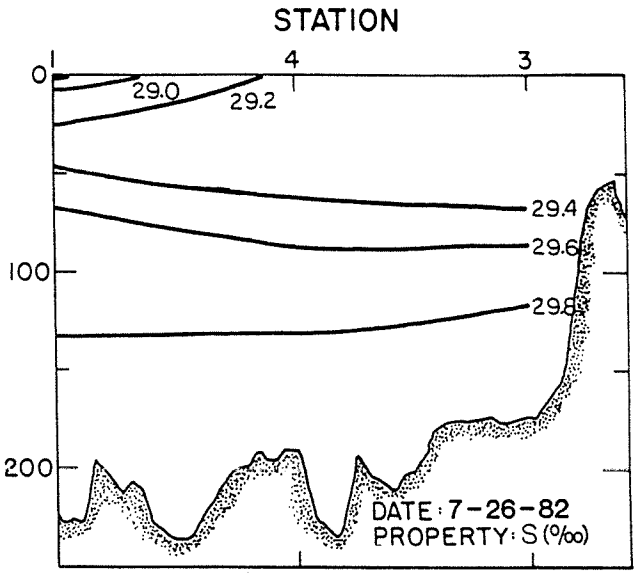

STATION
1
4
3
0
100
200
DEPTH (m)
13.0
12.5
12.0
11.5
11.0
10.5
10.4
10.3
DATE: 7-16-82
PROPERTY: T (°C)

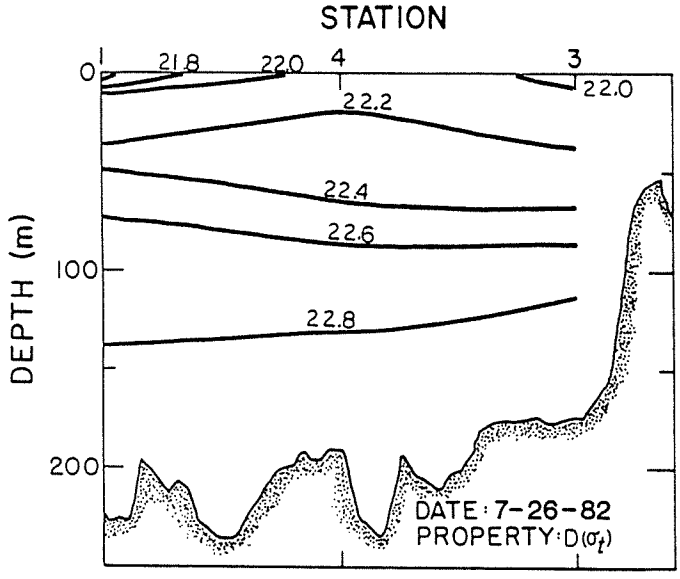

STATION
1
28.2
28.4
4
28.4
28.2
28.0
3
0
100
200
28.6
28.8
29.0
29.2
29.4
29.6
29.8
30.0
DATE: 7-16-82
PROPERTY: S (‰)

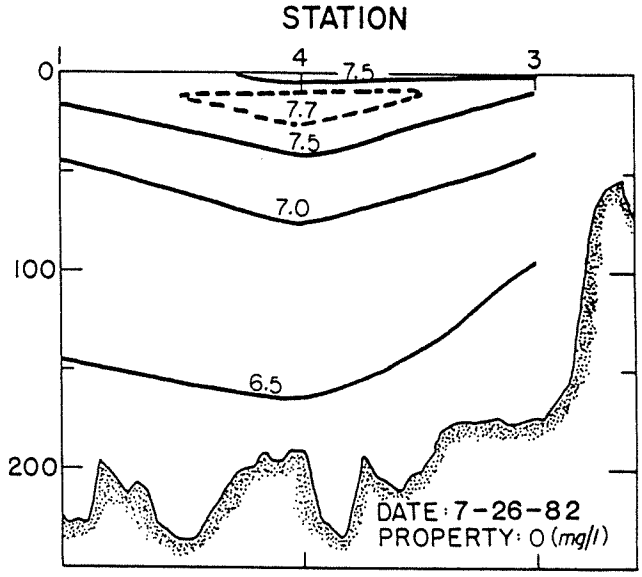

STATION
1
21.2
4
21.2
21.0
21.8
3
0
100
200
DEPTH (m)
21.4
21.6
21.8
22.0
22.2
22.4
22.6
22.8
23.0
DATE: 7-16-82
PROPERTY: D(σt)

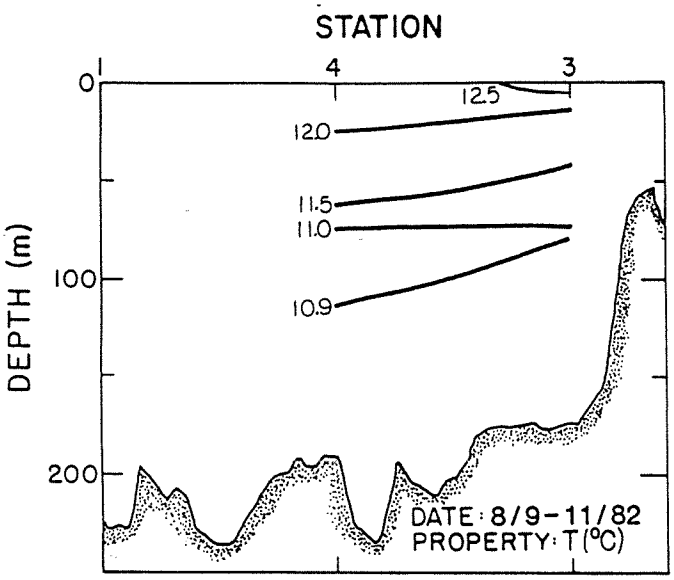

STATION
1
4
3
0
100
200
9.0
8.5
8.0
7.5
7.0
6.5
6.5
7.0
DATE: 7-16-82
PROPERTY: O (mg/l)

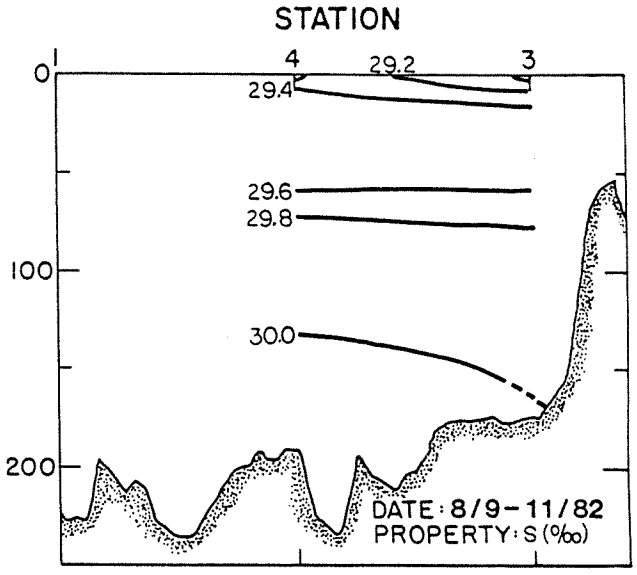

STATION
1
4
3
0
100
200
DEPTH (m)
12.5
12.0
11.5
11.0
10.6
DATE: 7-26-82
PROPERTY: T (°C)

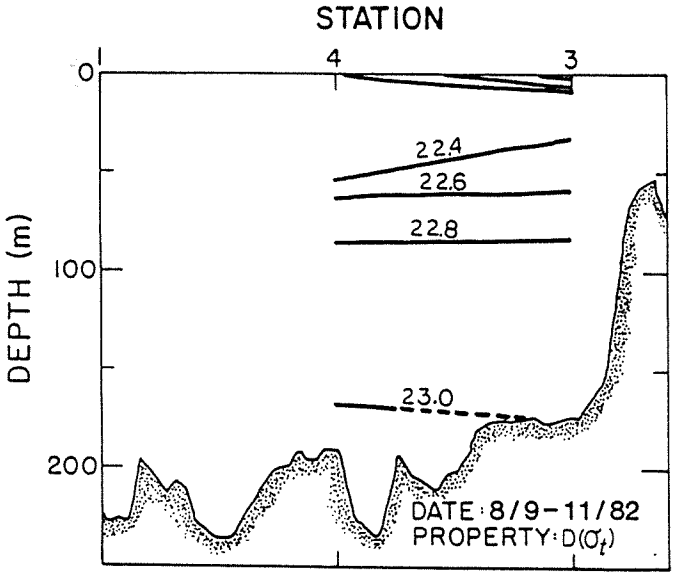

STATION
1
4
3
0
100
200
29.0
29.2
29.4
29.6
29.8
DATE: 7-26-82
PROPERTY: S (‰)

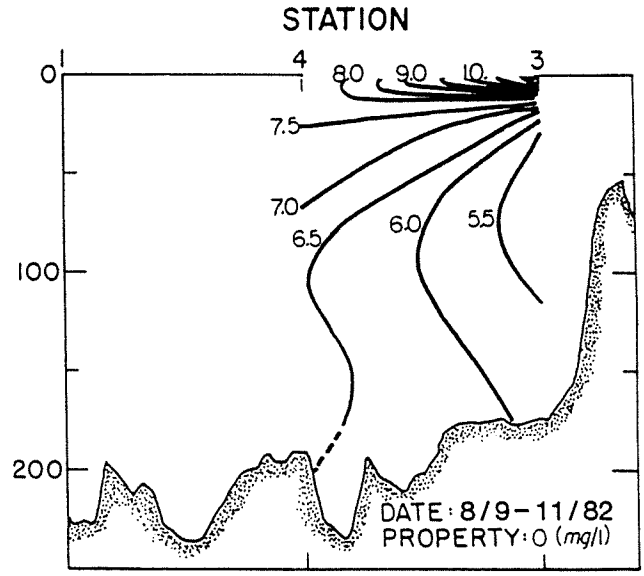

STATION
1
21.8
22.0
4
3
22.0
0
100
200
DEPTH (m)
22.2
22.4
22.6
22.8
DATE: 7-26-82
PROPERTY: D(σt)

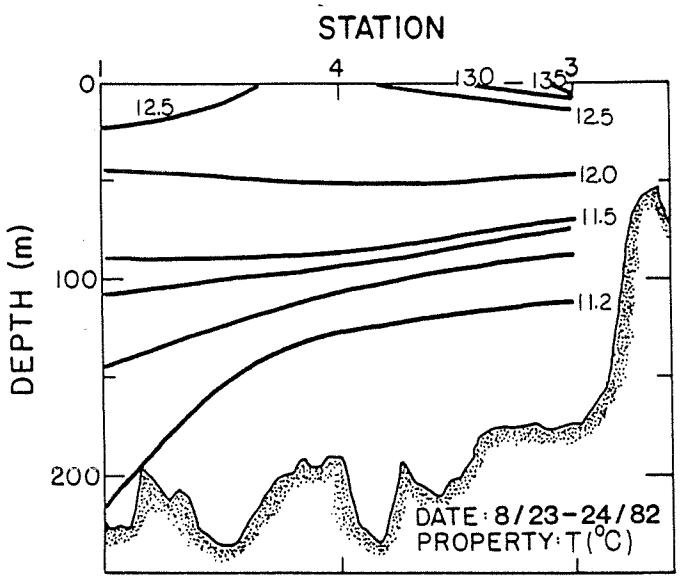

STATION
1
4
7.5
3
0
100
200
7.7
7.5
7.0
6.5
DATE: 7-26-82
PROPERTY: O (mg/l)

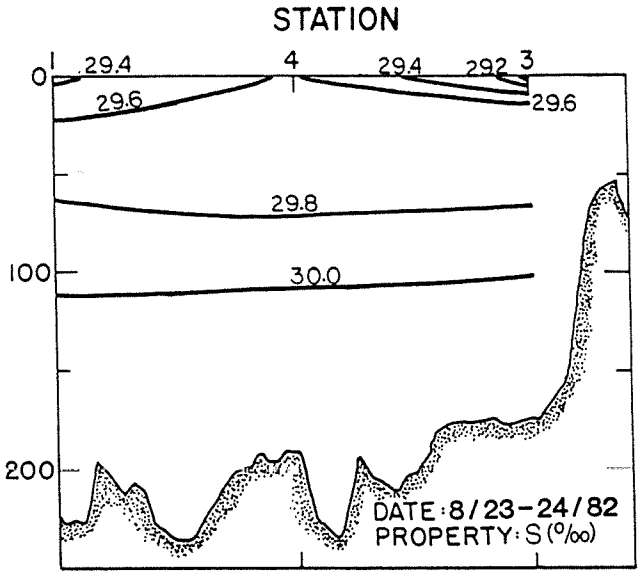

STATION
4
3
0
100
200
DEPTH (m)
12.5
12.0
11.5
11.0
10.9
DATE: 8/9-11/82
PROPERTY: T (°C)

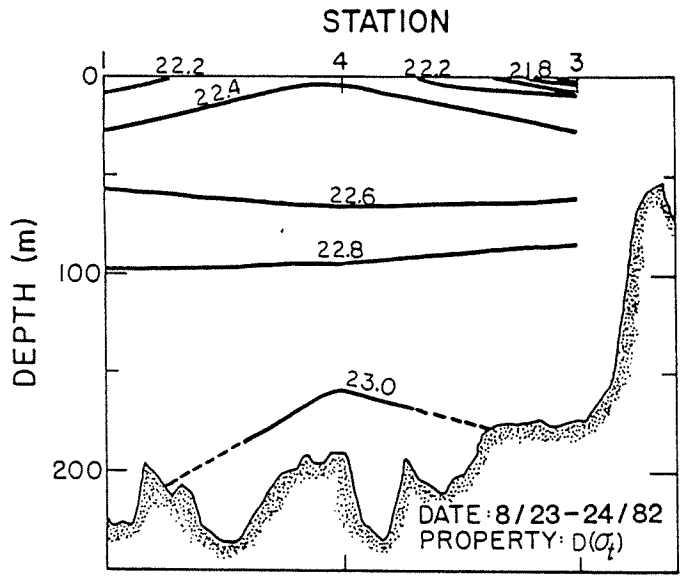

STATION
4
29.2
3
0
100
200
29.4
29.6
29.8
30.0
DATE: 8/9-11/82
PROPERTY: S (‰)

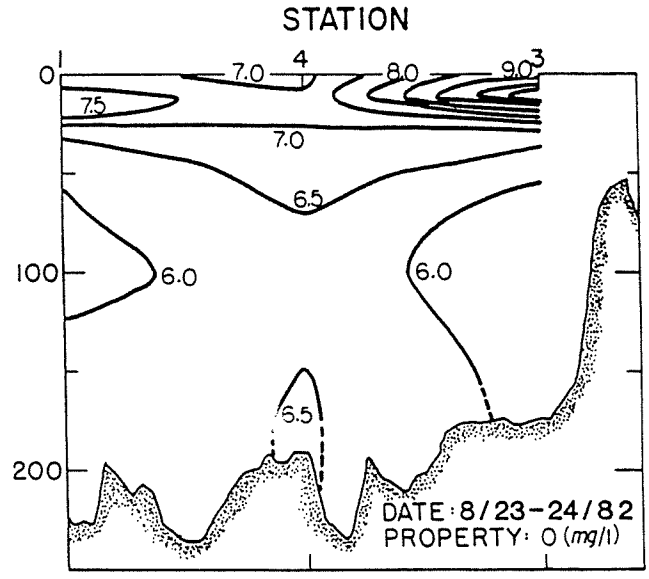

STATION
4
3
0
100
200
DEPTH (m)
22.4
22.6
22.8
23.0
DATE: 8/9-11/82
PROPERTY: D(σt)

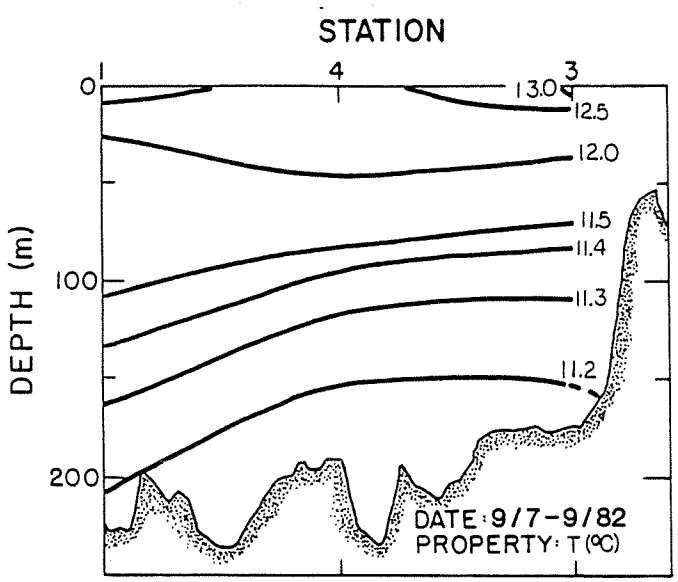

STATION
4
8.0
9.0
10.
3
0
100
200
7.5
7.0
6.5
6.0
5.5
DATE: 8/9-11/82
PROPERTY: O (mg/l)

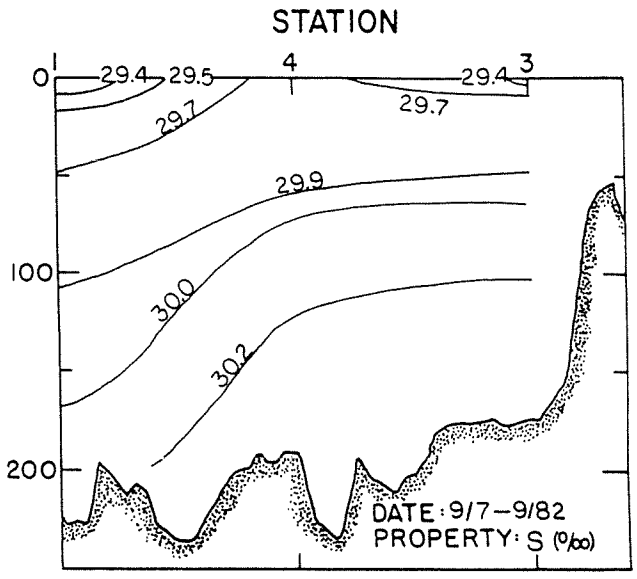

STATION
1
4
3
0
100
200
DEPTH (m)
12.5
13.0 – 13.5
12.5
12.0
11.5
11.2
DATE: 8/23-24/82
PROPERTY: T (°C)

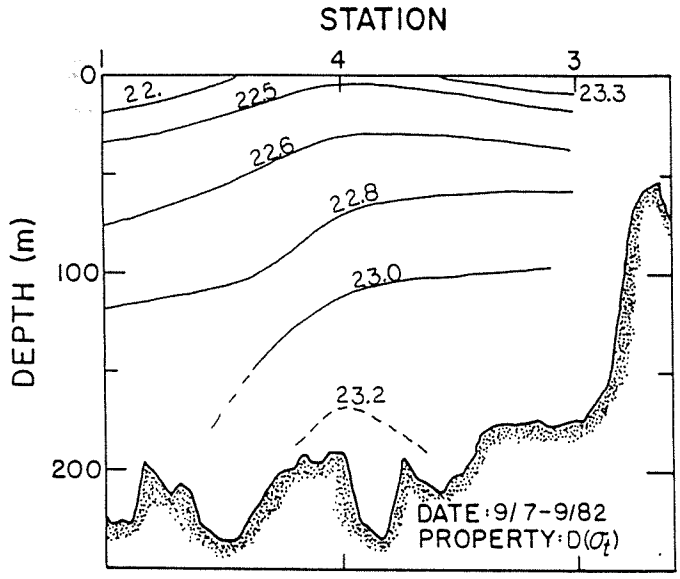

STATION
1
4
3
0
100
200
29.4
29.4
29.2
29.6
29.6
29.8
30.0
DATE: 8/23-24/82
PROPERTY: S (‰)

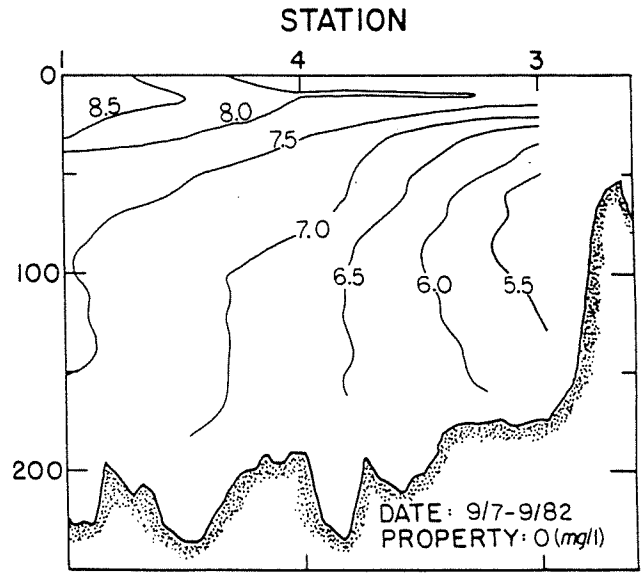

STATION
1
4
3
0
100
200
DEPTH (m)
22.2
22.2
21.8
22.4
22.6
22.8
23.0
DATE: 8/23-24/82
PROPERTY: D(σt)

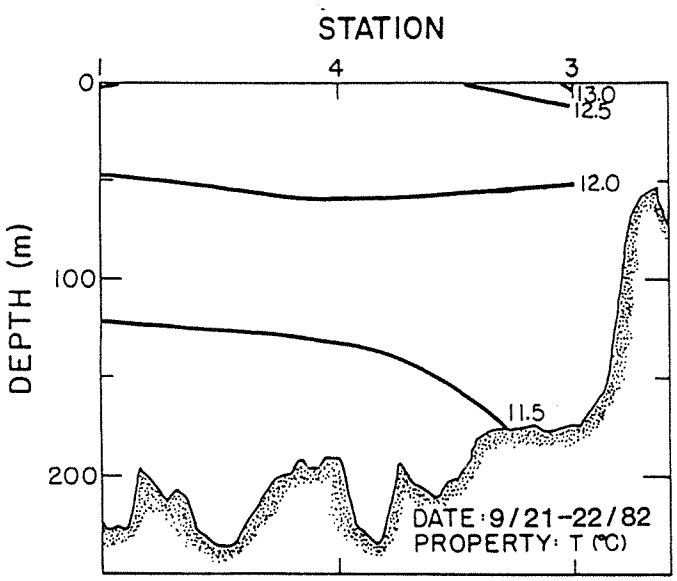

STATION
1
4
3
0
100
200
7.0
8.0
9.0
7.5
7.0
6.5
6.0
6.0
6.5
DATE: 8/23-24/82
PROPERTY: O (mg/l)

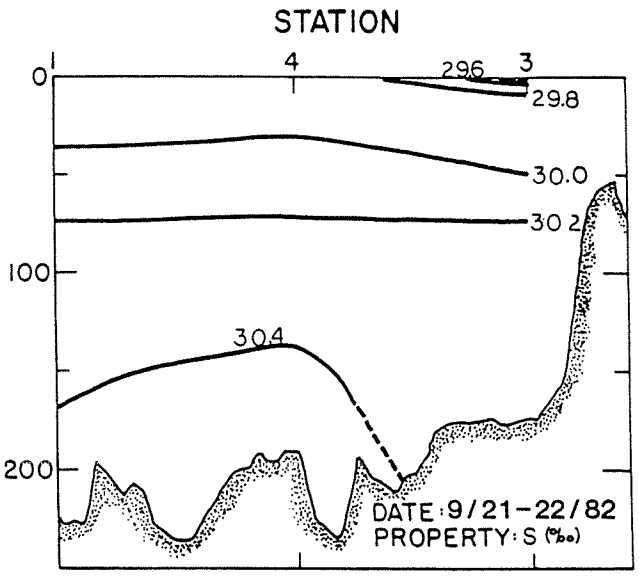

STATION
1
4
3
0
100
200
DEPTH (m)
13.0
12.5
12.0
11.5
11.4
11.3
11.2
DATE: 9/7-9/82
PROPERTY: T (°C)

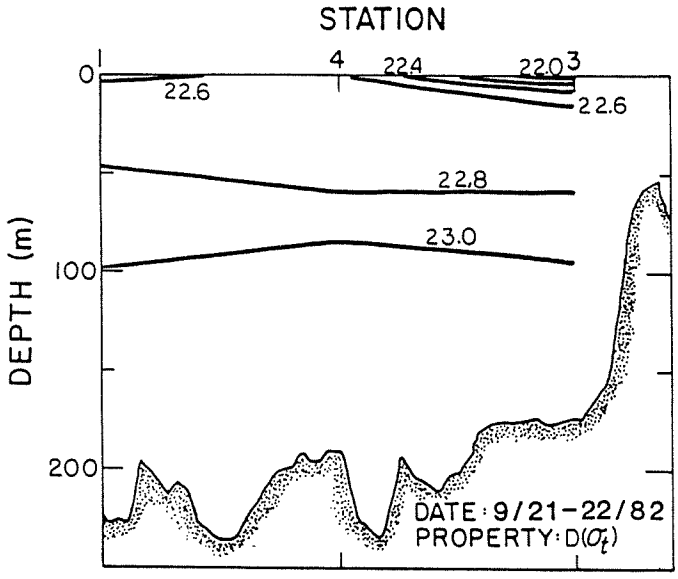

STATION
1
4
3
0
100
200
29.4
29.5
29.4
29.7
29.7
29.9
30.0
30.2
DATE: 9/7-9/82
PROPERTY: S (‰)

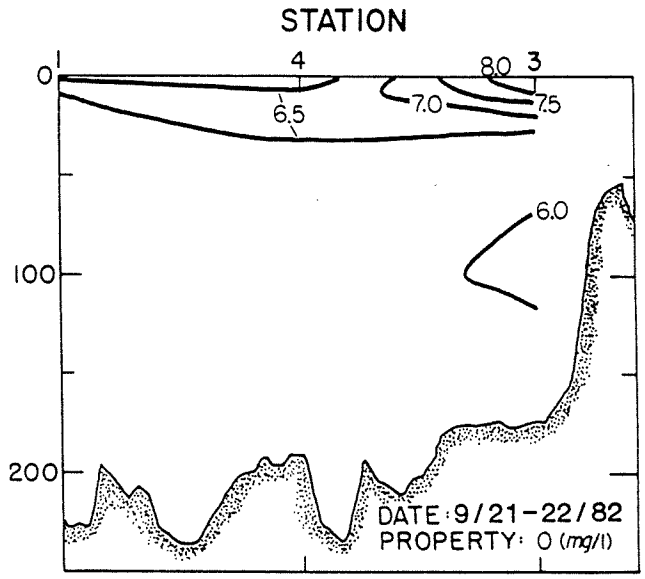

STATION
1
4
3
0
100
200
DEPTH (m)
22.
22.5
22.6
22.8
23.0
23.2
23.3
DATE: 9/7-9/82
PROPERTY: D(σt)

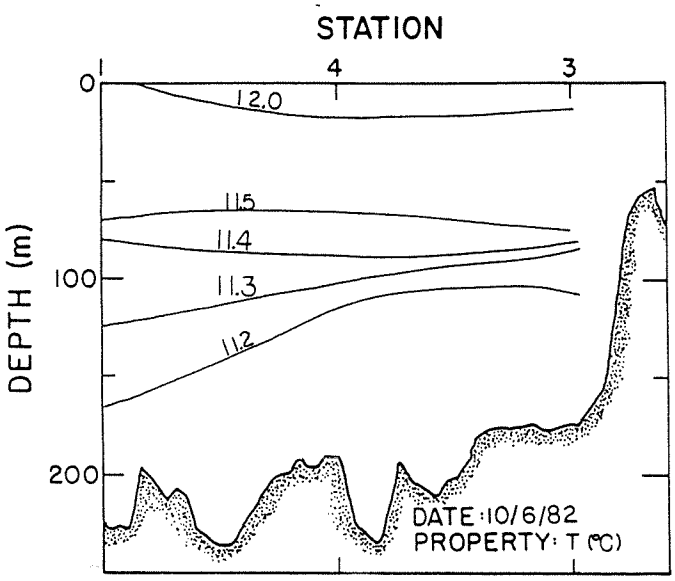

STATION
1
4
3
0
100
200
8.5
8.0
7.5
7.0
6.5
6.0
5.5
DATE: 9/7-9/82
PROPERTY: O (mg/l)

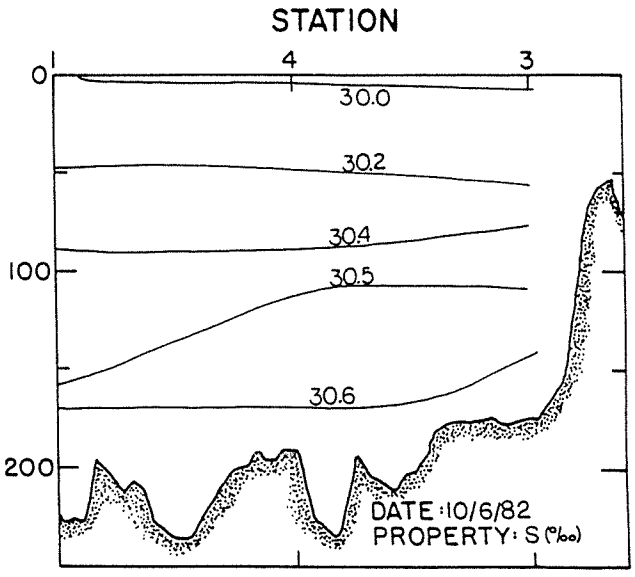

STATION
1
4
3
0
100
200
DEPTH (m)
13.0
12.5
12.0
11.5
DATE: 9/21-22/82
PROPERTY: T (°C)

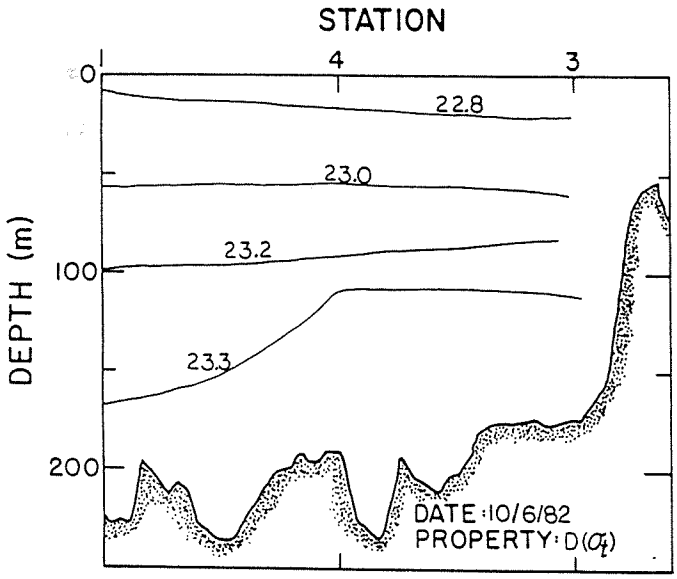

STATION
1
4
3
0
100
200
29.6
29.8
30.0
30.2
30.4
DATE: 9/21-22/82
PROPERTY: S (‰)

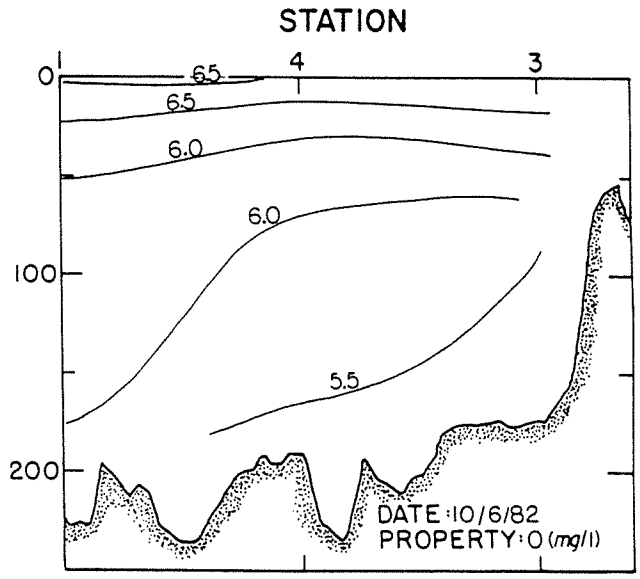

STATION
1
4
3
0
100
200
DEPTH (m)
22.4
22.0
22.6
22.6
22.8
23.0
DATE: 9/21-22/82
PROPERTY: D(σt)

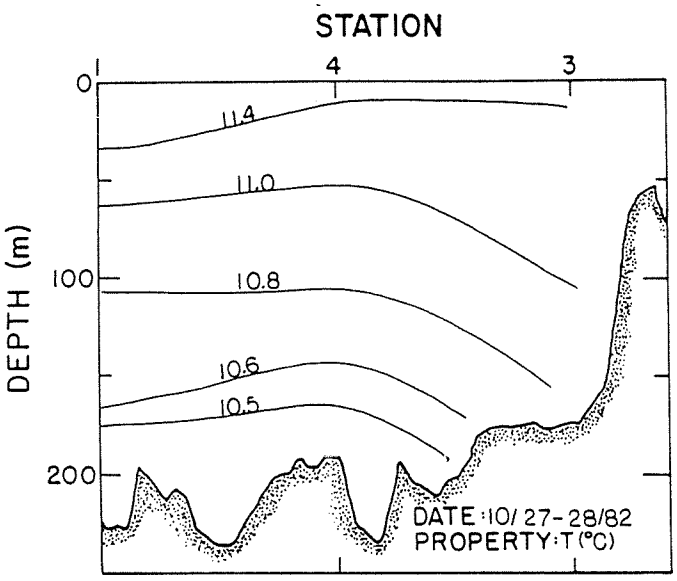

STATION
1
4
3
0
100
200
8.0
7.0
7.5
6.5
6.0
DATE: 9/21-22/82
PROPERTY: O (mg/l)

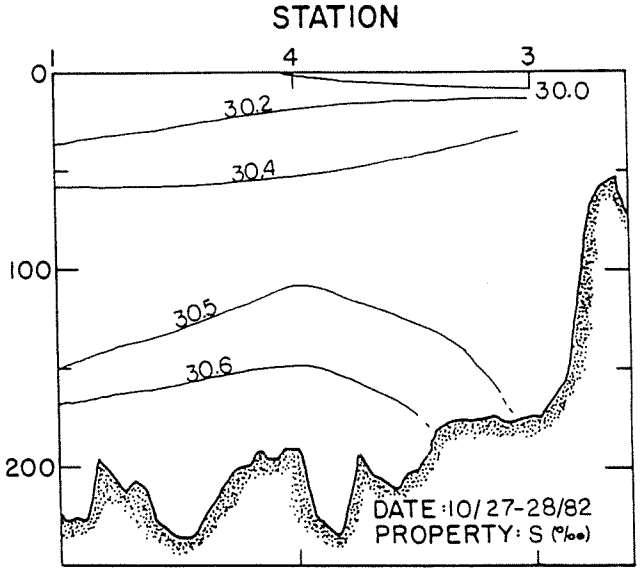

STATION
1
4
3
0
100
200
DEPTH (m)
12.0
11.5
11.4
11.3
11.2
DATE:10/6/82
PROPERTY: T (°C)

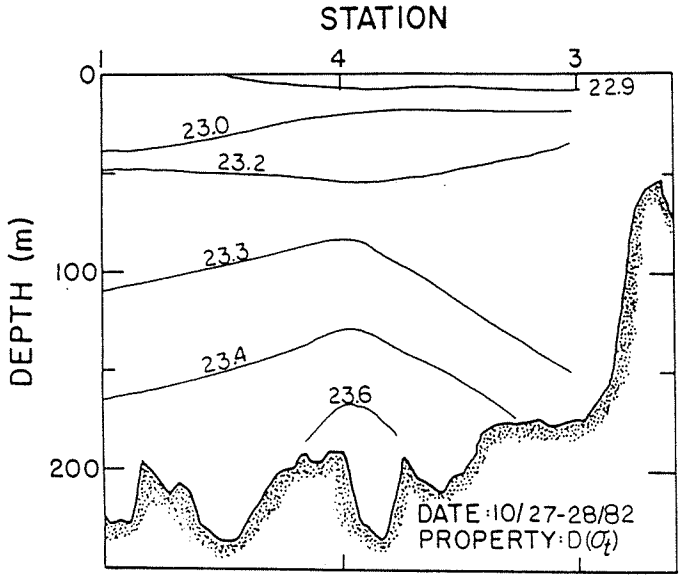

STATION
1
4
3
0
100
200
30.0
30.2
30.4
30.5
30.6
DATE:10/6/82
PROPERTY: S (‰)

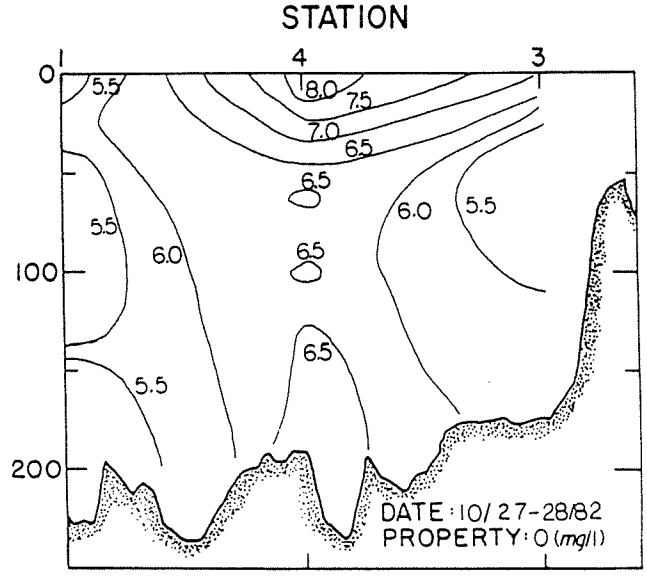

STATION
4
3
0
100
200
DEPTH (m)
22.8
23.0
23.2
23.3
DATE:10/6/82
PROPERTY: D(σt)

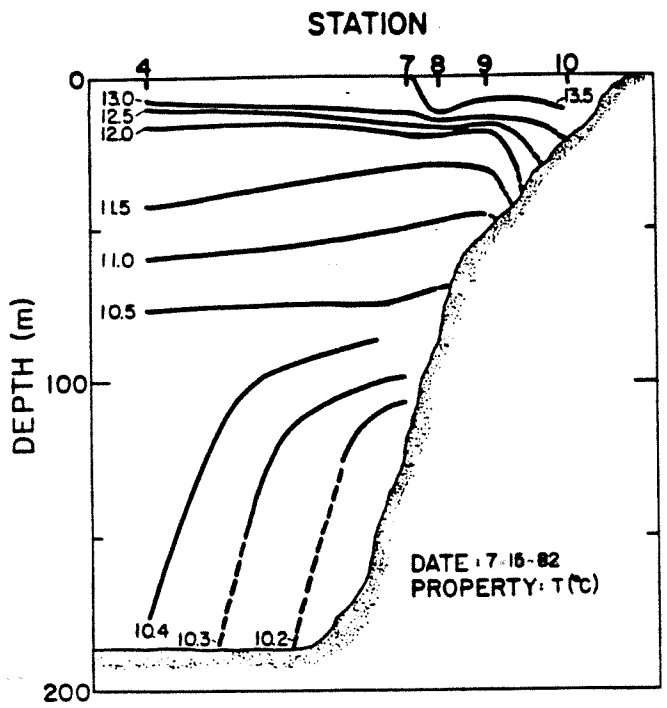

STATION
4
3
0
100
200
6.5
6.5
6.0
6.0
5.5
DATE:10/6/82
PROPERTY: O (mg/l)

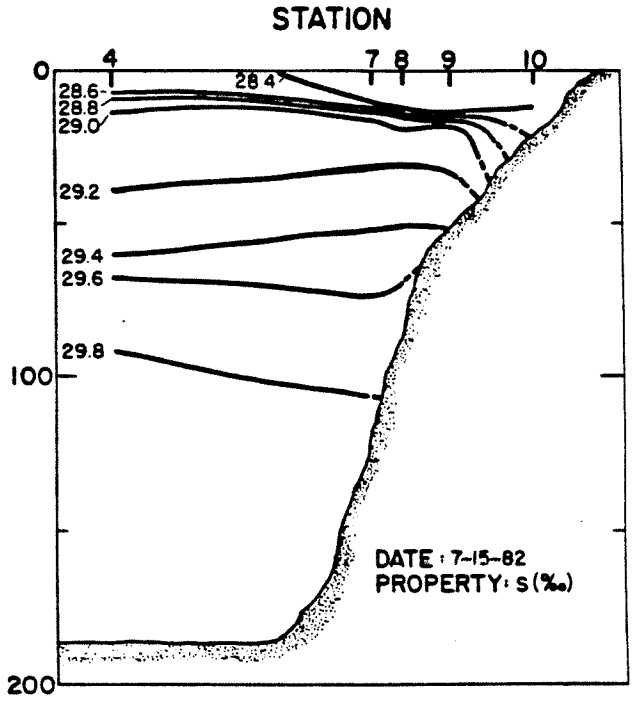

STATION
1
4
3
0
100
200
DEPTH (m)
11.4
11.0
10.8
10.6
10.5
DATE:10/27-28/82
PROPERTY:T(°C)

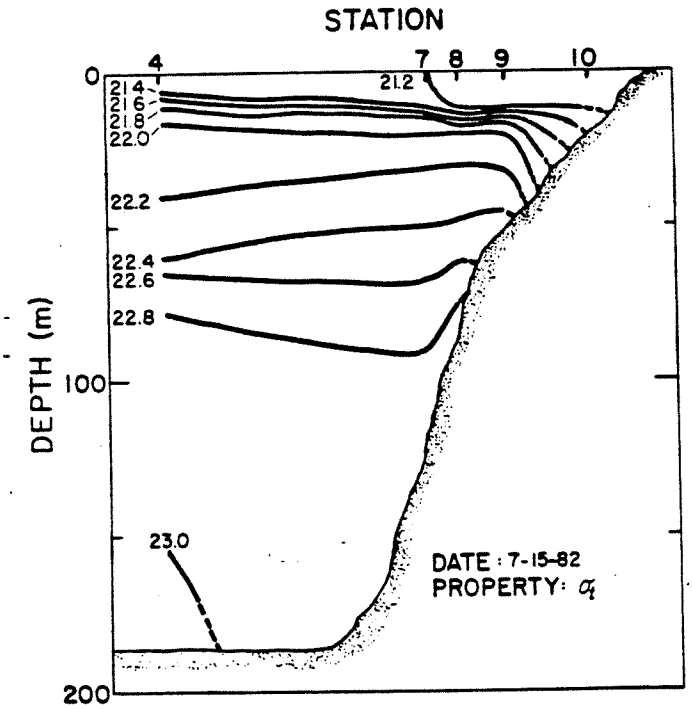

STATION
1
4
3
0
100
200
30.0
30.2
30.4
30.5
30.6
DATE:10/27-28/82
PROPERTY:S (‰)

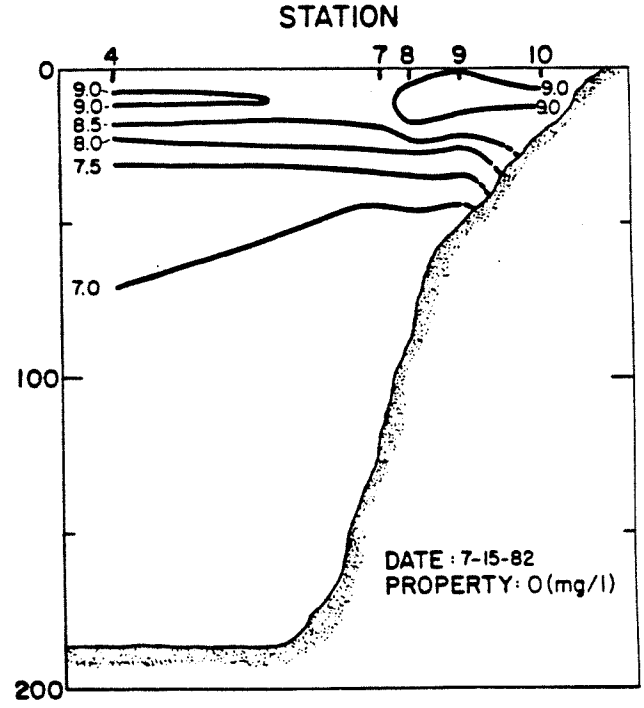

STATION
1
4
3
0
100
200
DEPTH (m)
22.9
23.0
23.2
23.3
23.4
23.6
DATE:10/27-28/82
PROPERTY:D(σt)

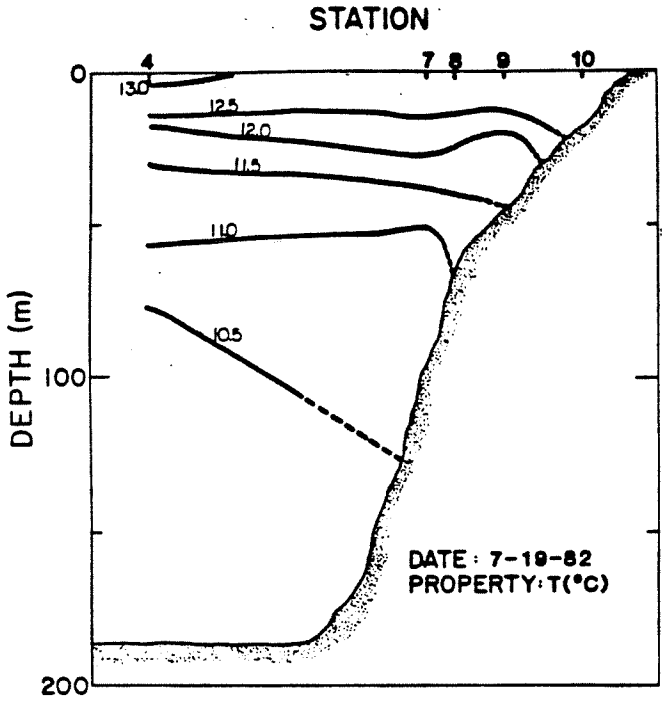

STATION
1
4
3
0
100
200
5.5
8.0
7.5
7.0
6.5
6.5
6.0
5.5
5.5
6.0
6.5
6.5
5.5
DATE:10/27-28/82
PROPERTY:O(mg/l)

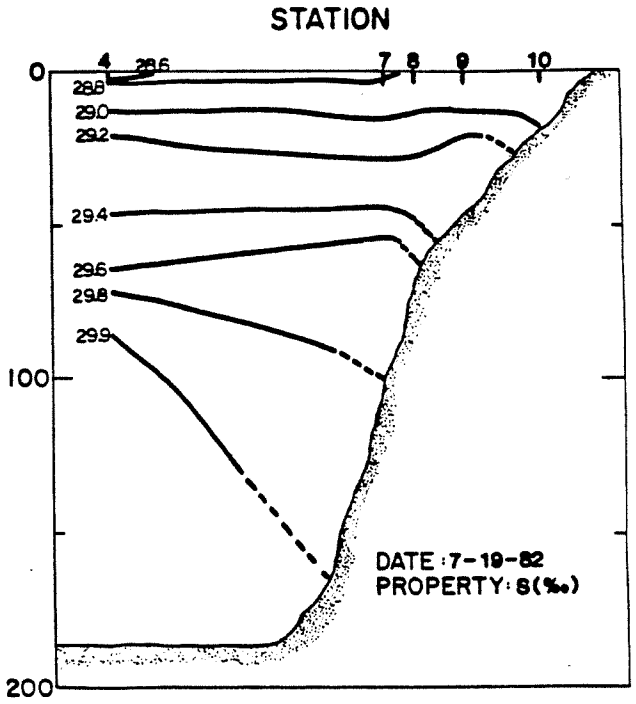

STATION
4
7
8
9
10
0
13.0
12.5
12.0
13.5
11.5
11.0
10.5
DEPTH (m)
100
10.4
10.3
10.2
200
DATE : 7-16-82
PROPERTY: T(°C)

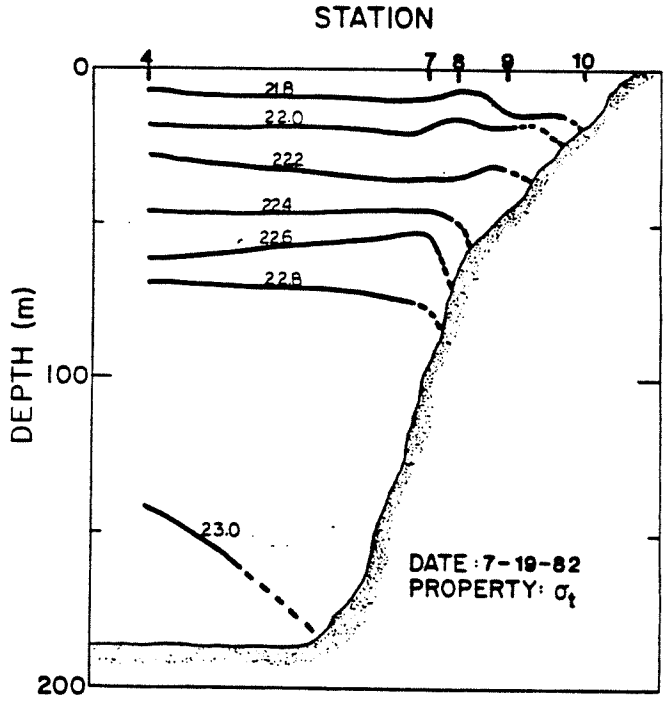

STATION
4
7
8
9
10
0
28.6
28.8
29.0
28.4
29.2
29.4
29.6
29.8
100
200
DATE : 7-15-82
PROPERTY: S(‰)

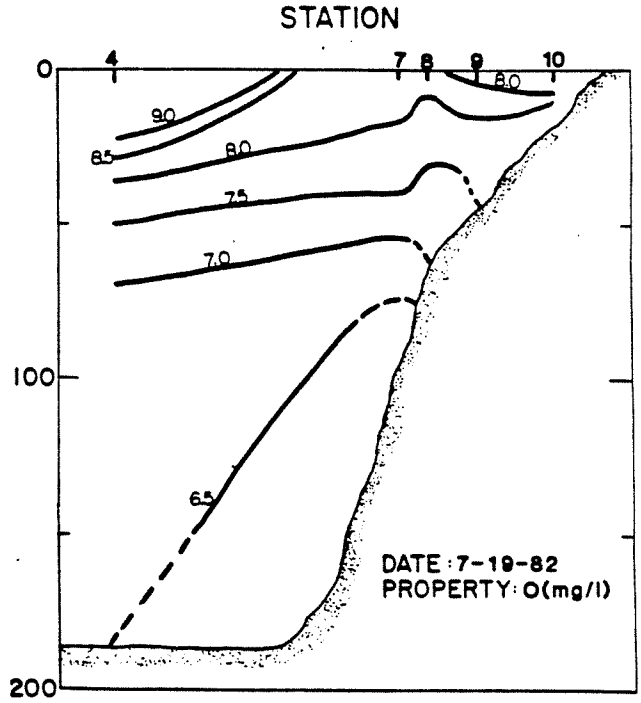

STATION
4
7
8
9
10
0
21.4
21.6
21.8
22.0
21.2
22.2
22.4
22.6
22.8
DEPTH (m)
100
23.0
200
DATE : 7-15-82
PROPERTY: σt

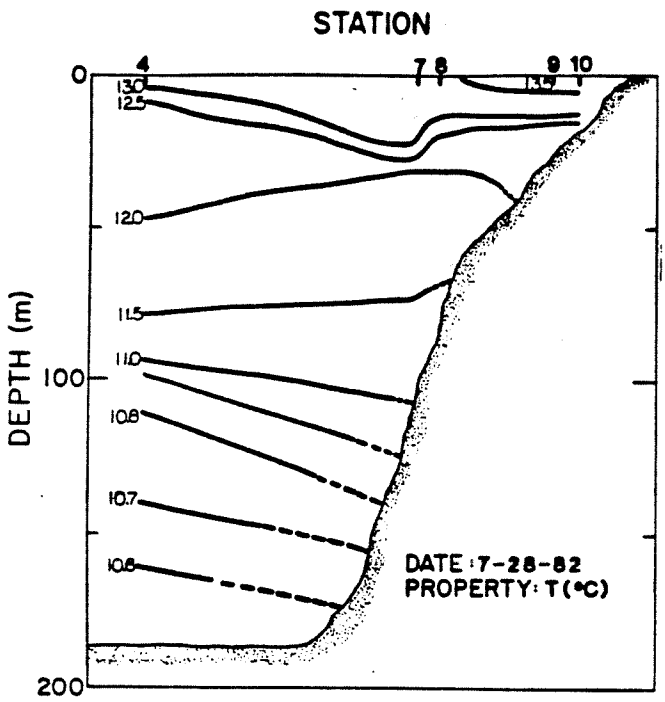

STATION
4
7
8
9
10
0
9.0
9.0
8.5
8.0
7.5
9.0
9.0
7.0
100
200
DATE : 7-15-82
PROPERTY: O(mg/l)

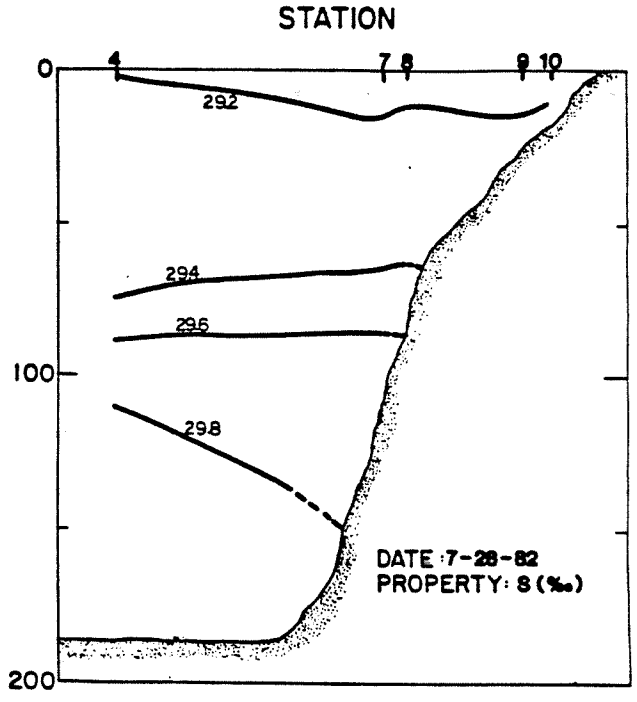

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
13.0
12.5
12.0
11.5
11.0
10.5
DATE : 7-19-82
PROPERTY: T(°C)

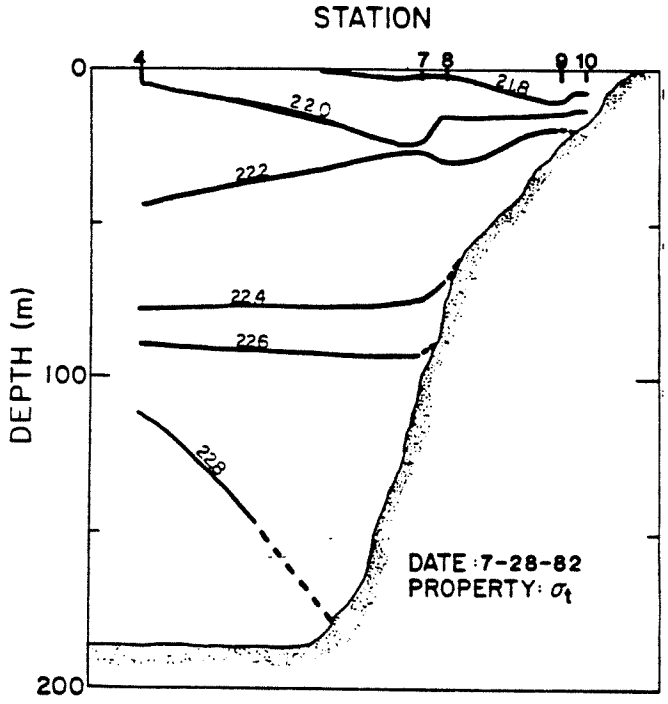

STATION
4
7
8
9
10
0
100
200
28.6
28.8
29.0
29.2
29.4
29.6
29.8
29.9
DATE : 7-19-82
PROPERTY: S(‰)

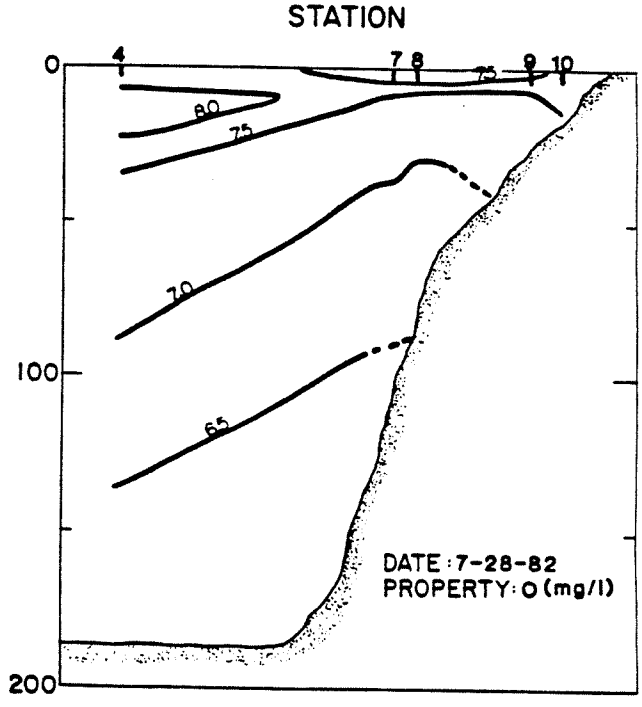

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
21.8
22.0
22.2
22.4
22.6
22.8
23.0
DATE : 7-19-82
PROPERTY: $\sigma_t$

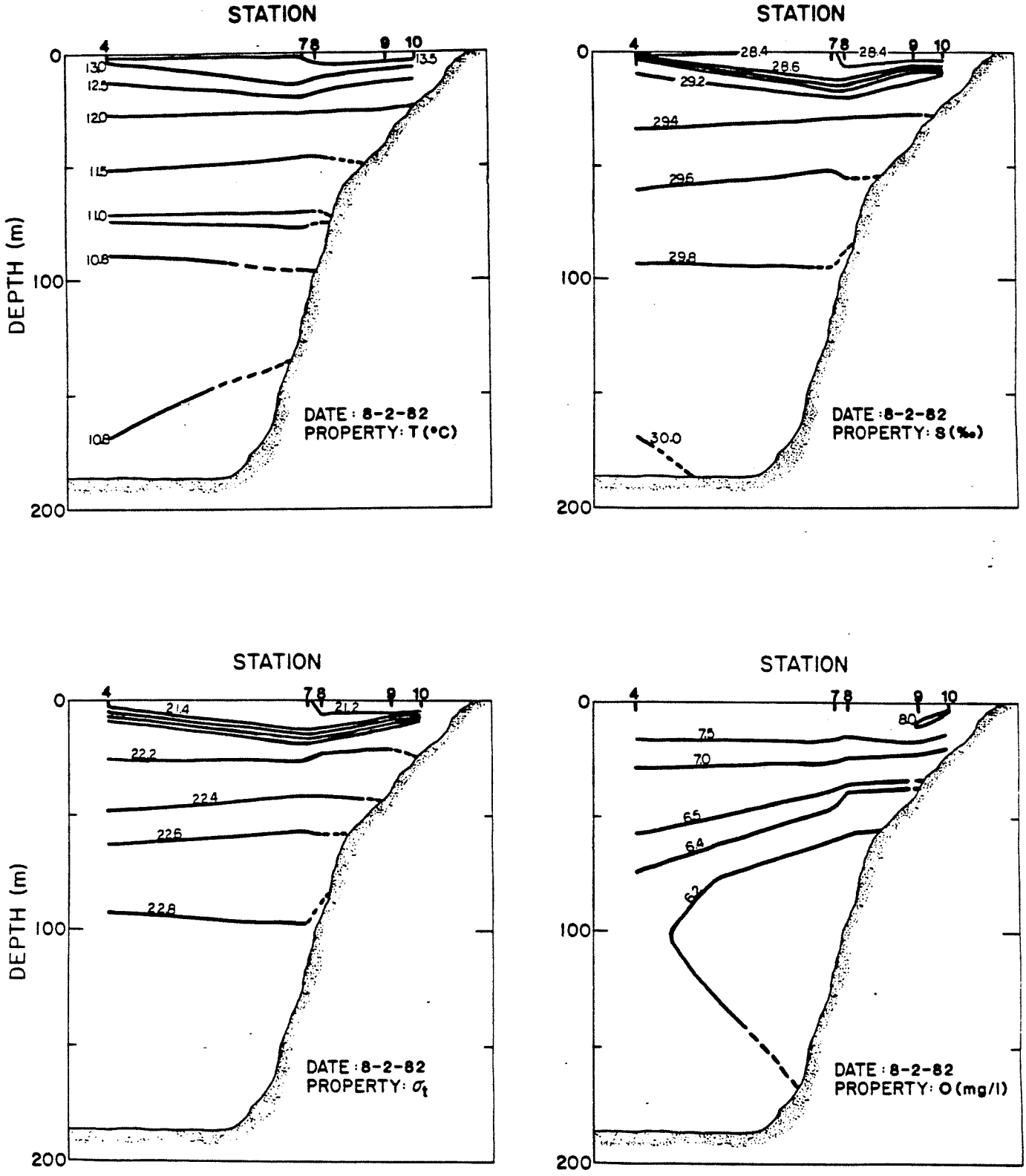

STATION
4
7
8
9
10
0
100
200
9.0
8.5
8.0
7.5
7.0
6.5
DATE : 7-19-82
PROPERTY: O(mg/l)

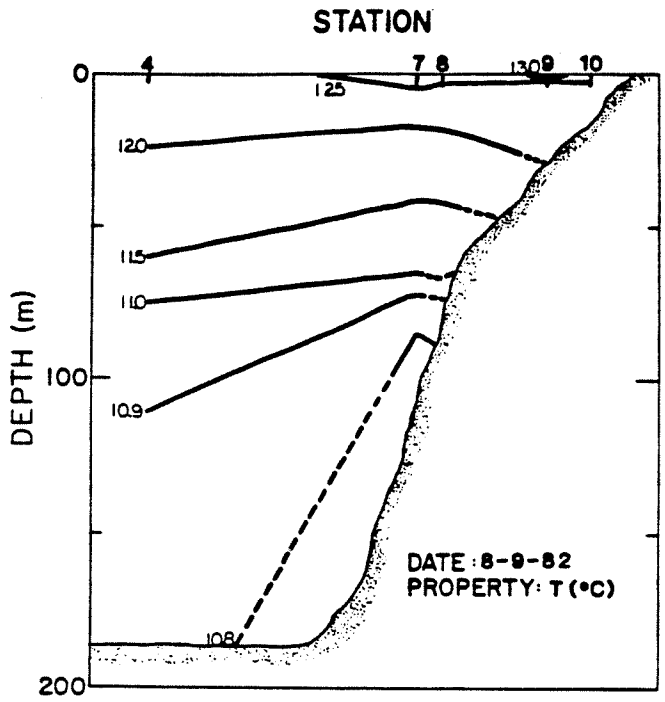

STATION
4
7 8
9 10
0
100
200
DEPTH (m)
13.0
12.5
12.0
11.5
11.0
10.8
10.7
10.6
DATE: 7-28-82
PROPERTY: T(°C)

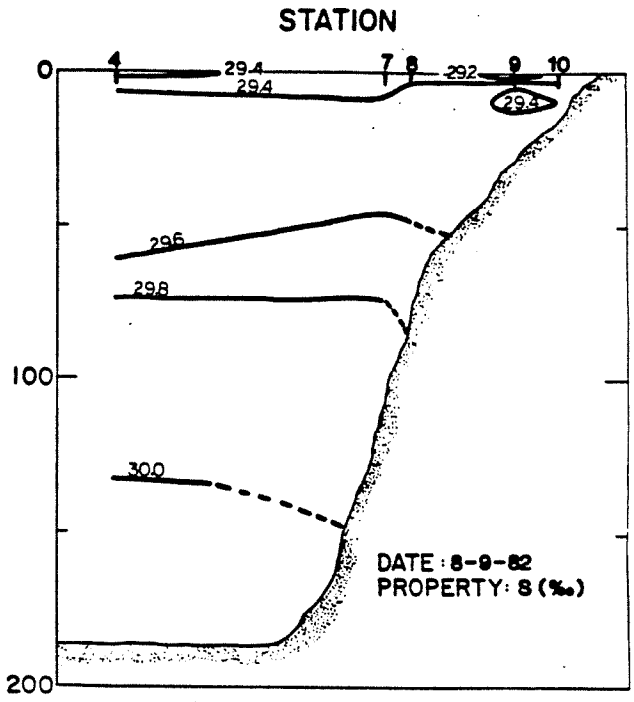

STATION
4
7 8
9 10
0
100
200
29.2
29.4
29.6
29.8
DATE: 7-28-82
PROPERTY: S(‰)

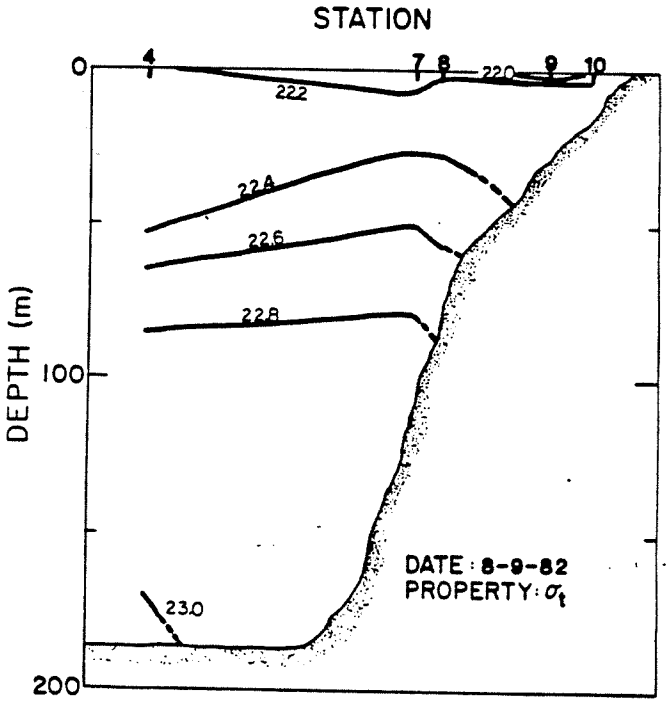

STATION
4
7 8
9 10
0
100
200
DEPTH (m)
22.0
22.2
22.4
22.6
22.8
DATE: 7-28-82
PROPERTY: σt

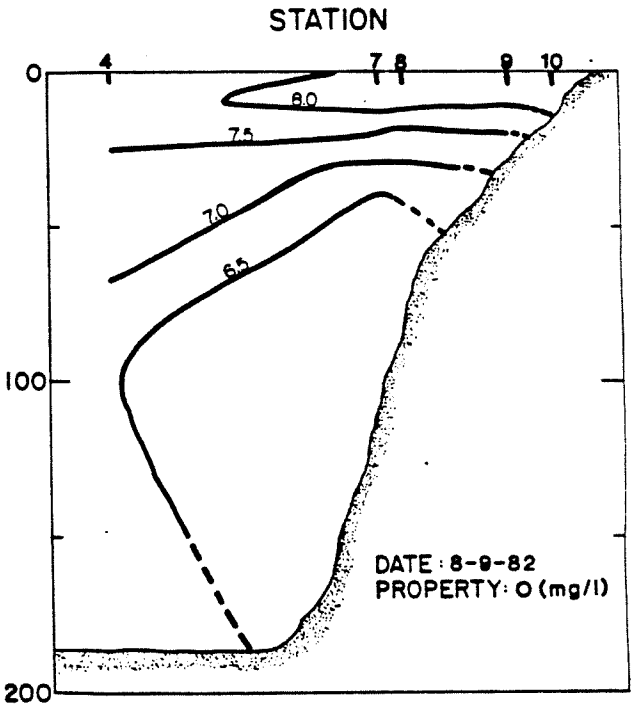

STATION
4
7 8
9 10
0
100
200
8.0
7.5
7.0
6.5
DATE: 7-28-82
PROPERTY: O(mg/l)

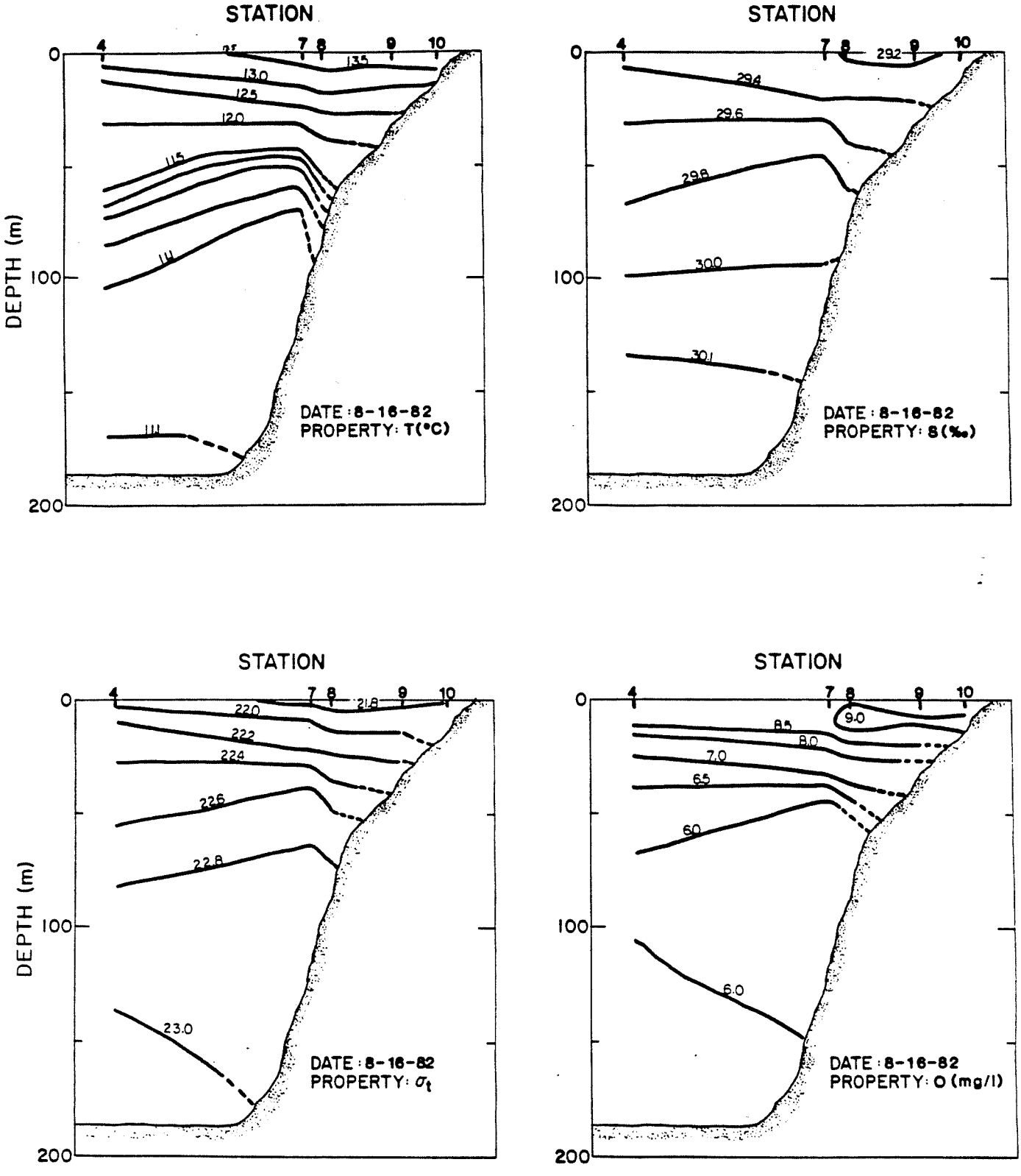

STATION
4
7 8
9
10
0
100
200
DEPTH (m)
13.0
12.5
12.0
11.5
11.0
10.8
10.8
13.5
DATE : 8-2-82
PROPERTY: T (°C)
STATION
28.4
28.6
29.2
29.4
29.6
29.8
30.0
DATE : 8-2-82
PROPERTY: S (‰)
STATION
21.4
21.2
22.2
22.4
22.6
22.8
DATE : 8-2-82
PROPERTY: $\sigma_t$
STATION
8.0
7.5
7.0
6.5
6.4
6.2
DATE : 8-2-82
PROPERTY: O (mg/l)

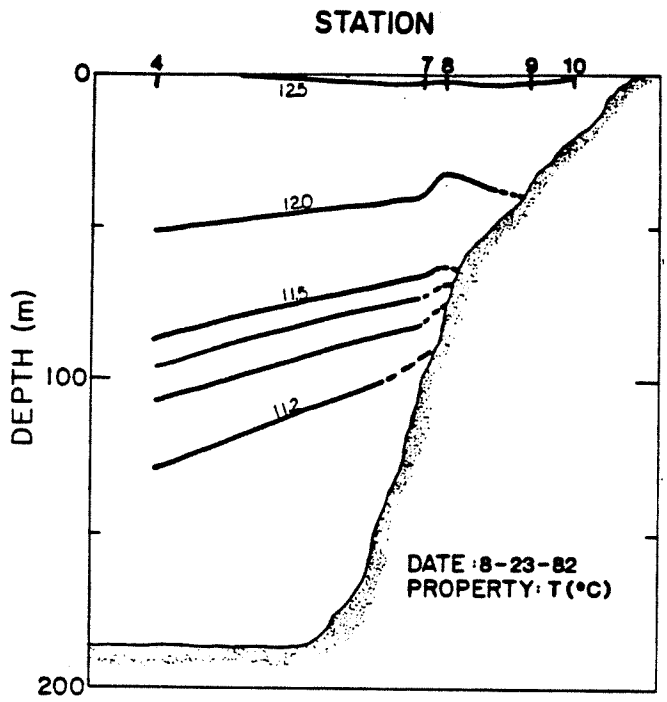

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
12.5
12.0
11.5
11.0
10.9
10.8
DATE : 8-9-82
PROPERTY: T (°C)

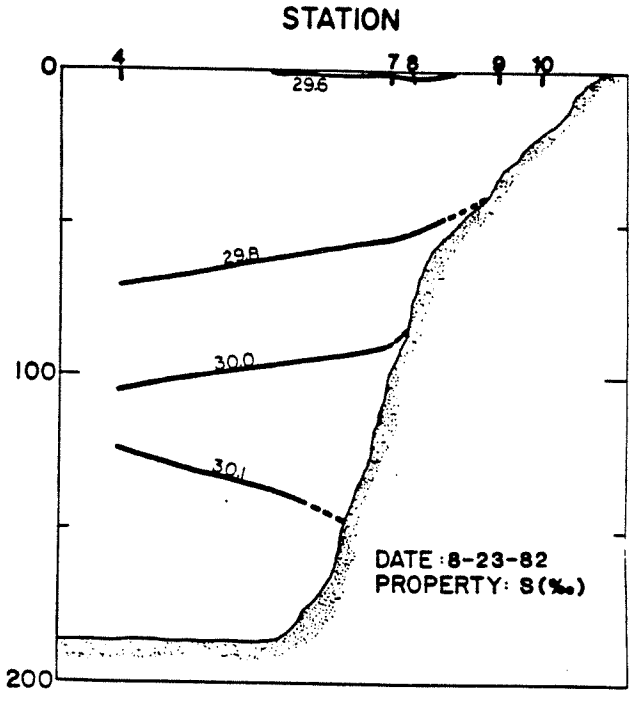

STATION
4
7
8
9
10
0
100
200
29.4
29.4
29.2
29.4
29.6
29.8
30.0
DATE : 8-9-82
PROPERTY: S (‰)

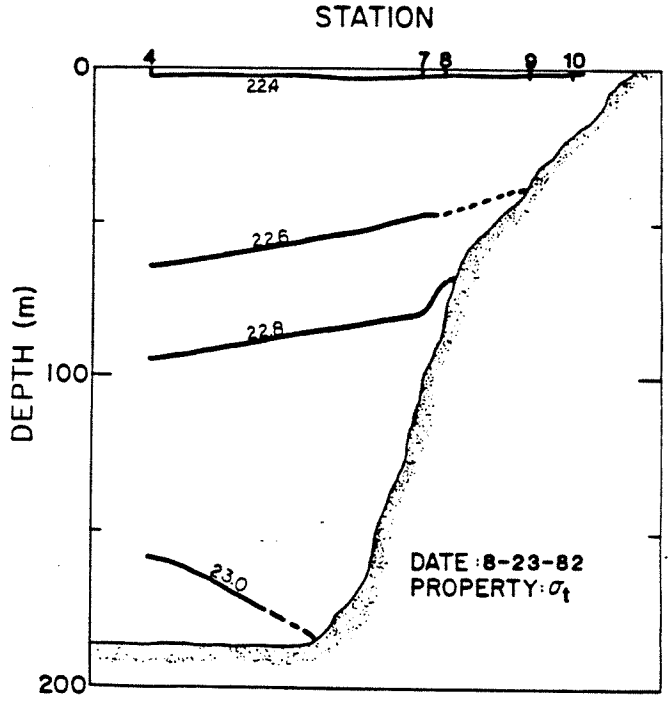

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
22.2
22.0
22.4
22.6
22.8
23.0
DATE : 8-9-82
PROPERTY: $\sigma_t$

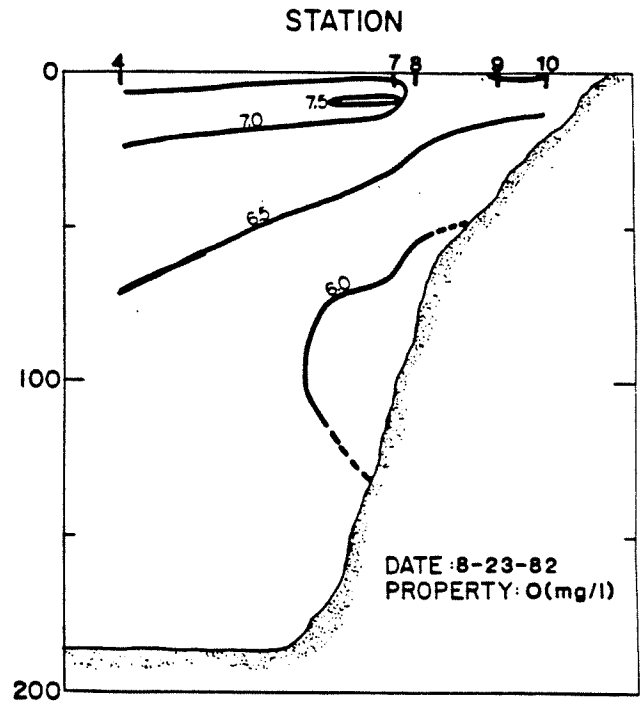

STATION
4
7
8
9
10
0
100
200
8.0
7.5
7.0
6.5
DATE : 8-9-82
PROPERTY: O (mg/l)

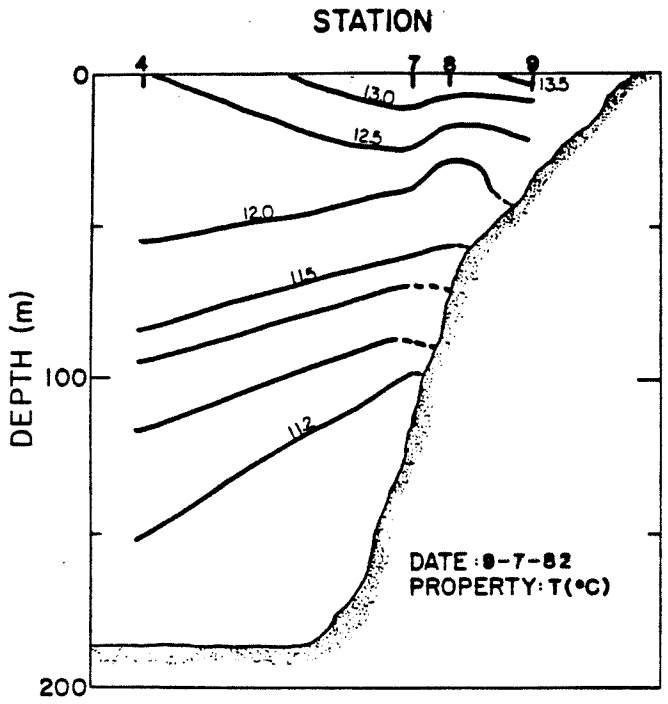

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
13.5
13.0
12.5
12.0
11.5
11.1
11.1
DATE : 8-16-82
PROPERTY: T(°C)
STATION
29.2
29.4
29.6
29.8
30.0
30.1
DATE : 8-16-82
PROPERTY: S(‰)
STATION
21.8
22.0
22.2
22.4
22.6
22.8
23.0
DATE : 8-16-82
PROPERTY: $\sigma_t$
STATION
9.0
8.5
8.0
7.0
6.5
6.0
6.0
DATE : 8-16-82
PROPERTY: O (mg/l)

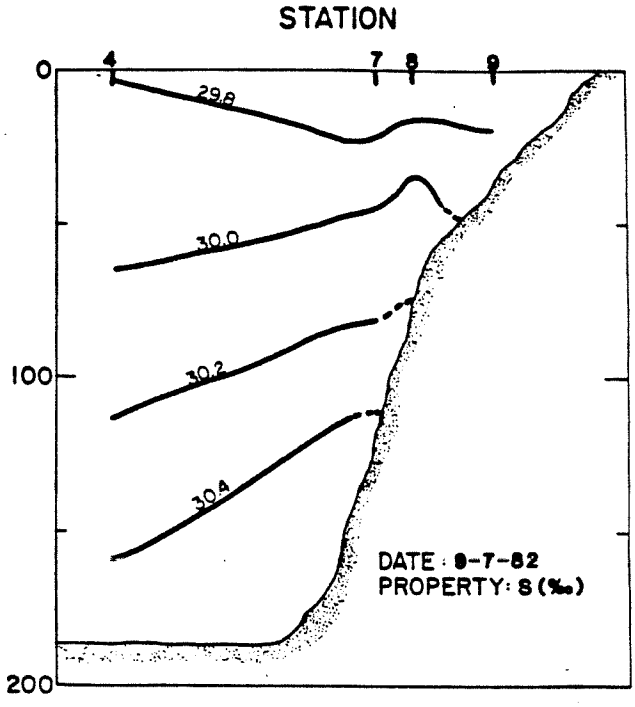

STATION
4
7 8
9
10
0
100
200
DEPTH (m)
12.5
12.0
11.5
11.2
DATE : 8-23-82
PROPERTY: T(°C)

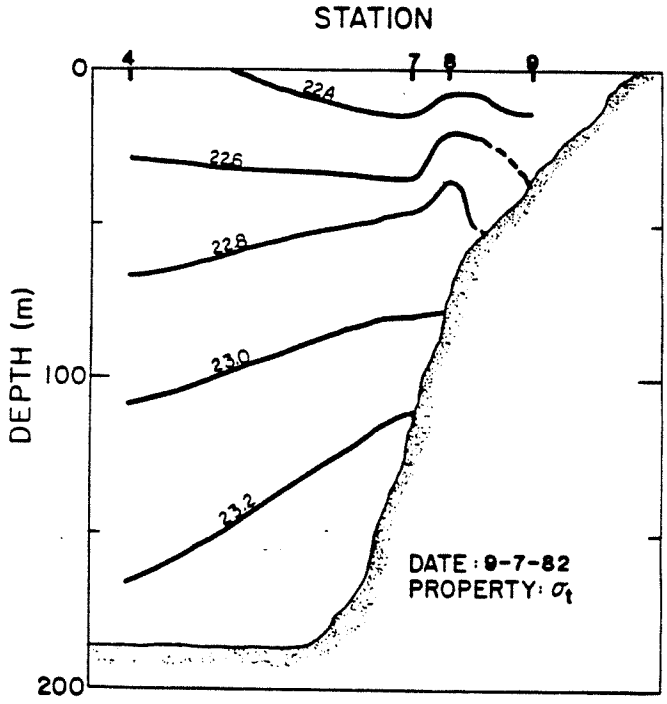

STATION
4
7 8
9
10
0
100
200
29.6
29.8
30.0
30.1
DATE : 8-23-82
PROPERTY: S(‰)

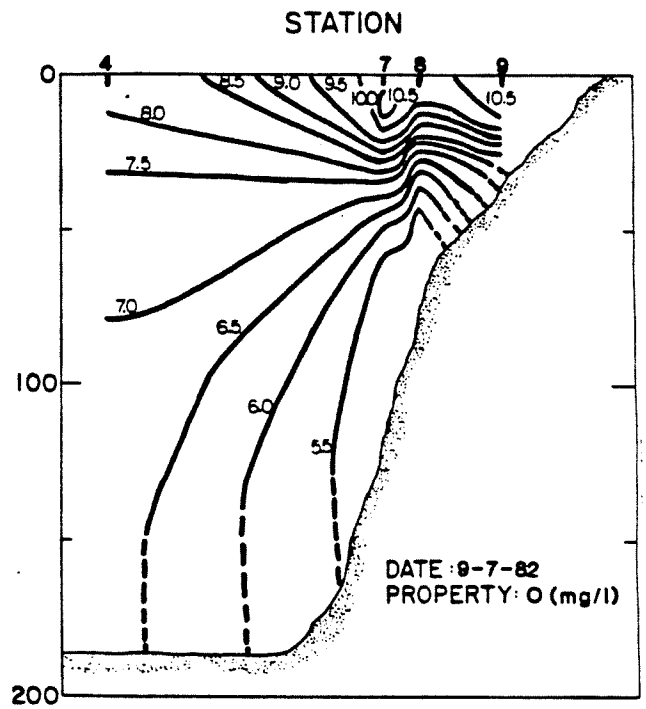

STATION
4
7 8
9
10
0
100
200
DEPTH (m)
22.4
22.6
22.8
23.0
DATE : 8-23-82
PROPERTY: $\sigma_t$

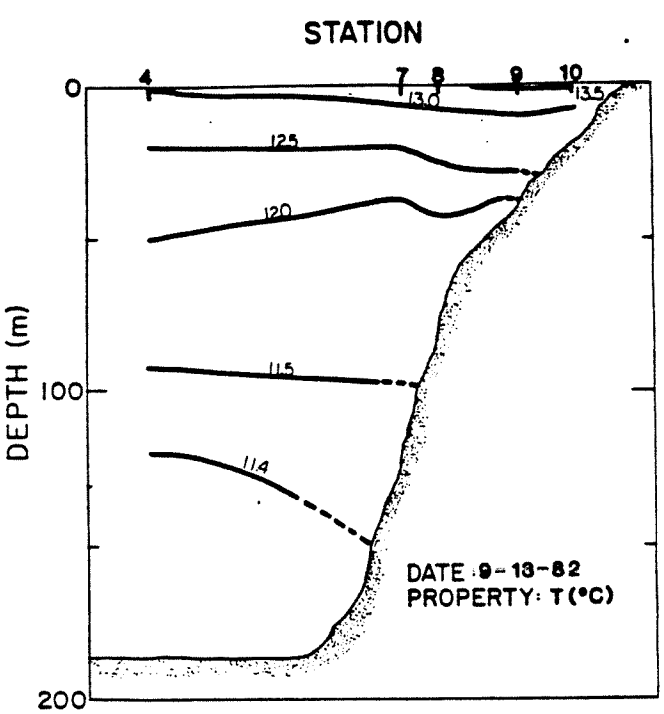

STATION
4
7 8
9
10
0
100
200
7.5
7.0
6.5
6.0
DATE : 8-23-82
PROPERTY: O(mg/l)

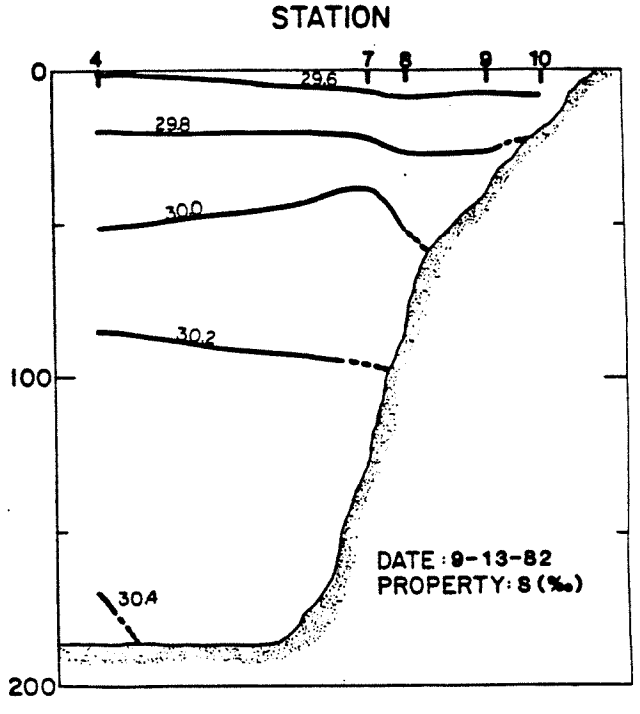

STATION
4
7
8
9
0
100
200
DEPTH (m)
13.0
13.5
12.5
12.0
11.5
11.2
DATE : 8-7-82
PROPERTY: T(°C)

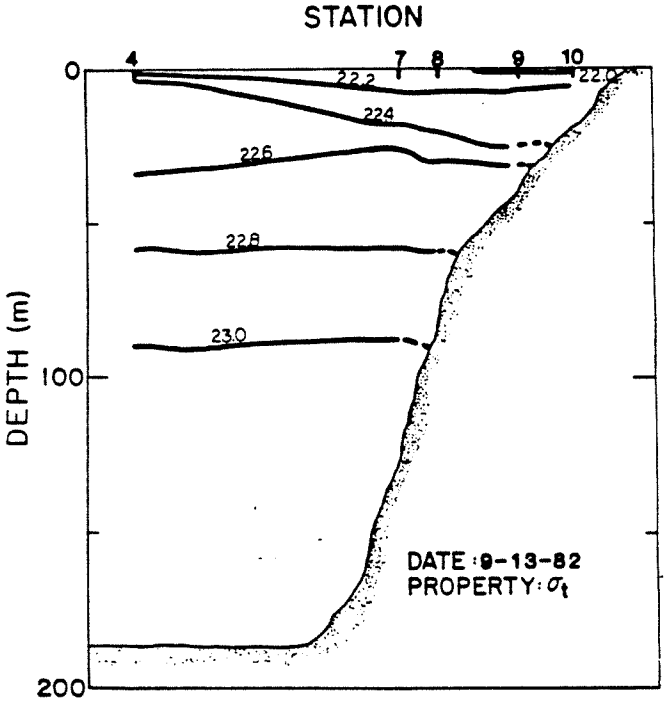

STATION
4
7
8
9
0
100
200
29.8
30.0
30.2
30.4
DATE : 8-7-82
PROPERTY: S (‰)

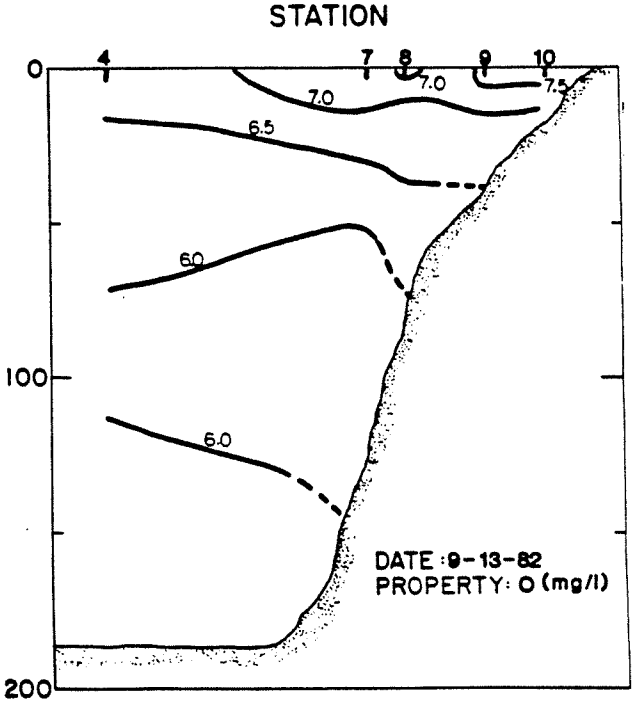

STATION
4
7
8
9
0
100
200
DEPTH (m)
22.4
22.6
22.8
23.0
23.2
DATE : 8-7-82
PROPERTY: $\sigma_t$

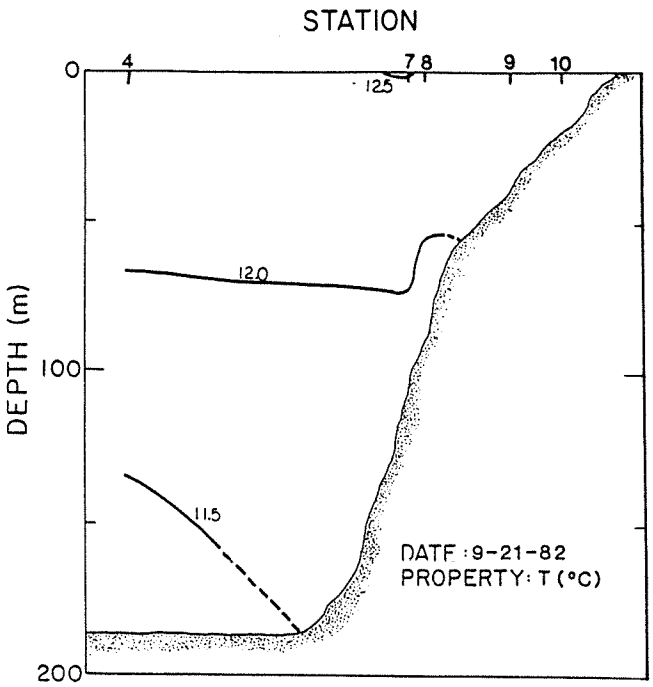

STATION
4
7
8
9
0
100
200
8.5
9.0
9.5
10.0
10.5
10.5
8.0
7.5
7.0
6.5
6.0
5.5
DATE : 8-7-82
PROPERTY: O (mg/l)

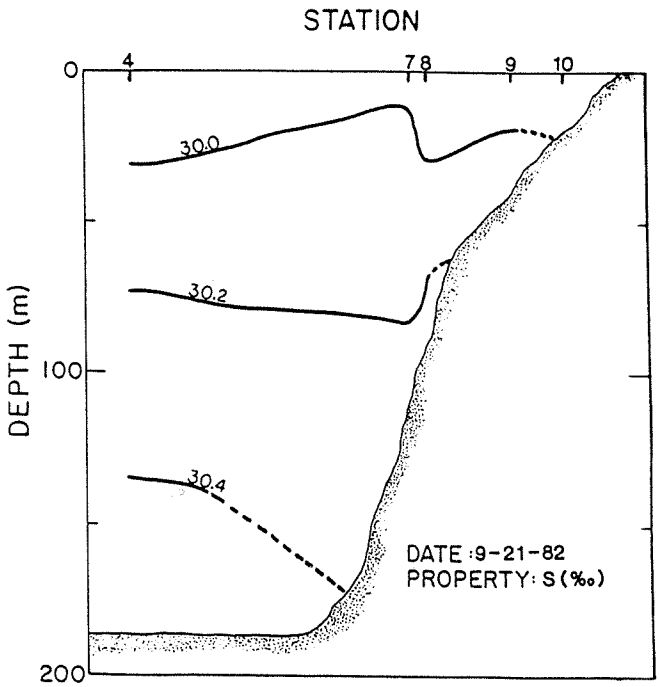

STATION
4
7
8
9
10
0
13.0
13.5
12.5
12.0
11.5
11.4
DEPTH (m)
100
200
DATE : 9-13-82
PROPERTY: T (°C)

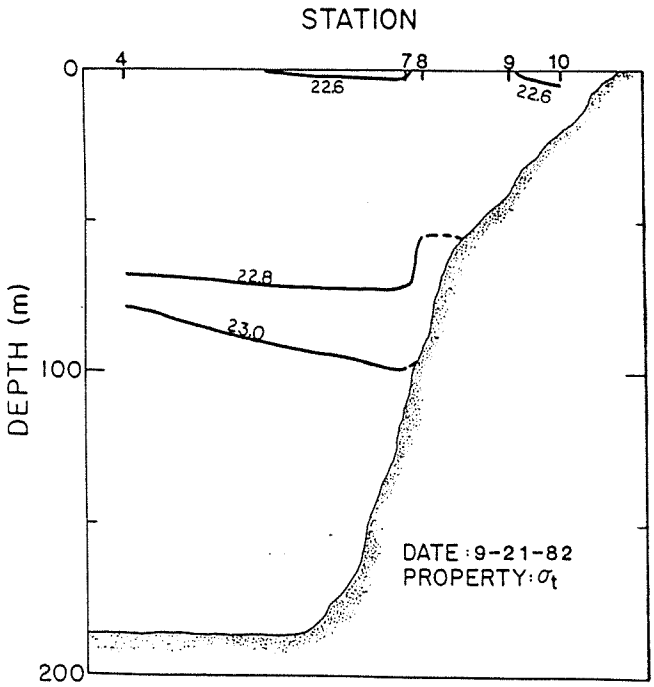

STATION
4
7
8
9
10
0
29.6
29.8
30.0
30.2
30.4
100
200
DATE : 9-13-82
PROPERTY: S (‰)

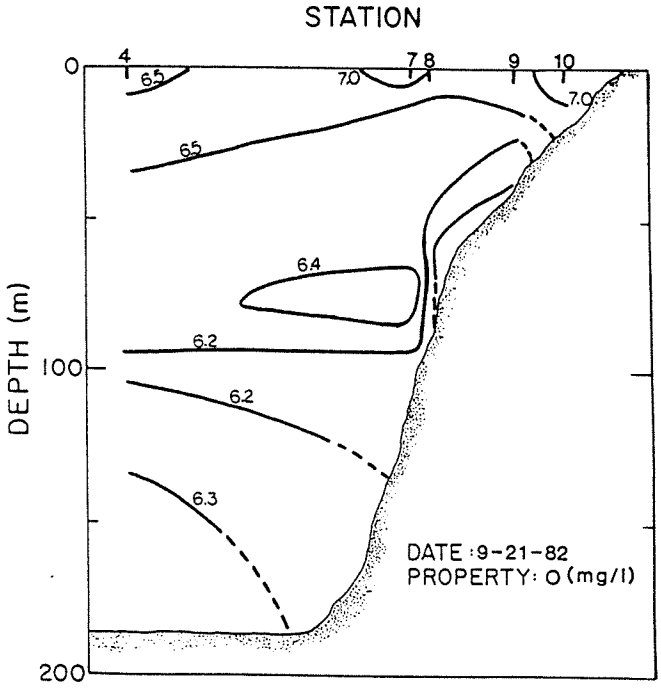

STATION
4
7
8
9
10
0
22.2
22.0
22.4
22.6
22.8
23.0
DEPTH (m)
100
200
DATE : 9-13-82
PROPERTY: $\sigma_t$

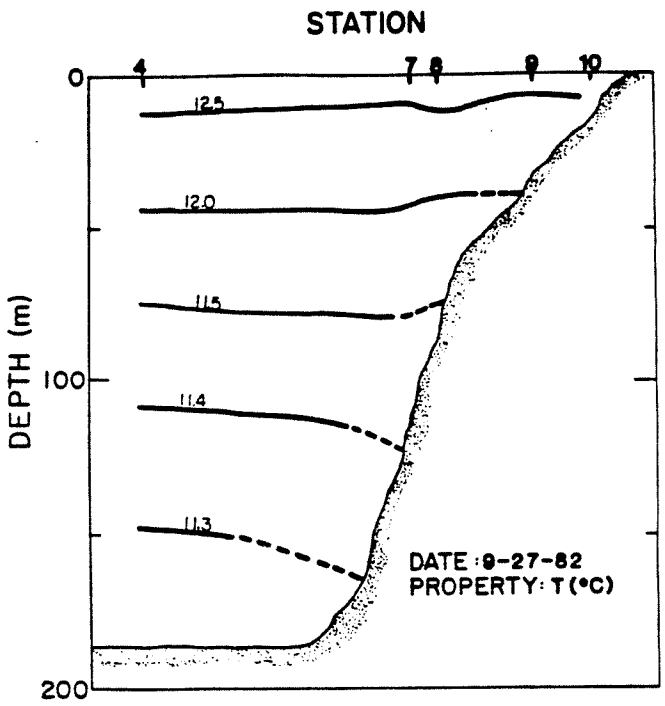

STATION
4
7
8
9
10
0
7.0
7.0
7.5
6.5
6.0
6.0
100
200
DATE : 9-13-82
PROPERTY: O (mg/l)

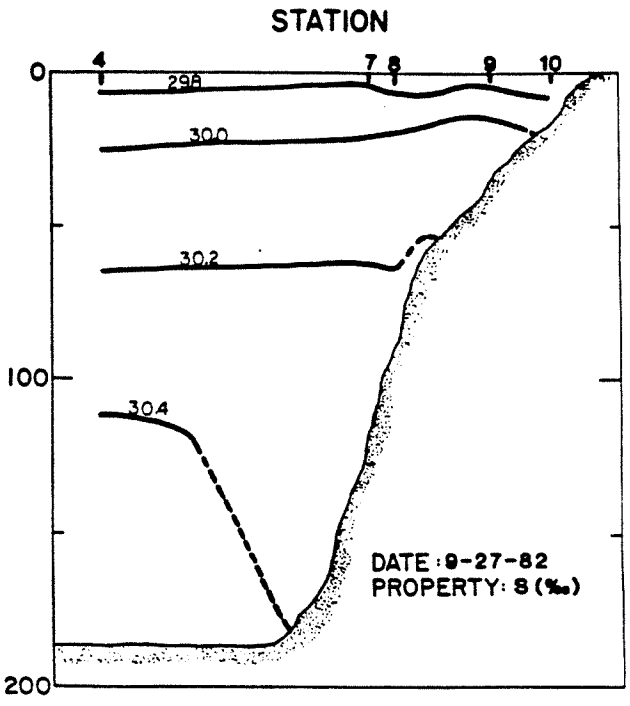

STATION
0
4
7 8
9
10
12.5
12.0
11.5
DEPTH (m)
100
200
DATF : 9-21-82
PROPERTY: T (°C)

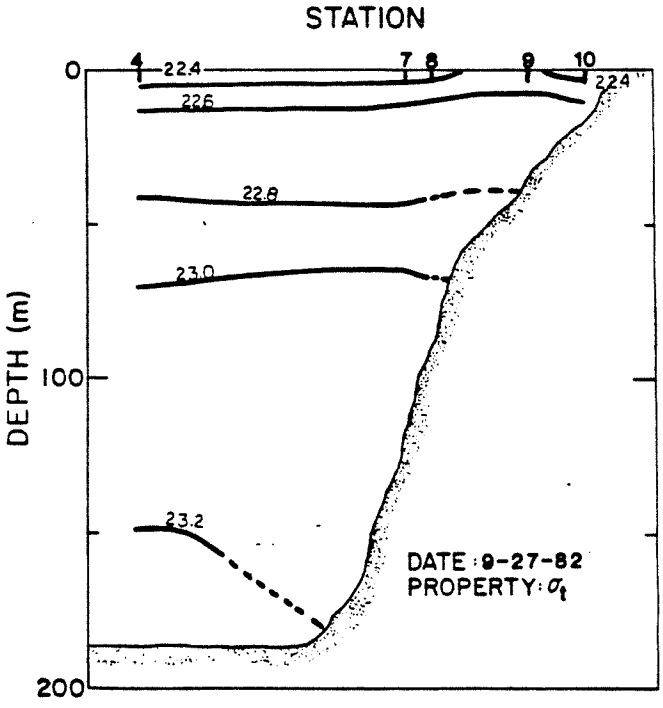

STATION
0
4
7 8
9
10
30.0
30.2
30.4
DEPTH (m)
100
200
DATE : 9-21-82
PROPERTY: S (‰)

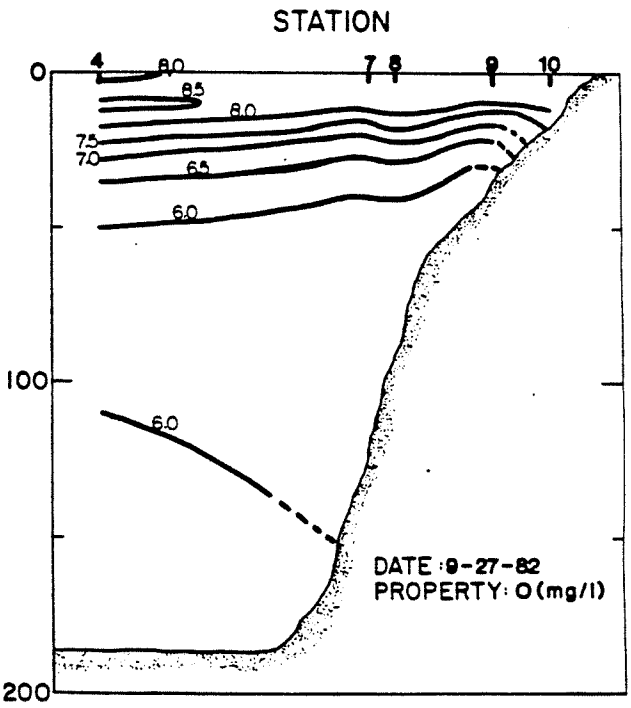

STATION
0
4
7 8
9
10
22.6
22.6
22.8
23.0
DEPTH (m)
100
200
DATE : 9-21-82
PROPERTY: $\sigma_t$

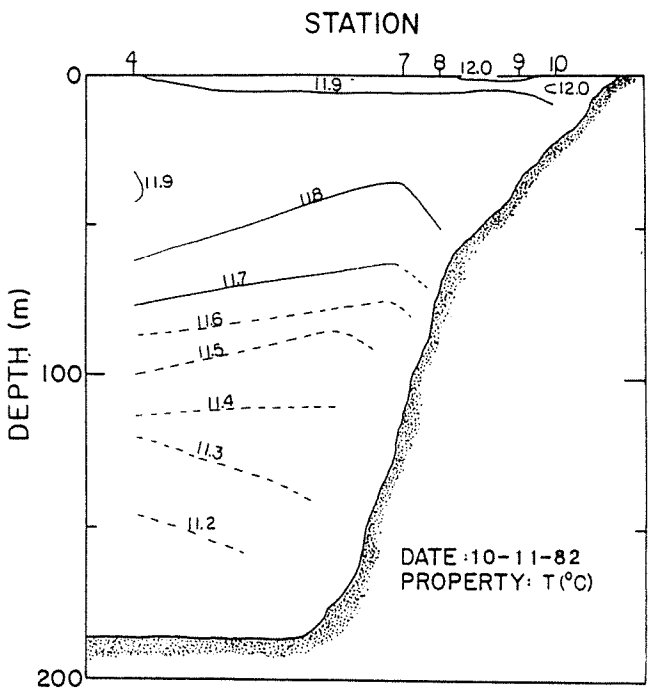

STATION
0
4
7 8
9
10
6.5
7.0
7.0
6.5
6.4
6.2
6.2
6.3
DEPTH (m)
100
200
DATE : 9-21-82
PROPERTY: O (mg/l)

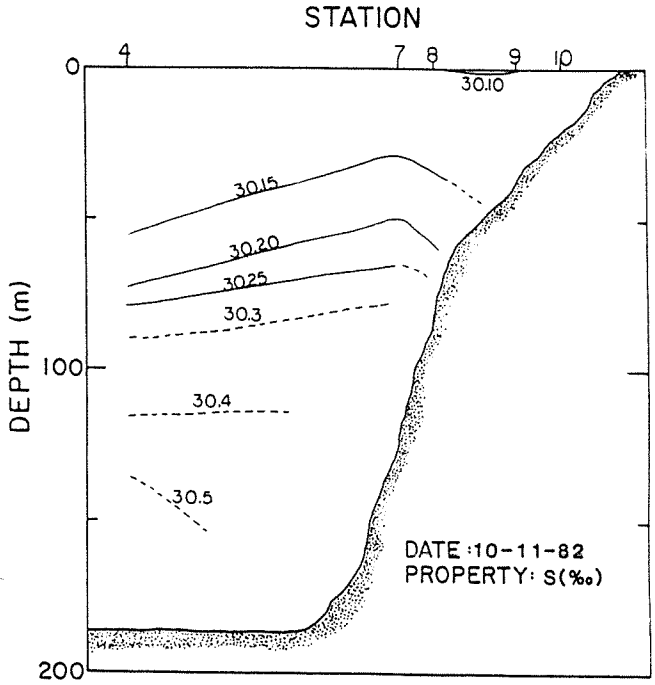

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
12.5
12.0
11.5
11.4
11.3
DATE: 9-27-82
PROPERTY: T (°C)

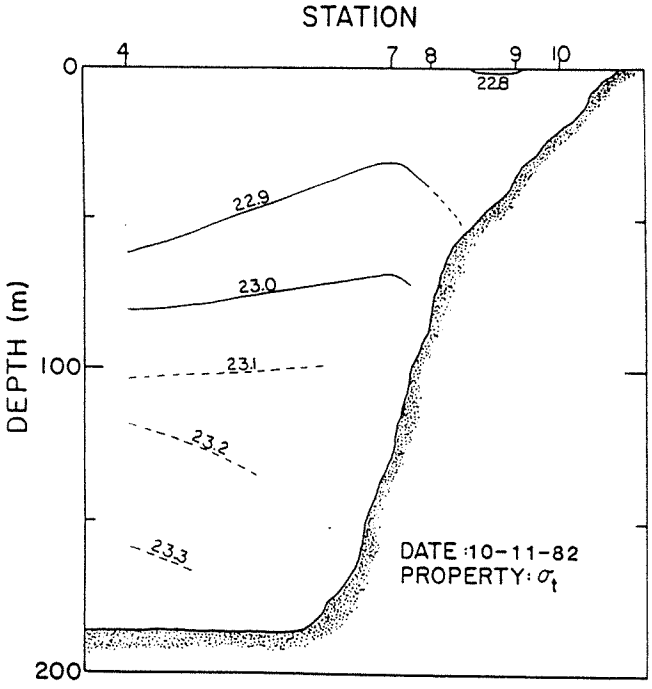

STATION
4
7
8
9
10
0
100
200
29.8
30.0
30.2
30.4
DATE: 9-27-82
PROPERTY: S (‰)

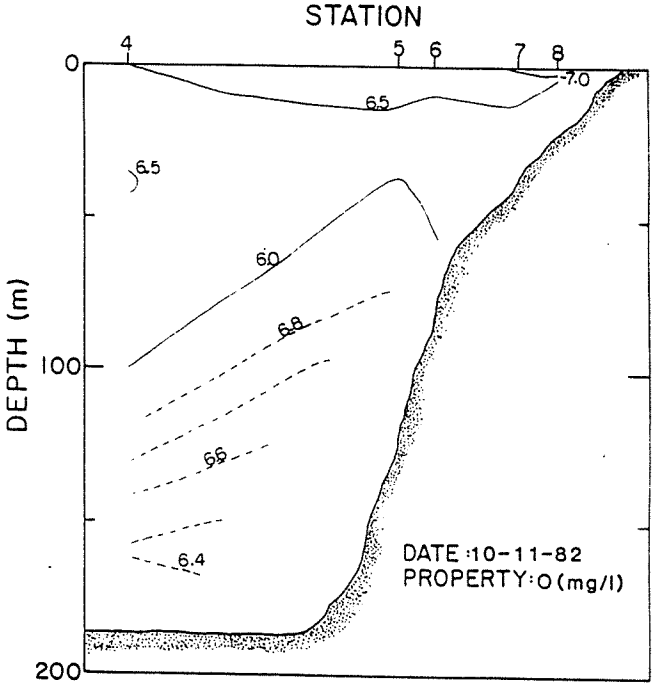

STATION
4
7
8
9
10
0
100
200
DEPTH (m)
22.4
22.6
22.8
23.0
23.2
22.4
DATE: 9-27-82
PROPERTY: $\sigma_t$

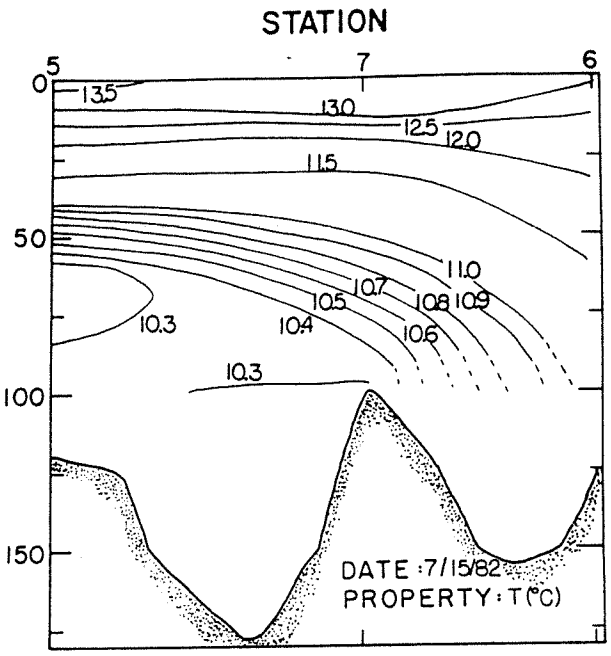

STATION
4
7
8
9
10
0
100
200
8.0
8.5
8.0
7.5
7.0
6.5
6.0
6.0
DATE: 9-27-82
PROPERTY: O (mg/l)

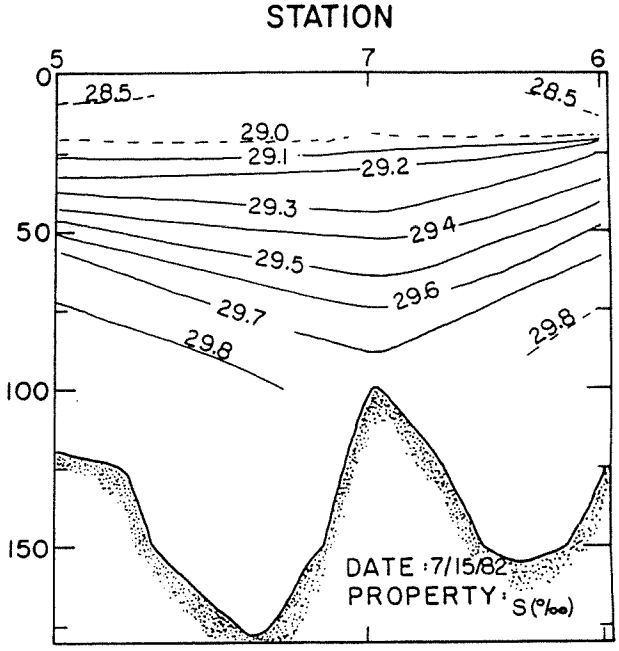

STATION
4
7
8
12.0
9
10
0
11.9
<12.0
11.9
11.8
11.7
11.6
11.5
11.4
11.3
11.2
DEPTH (m)
100
200
DATE :10-11-82
PROPERTY: T(°C)

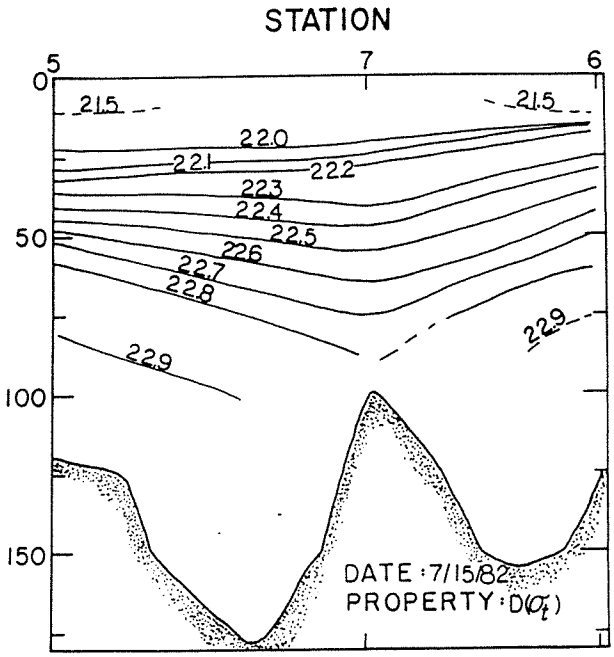

STATION
4
7
8
9
10
0
30.10
30.15
30.20
30.25
30.3
30.4
30.5
DEPTH (m)
100
200
DATE :10-11-82
PROPERTY: S(‰)

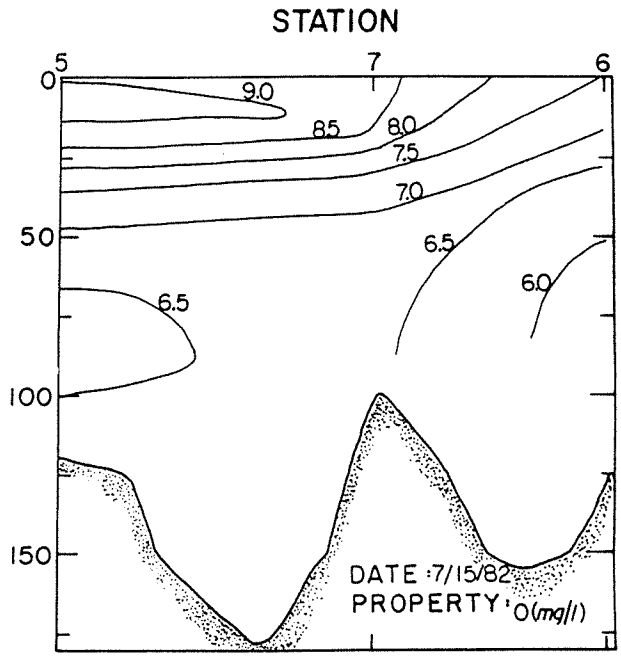

STATION
4
7
8
9
10
0
22.8
22.9
23.0
23.1
23.2
23.3
DEPTH (m)
100
200
DATE :10-11-82
PROPERTY: $\sigma_t$

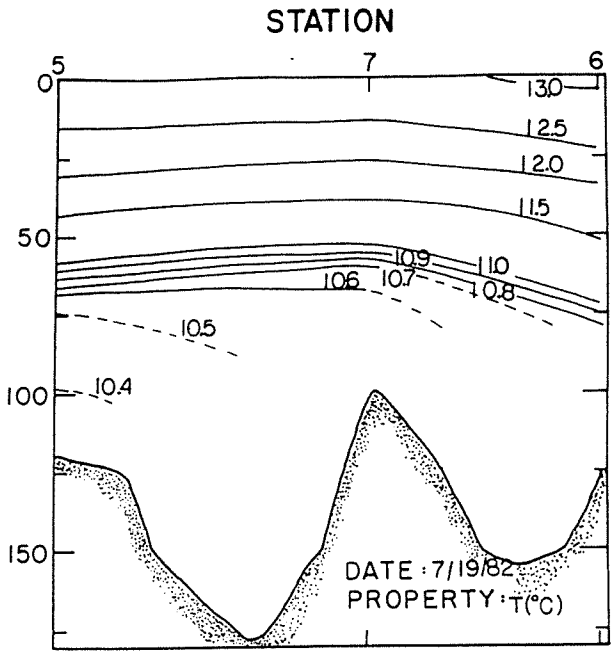

STATION
4
5
6
7
8
0
7.0
6.5
6.5
6.0
6.8
6.6
6.4
DEPTH (m)
100
200
DATE :10-11-82
PROPERTY: O(mg/l)

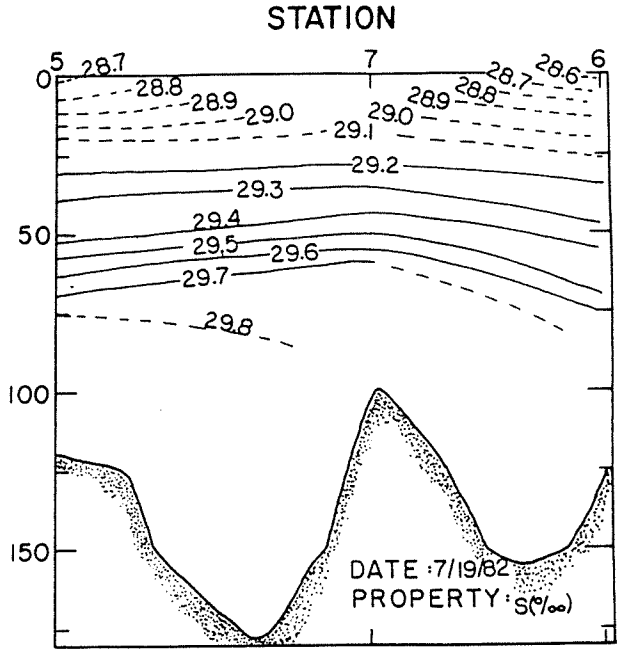

STATION
5
7
6
0
50
100
150
13.5
13.0
12.5
12.0
11.5
11.0
10.7
10.5
10.8
10.9
10.3
10.4
10.6
10.3
DATE : 7/15/82
PROPERTY : T(°C)

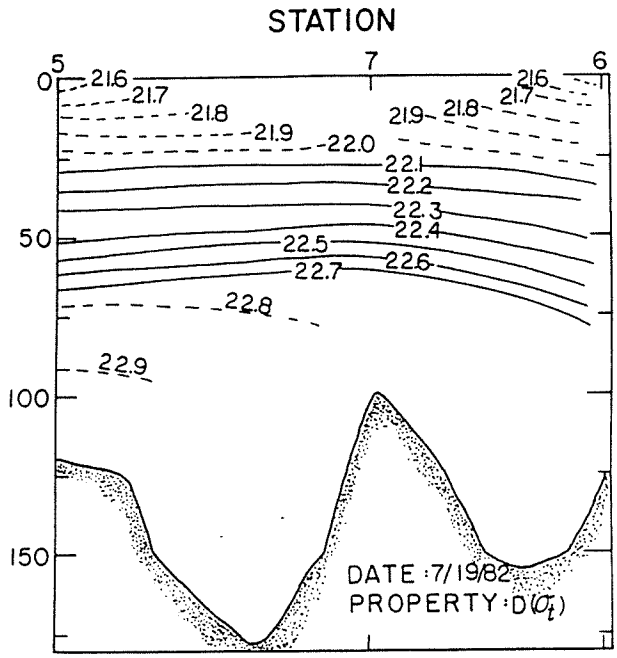

STATION
5
7
6
0
50
100
150
28.5
28.5
29.0
29.1
29.2
29.3
29.4
29.5
29.6
29.7
29.8
29.8
DATE : 7/15/82
PROPERTY : S(‰)

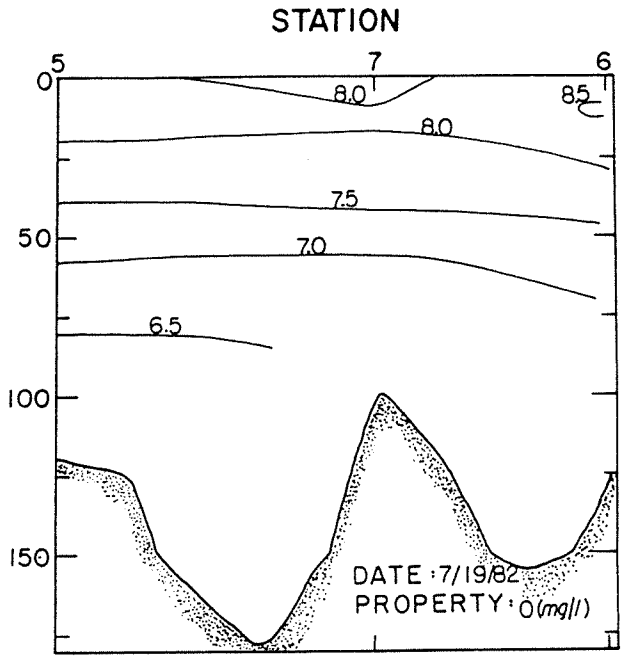

STATION
5
7
6
0
50
100
150
21.5
21.5
22.0
22.1
22.2
22.3
22.4
22.5
22.6
22.7
22.8
22.9
22.9
DATE : 7/15/82
PROPERTY : D(σt)

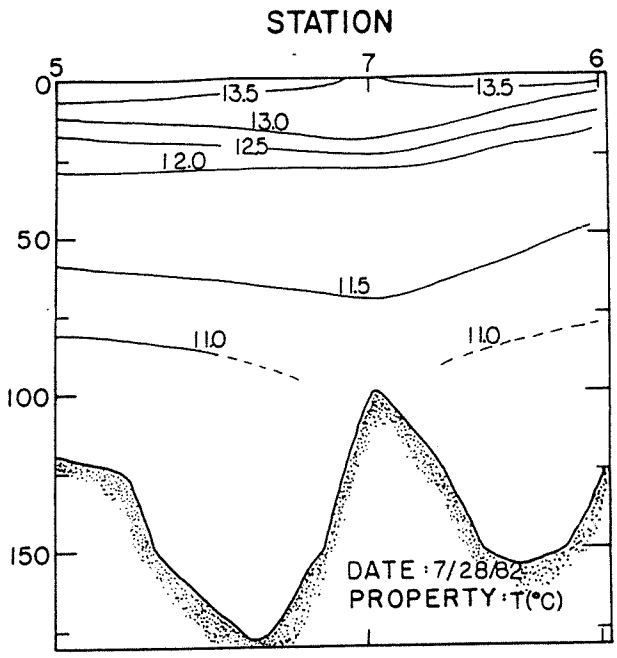

STATION
5
7
6
0
50
100
150
9.0
8.5
8.0
7.5
7.0
6.5
6.0
6.5
DATE : 7/15/82
PROPERTY : O(mg/l)

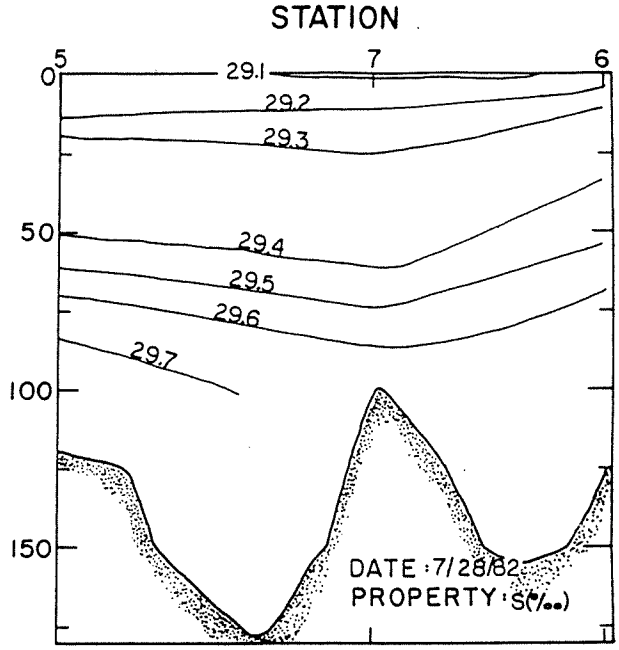

STATION
5
7
6
0
50
100
150
13.0
12.5
12.0
11.5
10.9
11.0
10.6
10.7
10.8
10.5
10.4
DATE : 7/19/82
PROPERTY : T(°C)

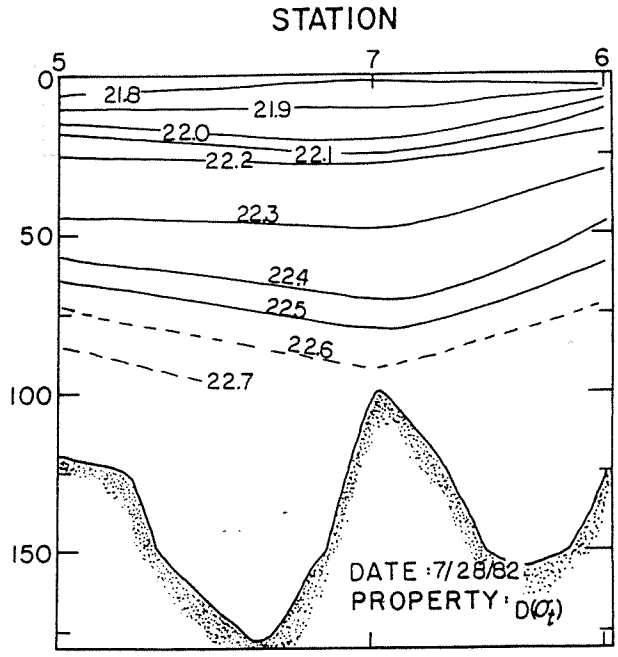

STATION
5
7
6
0
50
100
150
28.7
28.8
28.9
29.0
29.1
29.2
29.3
29.4
29.5
29.6
29.7
29.8
DATE : 7/19/82
PROPERTY : S(‰)

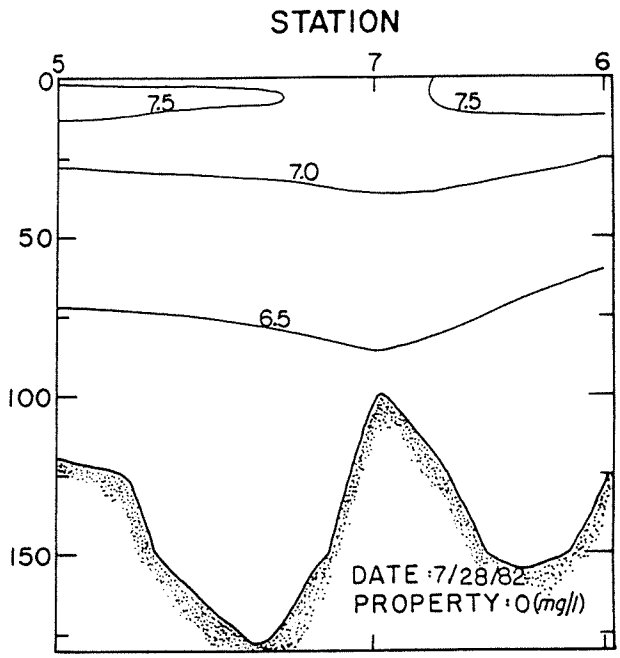

STATION
5
7
6
0
50
100
150
21.6
21.7
21.8
21.9
22.0
22.1
22.2
22.3
22.4
22.5
22.6
22.7
22.8
22.9
DATE : 7/19/82
PROPERTY : D(σt)

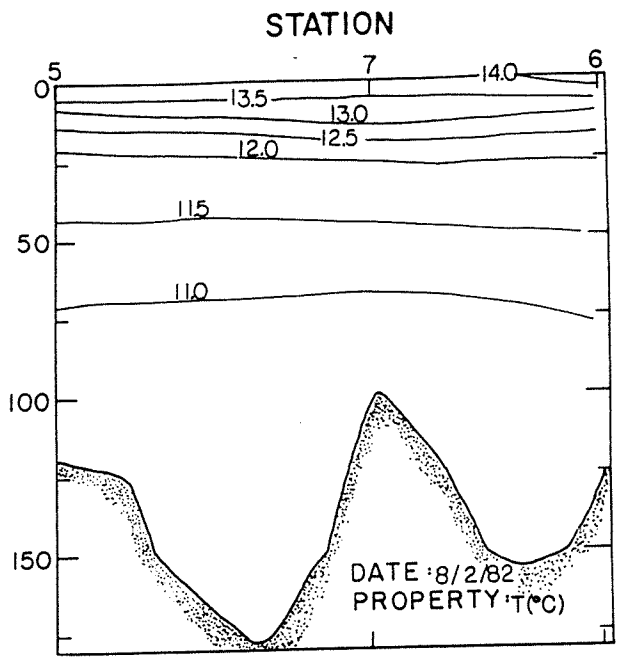

STATION
5
7
6
0
50
100
150
8.0
8.5
8.0
7.5
7.0
6.5
DATE : 7/19/82
PROPERTY : O(ml/l)

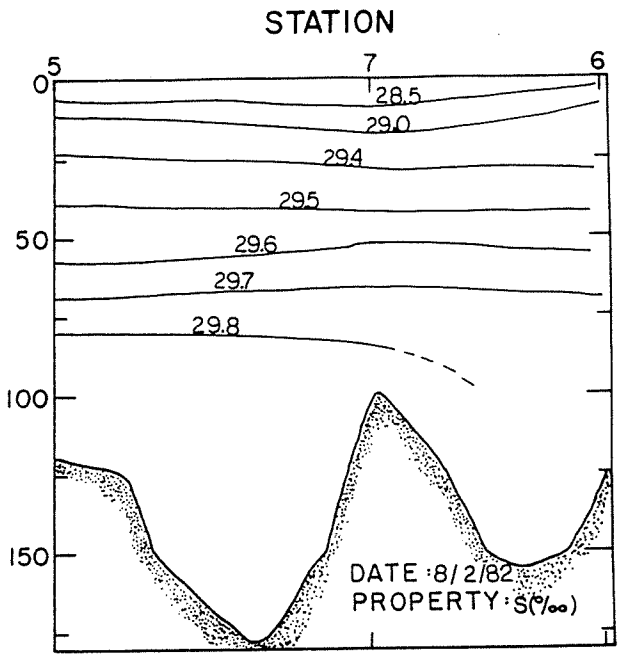

STATION
5
7
6
0
50
100
150
13.5
13.5
13.0
12.5
12.0
11.5
11.0
11.0
DATE : 7/28/82
PROPERTY : T(°C)

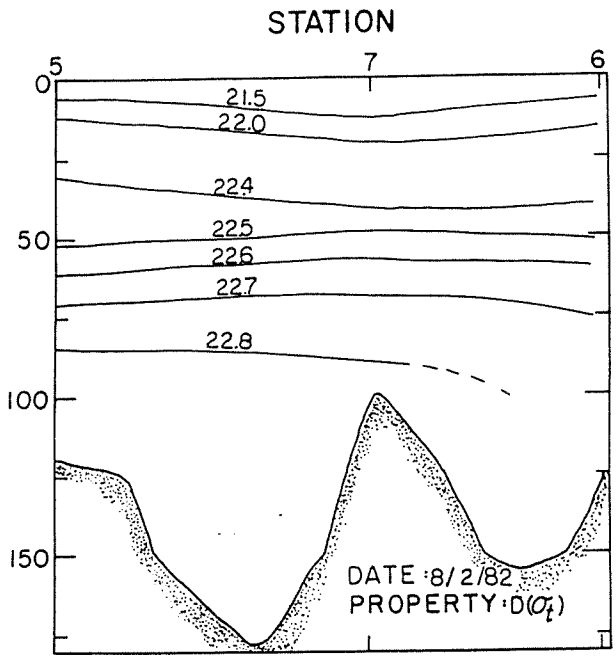

STATION
5
7
6
0
50
100
150
29.1
29.2
29.3
29.4
29.5
29.6
29.7
DATE : 7/28/82
PROPERTY : S(‰)

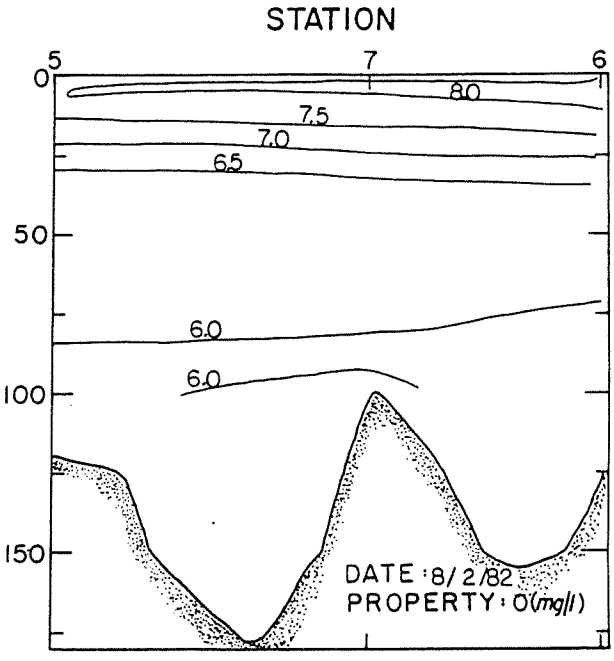

STATION
5
7
6
0
50
100
150
21.8
21.9
22.0
22.2
22.1
22.3
22.4
22.5
22.6
22.7
DATE : 7/28/82
PROPERTY : D(σt)

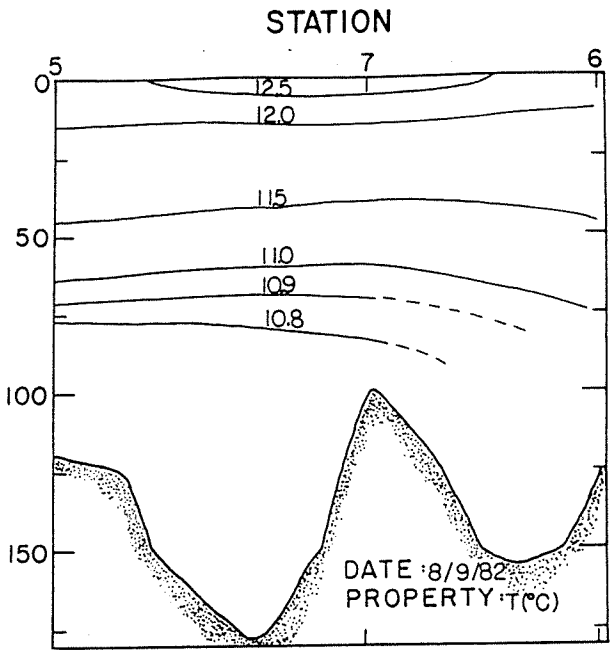

STATION
5
7
6
0
50
100
150
7.5
7.5
7.0
6.5
DATE : 7/28/82
PROPERTY : O(ml/l)

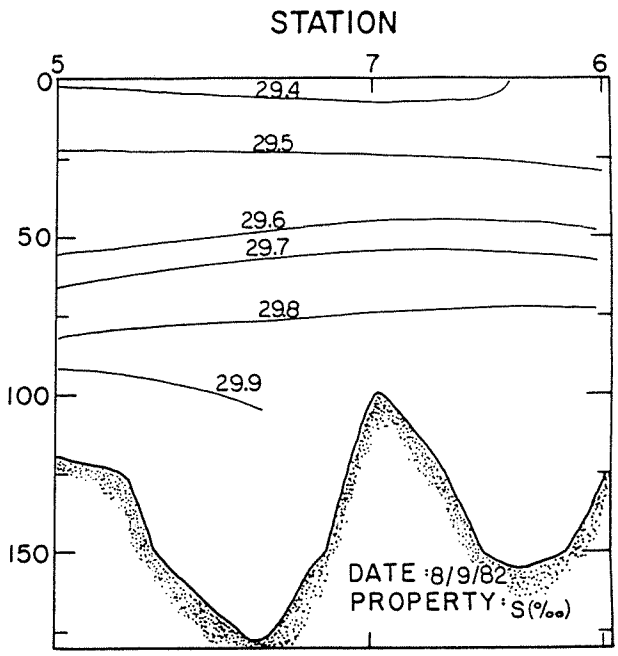

STATION
5
7
6
0
14.0
13.5
13.0
12.5
12.0
11.5
50
11.0
100
150
DATE : 8/2/82
PROPERTY : T(°C)

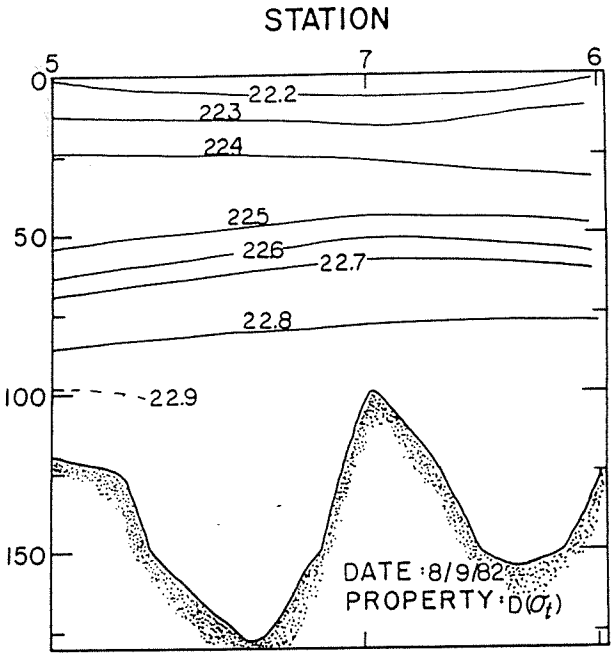

STATION
5
7
6
0
28.5
29.0
29.4
29.5
50
29.6
29.7
29.8
100
150
DATE : 8/2/82
PROPERTY : S(‰)

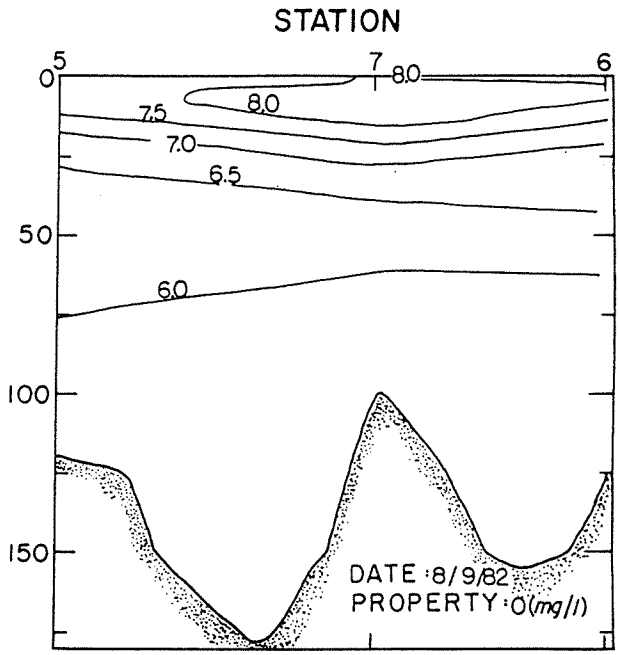

STATION
5
7
6
0
21.5
22.0
22.4
50
22.5
22.6
22.7
22.8
100
150
DATE : 8/2/82
PROPERTY : D(σt)

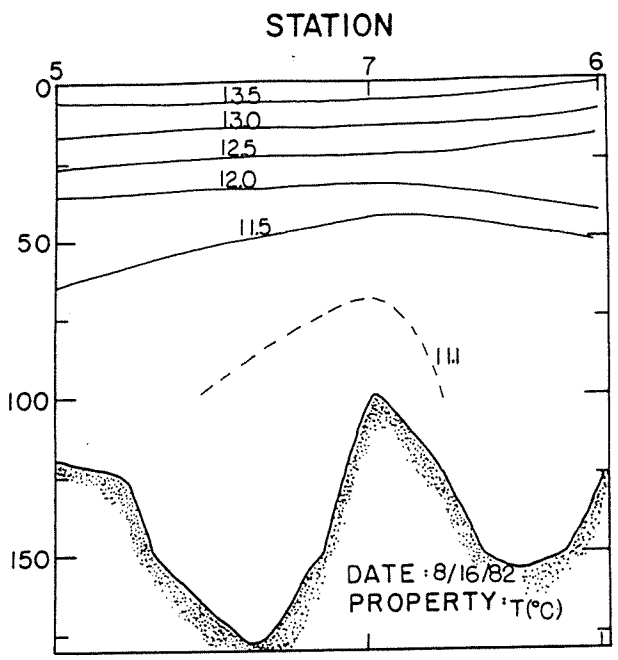

STATION
5
7
6
0
8.0
7.5
7.0
6.5
50
6.0
6.0
100
150
DATE : 8/2/82
PROPERTY : O(mg/l)

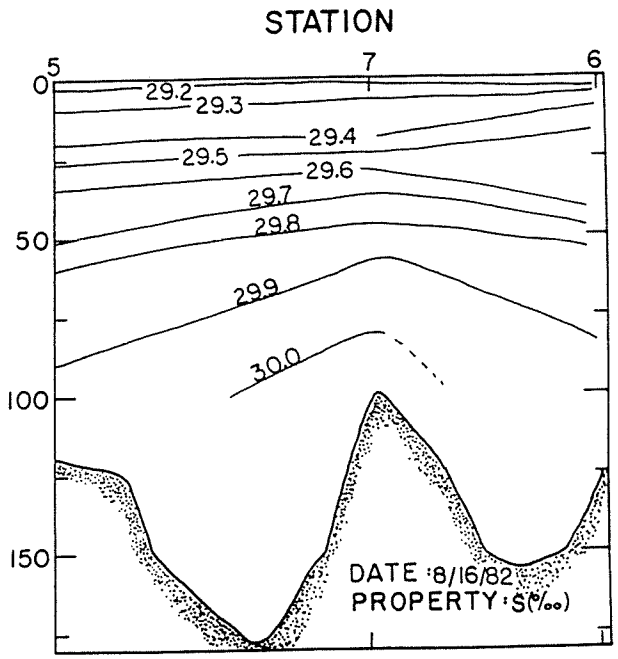

STATION
5
7
6
0
50
100
150
12.5
12.0
11.5
11.0
10.9
10.8
DATE : 8/9/82
PROPERTY : T(°C)

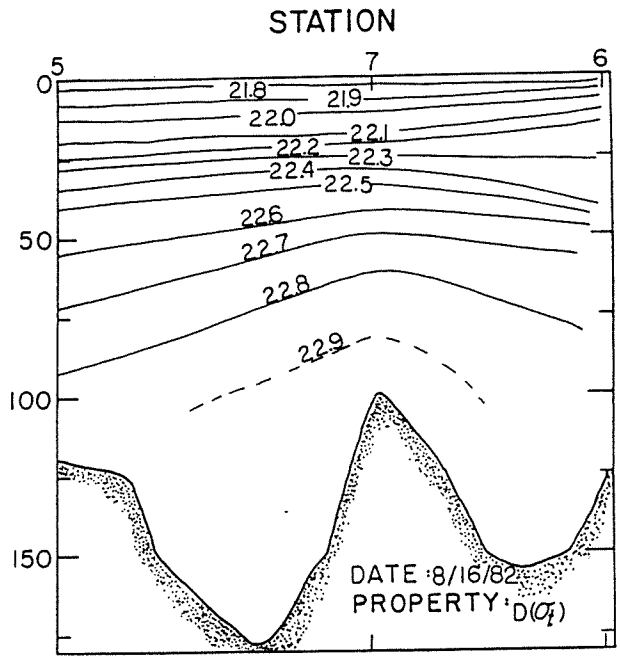

STATION
5
7
6
0
50
100
150
29.4
29.5
29.6
29.7
29.8
29.9
DATE : 8/9/82
PROPERTY : S(‰)

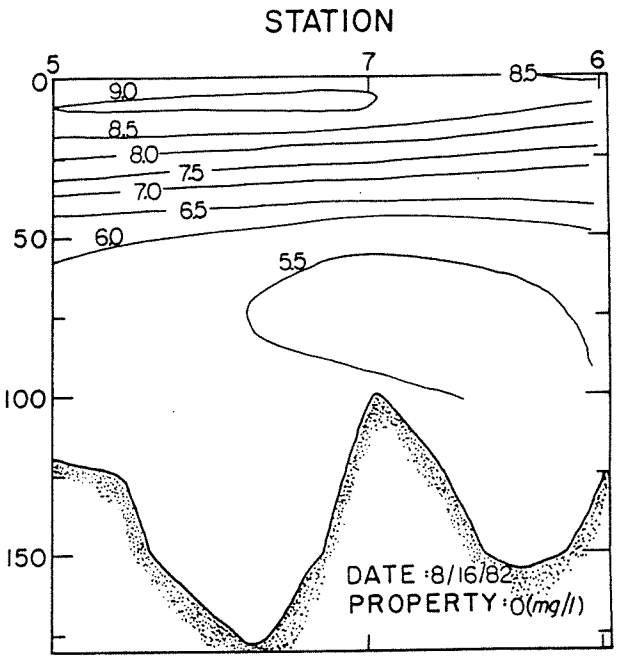

STATION
5
7
6
0
50
100
150
22.2
22.3
22.4
22.5
22.6
22.7
22.8
22.9
DATE : 8/9/82
PROPERTY : D(σt)

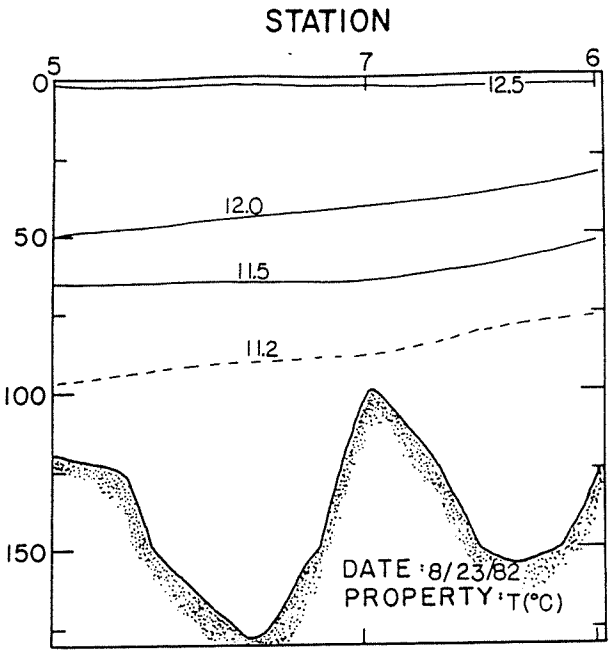

STATION
5
7
8.0
6
0
50
100
150
8.0
7.5
7.0
6.5
6.0
DATE : 8/9/82
PROPERTY : O(mg/l)

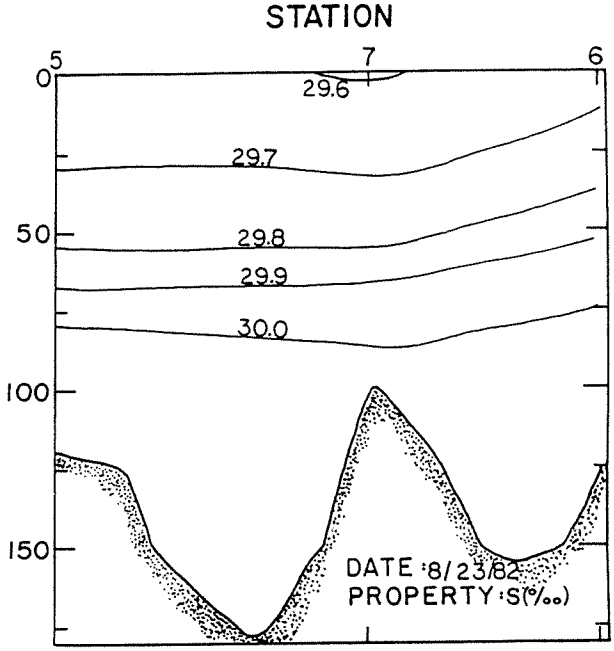

STATION
5
7
6
0
50
100
150
13.5
13.0
12.5
12.0
11.5
11.1
DATE : 8/16/82
PROPERTY : T(°C)

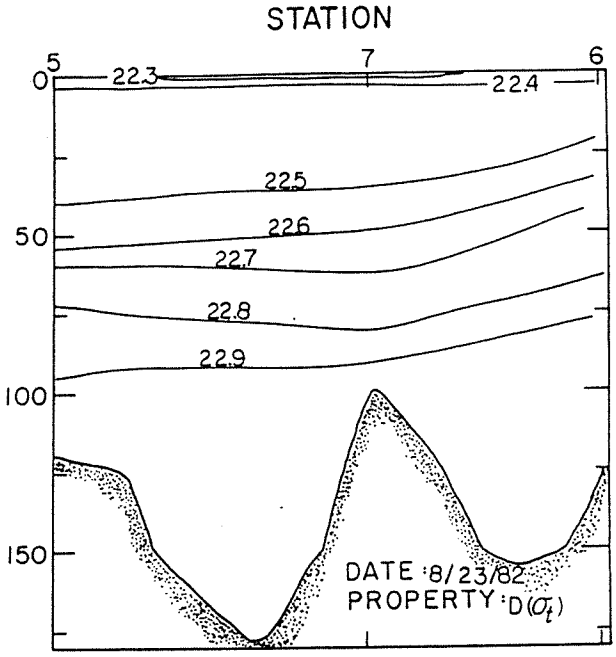

STATION
5
7
6
0
50
100
150
29.2
29.3
29.4
29.5
29.6
29.7
29.8
29.9
30.0
DATE : 8/16/82
PROPERTY : S(‰)

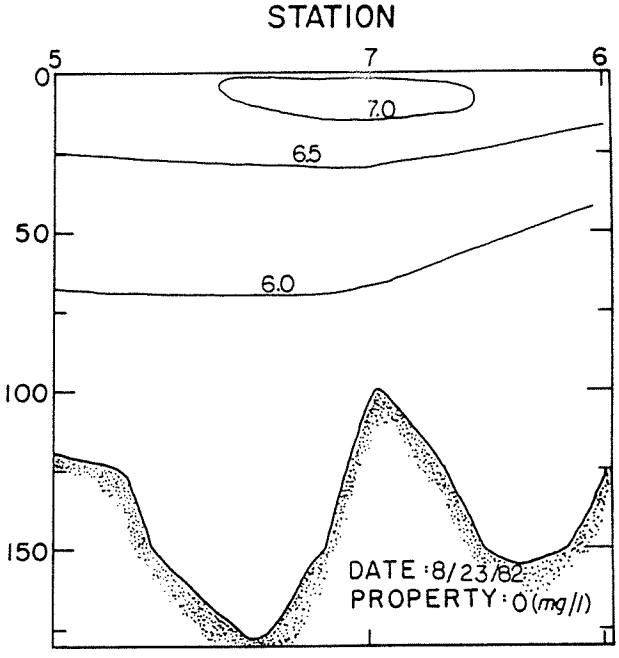

STATION
5
7
6
0
50
100
150
21.8
21.9
22.0
22.1
22.2
22.3
22.4
22.5
22.6
22.7
22.8
22.9
DATE : 8/16/82
PROPERTY : D(σt)

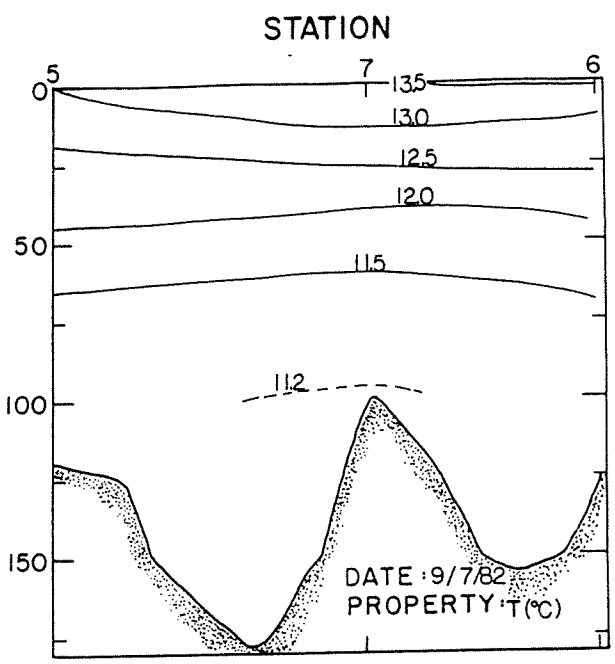

STATION
5
7
6
0
50
100
150
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
DATE : 8/16/82
PROPERTY : O(mg/l)

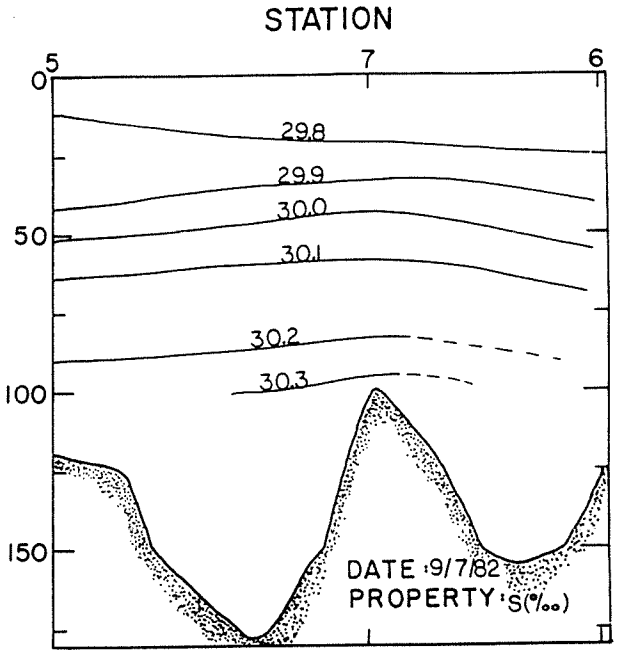

STATION
5
7
6
0
50
100
150
12.5
12.0
11.5
11.2
DATE : 8/23/82
PROPERTY : T(°C)

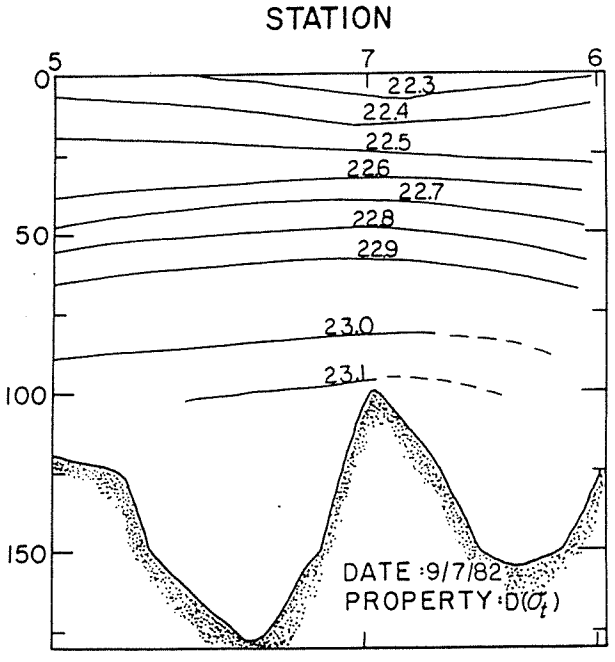

STATION
5
7
6
0
50
100
150
29.6
29.7
29.8
29.9
30.0
DATE : 8/23/82
PROPERTY : S(‰)

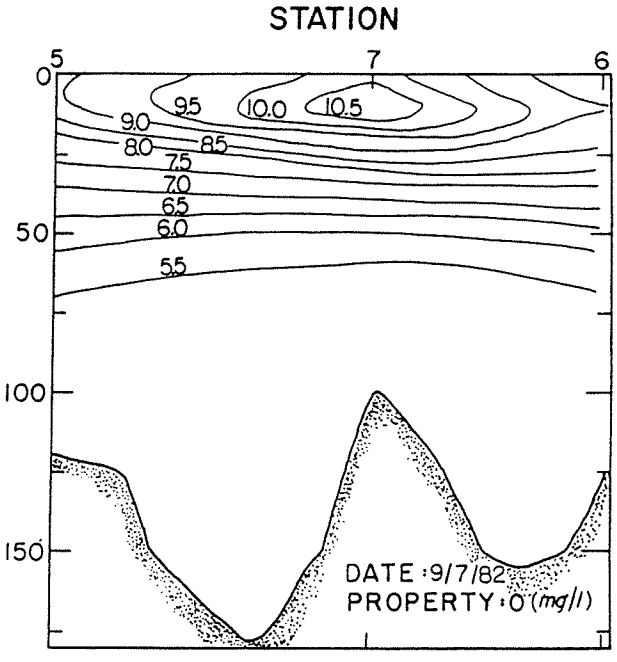

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7
6
0
50
100
150
22.3
22.4
22.5
22.6
22.7
22.8
22.9
DATE : 8/23/82
PROPERTY : D(σt)

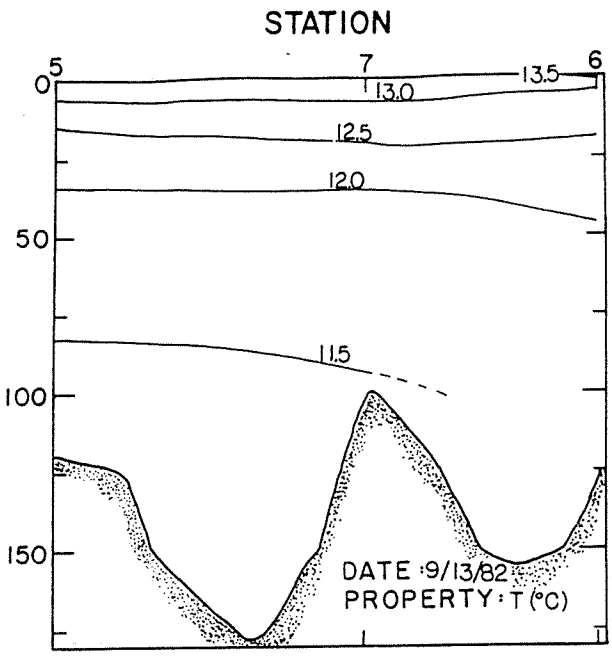

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6.5
6.0
DATE : 8/23/82
PROPERTY : O(mg/l)

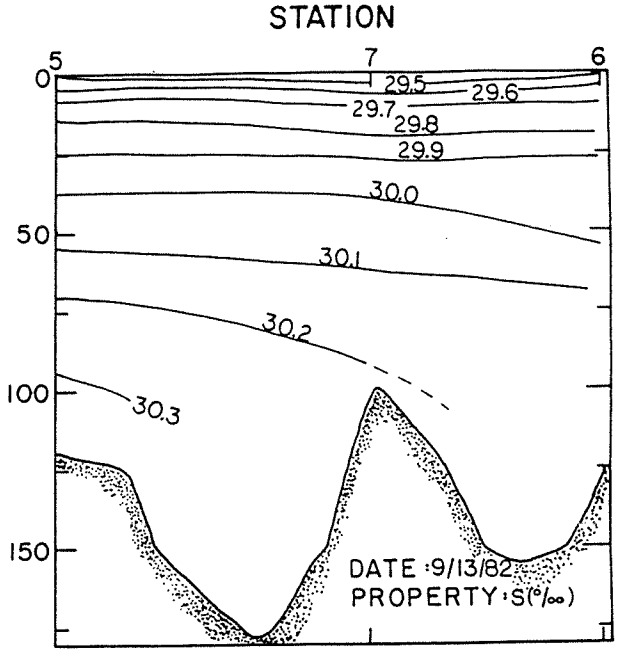

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12.0
11.5
11.2
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PROPERTY : T(°C)

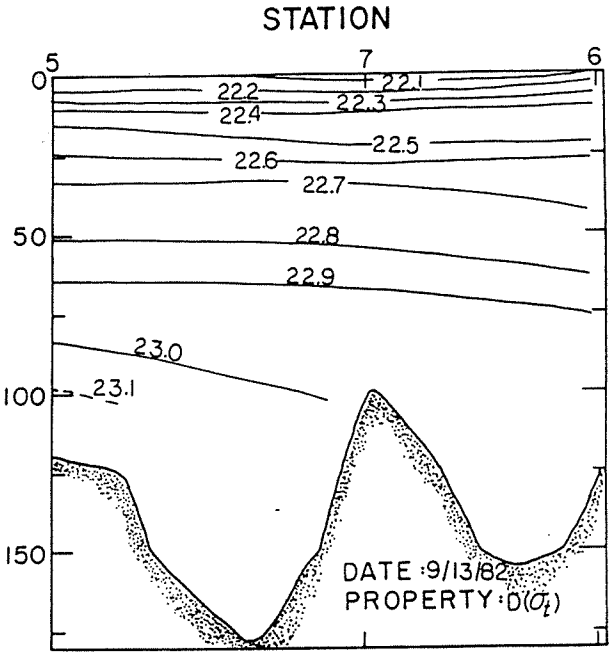

STATION
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29.8
29.9
30.0
30.1
30.2
30.3
DATE : 9/7/82
PROPERTY : S(‰)

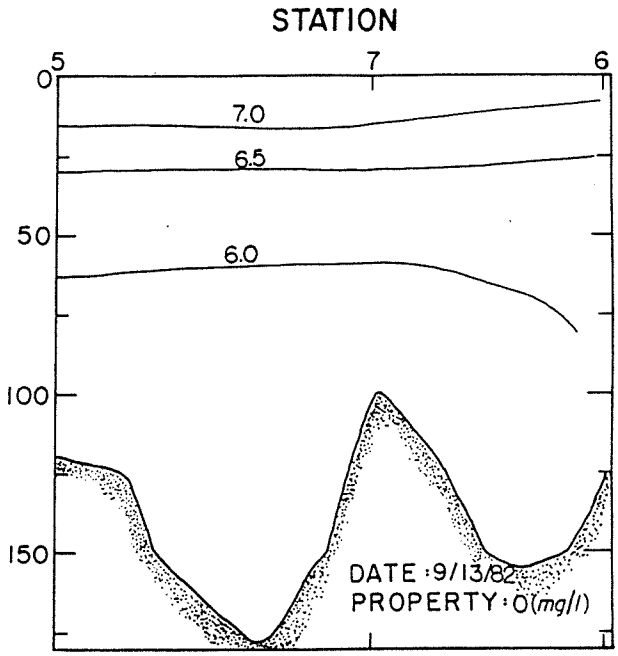

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100
150
22.3
22.4
22.5
22.6
22.7
22.8
22.9
23.0
23.1
DATE : 9/7/82
PROPERTY : D(σt)

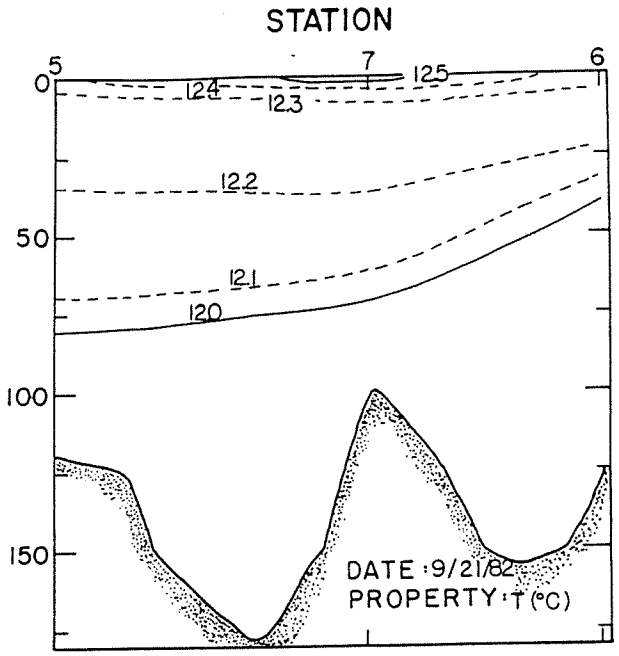

STATION
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150
9.5
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10.5
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8.0
7.5
7.0
6.5
6.0
5.5
DATE : 9/7/82
PROPERTY : O (mg/l)

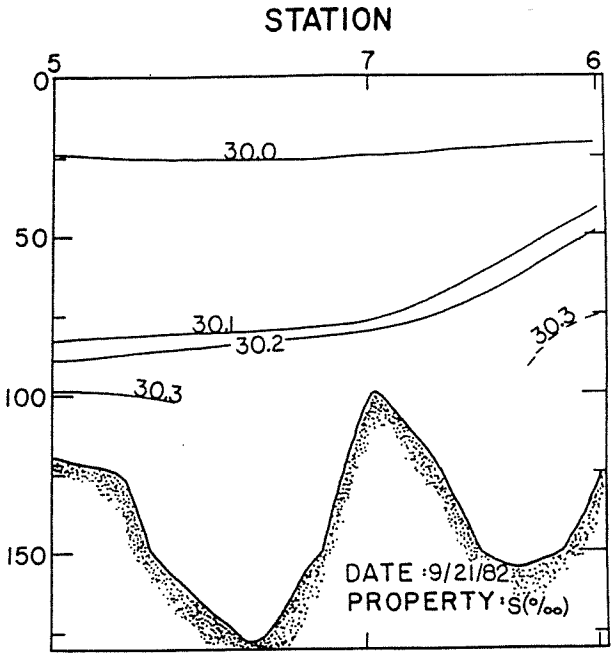

STATION
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100
150
13.5
13.0
12.5
12.0
11.5
DATE :9/13/82
PROPERTY : T (°C)

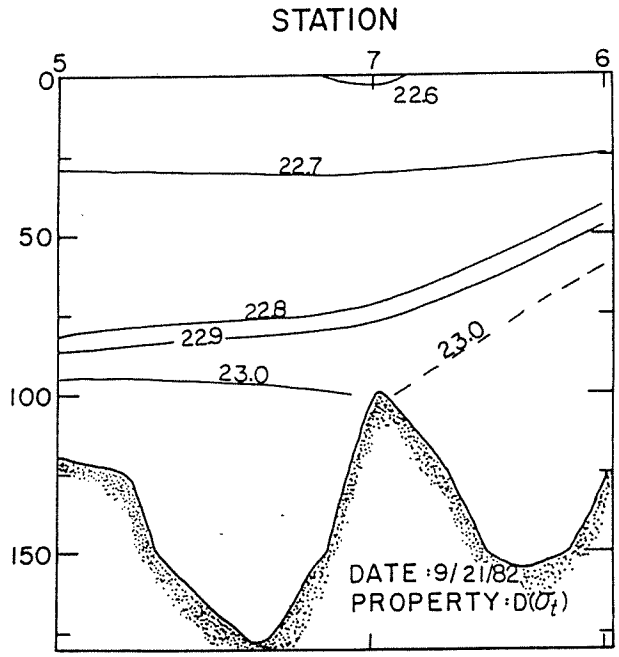

STATION
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6
0
50
100
150
29.5
29.6
29.7
29.8
29.9
30.0
30.1
30.2
30.3
DATE :9/13/82
PROPERTY : S(‰)

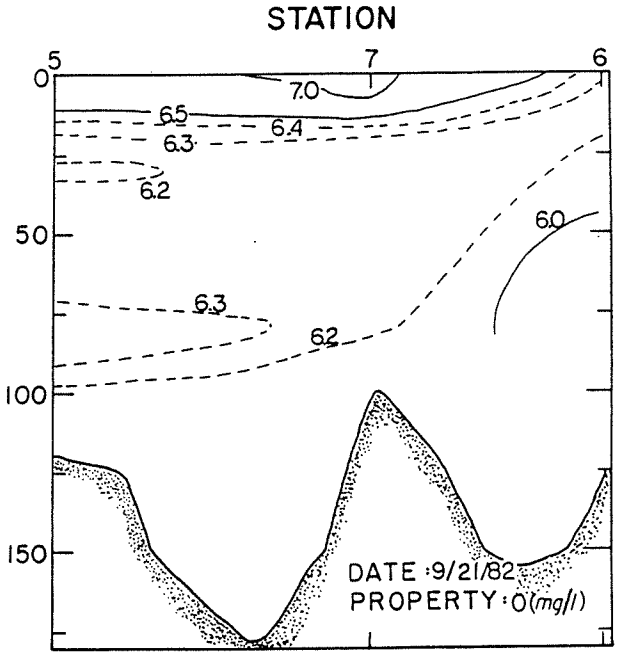

STATION
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0
50
100
150
22.1
22.2
22.3
22.4
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22.6
22.7
22.8
22.9
23.0
23.1
DATE :9/13/82
PROPERTY : σ(σt)

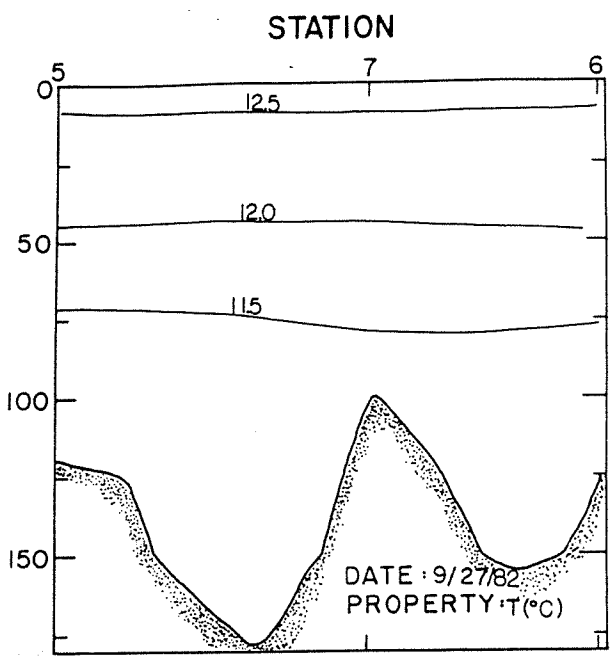

STATION
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0
50
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150
7.0
6.5
6.0
DATE :9/13/82
PROPERTY : O(mg/l)

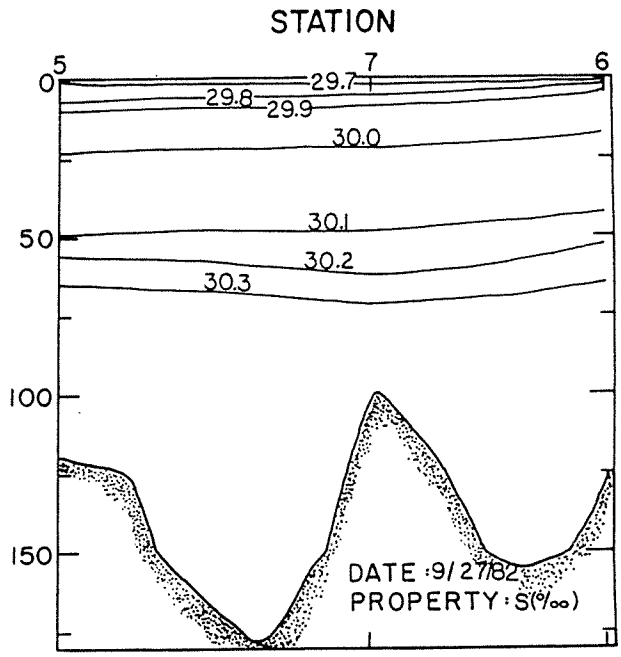

STATION
5
7
6
0
50
100
150
12.4
12.5
12.3
12.2
12.1
12.0
DATE : 9/21/82
PROPERTY : T (°C)

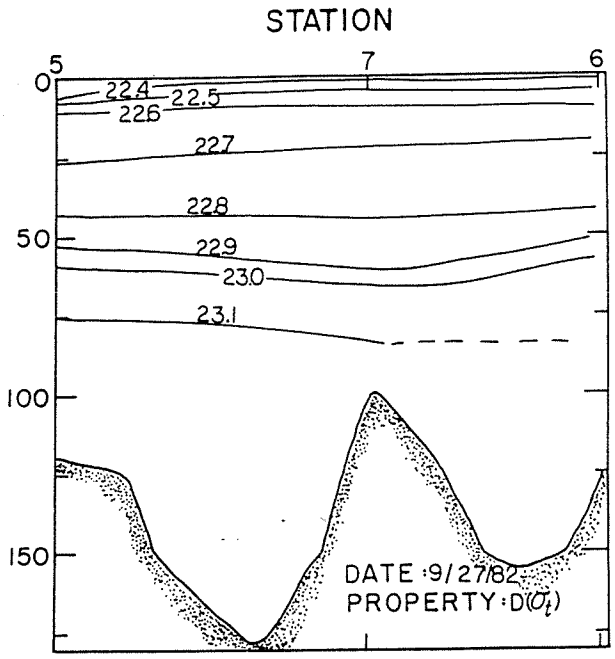

STATION
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0
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100
150
30.0
30.1
30.2
30.3
30.3
DATE : 9/21/82
PROPERTY : S(‰)

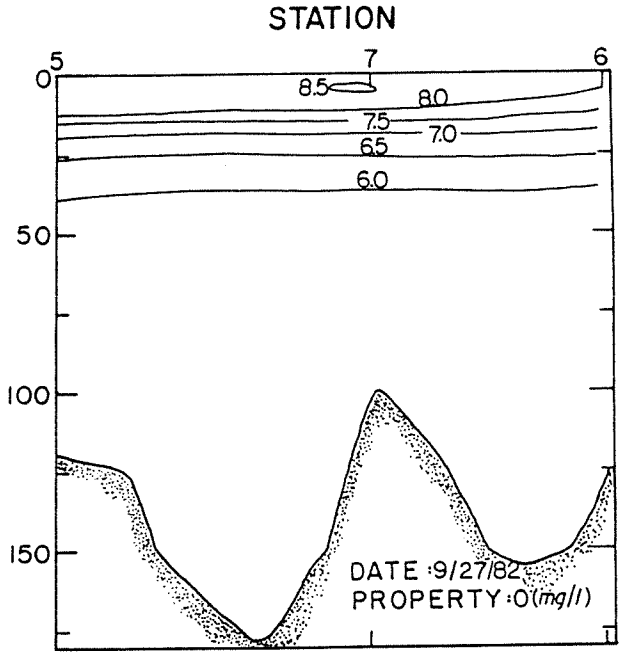

STATION
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7
6
0
50
100
150
22.6
22.7
22.8
22.9
23.0
23.0
DATE : 9/21/82
PROPERTY : D(σt)

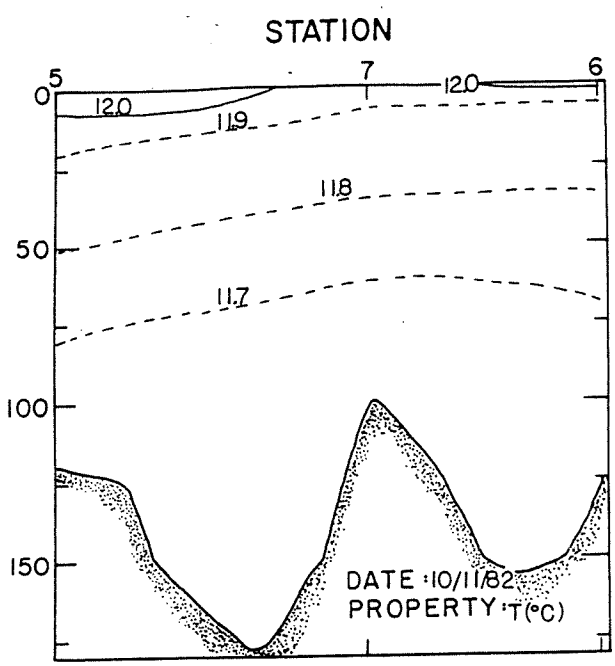

STATION
5
7
6
0
50
100
150
7.0
6.5
6.4
6.3
6.2
6.0
6.3
6.2
DATE : 9/21/82
PROPERTY : O(mg/l)

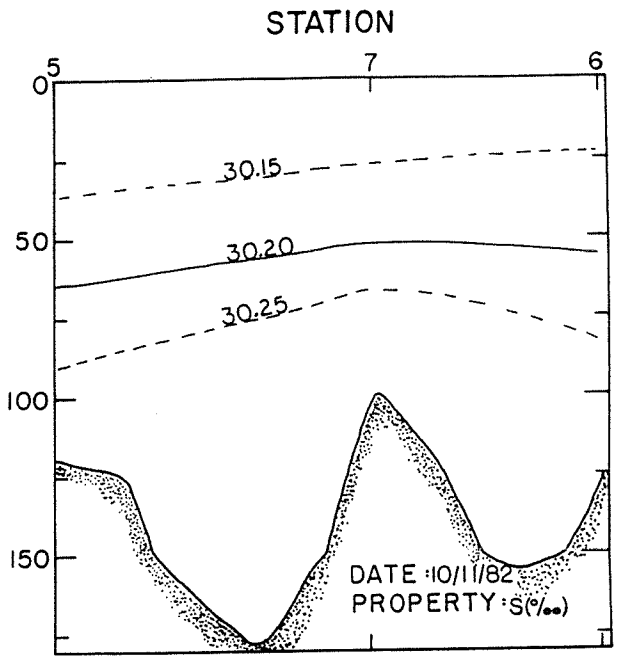

STATION
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7
6
0
50
100
150
12.5
12.0
11.5
DATE : 9/27/82
PROPERTY : T(°C)

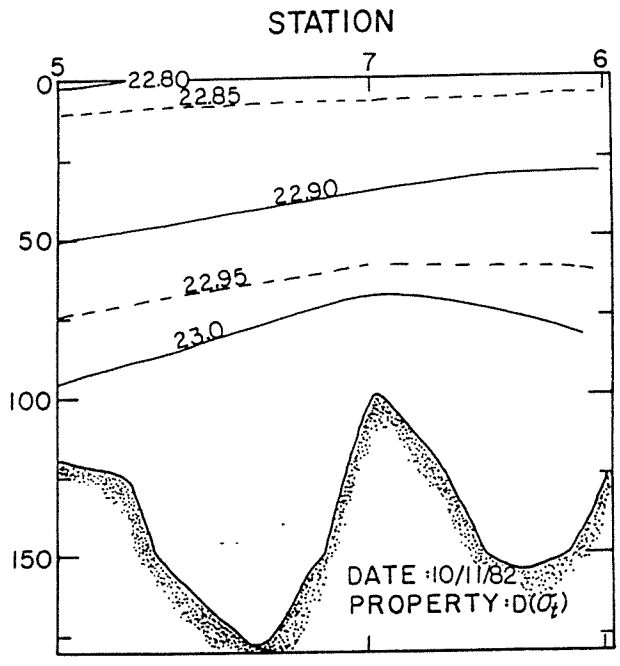

STATION
5
7
6
0
50
100
150
29.7
29.8
29.9
30.0
30.1
30.2
30.3
DATE : 9/27/82
PROPERTY : S(‰)

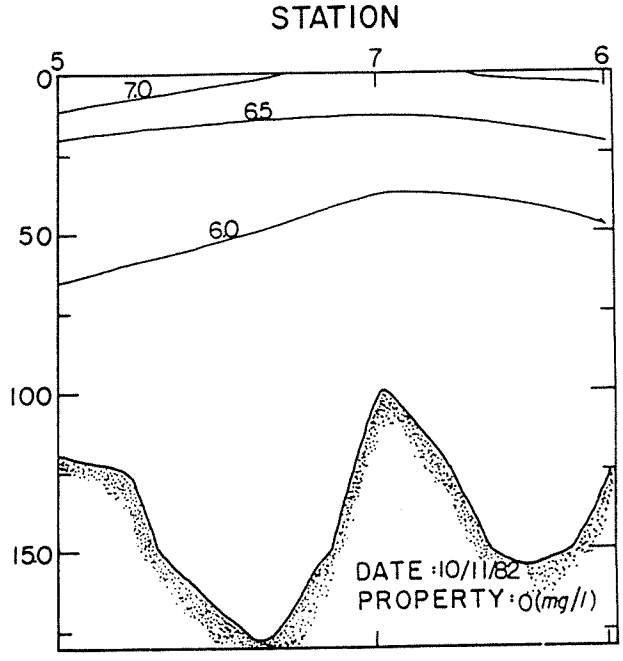

STATION
5
7
6
0
50
100
150
22.4
22.5
22.6
22.7
22.8
22.9
23.0
23.1
DATE : 9/27/82
PROPERTY : D(σt)


STATION
5
7
6
0
50
100
150
8.5
8.0
7.5
7.0
6.5
6.0
DATE : 9/27/82
PROPERTY : O(mg/l)


STATION
5
7
6
0
50
100
150
12.0
11.9
11.8
11.7
DATE :10/11/82
PROPERTY :T(°C)


STATION
5
7
6
0
50
100
150
30.15
30.20
30.25
DATE :10/11/82
PROPERTY :S(‰)


STATION
5
7
6
0
50
100
150
22.80
22.85
22.90
22.95
23.0
DATE :10/11/82
PROPERTY :D(Ot)


STATION
5
7
6
0
50
100
150
7.0
6.5
6.0
DATE :10/11/82
PROPERTY :O(mg/l)

## 6.9 Appendix

### 6.9.1 Progress

The progress during the fourth quarter consisted of third quarter sample collection (see Appendix Table 6A1), sample analyses, data analysis, and writing of the annual report. Early in the fourth quarter, a decision was made to prioritize sample processing due to time constraints induced by the unexpectedly large number of replicate samples. Samples from intertidal sites at Seahurst Park, Normandy, Tramp Harbor and Aquarium beaches will be highest priority. Small infauna samples from low intertidal sites at these beaches will have highest priority among all intertidal infauna samples collected. Shallow subtidal small infauna samples with highest priority are those from the sand and eelgrass habitats of Seahurst Park and the Aquarium beaches.

Appendix Table 6A1. Status of samples collected through 28 February 1983 on the intertidal/shallow subtidal studies

| Sample Type | No. Collected | No. Analyzed | Percent Analyzed |
|---|---|---|---|
| Prestudy: | | | |
| (all sample types) | 252 | 252 | 100 |
| Habitat Distribution: | | | |
| (all sample types) | 400 | 400 | 100 |
| First Quarter: | | | |
| drift | 36 | 36 | 100 |
| large infauna | 51 | 51 | 100 |
| small infauna | 228 | 209 | 91 |
| epibenthos | 116 | 116 | 100 |
| macroalgal assemblage | 270 | 270 | 100 |
| macroalgal productivity | 54 | 54 | 100 |
| microalgal biomass | 3 | 3 | 100 |
| microalgal productivity | 3 | 3 | 100 |
| eelgrass density | 80 | 80 | 100 |
| sedimental chemistry | 19 | 19 | 100 |
| Second Quarter: | | | |
| drift | 42 | 42 | 100 |
| large infauna | 51 | 51 | 100 |
| small infauna | 228 | 57 | 25 |
| epibenthos | 60 | 60 | 100 |
| macroalgal assemblage | 315 | 315 | 100 |
| macroalgal productivity | 75 | 75 | 100 |
| microalgal biomass | 20 | 20 | 100 |
| microalgal productivity | 10 | 10 | 100 |
| eelgrass density | 80 | 80 | 100 |
| sediment chemistry | 19 | 19 | 100 |
| Third Quarter: | | | |
| drift | 36 | 0 | 0 |
| large infauna | 51 | 0 | 0 |
| small infauna | 144 | 0 | 0 |
| epibenthos | 77 | 52 | 68 |
| macroalgal assemblage | 210 | 0 | 0 |
| macroalgal productivity | 40 | 40 | 100 |
| microalgal biomass | 5 | 5 | 100 |
| microalgal productivity | 10 | 10 | 100 |
| ellgrass density | 0 | 0 | - |
| sediment chemistry | 15 | 0 | 0 |
| Water Chemistry | 1,583 | 1,247 | 79 |
| Total | 4,583 | 3,576 | 78 |

Appendix Table 7.1a.
Numerical log of baseline samples
Chemistry: Subtidal



| Code No. | Station designation | Date sampled | Chem. required |
|---|---|---|---|
| 1 | L-ALT 50 E | 14 Jun 82 | (VCS) G |
| 2 | L-ALT 75 E | 14 Jun 82 | (VCS) G |
| 3 | L-ALT 200 E | 14 Jun 82 | (VCS) G |
| 4 | L-ALT 400 E | 14 Jun 82 | (VCS) G |
| 5 | A-50 W | 15 Jun 82 | (VCS) G |
| 6 | A-200 W | 15 Jun 82 | (VCS) G |
| 7 | A-400 W | 15 Jun 82 | (VCS) G |
| 8 | A-720 | 15 Jun 82 | (VCS) G |
| 9 | A-600 E | 15 Jun 82 | (VCS) G |
| 10 | A-400 E | 15 Jun 82 | (VCS) G |
| 11 | A-200 E | 15 Jun 82 | (VCS) G |
| 12 | B-50 E | 15 Jun 82 | (VCS) G |
| 13 | B-50 W | 16 Jun 82 | (VCS) G |
| 14 | B-75 W | 16 Jun 82 | (VCS) G |
| 15 | B-660 | 16 Jun 82 | (VCS) G |
| 16 | B-600 E | 16 Jun 82 | (VCS) G |
| 17 | B-400 E | 16 Jun 82 | (VCS) G |
| 18 | B-200 E | 16 Jun 82 | (VCS) G |
| 19 | C-50 E | 16 Jun 82 | (VCS) G |
| 20 | C-75 E | 16 Jun 82 | (VCS) G |
| 21 | C-200 E | 16 Jun 82 | (VCS) G |
| 22 | C-400 E | 16 Jun 82 | (VCS) G |
| 23 | C-600 E | 16 Jun 82 | (VCS) G |
| 24 | C-640 | 16 Jun 82 | (VCS) G |
| 25 | C-75 W | 16 Jun 82 | (VCS) G |
| 26 | C-50 W | 16 Jun 82 | (VCS) G |
| 27 | D-50 E | 18 Jun 82 | (VCS) G |
| 28 | D-75 E | 18 Jun 82 | (VCS) G |
| 29 | D-250 E | 18 Jun 82 | (VCS) G |
| 30 | D-400 E | 18 Jun 82 | (VCS) G |
| 31 | D-660 | 18 Jun 82 | (VCS) G |
| 32 | D-75 W | 19 Jun 82 | (VCS) G |
| 33 | D-50 W | 19 Jun 82 | (VCS) G |
| 34 | E-50 W | 19 Jun 82 | (VCS) G |
| 35 | OT-1 | 19 Jun 82 | (VCS) G |
| 36 | OT-2 | 18 Jun 82 | (VCS) G |
| 37 | E-75 W | 19 Jun 82 | (VCS) G |
| 38 | E-750 | 19 Jun 82 | (VCS) G |

V = volatile solids and B.O.D. (frozen)
C = organic carbon and nitrogen (frozen)
S = sulfides (frozen)
G = grain size and metals (frozen)

Appendix Table 7.1a.
Numerical log of baseline samples
Chemistry: Subtidal



| Code No. | Station designation | Date sampled | Chem. required |
|---|---|---|---|
| 39 | E-600 E | 19 Jun 82 | (VCS) G |
| 40 | E-200 E | 19 Jun 82 | (VCS) G |
| 41 | E-75 E | 19 Jun 82 | (VCS) G |
| 42 | E-50 E | 19 Jun 82 | (VCS) G |
| 43 | F-200 E | 19 Jun 82 | (VCS) G |
| 44 | F-600 E | 19 Jun 82 | (VCS) G |
| 45 | F-780 | 28 Jun 82 | (VCS) G |
| 46 | F-75 W | 28 Jun 82 | (VCS) G |
| 47 | F-50 W | 28 Jun 82 | (VCS) G |
| 48 | G-50 E | 29 Jun 82 | (VCS) G |
| 49 | G-75 E | 29 Jun 82 | (VCS) G |
| 50 | G-200 E | 29 Jun 82 | (VCS) G |
| 51 | G-400 E | 29 Jun 82 | (VCS) G |
| 52 | G-600 E | 29 Jun 82 | (VCS) G |
| 53 | G-780 | 29 Jun 82 | (VCS) G |
| 54 | G-75 W | 29 Jun 82 | (VCS) G |
| 55 | G-50 W | 29 Jun 82 | (VCS) G |
| 56 | H-50 E | 29 Jun 82 | (VCS) G |
| 57 | H-75 E | 29 Jun 82 | (VCS) G |
| 58 | H-400 E | 29 Jun 82 | (VCS) G |
| 59 | H-600 E | 29 Jun 82 | (VCS) G |
| 60 | H-640 | 29 Jun 82 | (VCS) G |
| 61 | H-75 W | 29 Jun 82 | (VCS) G |
| 62 | I-50 W | 30 Jun 82 | (VCS) G |
| 63 | I-75 W | 30 Jun 82 | (VCS) G |
| 64 | I-690 | 30 Jun 82 | (VCS) G |
| 65 | I-600 E | 30 Jun 82 | (VCS) G |
| 66 | I-400 E | 30 Jun 82 | (VCS) G |
| 67 | I-200 E | 30 Jun 82 | (VCS) G |
| 68 | J-50 W | 30 Jun 82 | (VCS) G |
| 69 | J-75 W | 30 Jun 82 | (VCS) G |
| 70 | J-690 | 30 Jun 82 | (VCS) G |
| 71 | J-600 E | 30 Jun 82 | (VCS) G |
| 72 | J-400 E | 30 Jun 82 | (VCS) G |
| 73 | J-75 E | 30 Jun 82 | (VCS) G |
| 74 | J-50 E | 30 Jun 82 | (VCS) G |
| 75 | K-50 E | 1 Jul 82 | (VCS) G |
| 76 | K-75 E | 1 Jul 82 | (VCS) G |

V = volatile solids and B.O.D. (frozen)
C = organic carbon and nitrogen (frozen)
S = sulfides (frozen)
G = grain size and metals (frozen)

Appendix Table 7.1a.
Numerical log of baseline samples
Chemistry: Subtidal



| Code No. | Station designation | Date sampled | Chem. required |
|---|---|---|---|
| 77 | K-200 E | 1 Jul 82 | (VCS) G |
| 78 | K-400 E | 1 Jul 82 | (VCS) G |
| 79 | K-570 | 1 Jul 82 | (VCS) G |
| 80 | K-75 W | 1 Jul 82 | (VCS) G |
| 81 | K-50 W | 1 Jul 82 | (VCS) G |
| 82 | L (alt) 50 W | 1 Jul 82 | (VCS) G |
| 83 | L 75 W | 1 Jul 82 | (VCS) G |
| 84 | L-570 | 1 Jul 82 | (VCS) G |
| 85 | QM 1 | 1 Jul 82 | (VCS) G |
| 86 | QM 2 | 1 Jul 82 | (VCS) G |
| 87 | M-200 | 1 Jul 82 | (VCS) G |
| 88 | N-50 E | 2 Jul 82 | (VCS) G |
| 89 | N-75 E | 2 Jul 82 | (VCS) G |
| 90 | N-200 E | 2 Jul 82 | (VCS) G |
| 91 | N-300 | 2 Jul 82 | (VCS) G |
| 92 | N-75 W | 2 Jul 82 | (VCS) G |
| 93 | N-50 W | 2 Jul 82 | (VCS) G |

V = volatile solids and B.O.D. (frozen)
C = organic carbon and nitrogen (frozen)
S = sulfides (frozen)
G = grain size and metals (frozen)

Appendix Table 7.1b. Summary of descriptive information on subtidal baseline grab samples.

---

Key to sediment type

1. Rock
2. Cobble
3. Gravel
4. Sand - C = coarse; M = medium; F = fine
5. Silt
6. Clay
7. Wood chips

Key to sediment color

| | |
|---|---|
| DO | Drab olive |
| DOS | Drab olive surface |
| G | Green |
| GY | Gray |
| B | Black |
| BWN | Brown |

Key to sediment odor

1. $H_2S$
2. Petroleum
3. None

Grades of odor

A. Slight
B. Moderate
C. Strong
D. Overwhelming

When a slash separates two or more sediment types, the last number is the dominant type. The first numbers are the modifiers. A dash separating two types indicates equal amounts of each type.

e.g. 4/5 C Sandy silt with coarse sand.
e.g. 3/4 C/M-F Sand with some gravel, equal amounts of M and F sand, with a smaller fraction of coarse sand.

A slash separating two colors indicates sediment layers of distinctly different color; the first letter is the surface layer. A dash indicates an intermediate shade.

e.g. BWN/G-GY Brown surface with greenish-gray below.

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| L ALT 50 E | A | 1 C | 4/3/2 C | G-GY | 3 | 6 | Chaetopteridae tubes |
| L ALT 50 E | B | 2 B | 4 C | G | 3 | 8 | Chaetopteridae tubes |
| L ALT 50 E | C | 3 B | 4 C | G | 3 | 7 | Chaetopteridae tubes |
| L ALT 75 E | A | 4 C | 4 MC | G | 3 | 8 | |
| L ALT 75 E | B | 5 B | 4 MC | G | 3 | 10 | |
| L ALT 75 E | C | 6 B | 4 MC | G | 3 | 9.5 | |
| L ALT 200 E | A | 7 B | 4/5 F | G-GY | 3 | 17 | Large poly. tube |
| L ALT 200 E | B | 8 B | 4/5 F | G | 3 | 16 | Large poly. tube |
| L ALT 200 E | C | 9 C | 4/5 F | G | 3 | | |
| L ALT 400 | A | 10 B | 4/5 some F | G | 3 | 17 | Few Chaet. tubes |
| L ALT 400 | B | 11 B | 5 | G | 3 | 17 | 2 Molpadidae |
| L ALT 400 | C | 12 C | 5 | G | 3 | 17 | |
| A 50 W | B | 13 C | 4 MC | G-GY | 3 | 7 | Some leakage |
| A 50 W | C | 14 B | 7/4 MC | G | 3 | 10 | Some leakage |
| A 50 W | D | 15 B | 4 M | G-GY | 3 | 7 | Chaet/Onophidae tubes |
| A 200 W | A | 16 C | 4 MC | BWN-G | 3 | 6.5 | Some algae present |
| A 200 W | B | 17 B | 5/4 MC | G | 3 | 7.5 | Shell fragments |
| A 200 W | C | 18 B | 4 FM | G | 3 | 7 | Shell fragments |
| A 400 W | A | 19 B | 4/5 F | G | 3 | 13 | Travisia/Cistena pres. |
| A 400 W | B | 20 B | 4/5 F | BWN/G | 3 | 15.5 | Molpadidae present |
| A 400 W | C | 21 C | 4/5 F | BWN/G | 3 | 12 | |
| A 720 | A | 22 B | 4/5 F | BWN/G | 3 | 17 | Very slight fine sand |
| A 720 | B | 23 B | 5 | G | 3 | 17.5 | |
| A 720 | C | 24 C | 5 | G | 3 | 17 | |
| A 600 E | A | 25 B | 5 | G | 3 | 17.5 | 4 Brisaster, 1 Molpad. |
| A 600 E | B | 26 B | 5 | G | 3 | 17.5 | Travisia present |
| A 600 E | C | 27 C | 5 | G | 3 | 17 | Molpadidae present |
| A 400 E | A | 28 B | 4/2/5 CM | G | 3 | 17 | |
| A 400 E | B | 29 C | 4/5 CM | G | 3 | 17 | Some leakage |
| A 400 E | C | 30 B | 4/5 CM | G | 3 | 17 | |
| A 200 E | A | 31 C | 4 M | B/G | | 8 | |
| A 200 E | C,D(B) | 32 B | 2/3/4 C | G | 3 | 10.5 | See field data sheet |
| A 200 E | D,F(C) | 33 B | 7/4 C | G | 3 | 10.5 | Sort first |
| B 50 E | A | 37 B | 7/4 MF | G | 3 | 9.5 | |
| B 50 E | B | 38 C | 7/4 MF | G | 3 | 9 | |
| B 50 E | C | 39 C | 4 MF | G | 3 | 8 | |
| B 50 W | A | 43 B | 4 MF | G | 3 | 8 | Algae, Chaet, Onoph., algae. |
| B 50 W | B | 44 B | 4 MF | G | 3 | 8 | Ascidians, Chaet., Onoph., algae |
| B 50 W | C | 45 C | 4 MF | G | 3 | 9 | Ascidians, Chaet., Ono |
| B 75 W | A | 46 B | 2* | BWN | 3 | 6.5 | *Gravel & shell debris |
| B 75 W | B | 47 C | 2* | BWN | 3 | 7.5 | As above |
| B 75 W | C | 48 B | 2* | BWN | 3 | 5 | As above |
| B 660 | A | 49 B | 5 | BWN/G | 3 | 17 | 4 Brisaster, 3 Molpad |
| B 660 | B | 50 B | 5 | BWN/G | 3 | 17 | 3 Brisaster, 3 Molpad |

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| B 660 | C | 51 C | 5 | G | 3 | 17 | 2 Brisaster, 2 Molpad. |
| B 600 E | A | 52 B | 5 | BWN/G | 3 | 17 | 1 Brisaster, 1 Molpad. |
| B 600 E | B | 53 C | 5 | BWN/G | 3 | 17 | |
| B 600 E | C | 54 B | 5 | G | 3 | 17 | |
| B 400 E | A | 55 B | 6/3/5 | G | 3 | 17 | |
| B 400 E | B | 56 C | 6/3/4/5 C | DO | 3 | 17 | |
| B 400 E | C | 57 B | | | | 17 | |
| B 200 E | A | 58 C | 3/4 CM | DO | 3 | 8 | |
| B 200 E | B | 59 B | 3/4 CM | DO | 3 | 8.5 | |
| B 200 E | C | 60 B | 3/4 CM | DO | 3 | 8 | Chaet. & Onuphid tubes |
| C 50 E | A | 61 B | 4 CM | DO | 3 | 8.5 | Ptilosarcus present |
| C 50 E | B | 62 C | 4 CM | DO | 3 | 6 | Ptilosarcus present |
| C 50 E | C | 63 B | 4 CM | DO | 3 | 9 | Ptilosarcus present |
| C 75 E | A | 64 C | 4 CM | DO | 3 | 11 | Some washout |
| C 75 E | B | 65 B | 4 CM | DO | 3 | 9 | Some washout |
| C 75 E | C | 66 B | 4 CM | DO | 3 | 10 | Sort first |
| C 200 E | A | 67 C | 4 CM | *DO/BWN | 3 | 8 | Sed. color DO yellow BWN |
| C 200 E | B | 68 B | 4 CM | *DO/BWN | 3 | 8 | Sed. color DO yellow BWN |
| C 200 E | C | 69 B | 4 CM | *DO/BWN | 3 | 8 | Sed. color DO yellow BWN |
| C 400 E | A | 70 B | 5 F | *DO/BWN | 3 | 13 | Sed. color DO yellow BWN |
| C 400 E | B | 71 C | 5 F | *DO/BWN | 3 | 14 | Sed. color DO yellow BWN |
| C 400 E | C | 72 B | 5 F | *DO/BWN | 3 | 14.5 | Sed. color DO yellow BWN |
| C 600 E | A | 73 B | 5 | BWN/DO | 3 | 17 | 2 Brisaster, 3 Molpadids |
| C 600 E | B | 74 C | 5 | BWN/DO | 3 | 17.5 | Molpadidae present |
| C 600 E | C | 75 B | 5 | BWN/DO | 3 | 17 | |
| C 650 | A | 76 B | 5 | DO | 3 | 17 | |
| C 640 | B | 77 C | 5 | DO | 3 | 17 | |
| C 640 | C | 78 B | 5 | DO | 3 | 17 | Molpadidae present |
| C 75 W | A | 79 B | 4 M | DO | 3 | 7 | Chaet. & Onuphid tubes |
| C 75 W | B | 80 C | 4 M | DO | 3 | 7.5 | Chaet. & Onuphid tubes |
| C 75 W | C | 81 B | 4 M | DO | 3 | | |
| C 50 W | A | 82 C | 4 CM | DO | 3 | 7 | Some leakage |
| C 50 W | B | 83 B | 4 CM | DO | 3 | 7 | |
| C 50 W | C | 84 B | 4 CM | DO | 3 | 10 | |
| D 50 E | A | 85 B | 4 M | DO | 3 | 7.5 | Chaet. tubes |
| D 50 E | B | 86 C | 4 M | DO | 3 | 7 | Chaet. tubes |
| D 50 E | C | 87 B | 4 M | DO | 3 | 6.5 | Chaet. tubes |
| D 75 E | A | 88 C | 4 M | DO | 3 | 7.5 | Chaet. tubes |
| D 75 E | B | 89 B | 4 M | DO | 3 | 6 | Few Chaet. tubes |
| D 75 E | C | 90 B | 4 M | DO | 3 | 9.5 | Chaet. tubes |
| D 250 E | A | 91 C | 5/4 MF | DO | 3 | 8 | |
| D 250 E | B | 92 B | 4 F | DO | 3 | 12 | |
| D 250 E | C | 93 B | 5/4 F | DO | 3 | 9 | Many dead Mollusca |
| D 250 E | D | 94 B | 5/4 F | DO | 3 | 7.5 | Many dead Mollosca |
| D 250 E | E | 95 B | 5/4 F | DO | 3 | 9 | |
| D 250 E | F | 96 B | 5/4 F | DO | 3 | 6 | |

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| D 400 E | A | 97 B | 6/3/5/4 CF | DO | 3 | 13.5 | |
| D 400 E | B | 98 C | 4 MF | DO | 3 | 3 | |
| $OT_1$ (620) | A | 99 B | 5 | BWN/DO | 3 | 17.5 | 2 Molpadidae |
| $OT_1$ (620) | B | 100 C | 5 | DO | 3 | 17.5 | 3 Molpadidae |
| $OT_1$ (620) | C | 101 B | 5 | DO | 3 | 17.5 | 1 Molpadidae |
| $OT_1$ (620) | D | 102 B | 5 | DO | 3 | 17.5 | 2 Molpadidae |
| $OT_1$ (620) | E | 103 B | 5 | DO | 3 | 17.5 | 4 Molpadidae |
| $OT_1$ (620) | F | 104 B | 5 | DO | 3 | 17.5 | 2 Molpadidae |
| $OT_2$ (620) | A | 105 B | 5 | DO | 3 | 17.5 | 1 Brisaster, 1 Molpad. |
| $OT_2$ (620) | B | 106 B | 5 | DO | 3 | 17.5 | 3 Brisaster, 1 Travisia |
| $OT_2$ (620) | C | 107 B | 5 | DO | 3 | 17.5 | 1 Molpadidae, 2 Travisia |
| $OT_2$ (620) | D | 108 C | 5 | DO | 3 | 17.5 | 5 Brisaster, 1 Molpad. |
| $OT_2$ (620) | E | 109 B | 5 | DO | 3 | 17.5 | 1 Brisaster, 1 Molpad. |
| $OT_2$ (620) | F | 110 B | 5 | DO | 3 | 17.5 | |
| D 660 | A | 111 B | 5 | DO | 3 | 17.5 | 6 Molpadidae |
| D 660 | B | 112 B | 5 | DO | 3 | 17.5 | 1 Molpadidae |
| D 660 | C | 113 C | 5 | DO | 3 | 17.5 | |
| D 75 W | A | 114 C | 4 CM | DO | 3 | 7.5 | Chaet. & large Humillae. |
| D 75 W | B | 115 B | 4 CM | DO | 3 | 7 | Chaetopteridae present |
| D 75 W | C | 116 B | 4 CM | DO | 3 | 6.5 | Chaetopteridae present |
| D 50 W | A | 117 B | 4 CM | DO | 3 | 5 | Chaet. & Onophidae |
| D 50 W | B | 118 C | 4 CM | DO | 3 | 8 | Chaet. & Onophidae |
| D 50 W | C | 119 B | 4 CM | DO | 3 | 7 | Chaet. & Onophidae |
| E 50 W | A | 120 B | 4 F | DO | 3 | 9.5 | Chaet. & Onophidae |
| E 50 W | B | 121 C | 4 F | DO | 3 | 8 | Chaet. & Onophidae |
| E 50 W | C | 122 B | 4 F | DO | 3 | 10 | |
| E 75 W | A | 123 C | 4 F | DO | 3 | 7 | |
| E 75 W | B | 124 B | 4 F | DO | 3 | 10 | |
| E 75 W | C | 125 B | 4 F | DO | 3 | 8.5 | |
| E 750 | A | 126 B | 5 | DO | 3 | 17 | 2 Brisaster, 1 Molpad. |
| E 750 | B | 127 B | 4/5 F | DO | 3 | 17 | 1 Brisaster, 1 Axiopsis |
| E 750 | C | 128 C | 4/5 F | DO | 3 | 17 | 2 Molpadidae |
| E 600 E | A | 129 B | 6/4/5 F | DO | 3 | 16 | Some small rocks |
| E 600 E | B | 130 B | 6/4/5 F | DO | 3 | 17 | |
| E 600 E | C | 131 C | 4/5 F | DO | 3 | 17 | |
| E 200 E | A | 132 C | 4 MF | DO | 3 | 8 | |
| E 200 E | B | 133 B | 4 MF | DO | 3 | 12 | |
| E 200 E | C | 134 B | 4 MF | DO | 3 | 9 | |
| E 75 E | A | 135 B | 4 MF | DO | 3 | 7.5 | |
| E 75 E | B | 136 C | 4 MF | DO | 3 | 7.5 | |
| E 75 E | C | 137 B | 4 MF | DO | 3 | 8 | |
| E 50 E | A | 138 B | 4 MF | DO | 3 | 9 | |
| E 50 E | B | 139 B | 4 MF | DO | 3 | 9 | |
| E 50 E | C | 140 C | 4 MF | DO | 3 | | |

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| F 75 E | A | 141 B | 1/2 | | 3 | | Saved sample, Station R. |
| F 200 E | A | 142 B | 2/3/4 CM | DO | 3 | 9 | Hydroids, tubularia |
| F 200 E | B | 143 C | 3/4 CM | DO | 3 | 7.5 | |
| F 200 E | C | 144 B | 2/3/4 CM | DO | 3 | 4 | Chaetopteridae To. |
| F 600 E | A | 145 C | 4 CM | DO | 3 | 9 | |
| F 600 E | B | 146 B | 4 CM | DO | 3 | 13 | |
| F 600 E | C | 147 B | 4 CM | DO | 3 | 9.5 | |
| F 780 | A | 148 B | 3/4/5 C-M | DO | 3 | 17 | 1 Brisaster |
| F 780 | B | 149 B | 3/4/5 C-M | DO | 3 | 17 | |
| F 780 | C | 150 C | 3/4/5 C-M | DO | 3 | 16 | |
| F 75 W | A | 151 B | 4 MF | DO | 3 | 8 | Chaetopteridae tubes |
| F 75 W | B | 152 B | 4 MF | DO | 3 | 10 | Chaetopteridae tubes |
| F 75 W | C | 153 C | 4 MF | DO | 3 | 10 | Chaetopteridae tubes |
| F 50 W | A | 154 C | 4 CM | DO | 3 | 7 | Chaetopteridae tubes |
| F 50 W | B | 155 B | 4 CM | DO | 3 | 7 | Chaetopteridae tubes |
| F 50 W | C | 156 B | 4 M | DO | 3 | 7 | Agaridilla present |
| G 50 E | A | 157 B | 4 MF | DO | 3 | 10 | Some wood chips |
| G 50 E | B | 158 B | 4 CM | DO | 3 | 10.5 | Ulva |
| G 50 E | C | 159 C | 4 CM | DO | 3 | 11.5 | More Ulva |
| G 75 E | A | 160 B | 4 CM | DO | 3 | 10 | All sand |
| G 75 E | B | 161 B | 4 CM | DO | 3 | 7.5 | All sand |
| G 75 E | C | 162 C | 4 CM | DO | 3 | 9.5 | All sand |
| G 200 E | A | 163 B | 6/4 CM | DO | 3 | 10 | Chunks of clay |
| G 200 E | B | 164 B | 4 MF | DO | 3 | 9 | |
| G 200 E | C | 165 C | 6/4 C | DO | 3 | 5 | |
| G 400 E | A | 166 B | 1/6/2/C 3/4 | DO | 3 | 8 | Rocks and gravel, clay balls |
| G 400 E | B | 167 B | 1/6/2/C 3/4 | DO | 3 | 14.5 | Rocks and gravel, clay balls |
| G 400 E | C | 168 C | 6/2/3/C 4 | DO | 3 | 12 | |
| G 600 E | A | 169 B | 6/3/4/C 5 | DO | 3 | 17 | |
| G 600 E | B | 170 B | 3/4/5 C | DO | 3 | 17 | |
| G 600 E | C | 171 C | 6/3/4/C 5 | DO | 3 | 17 | |
| G 780 | A | 172 B | 5 | DO | 3 | 17 | 3 Molpadidae |
| G 780 | B | 173 B | 5 | DO | 3 | 17 | |
| G 780 | C | 174 C | 5 | DO | 3 | 17 | |
| G 75 W | A | 175 B | 4 M | DO | 3 | 7.5 | Slight leakage |
| G 75 W | B | 176 C | 4 M | DO | 3 | 6 | Slight leakage |
| G 75 W | C | 177 B | 4 M | DO | 3 | 8 | Slight leakage |
| G 50 W | A | 178 B | 4 M | DO | 3 | 8 | Ulva |
| G 50 W | B | 179 B | 4 CM | DO | 3 | 9 | Ulva |
| G 50 W | C | 180 C | 4 M | DO | 3 | 7.5 | Ulva |

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| H 50 E | A | 181 B | 4 C | DO | 3 | 10.5 | |
| H 50 E | B | 182 B | 4 C | DO | 3 | 11.5 | |
| H 50 E | C | 183 C | 4 C | DO | 3 | 12.5 | |
| H 75 E | A | 184 B | 4 C | DO | 3 | 11 | |
| H 75 E | B | 185 B | 4 C | DO | 3 | 9 | |
| H 75 E | C | 186 C | 3/4 C | DO | 3 | 11 | |
| H 400 E | A | 187 B | 4/5 C | DO | 3 | 17 | 1 Molpadidae |
| H 400 E | B | 188 B | 3/4/5 C | DO | 3 | 17 | Brisaster present |
| H 400 E | C | 189 C | 3/4/5 C | DO | 3 | 17 | |
| H 600 E | A | 190 B | 5 | DO | 3 | 17 | |
| H 600 E | B | 191 B | 5 | DO | 3 | 17 | 5 Molpadidae |
| H 600 E | C | 192 C | 5 | DO | 3 | 17 | |
| H 640 | A | 193 B | 5 | DO | 3 | 17 | |
| H 640 | B | 194 B | 5 | DO | 3 | 17 | |
| H 640 | C | 195 B | 5 | DO | 3 | 17 | |
| H 640 | D | 196 B | 5 | DO | 3 | 17 | |
| H 640 | E | 197 B | 5 | DO | 3 | 17 | |
| H 640 | F | 198 C | 5 | DO | 3 | 17 | |
| H 75 W | A | 199 B | 5 MF | DO | 3 | 8.5 | |
| H 75 W | B | 200 B | 4 MF | DO | 3 | 9 | |
| H 75 W | C | 201 C | 4 MF | DO | 3 | 10.5 | |
| I 50 W | A | 202 B | 4 MF | DO | 3 | 7 | Chaetopteridae tubes |
| I 50 W | B | 203 B | 4 MF | DO | 3 | 10 | Chaetopteridae tubes |
| I 50 W | C | 204 C | 4 MF | DO | 3 | 9 | Chaetopteridae tubes |
| I 75 W | A | 205 C | 4 MF | DO | 3 | 9 | |
| I 75 W | B | 206 B | 4 M | DO | 3 | 9 | |
| I 75 W | C | 207 B | 4 M | DO | 3 | 9 | |
| I 690 | A | 208 B | 5 | DO | 3 | 17 | |
| I 690 | B | 209 B | 5 | DO | 3 | 17 | |
| I 690 | C | 210 C | 5 | DO | 3 | 17 | |
| I 600 E | A | 211 B | 3/5 | DO | 3 | 17 | |
| I 600 E | B | 212 B | 3/5 | DO | 3 | 17 | |
| I 600 E | C | 213 C | 3/5 | DO | 3 | 17 | |
| I 400 E | A | 214 C | 2/3/5/C 4 | DO | 3 | 8.5 | |
| I 400 E | B | 215 B | 2/3/4/C 4 | DO | 3 | 16 | |
| I 400 E | C | 216 B | 2/3/5/C 4 | DO | 3 | 12 | |
| I 200 E | A | 217 B | 2/3/5/C 4 | DO | 3 | 9.5 | |
| I 200 E | B | 218 B | 2/3/5/C 4 | DO | 3 | 10 | |
| I 200 E | C | 219 C | 2/3/4 C | DO | 3 | 8 | |

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| J 75 W | A | 220 B | 4 CM | DO | 3 | 9.5 | Chaetopteridae tubes |
| J 75 W | B | 221 B | 4 CM | DO | 3 | 9.5 | |
| J 75 W | C | 222 C | 4 CM | DO | 3 | 9.5 | |
| J 690 | A | 223 B | 5 | DO | 3 | 17 | |
| J 690 | B | 224 B | 5 | DO | 3 | 17 | |
| J 690 | C | 225 C | 5 | DO | 3 | 17 | |
| J 600 E | A | 226 B | 5 | DO | 3 | 17 | |
| J 600 E | B | 227 B | 5 | DO | 3 | 17 | |
| J 600 E | C | 228 C | 5 | DO | 3 | 17 | |
| J 400 E | A | 229 B | 3/4/5 C | DO | 3 | 17 | |
| J 400 E | B | 230 B | 3/4/5 C | DO | 3 | 7.5 | |
| J 400 E | C | 231 C | 3/4/5 C | DO | 3 | 10 | |
| J 75 E | A | 232 B | 4 CM | DO | 3 | 8 | |
| J 75 E | B | 233 B | 4 C | DO | 3 | 9 | |
| J 75 E | C | 234 C | 4 CM | DO | 3 | 9 | |
| J 50 E | A | 235 B | 4 CM | DO | 3 | 11 | |
| J 50 E | B | 236 B | 4 CM | DO | 3 | 11 | |
| J 50 E | C | 237 C | 4 CM | DO | 3 | 10 | |
| K 50 E | A | 238 B | 4 MF | DO | 3 | 9.5 | |
| K 50 E | B | 239 B | 4 MF | DO | 3 | 9 | |
| K 50 E | C | 240 C | 4 MF | DO | 3 | 9.5 | |
| K 75 E | A | 241 B | 4 CM | DO | 3 | 7.5 | |
| K 75 E | B | 242 B | 4 CM | DO | 3 | 9 | |
| K 75 E | C | 243 C | 4 CM | DO | 3 | 7.5 | |
| K 200 E | A | 244 B | 3/4 C | DO | 3 | 10 | |
| K 200 E | B | 245 B | 3/4 CM | DO | 3 | 9.5 | |
| K 200 E | C | 246 C | 3/4 CM | DO | 3 | 10 | |
| K 400 E | A | 247 B | 3/4/5 C | BWN/DO | 3 | 10 | 2 Molpadidae, 1 Brisaster |
| K 400 E | B | 248 B | 4/5 F | DO | 3 | 9.5 | 1 Molpadidae, 1 Brisaster |
| K 400 E | C | 249 C | 4/5 F | DO | 3 | 10 | |
| K 570 | A | 250 B | 5 | DO | 3 | 17 | 3 Molpadidae, 1 Brisaster |
| K 570 | B | 251 B | 5 | DO | 3 | 17 | |
| K 570 | C | 252 C | 5 | DO | 3 | 17 | 2 Molpadidae |
| K 75 W | A | 253 B | 4 MF | DO | 3 | 8.5 | |
| K 75 W | B | 254 B | 4 MF | DO | 3 | 9.5 | Diopatra w/Chaetopteridae |
| K 75 W | C | 255 C | 4 MF | DO | 3 | — | |
| K 75 W | A | 256 B | 4 MF | DO | 3 | 7.0 | Diopatra w/Chaetopteridae |
| K 50 W | B | 257 B | 4 M | DO | 3 | 8.5 | Diopatra w/Chaetopteridae |
| K 50 W | C | 258 C | 4 MF | DO | 3 | — | |
| L(ALT) 50 W | A | 259 B | 5/4 F | DO | 3 | 9 | Diopatra w/Chaetopteridae |
| L(ALT) 50 W | B | 260 B | 5/4 F | DO | 3 | 8.5 | |
| L(ALT) 50 W | C | 261 C | 5/4 F | DO | 3 | 9.5 | |
| L(ALT) 75 W | A | 262 C | 2-3-4 C | DO | 3 | — | |
| L(ALT) 75 W | B | 263 B | 3-4 C | DO | 3 | 7.5 | |

Appendix Table 7.1b (continued)

| Station | Rep. | Code | Sed.-type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| L(ALT) 75 W | C | 264 B | 2-3-4 C | DO | 3 | 9 | |
| L(ALT) 570 | A | 265 B | 7/5 | DO | 3 | 17 | |
| L(ALT) 570 | B | 266 B | 7/5 | DO | 3 | 17 | |
| L(ALT) 570 | C | 267 C | 7/5 | DO | 3 | 17 | |
| QM 1 | A | 268 B | 5 | DO | 3 | 17 | |
| QM 1 | B | 269 B | 5 | DO | 3 | 17 | |
| QM 1 | C | 270 C | 5 | DO | 3 | 17 | |
| QM 2 | A | 271 B | 6/5 | DO | 3 | 17 | |
| QM 2 | B | 272 B | 6/5 | DO | 3 | 17 | |
| QM 2 | C | 273 C | 6/5 | DO | 3 | 17 | |
| M 200 | A | 274 C | 2-3 | DO | 3 | 5 | |
| M 200 | B | 275 B | 2-3 | DO | 3 | — | |
| M 200 | C | 276 B | 2-3 | DO | 3 | 5 | |
| N 50 E | A | 277 B | 4 CM | DO | 3 | 10 | |
| N 50 E | B | 278 B | 4 CM | DO | 3 | 10 | Solaster/Ptilosarcus |
| N 50 E | C | 279 C | 4 CM | DO | 3 | 10 | |
| N 75 E | A | 280 B | 4 MF | DO | 3 | 12 | |
| N 75 E | B | 281 B | 4 MF | DO | 3 | 9 | |
| N 75 E | C | 282 C | 4 MF | DO | 3 | 8 | |
| N 200 E | A | 283 B | 2/3/4 CM | DO | 3 | 8 | |
| N 200 E | B | 284 B | 2/3/4 MF | DO | 3 | 9 | |
| N 200 E | C | 285 C | 2/3/4 CMF | DO | 3 | 8 | |
| N 300 | A | 286 C | 4 MF | DO | 3 | 7 | |
| N 300 | B | 287 B | Reject | — | — | — | Station rejected |
| N 300 | C | 288 B | Reject | — | — | — | |
| N 75 W | A | 289 B | 4 C | DO | 3 | 10 | |
| N 75 W | B | 290 B | 4 CM | DO | 3 | 9 | |
| N 75 W | C | 291 C | 4 CM | DO | 3 | 8 | |
| N 50 W | A | 292 B | 4 M | DO | 3 | 8 | |
| N 50 W | B | 293 B | 4 M | DO | 3 | 12 | |
| N 50 W | C | 294 C | 4 CM | DO | 3 | 8 | Lots of Ulva and other algae |

Appendix Table 7.1c. Station location summarization (subtidal baseline grab samples).

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| L-ALT 50 E | A | 1 C | 14 Jun 82 | 48 | 27885.9 | 42255.5 | | |
| L-ALT 50 E | B | 2 B | 14 Jun 82 | 49 | 27885.9 | 42255.5 | | |
| L-ALT 50 E | C | 3 B | 14 Jun 82 | 50 | 27886.0 | 42255.5 | | |
| L-ALT 75 E | A | 4 C | 14 Jun 82 | 77 | 27886.3 | 42255.2 | | |
| L-ALT 75 E | B | 5 B | 14 Jun 82 | 75 | 27886.3 | 42255.0 | | |
| L-ALT 75 E | C | 6 B | 14 Jun 82 | 77 | 27886.3 | 42255.1 | | |
| L-ALT 200 E | A | 7 B | 14 Jun 82 | 202 | 27887.4 | 42255.0 | | |
| L-ALT 200 E | B | 8 B | 14 Jun 82 | 201 | 27887.3 | 42255.0 | | |
| L-ALT 200 E | C | 9 C | 14 Jun 82 | 200 | 27887.3 | 42255.0 | | |
| L-ALT 400 E | A | 10 B | 14 Jun 82 | 385 | 27889.3 | 42255.1 | | |
| L-ALT 400 E | B | 11 B | 14 Jun 82 | 400 | 27889.3 | 42255.2 | | |
| L-ALT 400 E | C | 12 C | 14 Jun 82 | 410 | 27889.2 | 42255.2 | | |
| A 50 W | B | 13 C | 15 Jun 82 | 47 | 27983.8 | 42269.7 | | |
| A 50 W | C | 14 B | 15 Jun 82 | 46 | 27983.8 | 42269.7 | | |
| A 50 W | D | 15 B | 15 Jun 82 | 49 | 27983.6 | 42269.7 | | |
| A 200 W | A | 16 C | 15 Jun 82 | 200 | 27984.3 | 42271.2 | | |
| A 200 W | B | 17 B | 15 Jun 82 | 206 | 27984.2 | 42271.2 | | |
| A 200 W | C | 18 B | 15 Jun 82 | 210 | 27984.3 | 42271.1 | | |
| A 400 W | A | 19 B | 15 Jun 82 | 400 | 27982.4 | 42273.9 | | |
| A 400 W | B | 20 B | 15 Jun 82 | 395 | 27982.3 | 42273.9 | | |
| A 400 W | C | 21 C | 15 Jun 82 | 395 | 27982.4 | 42273.9 | | |
| A 720 | A | 22 B | 15 Jun 82 | 760 | 27980.0 | 42277.4 | | |
| A 720 | B | 23 B | 15 Jun 82 | 760 | 27980.0 | 42277.4 | | |
| A 720 | C | 24 C | 15 Jun 82 | 760 | 27980.0 | 42277.5 | | |
| A 600 E | A | 25 B | 15 Jun 82 | 600 | 27977.4 | 42283.1 | | |
| A 600 E | B | 26 B | 15 Jun 82 | 600 | 27977.5 | 42283.1 | | |
| A 600 E | C | 27 C | 15 Jun 82 | 600 | 27977.4 | 42283.1 | | |
| A 400 E | A | 28 B | 15 Jun 82 | 390 | 27977.1 | 42283.8 | | |
| A 400 E | B | 29 C | 15 Jun 82 | 394 | 27977.1 | 42283.8 | | |
| A 400 E | C | 30 B | 15 Jun 82 | 385 | 27977.1 | 42283.9 | | |
| A 200 E | A | 31 C | 15 Jun 82 | 206 | 27975.8 | 42283.9 | | |
| A 200 E | C,D(B) | 32 B | 15 Jun 82 | 215 | 27975.9 | 42283.8 | | |
| A 200 E | E,F(C) | 33 B | 15 Jun 82 | 205 | 27975.8 | 42283.8 | | |
| B 50 E | A | 37 B | 15 Jun 82 | 49 | 27965.3 | 42282.1 | | |
| B 50 E | B | 38 C | 15 Jun 82 | 48 | 27965.3 | 42282.0 | | |
| B 50 E | C | 39 B | 15 Jun 82 | 49 | 27965.3 | 42282.1 | | |
| B 50 W | A | 43 B | 16 Jun 82 | 49 | 27974.9 | 42272.3 | | |
| B 50 W | B | 44 B | 16 Jun 82 | 49 | 27974.9 | 42272.3 | | |
| B 50 W | C | 45 C | 16 Jun 82 | 45 | 27974.9 | 42272.3 | | |
| B 75 W | A | 46 B | 16 Jun 82 | 75 | 27973.9 | 42272.6 | | |
| B 75 W | B | 47 C | 16 Jun 82 | 71 | 27973.8 | 42272.6 | | |
| B 75 W | C | 48 B | 16 Jun 82 | 68 | 27973.9 | 42272.6 | | |
| B 660 | A | 49 B | 16 Jun 82 | 660 | 27968.9 | 42277.0 | | |
| B 660 | B | 50 B | 16 Jun 82 | 655 | 27968.8 | 42277.0 | | |

C = Chemistry sample

B = Biological sample

Appendix Table 7.1c (continued)

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP 2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| B 660 | C | 51 C | 16 Jun 82 | 660 | 27968.8 | 42277.1 | | |
| B 600 E | A | 52 B | 16 Jun 82 | 595 | 27967.3 | 42280.8 | | |
| B 600 E | B | 53 C | 16 Jun 82 | 600 | 27967.2 | 42280.9 | | |
| B 600 E | C | 54 B | 16 Jun 82 | 560 | 27967.3 | 42280.9 | | |
| B 400 E | A | 55 B | 16 Jun 82 | 393 | 27966.7 | 42281.2 | | |
| B 400 E | B | 56 C | 16 Jun 82 | 400 | 27966.6 | 42281.2 | | |
| B 400 E | C | 57 B | 16 Jun 82 | 390 | 27966.6 | 42281.3 | | |
| B 200 E | A | 58 C | 16 Jun 82 | 195 | 27966.2 | 42281.7 | | |
| B 200 E | B | 59 B | 16 Jun 82 | 195 | 27966.2 | 42281.7 | | |
| B 200 E | C | 60 B | 16 Jun 82 | 195 | 27966.1 | 42281.6 | | |
| C 50 E | A | 61 B | 16 Jun 82 | 50 | 27953.1 | 42283.1 | | |
| C 50 E | B | 62 C | 16 Jun 82 | 52 | 27953.2 | 42283.1 | | |
| C 50 E | C | 63 B | 16 Jun 82 | 51 | 27953.2 | 42283.1 | | |
| C 75 E | A | 64 C | 16 Jun 82 | 77 | 27953.5 | 42282.8 | | |
| C 75 E | B | 65 B | 16 Jun 82 | 78 | 27953.5 | 42282.9 | | |
| C 75 E | C | 66 B | 16 Jun 82 | 77 | 27953.6 | 42282.8 | | |
| C 200 E | A | 67 C | 16 Jun 82 | 198 | 27954.1 | 42282.5 | | |
| C 200 E | B | 68 B | 16 Jun 82 | 210 | 27954.1 | 42282.4 | | |
| C 200 E | C | 69 B | 16 Jun 82 | 205 | 27954.1 | 42282.4 | | |
| C 400 E | A | 70 B | 16 Jun 82 | 420 | 27954.9 | 42281.9 | | |
| C 400 E | B | 71 C | 16 Jun 82 | 440 | 27954.9 | 42281.8 | | |
| C 400 E | C | 72 B | 16 Jun 82 | 425 | 27954.9 | 42281.8 | | |
| C 600 E | A | 73 B | 16 Jun 82 | 620 | 27955.5 | 42281.0 | | |
| C 600 E | B | 74 C | 16 Jun 82 | 620 | 27955.5 | 42281.0 | | |
| C 600 E | C | 75 B | 16 Jun 82 | 620 | 27955.5 | 42280.9 | | |
| C 640 | A | 76 B | 16 Jun 82 | 660 | 27958.0 | 42278.0 | | |
| C 640 | B | 77 C | 16 Jun 82 | 660 | 27958.0 | 42278.1 | | |
| C 640 | C | 78 B | 16 Jun 82 | 660 | 27957.9 | 42278.1 | | |
| C 75 W | A | 79 B | 16 Jun 82 | 75 | 27969.2 | 42269.9 | | |
| C 75 W | B | 80 C | 16 Jun 82 | 74 | 27969.1 | 42269.7 | | |
| C 75 W | C | 81 B | 16 Jun 82 | 74 | 27969.2 | 42269.7 | | |
| C 50 W | A | 82 C | 16 Jun 82 | 50 | 27969.3 | 42269.5 | | |
| C 50 W | B | 83 B | 16 Jun 82 | 51 | 27969.2 | 42269.6 | | |
| C 50 W | C | 84 B | 16 Jun 82 | 53 | 27969.3 | 42269.6 | | |
| D 50 E | A | 85 B | 18 Jun 82 | 57 | 27939.6 | 42281.3 | | |
| D 50 E | B | 86 C | 18 Jun 82 | 57 | 27939.7 | 42281.4 | | |
| D 50 E | C | 87 B | 18 Jun 82 | 57 | 27939.6 | 42281.4 | | |
| D 75 E | A | 88 C | 18 Jun 82 | 74 | 27939.6 | 42281.* | | |
| D 75 E | B | 89 B | 18 Jun 82 | 81 | 27939.6 | 42281.* | | |
| D 75 E | C | 90 B | 18 Jun 82 | 80 | 27939.5 | 42281.* | | |
| D 250 E | A | 91 C | 18 Jun 82 | 243 | 27940.3 | 42* | | |
| D 250 E | B | 92 B | 18 Jun 82 | 240 | 27940.2 | 42* | | |
| D 250 E | C | 93 B | 18 Jun 82 | 238 | 27940.1 | 42280.* | | |
| D 250 E | D | 94 B | 18 Jun 82 | 240 | 27940.2 | 42280.* | | |

C = Chemistry sample B = Biological sample
* Loran signal lost for this coordinate

Appendix Table 7.1c (continued)

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP 2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| D 250 E | E | 95 B | 18 Jun 82 | 238 | 27940.2 | 42281.2 | | |
| D 250 E | F | 96 B | 18 Jun 82 | 244 | 27940.1 | 42281.2 | | |
| D 400 E | A | 97 B | 18 Jun 82 | 400 | 27939.1 | 42* | | |
| D 400 E | B | 98 C | 18 Jun 82 | 380 | 27939.0 | 42279.1 | | |
| OT1 (620) | A | 99 B | 18 Jun 82 | 640 | 27950.5 | 42279.9 | | |
| OT1 (620) | B | 100 C | 18 Jun 82 | 640 | 27950.5 | 42279.9 | | |
| OT1 (620) | C | 101 B | 18 Jun 82 | 640 | 27950.5 | 42279.* | | |
| OT1 (620) | D | 102 B | 18 Jun 82 | 640 | 27950.5 | 42279.* | | |
| OT1 (620) | E | 103 B | 18 Jun 82 | 640 | 27950.5 | 42279.* | | |
| OT1 (620) | F | 104 B | 18 Jun 82 | 640 | 27950.5 | 42279.* | | |
| OT2 (620) | A | 105 B | 18 Jun 82 | 640 | 27945.8 | 42* | | |
| OT2 (620) | B | 106 B | 18 Jun 82 | 640 | 27945.9 | 42* | | |
| OT2 (620) | C | 107 B | 18 Jun 82 | 640 | 27945.8 | 42* | | |
| OT2 (620) | D | 108 C | 18 Jun 82 | 640 | 27945.8 | 42* | | |
| OT2 (620) | E | 109 B | 18 Jun 82 | 640 | 27945.8 | 42* | | |
| OT2 (620) | F | 110 B | 18 Jun 82 | 640 | 27945.8 | 42* | | |
| D 660 | A | 111 B | 18 Jun 82 | 650 | 27948.5 | 42275.6 | | |
| D 660 | B | 112 B | 18 Jun 82 | 650 | 27948.5 | 42275.6 | | |
| D 660 | C | 113 C | 18 Jun 82 | 650 | 27948.5 | 42275.6 | | |
| D 75 W | A | 114 C | 19 Jun 82 | 75 | * | * | | |
| D 75 W | B | 115 B | 19 Jun 82 | 75 | * | * | | |
| D 75 W | C | 116 B | 19 Jun 82 | 75 | 27954.* | * | | |
| D 50 W | A | 117 B | 19 Jun 82 | 50 | * | * | | |
| D 50 W | B | 118 C | 19 Jun 82 | 52 | | | | |
| D 50 W | C | 119 B | 19 Jun 82 | 53 | 27953.9 | 42271.4 | | |
| E 50 W | A | 120 B | 19 Jun 82 | 50 | 27948.9 | * | | |
| E 50 W | B | 121 C | 19 Jun 82 | 51 | 27948.* | * | | |
| E 50 W | C | 122 B | 19 Jun 82 | 50 | * | * | | |
| E 75 W | A | 123 C | 19 Jun 82 | 75 | * | * | | |
| E 75 W | B | 124 B | 19 Jun 82 | 75 | * | * | | |
| E 75 W | C | 125 B | 19 Jun 82 | 75 | * | * | | |
| E 750 | A | 126 B | 19 Jun 82 | 800 | 27940.1 | 42276.4 | | |
| E 750 | B | 127 B | 19 Jun 82 | 800 | 27940.1 | 42276.4 | | |
| E 750 | C | 128 C | 19 Jun 82 | 800 | 27940.1 | 42276.4 | | |
| E 600 E | A | 129 B | 19 Jun 82 | 610 | 27938.0 | 42278.4 | | |
| E 600 E | B | 130 B | 19 Jun 82 | 610 | 27938.0 | 42278.4 | | |
| E 600 E | C | 131 C | 19 Jun 82 | 605 | 27938.0 | 42278.4 | | |
| E 200 E | A | 132 C | 19 Jun 82 | 200 | 27935.6 | 42280.2 | | |
| E 200 E | B | 133 B | 19 Jun 82 | 200 | 27935.6 | 42280.2 | | |
| E 200 E | C | 134 B | 19 Jun 82 | 204 | 27935.5 | 42280.2 | | |
| E 75 E | A | 135 B | 19 Jun 82 | 75 | 27934.6 | 42281.0 | | |
| E 75 E | B | 136 C | 19 Jun 82 | 73 | 27934.5 | 42281.0 | | |

C = Chemistry sample B = Biological sample
* Loran signal lost for this coordinate

Appendix Table 7.1c (continued)

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP 2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| E 75 E | C | 137 B | 19 Jun 82 | 76 | 27944.6 | 42281.0 | | |
| E 50 E | A | 138 B | 19 Jun 82 | 49 | 27934.3 | 42281.2 | | |
| E 50 E | B | 139 B | 19 Jun 82 | 50 | 27934.4 | 42281.1 | | |
| E 50 E | C | 140 C | 19 Jun 82 | 50 | 27934.3 | 42281.1 | | |
| F 75 E | A | 141 B | 19 Jun 82 | 75 | 27943.5 | 42277.6 | | |
| F 200 E | A | 142 B | 19 Jun 82 | 200 | 27943.6 | 42277.5 | | |
| F 200 E | B | 143 C | 19 Jun 82 | 208 | 27943.7 | 42277.5 | | |
| F 200 E | C | 144 B | 19 Jun 82 | 198 | 27943.7 | 42277.7 | | |
| F 600 E | A | 145 C | 19 Jun 82 | 620 | 27945.0 | 42* | | |
| F 600 E | B | 146 B | 19 Jun 82 | 650 | 27945.0 | 42* | | |
| F 600 E | C | 147 B | 19 Jun 82 | 620 | 27945.1 | 42* | | |
| F 780 | A | 148 B | 28 Jun 82 | 790 | 27932.5 | 42275.* | | |
| F 780 | B | 149 B | 28 Jun 82 | 790 | 27932.5 | 42275.* | | |
| F 780 | C | 150 C | 28 Jun 82 | 790 | 27932.4 | 42275.4 | | |
| F 75 W | A | 151 B | 28 Jun 82 | 77 | 27940.4 | 42268.4* | | |
| F 75 W | B | 152 B | 28 Jun 82 | 78 | 27940.4 | 42268.4* | | |
| F 75 W | C | 153 C | 28 Jun 82 | 79 | 27940.4 | 422* | | |
| F 50 W | A | 154 C | 28 Jun 82 | 50 | 27940.4 | * | | |
| F 50 W | B | 155 B | 28 Jun 82 | 50 | 27940.4 | * | | |
| F 50 W | C | 156 B | 28 Jun 82 | 49 | 27940.4 | * | | |
| G 50 E | A | 157 B | 29 Jun 82 | 52 | 27929.2 | * | | |
| G 50 E | B | 158 B | 29 Jun 82 | 53 | 27929.3 | * | | |
| G 50 E | C | 159 C | 29 Jun 82 | 55 | 27929.3 | * | | |
| G 75 E | A | 160 B | 29 Jun 82 | 74 | 27929.3 | * | | |
| G 75 E | B | 161 B | 29 Jun 82 | 72 | 27929.3 | * | | |
| G 75 E | C | 162 C | 29 Jun 82 | 72 | 27929.3 | * | | |
| G 200 E | A | 163 B | 29 Jun 82 | 198 | 27929.7 | * | | |
| G 200 E | B | 164 B | 29 Jun 82 | 205 | 27929.6 | * | | |
| G 200 E | C | 165 C | 29 Jun 82 | 204 | 27929.7 | * | | |
| G 400 E | A | 166 B | 29 Jun 82 | 405 | 27929.0 | 42277.2* | | |
| G 400 E | B | 167 B | 29 Jun 82 | 420 | 27928.9 | 422* | | |
| G 400 E | C | 168 C | 29 Jun 82 | 405 | 27929.2 | 422* | | |
| G 600 E | A | 169 B | 29 Jun 82 | 610 | 27928.6 | 42267.8 | | |
| G 600 E | B | 170 B | 29 Jun 82 | 635 | 27928.4 | 42267.* | | |
| G 600 E | C | 171 C | 29 Jun 82 | 630 | 27928.5 | 42267.* | | |
| G 780 | A | 172 | 29 Jun 82 | 720 | 27928.1 | 42276.* | | |
| G 780 | B | 173 | 29 Jun 82 | 720 | 27928.1 | 42276.* | | |
| G 780 | C | 174 | 29 Jun 82 | 715 | 27928.* | 42276.* | | |
| G 75 W | A | 175 B | 29 Jun 82 | 80 | OUT | | | |
| G 75 W | B | 176 C | 29 Jun 82 | 75 | OUT | | | |
| G 75 W | C | 177 B | 29 Jun 82 | 76 | OUT | | | |
| G 50 W | A | 178 B | 29 Jun 82 | 50 | OUT | | | |
| G 50 W | B | 179 B | 29 Jun 82 | 51 | OUT | | | |
| G 50 W | C | 180 C | 29 Jun 82 | 50 | OUT | | | |

C = Chemistry sample B = Biological sample
* Loran signal lost for this coordinate (see Range Information Descriptions)

Appendix Table 7.1c (continued)

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP 2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| H 50 E | A | 181 B | 29 Jun 82 | 47 | 27923.4 | * | | |
| H 50 E | B | 182 B | 29 Jun 82 | 52 | 27923.4 | * | | |
| H 50 E | C | 183 C | 29 Jun 82 | 52 | 27923.4 | * | | |
| H 75 E | A | 184 B | 29 Jun 82 | 75 | 27923.2 | * | | |
| H 75 E | B | 185 B | 29 Jun 82 | 75 | 27923.2 | * | | |
| H 75 E | C | 186 C | 29 Jun 82 | 73 | 27923.2 | * | | |
| H 400 E | A | 187 B | 29 Jun 82 | 400 | 27924.0 | * | | |
| H 400 E | B | 188 B | 29 Jun 82 | 395 | 27924.0 | * | | |
| H 400 E | C | 189 C | 29 Jun 82 | 405 | 27924.0 | * | | |
| H 600 E | A | 190 B | 29 Jun 82 | 600 | 27930.0 | 42277.2 | | |
| H 600 E | B | 191 B | 29 Jun 82 | 600 | 27929.9 | 4227* | | |
| H 600 E | C | 192 C | 29 Jun 82 | 600 | 2792* | 4227* | | |
| H 640 | A | 193 B | 29 Jun 82 | 650 | 27925.8 | * | | |
| H 640 | B | 194 B | 29 Jun 82 | 650 | 27925.8 | * | | |
| H 640 | C | 195 B | 29 Jun 82 | 650 | 27925.8 | * | | |
| H 640 | D | 196 B | 29 Jun 82 | 650 | 27925.8 | * | | |
| H 640 | E | 197 B | 29 Jun 82 | 650 | 27925.8 | * | | |
| H 640 | F | 198 C | 29 Jun 82 | 650 | 27925.8 | * | | |
| H 75 W | A | 199 B | 29 Jun 82 | 75 | OUT | | | |
| H 75 W | B | 200 B | 29 Jun 82 | 76 | OUT | | | |
| H 75 W | C | 201 C | 29 Jun 82 | 74 | OUT | | | |
| I 50 W | A | 202 B | 30 Jun 82 | 50 | 27912.8 | 42272.0 | | |
| I 50 W | B | 203 B | 30 Jun 82 | 49 | 27912.8 | 42271.9 | | |
| I 50 W | C | 204 C | 30 Jun 82 | 50 | 27912.9 | 42271.9 | | |
| I 75 W | A | 205 C | 30 Jun 82 | 75 | 27912.8 | 42271.6 | | |
| I 75 W | B | 206 B | 30 Jun 82 | 77 | 27912.8 | 42271.8 | | |
| I 75 W | C | 207 B | 30 Jun 82 | 76 | 27912.8 | 42271.8 | | |
| I 690 | A | 208 B | 30 Jun 82 | 700 | 27910.6 | 42275.9 | | |
| I 690 | B | 209 B | 30 Jun 82 | 700 | 27910.7 | 42275.9 | | |
| I 690 | C | 210 C | 30 Jun 82 | 700 | 27910.7 | 42276.0 | | |
| I 600 E | A | 211 B | 30 Jun 82 | 600 | 27911.5 | 42279.0 | | |
| I 600 E | B | 212 B | 30 Jun 82 | 600 | 27911(*) | 42279(*) | | |
| I 600 E | C | 213 C | 30 Jun 82 | 605 | 27911.6 | 42279. | | |
| I 400 E | A | 214 C | 30 Jun 82 | 395 | 27911.6 | 42279.2 | | |
| I 400 E | B | 215 B | 30 Jun 82 | 415 | 27911.6 | 42279.2 | | |
| I 400 E | C | 216 B | 30 Jun 82 | 405 | 27911.8 | 42279.2 | | |
| I 200 E | A | 217 B | 30 Jun 82 | 200 | 27911.6 | 42279.9 | | |
| I 200 E | B | 218 B | 30 Jun 82 | 204 | 27911.7 | 42279.8 | | |
| I 200 E | C | 219 C | 30 Jun 82 | 204 | 27911.7 | 42280.0 | | |
| J 75 W | A | 220 B | 30 Jun 82 | 73 | 27904.0 | * | | |
| J 75 W | B | 221 B | 30 Jun 82 | 72 | 27903.9 | * | | |
| J 75 W | C | 222 C | 30 Jun 82 | 72 | 27903.9 | * | | |
| J 690 | A | 223 B | 30 Jun 82 | 700 | 27899.1 | 42276.3 | | |
| J 690 | B | 224 B | 30 Jun 82 | 700 | 27899.1 | 42276.3 | | |
| J 690 | C | 225 C | 30 Jun 82 | 700 | 27899.1 | 42276.2 | | |
| J 600 E | A | 226 B | 30 Jun 82 | 610 | 27895.8 | 42279.3 | | |

C = Chemistry sample B = Biological sample
* Loran signal lost for this coordinate (see Range Information Descriptions)
(*) Indicates Loran was cycling.

Appendix Table 7.1c (continued)

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP 2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| J 600 E | B | 227 B | 30 Jun 82 | 600 | 27895.8 | 42279.3 | | |
| J 600 E | C | 228 C | 30 Jun 82 | 610 | 27895.9 | 42279.3 | | |
| J 400 E | A | 229 B | 30 Jun 82 | 405 | 27895.2 | 42279.7 | | |
| J 400 E | B | 230 B | 30 Jun 82 | 400 | 27895.2 | 42279.6 | | |
| J 400 E | C | 231 C | 30 Jun 82 | 396 | 27895.2 | 42279.7 | | |
| J 75 E | A | 232 B | 30 Jun 82 | 77 | 27894.5 | 42280.6 | | |
| J 75 E | B | 233 B | 30 Jun 82 | 78 | 27894.5 | 42280.6 | | |
| J 75 E | C | 234 C | 30 Jun 82 | 73 | 27894.4 | 42280.6 | | |
| J 50 E | A | 235 B | 30 Jun 82 | 50 | 27894.1 | 42280.6 | | |
| J 50 E | B | 236 B | 30 Jun 82 | 51 | 27894.1 | 42280.8 | | |
| J 50 E | C | 237 C | 30 Jun 82 | 49 | 27894.1 | 42280.8 | | |
| K 50 E | A | 238 B | 1 Jul 82 | 51 | 27881.3 | 42269.1(*) | | |
| K 50 E | B | 239 B | 1 Jul 82 | 50 | 27881.3 | 42269.2(*) | | |
| K 50 E | C | 240 C | 1 Jul 82 | 51 | 27881.4 | 42269.2(*) | | |
| K 75 E | A | 241 B | 1 Jul 82 | 75 | 27881.6 | 42269.(*) | | |
| K 75 E | B | 242 B | 1 Jul 82 | 76 | 27881.6 | 42269.0 | | |
| K 75 E | C | 243 C | 1 Jul 82 | 76 | 27881.6 | 42269.0 | | |
| K 200 E | A | 244 B | 1 Jul 82 | 204 | 27882.9 | 42268.8 | | |
| K 200 E | B | 245 B | 1 Jul 82 | 210 | 27882.9 | 42269.0(*) | | |
| K 200 E | C | 246 C | 1 Jul 82 | 207 | 27882.9 | 42268.(*) | | |
| K 400 E | A | 247 B | 1 Jul 82 | 415 | 27883.8 | 42269.(*) | | |
| K 400 E | B | 248 B | 1 Jul 82 | 405 | 27883.8 | 42269.(*) | | |
| K 400 E | C | 249 C | 1 Jul 82 | 405 | 27883.8 | 42269.(*) | | |
| K 570 | A | 250 B | 1 Jul 82 | 570 | 27894.2 | 42265.(*) | | |
| K 570 | B | 251 B | 1 Jul 82 | 570 | 27894.1 | 42265.(*) | | |
| K 570 | C | 252 C | 1 Jul 82 | 570 | 27894.1 | 42265.(*) | | |
| K 75 W | A | 253 B | 1 Jul 82 | 69 | 27907.6 | 42263.4(*) | | |
| K 75 W | B | 254 B | 1 Jul 82 | 76 | 27907.6 | 42263.4(*) | | |
| K 75 W | C | 255 C | 1 Jul 82 | 80 | 27907.6 | 42263.(*) | | |
| K 50 W | A | 256 B | 1 Jul 82 | 48 | 27907.6 | 42263.(*) | | |
| K 50 W | B | 257 B | 1 Jul 82 | 47 | 27907.6 | 42263.(*) | | |
| K 50 W | C | 258 C | 1 Jul 82 | 52 | 27907.7 | 422(*) | | |
| L 50 W | A | 259 B | 1 Jul 82 | 48 | 27904.5 | 42256.(*) | | |
| L 50 W | B | 260 B | 1 Jul 82 | 47 | 27904.4 | 42256.(*) | | |
| L 50 W | C | 261 C | 1 Jul 82 | 50 | 27904.4 | 42256.(*) | | |
| L 75 W | A | 262 C | 1 Jul 82 | 77 | 27904.1 | 42256.2 | | |
| L 75 W | B | 263 B | 1 Jul 82 | 75 | 27903.9 | 42256.(*) | | |
| L 75 W | C | 264 B | 1 Jul 82 | 75 | 27903.9 | 42256.(*) | | |
| L 570 | A | 265 B | 1 Jul 82 | 580 | 27896.0 | 42255.2(*) | | |
| L 570 | B | 266 B | 1 Jul 82 | 580 | 27896.0 | 42255.6(*) | | |
| L 570 | C | 267 C | 1 Jul 82 | 580 | 27895.5 | 42255.4(*) | | |

C = Chemistry sample B = Biological sample
* Loran signal lost for this coordinate.
** Indicates Loran was cycling.

Appendix Table 7.1c (continued)

| Station | Rep. | Code | Date | Depth (ft) | LOP 1 | LOP 2 | Longitude | Latitude |
|---|---|---|---|---|---|---|---|---|
| QM 1 | A | 268 B | 1 Jul 82 | 21 | OUT | | | |
| QM 1 | B | 269 B | 1 Jul 82 | 21 | OUT | | | |
| QM 1 | C | 270 C | 1 Jul 82 | 21 | OUT | | | |
| QM 2 | A | 271 B | 1 Jul 82 | 53 | 27912.8(*) | 42245.4(*) | | |
| QM 2 | B | 272 B | 1 Jul 82 | 53 | 27913.2(*) | 42255.2(*) | | |
| QM 2 | C | 273 C | 1 Jul 82 | 53 | 27913.2(*) | (*) | | |
| M 200 | A | 274 C | 1 Jul 82 | 200 | 27918.9 | 42240.4(*) | | |
| M 200 | B | 275 B | 1 Jul 82 | 195 | 27919.0 | 42240.4 | | |
| M 200 | C | 276 B | 1 Jul 82 | 195 | 27919.0 | (*) | | |
| N 50 E | A | 277 B | 2 Jul 82 | 51 | 27974.1 | 42263.6 | | |
| N 50 E | B | 278 B | 2 Jul 82 | 51 | 27974.1 | 42263.6 | | |
| N 50 E | C | 279 C | 2 Jul 82 | 50 | 27974.1 | 42263.6 | | |
| N 75 E | A | 280 B | 2 Jul 82 | 76 | 27974.9 | 42263.6 | | |
| N 75 E | B | 281 B | 2 Jul 82 | 77 | 27975.0 | 42263.5 | | |
| N 75 E | C | 282 C | 2 Jul 82 | 76 | 27975.0 | 42263.5 | | |
| N 200 E | A | 283 B | 2 Jul 82 | 204 | 27976.2 | 42263.4 | | |
| N 200 E | B | 284 B | 2 Jul 82 | 190 | 27976.1 | 42263.4 | | |
| N 200 E | C | 285 C | 2 Jul 82 | 201 | 27976.1 | 42263.5 | | |
| N 300 | A | 286 C | 2 Jul 82 | 315 | 27979.7 | 42262.6 | | |
| N 300 | B | 287 B | 2 Jul 82 | 315 | Rejected | | | |
| N 300 | C | 288 B | 2 Jul 82 | — | Rejected | | | |
| N 75 W | A | 289 B | 2 Jul 82 | 78 | 27981.3 | 42259.2 | | |
| N 75 W | B | 290 B | 2 Jul 82 | 77 | 27981.4 | 42259.2 | | |
| N 75 W | C | 291 C | 2 Jul 82 | 78 | 27981.3 | 42259.2 | | |
| N 50 W | A | 292 B | 2 Jul 82 | 52 | 27981.4 | 42259.0 | | |
| N 50 W | B | 293 B | 2 Jul 82 | 51 | 27981.4 | 42259.0 | | |
| N 50 W | C | 294 C | 2 Jul 82 | 52 | 27981.4 | 42259.0 | | |

C = Chemistry sample B = Biological sample
* Loran signal lost for this coordinate.
** Indicates Loran was cycling.

# APPENDIX 7.2

September/October 1982

Appendix Table 7.2a. Numerical listing of baseline samples chemistry: subtidal.

| Code | Station Desig. | Date Sampled | Chem. Reqd. |
|---|---|---|---|
| 104 | L.5 200 E | 20 Sept 82 | (VCS).G |
| 105 | L.5 400 E | 20 Sept 82 | (VCS).G |
| 106 | L.5 550 | 20 Sept 82 | (VCS).G |
| 107 | L.5 400 W | 20 Sept 82 | (VCS).G |
| 108 | M-200 | 20 Sept 82 | (VCS).G |
| 109 | Lalt 50 W | 20 Sept 82 | (VCS).G |
| 110 | Lalt 75 W | 20 Sept 82 | (VCS).G |
| 111 | QM-1 | 21 Sept 82 | (VCS).G |
| 112 | QM-2 | 21 Sept 82 | (VCS).G |
| 113 | Lalt 570 | 21 Sept 82 | (VCS).G |
| 114 | Lalt 400 E | 21 Sept 82 | (VCS).G |
| 115 | Lalt 75 E | 21 Sept 82 | (VCS).G |
| 116 | Lalt 200 E | 21 Sept 82 | (VCS).G |
| 117 | Lalt 50 E | 21 Sept 82 | (VCS).G |
| 118 | K-50 E | 21 Sept 82 | (VCS).G |
| 119 | K-75 E | 21 Sept 82 | (VCS).G |
| 120 | K-200 E | 21 Sept 82 | (VCS).G |
| 121 | K-400 E | 21 Sept 82 | (VCS).G |
| 122 | K-570 | 21 Sept 82 | (VCS).G |
| 123 | K-75 W | 21 Sept 82 | (VCS).G |
| 124 | K-50 W | 22 Sept 82 | (VCS).G |
| 125 | P.B.1 | 22 Sept 82 | (VCS).G |
| 126 | P.B.2 | 22 Sept 82 | (VCS).G |
| 127 | P.B.3 | 22 Sept 82 | (VCS).G |
| 128 | P.B.4 | 22 Sept 82 | (VCS).G |
| 129 | J.5 50 E | 22 Sept 82 | (VCS).G |
| 130 | J.5 75 E | 22 Sept 82 | (VCS).G |
| 131 | J.5 250 E | 22 Sept 82 | (VCS).G |
| 132 | J.5 400 E | 22 Sept 82 | (VCS).G |
| 133 | J.5 520 E | 22 Sept 82 | (VCS).G |
| 134 | J.5 600 | 22 Sept 82 | (VCS).G |
| 135 | J.5 75 W | 22 Sept 82 | (VCS).G |
| 136 | J-75 W | 22 Sept 82 | (VCS).G |
| 137 | J-690 | 22 Sept 82 | (VCS).G |
| 138 | J-50 E | 23 Sept 82 | (VCS).G |
| 139 | J-75 E | 23 Sept 82 | (VCS).G |
| 140 | J-400 E | 23 Sept 82 | (VCS).G |
| 141 | J-600 E | 23 Sept 82 | (VCS).G |
| 142 | I-200 E | 23 Sept 82 | (VCS).G |
| 143 | I-400 E | 23 Sept 82 | (VCS).G |
| 144 | I-600 E | 23 Sept 82 | (VCS).G |
| 145 | I-690 | 23 Sept 82 | (VCS).G |
| 146 | I-75 W | 23 Sept 82 | (VCS).G |
| 147 | I-50 W | 23 Sept 82 | (VCS).G |
| 148 | G-50 W | 23 Sept 82 | (VCS).G |

Appendix Table 7.2a (continued)

| Code | Station Desig. | Date Sampled | Chem. Reqd. |
|---|---|---|---|
| 149 | G-75 W | 23 Sept 82 | (VCS).G |
| 150 | F-50 W | 23 Sept 82 | (VCS).G |
| 151 | F-75 W | 23 Sept 82 | (VCS).G |
| 152 | H-75 W | 23 Sept 82 | (VCS).G |
| 153 | H-50 W | 23 Sept 82 | (VCS).G |
| 154 | H-640 | 24 Sept 82 | (VCS).G |
| 155 | H-600 E | 24 Sept 82 | (VCS).G |
| 156 | H-400 E | 24 Sept 82 | (VCS).G |
| 157 | H-75 E | 24 Sept 82 | (VCS).G |
| 158 | H-50 E | 24 Sept 82 | (VCS).G |
| 159 | G-50 E | 24 Sept 82 | (VCS).G |
| 160 | G-75 E | 24 Sept 82 | (VCS).G |
| 161 | G-200 E | 24 Sept 82 | (VCS).G |
| 162 | G-400 E | 4 Oct 82 | (VCS).G |
| 163 | G-600 E | 4 Oct 82 | (VCS).G |
| 164 | G-780 | 4 Oct 82 | (VCS).G |
| 165 | A-200 E | 4 Oct 82 | (VCS).G |
| 166 | A-400 E | 4 Oct 82 | (VCS).G |
| 167 | A-600 E | 4 Oct 82 | (VCS).G |
| 168 | A-720 | 4 Oct 82 | (VCS).G |
| 169 | A-400 W | 5 Oct 82 | (VCS).G |
| 170 | N-50 W | 5 Oct 82 | (VCS).G |
| 171 | N-75 W | 5 Oct 82 | (VCS).G |
| 172 | N-200 E | 5 Oct 82 | (VCS).G |
| 173 | N-75 E | 5 Oct 82 | (VCS).G |
| 174 | N-50 E | 5 Oct 82 | (VCS).G |
| 175 | A-50 W | 5 Oct 82 | (VCS).G |
| 176 | B-50 W | 5 Oct 82 | (VCS).G |
| 177 | B-75 W | 5 Oct 82 | (VCS).G |
| 178 | B-660 | 5 Oct 82 | (VCS).G |
| 179 | B-600 E | 5 Oct 82 | (VCS).G |
| 180 | B-400 E | 5 Oct 82 | (VCS).G |
| 181 | B-50 E | 5 Oct 82 | (VCS).G |
| 182 | B-200 E | 5 Oct 82 | (VCS).G |
| 183 | C-50 E | 6 Oct 82 | (VCS).G |
| 184 | C-75 E | 6 Oct 82 | (VCS).G |
| 185 | C-200 E | 6 Oct 82 | (VCS).G |
| 186 | C-400 E | 6 Oct 82 | (VCS).G |
| 187 | C-600 E | 7 Oct 82 | (VCS).G |
| 188 | C-640 | 7 Oct 82 | (VCS).G |
| 189 | C-50 W | 6 Oct 82 | (VCS).G |
| 190 | C-75 W | 6 Oct 82 | (VCS).G |
| 191 | D-50 W | 6 Oct 82 | (VCS).G |
| 192 | D-75 W | 6 Oct 82 | (VCS).G |
| 193 | E-50 E | 6 Oct 82 | (VCS).G |
| 194 | E-75 E | 6 Oct 82 | (VCS).G |

Appendix Table 7.2a (continued)

| Code | Station Desig. | Date Sampled | Chem. Reqd. | |
|---|---|---|---|---|
| 195 | D-50 E | 7 Oct 82 | (VCS).G | |
| 196 | OT-1 | 7 Oct 82 | (VCS).G | |
| 197 | OT-2 | 7 Oct 82 | (VCS).G | |
| 198 | D-250 E | 7 Oct 82 | (VCS).G | |
| 199 | D-660 | 7 Oct 82 | (VCS).G | Animals Collected |
| 200 | E-50 W | 8 Oct 82 | (VCS).G | |
| 201 | E-75 W | 8 Oct 82 | (VCS).G | |
| 202 | E-750 | 8 Oct 82 | (VCS).G | Animals Collected |
| 203 | E-600 E | 8 Oct 82 | (VCS).G | |
| 204 | E-200 E | 8 Oct 82 | (VCS).G | Animals Collected |
| 205 | E-75 E | 8 Oct 82 | (VCS).G | Animals Collected |
| 206 | D-75 E | 8 Oct 82 | (VCS).G | Animals Collected |
| 207 | F-200 E | 8 Oct 82 | (VCS).G | |
| 208 | F-600 E | 8 Oct 82 | (VCS).G | |
| 209 | F-780 | 8 Oct 82 | (VCS).G | |

V = volatile solids and B.O.D. (frozen)
C = organic carbon and nitrogen (frozen)
S = sulfides (frozen)
G = grain size and metals (unfrozen)

Appendix Table 7.2b. Summary of descriptive information on subtidal baseline grab samples.*

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| L.5 200E | A | 1 B | 3/5/4 C-M | G-GY | 3 | 15 | |
| | B | 2 B | 3/5/4 C-M | G-GY | 3 | 15 | |
| | C | 3 C | 3/5/4 C-M | G-GY | 3 | 15 | |
| L.5 400E | A | 4 B | 5/4 M-F | G-GY | 3 | 12 | |
| | B | 5 C | 5/4 M-F | G-GY | 3 | 17 | |
| | C | 6 B | 5/4 C | G-GY | 3 | 16 | |
| L.5 550 | A | 7 B | 4/5 F | G-GY | 3 | 10 | Lt BWN surface |
| | B | 8 B | 5 | G-GY | 3 | 17 | |
| | C | 9 C | 5 | G-GY | 3 | 16 | |
| L.5 400W | A | 10 B | 2/3/4/5 C | G-GY | 3 | 15 | |
| | B | 11 C | 3/4/5 C-M | G-GY | 3 | 15 | |
| | C | 12 B | 3/4 C | G-GY | 3 | 15 | |
| M-200 | A | 13 B | 2/3/4 C | G-GY | 3 | 5 | |
| | B | 14 B | 2/3/4 C | G-GY | 3 | 4 | Chaetopteridae |
| | C | 15 C | 2/3/4 C | G-GY | 3 | 5 | One corner washed |
| Lalt 50W | A | 16 B | 5/4 F | G-GY | 3 | 8 | |
| | B | 17 C | 5/4 F | G-GY | 3 | 8 | Some leakage |
| | C | 18 B | 5/4 F | G-GY | 3 | 9 | |
| Lalt 75W | A | 19 B | 3/4 C | G-GY | 3 | 7 | |
| | B | 20 B | 4 C | G-GY | 3 | 8 | |
| | C | 21 C | 4 C | G-GY | 3 | 8.5 | |
| QM-1 | A | 22 B | 5 | G-GY | 3 | 17 | |
| | B | 23 B | 5 | G-GY | 3 | 17 | Slight organic odor |
| | C | 24 C | 5 | G-GY | 3 | 17 | " |
| QM-2 | A | 25 B | 5 | G-GY | 3 | 14.5 | |
| | B | 26 C | 5 | G-GY | 3 | 17 | |
| | C | 27 B | 4/5 M | G-GY | 3 | 17 | |
| Lalt 570 | A | 28 B | 4/5 M-F | G-GY | 3 | 14.5 | Slight leakage |
| | B | 29 C | 4/5 F | G-GY | 3 | 14 | |
| | C | 30 B | 4/5 F | G-GY | 3 | 11 | |
| Lalt 400E | A | 31 C | 4/5 M-F | G-GY | 3 | 17 | |
| | B | 32 B | 4/5 M | G-GY | 3 | 15 | Maldanidae present |
| | C | 33 B | 4/5 M | G-GY | 3 | 17 | Trace of 4 |
| Lalt 200E | A | 34 B | 4/5 C | G-GY | 3 | 16 | Maldanidae present |
| | B | 35 C | 4/5 C | G-GY | 3 | 17 | " |
| | C | 36 B | 4/5 C | G-GY | 3 | 17 | " |
| Lalt 75E | A | 37 B | 3/4 C | G-GY | 3 | 8 | Onuphid & Chaeto's |
| | B | 38 C | 3/4 C | G-GY | 3 | 9 | " |
| | C | 39 B | 2/3/4 C | G-GY | 3 | 9 | |
| Lalt 50E | A | 40 B | 2/3/4 C | G-GY | 3 | 8 | |
| | B | 41 C | 2/3/4 C | G-GY | 3 | 7 | |
| | C | 42 B | 2/3/4 C | G-GY | 3 | 6.5 | |

Appendix Table 7.2b. (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| K-50E | A | 43 B | 4 M | G-GY | 3 | 7 | Ptilosarcus |
| | B | 44 C | 4 M | G-GY | 3 | 11 | |
| | C | 45 B | 4 M | G-GY | 3 | 8 | |
| K-75E | A | 46 B | 4 M | G-GY | 3 | 9 | Sea whips |
| | B | 47 C | 4 M | G-GY | 3 | 8 | |
| | C | 48 B | 4 M | G-GY | 3 | 8 | |
| K-200E | A | 49 C | 4 M-F | G-GY | 3 | 8 | Ctenophora present |
| | B | 50 B | 4 M-F | G-GY | 3 | 9 | Some leakage |
| | C | 51 B | 4 M | G-GY | 3 | 11 | |
| K-400E | A | 52 B | 4/5 F | G-GY | 3 | 17 | Maldanidae |
| | B | 53 C | 4/5 F | G-GY | 3 | 17 | |
| | C | 54 B | 4/5 M-F | G-GY | 3 | 17 | Lt BWN surface |
| K-570 | A | 55 B | 5 | G-GY | 3 | 17 | 3 Molpadidae |
| | B | 56 C | 5 | G-GY | 3 | 17 | |
| | C | 57 B | 5 | G-GY | 3 | 17 | 1 Molpadidae |
| K-75W | A | 58 B | 2/4 C | G-GY | 3 | 8 | |
| | B | 59 C | 4 C | G-GY | 3 | 6 | |
| | C | 60 B | 4 M | G-GY | 3 | 6 | Diopatra & Chaeto's |
| K-50W | A | 61 B | 4 C-M | G-GY | 3 | 9 | |
| | B | 62 C | 4 M | G-GY | 3 | 8.5 | |
| | C | 63 B | 4 M | G-GY | 3 | 8 | |
| PB-1 | A | 64 B | 4 M-F | G-GY | 3 | 11 | |
| | B | 65 C | 4 M-F | G-GY | 3 | 10.5 | |
| | C | 66 B | 4 M-F | G-GY | 3 | 11 | |
| PB-2 | A | 67 B | 3/4 M-F | G-GY | 3 | 11 | Trace of 3 |
| | B | 68 B | 4 M-F | G-GY | 3 | 10 | |
| | C | 69 C | 4 M-F | G-GY | 3 | 7 | |
| PB-3 | A | 70 B | 4 M-F | G-GY | 3 | 6 | |
| | B | 71 C | 4 M-F | G-GY | 3 | 6 | |
| | C | 72 B | 4 M-F | G-GY | 3 | 10.5 | |
| PB-4 | A | 73 B | 3/4 M-F | G-GY | 3 | 9 | |
| | B | 74 C | 4 M-F | G-GY | 3 | 10 | |
| | C | 75 B | 4 M-F | G-GY | 3 | 10 | |
| J.5 50E | A | 76 B | 4 F | G-GY | 3 | 7 | |
| | B | 77 C | 4 F | G-GY | 3 | 10 | |
| | C | 78 B | 4 F | G-GY | 3 | 10 | |
| J.5 75E | A | 79 C | 4 M-F | G-GY | 3 | 9 | |
| | B | 80 B | 4 M-F | G-GY | 3 | 10 | |
| | C | 81 B | 4 F | G-GY | 3 | 10 | |
| J.5 250E | A | 82 C | 4 M | G-GY | 3 | 10 | Shell fragments |
| | B | 83 B | 4 M | G-GY | 3 | 10 | Lt BWN surface |
| | C | 84 B | 4 M | G-GY | 3 | 10 | |

Appendix Table 7.2b (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| J.5 400E | A | 85 B | 3/4/5 C | G-GY | 3 | 17 | Lt BWN surface |
| | B | 86 C | 3/4/5 C | G-GY | 3 | 17 | One corner washed |
| | C | 87 B | 3/4/5 C | G-GY | 3 | 17 | Lt BWN surface |
| J.5 520E | A | 88 B | 5 | G-GY | 3 | 17 | 1 Molpadidae |
| | B | 89 B | 5 | G-GY | 3 | 17 | 1 Molpadidae |
| | C | 90 C | 5 | G-GY | 3 | 17 | Lt BWN surface |
| J.5 600 | A | 91 B | 5 | G-GY | 3 | 17 | " |
| | B | 92 B | 5 | G-GY | 3 | 17 | " |
| | C | 93 C | 5 | G-GY | 3 | 17 | " |
| J.5 75W | A | 94 B | 3/4 M | G-GY | 3 | 10 | |
| | B | 95 C | 3/4 M | G-GY | 3 | 6 | |
| | C | 96 B | 3/4 M | G-GY | 3 | 6 | |
| J-75W | A | 97 B | 4 F | G-GY | 3 | 6.5 | Onuphid tubes |
| | B | 98 B | 4 F | G-GY | 3 | 9 | " |
| | C | 99 C | 4 F | G-GY | 3 | 9 | " |
| J-690 | A | 100 B | 5 | G-GY | 3 | 17 | Lt BWN surface |
| | B | 101 C | 5 | G-GY | 3 | 17 | " |
| | C | 102 B | 5 | G-GY | 3 | 17 | 5 Molpadidae |
| J-50E | A | 103 B | 4 M | G-GY | 3 | 11 | |
| | B | 104 C | 4 M | G-GY | 3 | 11 | |
| | C | 105 B | 4 M | G-GY | 3 | 10.5 | |
| J-75E | A | 106 B | 4 M-F | G-GY | 3 | 8 | |
| | B | 107 C | 4 M-F | G-GY | 3 | 9 | Shell fragments |
| | C | 108 B | 4 M-F | G-GY | 3 | 10 | |
| J-400E | A | 109 B | 2/3/4/5 C-M | G-GY | 3 | 17 | Lt BWN surface |
| | B | 110 C | 3/4/5 C-M | G-GY | 3 | 17 | " |
| | C | 111 B | 2/3/4/5 C-M | G-GY | 3 | 17 | " |
| J-600E | A | 112 B | 5 | G-GY | 3 | 17 | 1 Molpadidae |
| | B | 113 B | 5 | G-GY | 3 | 17 | 1 Brisaster |
| | C | 114 C | 5 | G-GY | 3 | 17 | |
| I-200E | A | 115 B | 2/3/5/4 C | G-GY | 3 | 8 | |
| | B | 116 C | 2/3/5/4 C | G-GY | 3 | 11 | |
| | C | 117 B | 2/3/5/4 C | G-GY | 3 | 9 | |
| I-400E | A | 118 B | 3/4 C-M | G-GY | 3 | 10 | |
| | B | 119 C | 3/4 C-M | G-GY | 3 | 10 | |
| | C | 120 B | 3/4 C-M | G-GY | 3 | 10 | |
| I-600E | A | 121 B | 3/4/5 C-M | G-GY | 3 | 10 | Lt BWN surface |
| | B | 122 C | 3/4/5 C-M | G-GY | 3 | 17 | " |
| | C | 123 B | 3/4/5 C-M | G-GY | 3 | 17 | |
| I-690 | A | 124 B | 5 | G-GY | 3 | 17 | 1 Travisia |
| | B | 125 C | 5 | G-GY | 3 | 17 | |
| | C | 126 B | 5 | G-GY | 3 | 17 | 1 Molpadidae |

Appendix Table 7.2b (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| I-75W | A | 127 B | 4 F | G-GY | 3 | 8 | Onuphidae present |
| | B | 128 C | 4 M-F | G-GY | 3 | 7.5 | |
| | C | 129 B | 4 M-F | G-GY | 3 | 7 | |
| I-50W | A | 130 B | 4 M-F | G-GY | 3 | 8 | |
| | B | 131 C | 4 M-F | G-GY | 3 | 8 | |
| | C | 132 B | 4 M-F | G-GY | 3 | 8 | |
| G-50W | A | 133 B | 4 F | G-GY | 3 | 7 | Onuphidae & Ulva |
| | B | 134 C | 4 F | G-GY | 3 | 7 | |
| | C | 135 B | 4 F | G-GY | 3 | 6 | |
| G-75W | A | 136 B | 4 F | G-GY | 3 | 7 | |
| | B | 137 C | 4 F | G-GY | 3 | 8 | |
| | C | 138 B | 4 F | G-GY | 3 | 8 | |
| F-50W | A | 139 B | 4 M-F | G-GY | 3 | 9 | |
| | B | 140 C | 4 M-F | G-GY | 3 | 7 | 1 Ptilosarcus |
| | C | 141 B | 4 M-F | G-GY | 3 | 8 | |
| F-75W | A | 142 B | 4 F | G-GY | 3 | 9 | Chaetopteridae |
| | B | 143 C | 4 F | G-GY | 3 | 8 | " and Ascidians |
| | C | 144 B | 4 F | G-GY | 3 | 7 | |
| H-75W | A | 145 B | 4 F | G-GY | 3 | 7 | |
| | B | 146 C | 4 F | G-GY | 3 | 7 | |
| | C | 147 B | 4 F | G-GY | 3 | 8 | |
| H-50W | A | 148 B | 4 F | G-GY | 3 | 11 | |
| | B | 149 C | 4 F | G-GY | 3 | 10 | |
| | C | 150 B | 4 F | G-GY | 3 | 11 | |
| H-640 | A | 151 B | 5 | G-GY | 3 | 17 | Lt BWN surface |
| | B | 152 B | 5 | G-GY | 3 | 17 | " |
| | C | 153 B | 5 | G-GY | 3 | 17 | " |
| | D | 154 C | 5 | G-GY | 3 | 17 | " |
| | E | 155 B | 5 | G-GY | 3 | 17 | " |
| | F | 156 B | 5 | G-GY | 3 | 17 | " |
| H-600E | A | 157 B | 5 | G-GY | 3 | 17 | |
| | B | 158 B | 5 | G-GY | 3 | 17 | Lt BWN surface |
| | C | 159 C | 5 | G-GY | 3 | 17 | |
| H-400E | A | 160 B | 3/4/5 C | G-GY | 3 | 17 | |
| | B | 161 C | 3/4/5 C | G-GY | 3 | 17 | |
| | C | 162 B | 3/4/5 C | G-GY | 3 | 17 | |
| H-75E | A | 163 B | 3/4 C | G-GY | 3 | 7 | Trace of 3 |
| | B | 164 C | 4 C | G-GY | 3 | 12 | Shell fragments |
| | C | 165 B | 3/4 C | G-GY | 3 | 12 | Trace of 3 |
| H-50E | A | 166 B | 4 C-M | G-GY | 3 | 7 | |
| | B | 167 C | 4 C-M | G-GY | 3 | 11 | |
| | C | 168 B | 4 C-M | G-GY | 3 | 11 | |

Appendix Table 7.2b. (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| G-50E | A | 169 B | 4 F | G-GY | 3 | 12 | |
| | B | 170 C | 4 F | G-GY | 3 | 10 | |
| | C | 171 B | 4 F | G-GY | 3 | 11 | |
| G-75E | A | 172 B | 4 F | G-GY | 3 | 10 | |
| | B | 173 B | 4 F | G-GY | 3 | 10 | |
| | C | 174 C | 4 F | G-GY | 3 | 10 | |
| G-200E | A | 175 B | 5/4 F | G-GY | 3 | 12 | Approx 30% 5 |
| | B | 176 C | 5/4 F | G-GY | 3 | 11 | " |
| | C | 177 B | 5/4 F | G-GY | 3 | 9 | " |
| G-400E | A | 178 B | 1/2/3/4/5-6 CMF | DO | 3 | 7 | 50/50 5 & 6 |
| | B | 179 B | 1/2/3/4/5-6 CMF | DO | 3 | 12 | 50/50 5 & 6 |
| | C | 180 C | 1/2/3/4/5-6 CMF | DO | 3 | 12 | " |
| G-600E | A | 181 B | 4/6/5 CMF | DO | 3 | 11 | |
| | B | 182 B | 4/6/5 CMF | DO | 3 | 9 | Clay=small round beads |
| | C | 183 C | 4/6/5 CMF | DO | 3 | 17 | |
| G-780 | A | 184 B | 5 | DO | 3 | 17 | Lt BWN surface |
| | B | 185 B | 5 | DO | 3 | 17 | " |
| | C | 186 C | 5 | DO | 3 | 17 | " |
| A-200E | A | 187 B | 2/3/5/4 C-M | DO | 3 | 8 | |
| | B | 188 B | 2/3/5/4 C-M | DO | 3 | 6 | Chaetopteridae |
| | C | 189 C | 2/3/5/4 C-M | DO | 3 | 5 | |
| A-400E | A | 190 B | 3/4/5 CMF | DO | 3 | 12 | |
| | B | 191 C | 3/4/5 CMF | DO | 3 | 13 | |
| | C | 192 B | 3/4/5 CMF | DO | 3 | 15 | |
| A-600E | A | 193 B | 5 | DO | 3 | 8 | |
| | B | 194 B | 5 | DO | 3 | 8 | |
| | C | 195 C | 5 | DO | 3 | 8 | |
| A-720 | A | 196 B | 5 | DO | 3 | 15 | |
| | B | 197 C | 5 | DO | 3 | 16 | |
| | C | 198 B | 5 | DO | 3 | 17 | |
| A-400W | A | 199 B | 5 | DO | 3 | 15 | |
| | B | 200 B | 5 | DO | 3 | 16 | |
| | C | 201 C | 5 | DO | 3 | 16 | |
| A-200W | A | 202 B | 1/2/4 MF | DO | 3 | 7 | Shell fragments |
| | B | 203 C | 1/2/4 MF | DO | 3 | 8 | |
| | C | 204 B | 1/2/4 MF | DO | 3 | 7 | Chaetop & shell frags |
| N-50W | A | 205 B | 4 CMF | DO | 3 | 10 | |
| | B | 206 C | 4 CMF | DO | 3 | 9 | |
| | C | 207 B | 4 CMF | DO | 3 | 9 | |
| N-75W | A | 208 B | 4 M-F | B-BWN | 3 | 8 | |
| | B | 209 B | 4 M-F | B-BWN | 3 | 7 | |
| | C | 210 C | 4 M-F | B-BWN | 3 | 8 | |
| N-200E | A | 211 C | 2/3/4 CMF | B/BWN | 3 | 7.5 | |
| | B | 212 B | 2/3/4 CMF | B/BWN | 3 | 6 | |
| | C | 213 B | 2/3/4 CMF | B/BWN | 3 | 9 | |

Appendix Table 7.2b. (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| N-75E | A | 214 B | 3/4 CMF | DO/BWN | 3 | 7 | |
| | B | 215 B | 4 MF | DO/BWN | 3 | 7 | |
| | C | 216 C | 4 CMF | DO/BWN | 3 | 7 | |
| N-50E | A | 217 B | 4 M-F | GY-BWN | 3 | 7.5 | Chaetopteridae |
| | B | 218 C | 4 M-F | GY-BWN | 3 | 8 | " |
| | C | 219 B | 4 M-F | GY-BWN | 3 | 12.5 | " |
| A-50W | A | 220 B | 4 M-F | GY-BWN | 3 | 15 | |
| | B | 221 B | 4 M-F | GY-BWN | 3 | 10.5 | |
| | C | 222 C | 4 M-F | GY-BWN | 3 | 12 | |
| B-50W | A | 223 B | 4 M-F | GY-BWN | 3 | 8 | Chaetopteridae |
| | B | 224 C | 4 M-F | GY-BWN | 3 | 6 | Palastichopus in grab |
| | C | 225 B | 4 C-M | GY-BWN | 3 | 9 | Sea pens |
| B-75W | A | 226 B | 2/3/4 CMF | GY/B/BWN | 3 | 5 | Shell fragments |
| | B | 227 B | 2/3/4 CMF | GY/B/BWN | 3 | 5 | " |
| | C | 228 C | 2/3/4 CMF | GY/B/BWN | 3 | 6 | |
| B-660 | A | 229 B | 5 | DO | 3 | 11 | |
| | B | 230 C | 5 | DO | 3 | 11 | |
| | C | 231 B | 5 | DO | 3 | 15 | |
| B-600E | A | 232 B | 5 | DO | 3 | 14 | |
| | B | 233 C | 5 | DO | 3 | 14 | |
| | C | 234 B | 5 | DO | 3 | 17 | |
| B-400E | A | 235 B | 3/4/5-6 MF | DO | 3 | 9 | Clay balls |
| | B | 236 B | 3/4/5-6 MF | DO | 3 | 15 | " |
| | C | 237 C | 3/4/5-6 MF | DO | 3 | 5 | |
| B-50E | A | 238 B | 4 MF | GY/B | 3 | 9 | |
| | B | 239 B | 3/7/4 CM | DO/GY | 3 | 7 | |
| | C | 240 C | 4 CM | GY | 3 | 4 | Some leakage |
| B-200E | A | 241 B | 2/3/4 C | BWN | 3 | 9 | Chaetopteridae |
| | B | 242 B | 2/3/4 CM | BWN | 3 | 11 | " |
| | C | 243 C | 2/3/4 CM | BWN | 3 | 9 | " |
| C-50E | A | 244 B | 4 MF | GY-BWN | 3 | 9 | |
| | B | 245 C | 4 MF | GY-BWN | 3 | 6 | Ptilosarcus |
| | C | 246 B | 4 MF | GY-B | 3 | 10.5 | |
| C-75E | A | 247 B | 4 MF | GY/B | 3 | 8 | |
| | B | 248 B | 4 MF | GY/B | 3 | 9 | |
| | C | 249 C | 4 MF | GY-B | 3 | 3 | Ptilosarcus |
| C-200E | A | 250 C | 2/3/4 CM | GY-B | 3 | 3 | |
| | B | 251 B | 2/3/4/5 CM | GY-B | 3 | 8 | |
| | C | 252 B | 2/3/4 CM | GY-B | 3 | 11 | |
| C-400E | A | 253 B | 5/4 F | DO | 3 | 17 | Lt BWN surface |
| | B | 254 B | 2/3/5/4 F | DO | 3 | 11.5 | Lt BWN surface |
| | C | 255 C | 2/3/5/4 CMF | DO | 3 | 15.5 | Lt BWN surface |
| C-50W | A | 256 B | 4 MF | GY-BWN | 3 | 7.5 | |
| | B | 257 B | 4 MF | GY-BWN | 3 | 11 | |
| | C | 258 C | 4 MF | GY-BWN | 3 | 10 | |

Appendix Table 7.2b. (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| C-75W | A | 259 B | 4 MF | GY-BWN | 3 | 10 | Chaeto & Onuphiidae |
| | B | 260 B | 4 MF | GY-BWN | 3 | 11 | " |
| | C | 261 C | 4 MF | GY-BWN | 3 | 10 | " |
| D-50W | A | 262 B | 4 MF | GY-BWN | 3 | 10 | |
| | B | 263 C | 4 MF | GY-BWN | 3 | 9 | |
| | C | 264 B | 4 MF | GY-BWN | 3 | 9 | |
| D-75W | A | 265 B | 4 MF | GY-BWN | 3 | 9 | |
| | B | 266 C | 4 MF | GY-BWN | 3 | 9.5 | |
| | C | 267 B | 4 MF | GY-BWN | 3 | 11 | |
| E-50E | A | 268 B | 4 MF | GY-BWN | 3 | 9 | |
| | B | 269 B | 4 MF | GY-BWN | 3 | 9 | |
| | C | 270 C | 4 MF | GY-BWN | 3 | 8 | |
| C-640 | A | 271 B | 5 | DO | 3 | 16 | |
| | B | 272 B | 5 | DO | 3 | 15 | |
| | C | 273 C | 5 | DO | 3 | 17 | |
| C-600E | A | 274 B | 5 | DO | 3 | 17 | Lt BWN surface |
| | B | 275 B | 5 | DO | 3 | 15 | " |
| | C | 276 C | 5 | DO | 3 | 17 | " |
| OT-1 | A | 277 B | 5 | DO | 3 | 17 | " |
| | B | 278 C | 5 | DO | 3 | 17 | " |
| | C | 279 B | 5 | DO | 3 | 17 | " |
| | D | 280 B | 5 | DO | 3 | 17 | " |
| | E | 281 B | 5 | DO | 3 | 17 | " |
| | F | 282 B | 5 | DO | 3 | 17 | " |
| OT-2 | A | 283 B | 5 | DO | 3 | 17 | " |
| | B | 284 C | 5 | DO | 3 | 17 | " |
| | C | 285 B | 5 | DO | 3 | 17 | " |
| | D | 286 B | 5 | DO | 3 | 15 | " |
| | E | 287 B | 5 | DO | 3 | 17 | " |
| | F | 288 B | 5 | DO | 3 | 14 | " |
| D-250E | A | 289 B | 5/4 MF | GY/G | 3 | 10 | Trace of 5 |
| | B | 290 C | 6/4 MF | GY/G | 3 | 6 | Trace of 6 |
| | C | 291 B | 3/5/6/4 MF | GY/G | 3 | 10 | Trace of 3,5,6 |
| | D | 292 B | 3/5/6/4 MF | GY/G | 3 | 9 | " |
| | E | 293 B | 3/5/6/4 MF | GY/G | 3 | 10.5 | " |
| | F | 294 B | 3/5/6/4 MF | GY/G | 3 | 11 | " |
| D-660 | A | 295 B | 5 | DO | 3 | 17 | Lt BWN surface |
| | B | 296 C | 5 | DO | 3 | 17 | " |
| | C | 297 B | 5 | DO | 3 | 17 | " |
| E-50W | A | 298 B | 4 MF | GY-BWN | 3 | 10 | |
| | B | 299 B | 4 MF | GY-BWN | 3 | 11 | |
| | C | 300 C | 4 MF | GY-BWN | 3 | 9.5 | |
| E-75W | A | 301 B | 5/4 F | B-BWN | 3 | 8.5 | |
| | B | 302 B | 5/4 F | B-BWN | 3 | 8 | |
| | C | 303 C | 5/4 F | B-BWN | 3 | 7.5 | |

Appendix Table 7.2b. (continued)

| Station | Rep | Code | Sediment type | Color | Odor | Pen depth (cm) | Comments |
|---|---|---|---|---|---|---|---|
| E-750 | A | 304 B | 5 | DO | 3 | 17 | Lt BWN surface |
| | B | 305 B | 5 | DO | 3 | 17 | " |
| | C | 306 C | 5 | DO | 3 | 17 | " |
| E-600E | A | 307 B | 6/5 | DO | 3 | 17 | " |
| | B | 308 C | 6/5 | DO | 3 | 17 | " |
| | C | 309 B | 6/5 | DO | 3 | 17 | " |
| E-200E | A | 310 B | 5/4 MF | DO | 3 | 10 | |
| | B | 311 B | 5/4 MF | DO | 3 | 12 | |
| | C | 312 C | 5/4 MF | DO | 3 | 11 | |
| E-75E | A | 313 B | 4 MF | DO | 3 | 12 | Chaetopteridae |
| | B | 314 C | 4 MF | DO | 3 | 9 | " |
| | C | 315 B | 4 MF | DO | 3 | 9 | " |
| D-75E | A | 316 B | 4 MF | DO | 3 | 10 | |
| | B | 317 C | 4 MF | DO | 3 | 10 | |
| | C | 318 B | 4 MF | DO | 3 | 13 | |
| D-50E | A | 319 B | 4 MF | DO | 3 | 11 | |
| | B | 320 B | 4 MF | DO | 3 | 13 | |
| | C | 321 C | 4 MF | DO | 3 | 10 | |
| F-200E | A | 322 C | 4 CMF | DO | 3 | 9 | Lt BWN surface |
| | B | 323 B | 2/4 CMF | DO | 3 | 10 | " |
| | C | 324 B | 2/4 CMF | DO | 3 | 8 | " |
| F-600E | A | 325 B | 3/4/6/5 CMF | G-BWN | 3 | 11 | |
| | B | 326 C | 3/4/6/5 CMF | G-BWN | 3 | 11 | |
| | C | 327 B | 3/6/5/4 CMF | G-BWN | 3 | 13 | |
| F-780 | A | 328 C | 6/5-4 MF | G-BWN | 3 | 17 | |
| | B | 329 B | 6/5-4 MF | G-BWN | 3 | 17 | |
| | C | 330 B | 6/5-4 MF | G-BWN | 3 | 17 | |

*Key to Code column:
Number = sequence sample taken
B = biological sample
C = chemical sample

Key to Sediment Type:
1 = Rock
2 = Cobble
3 = Gravel
4 = Sand
5 = Silt
6 = Clay
7 = Wood chips
C = Coarse sand
M = Medium sand
F = Fine sand

Key to Sediment Color:
DO = Drab olive
DOS = Drab olive surface
G = Green
GY = Grey
B = Black
BWN = Brown

Appendix Table 7.2b. (continued)

Key to Sediment Odor:
1 = Has smell
2 = Petroleum smell
3 = No smell

Key to Grades of Odor:
A = Slight
B = Moderate
C = Strong
D = Overwhelming

When a slash separates two or more sediment or color types, the last number or latter is the dominant type, the first being modifiers. A dash separating two types indicates equal amounts of each. Examples:

| | |
|---|---|
| 4/5 C | Sandy silt with coarse sand |
| 3/4 C/M-F | Sand with some gravel; equal amounts of medium and fine sand with a smaller fraction of coarse sand |
| GY-G | A grey-green color |

Appendix Table 7.2c. Summary of Baseline Subtidal Station Locations.

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| L.5 200 E | A | 1 B | 20 Sept 82 | 200 | 27887.1 | 42252.9 | 1100 |
| | B | 2 B | 20 Sept 82 | 200 | 27887.1 | 42252.9 | 1120 |
| | C | 3 C | 20 Sept 82 | 200 | 27887.1 | 42252.8 | 1130 |
| L.5 400 E | A | 4 B | 20 Sept 82 | 400 | 27888.3 | 42252.1(2) | 1218 |
| | B | 5 | 20 Sept 82 | 400 | 27888.3 | 42252.1 | 1235 |
| | C | 6 B | 20 Sept 82 | 388 | 27888.4 | 42252.1 | 1248 |
| L.5 550 | A | 7 B | 20 Sept 82 | 531 | 27891.0(90.9) | 42249.2 | 1300 |
| | B | 8 B | 20 Sept 82 | 525 | 27891.0(90.9) | 42249.1 | 1315 |
| | C | 9 C | 20 Sept 82 | 531 | 27891.0(90.9) | 42249.2 | 1320 |
| L.5 400 W | A | 10 B | 20 Sept 82 | 400 | 27893.6(7) | 42244.7 | 1350 |
| | B | 11 C | 20 Sept 82 | 400 | 27893.6(7) | 42244.7 | 1400 |
| | C | 12 B | 20 Sept 82 | 400 | 27893.6(7) | 42244.7 | 1415 |
| M-200 | A | 13 B | 20 Sept 82 | 195 | 27919.1 | 42240.4 | 1635 |
| | B | 14 B | 20 Sept 82 | 192 | 27919.1 | 42240.4 | 1645 |
| | C | 15 C | 20 Sept 82 | 195 | 27919.1 | 42240.4 | 1651 |
| Lalt 50 W | A | 16 B | 20 Sept 82 | 52 | 27904.4 | 42256.0 | 1730 |
| | B | 17 C | 20 Sept 82 | 49 | 27904.4(3) | 42256.0 | 1735 |
| | C | 18 B | 20 Sept 82 | 48 | 27904.4 | 42256.9 | 1743 |
| Lalt 75 W | A | 19 B | 20 Sept 82 | 72 | 27903.9 | 42256.1 | 1750 |
| | B | 20 B | 20 Sept 82 | 73 | 27904.1 | 42256.9 | 1800 |
| | C | 21 C | 20 Sept 82 | 80 | 27903.9 | 42256.0 | 1809 |
| QM-1 | A | 22 B | 21 Sept 82 | 22 | 27928.3 | 42260.0 | 0805 |
| | B | 23 B | 21 Sept 82 | 22 | 27928.3 | 42260.0 | 0810 |
| | C | 24 C | 21 Sept 82 | 22 | 27928.2(3) | 42260.1 | 0815 |
| QM-2 | A | 25 B | 21 Sept 82 | 55 | 27923.0 | 42255.3 | 0840 |
| | B | 26 C | 21 Sept 82 | 55 | 27923.0 | 42255.5(4) | 0845 |
| | C | 27 B | 21 Sept 82 | 55 | 27923.0 | 42255.5(4) | 0900 |
| Lalt 570 | A | 28 B | 21 Sept 82 | 567 | 27896.0(95.6) | 42255.3 | 0945 |
| | B | 29 C | 21 Sept 82 | 567 | 27895.9 | 42255.4 | 1015 |
| | C | 30 B | 21 Sept 82 | 567 | 27896.0 | 42255.4 | 1030 |
| Lalt 400 E | A | 31 C | 21 Sept 82 | 400 | 27889.3(2) | 42255.3 | 1050 |
| | B | 32 B | 21 Sept 82 | 417 | 27889.3 | 42255.1(2) | 1100 |
| | C | 33 B | 21 Sept 82 | 396 | 27889.2 | 42255.3 | 1110 |
| Lalt 200 E | A | 34 B | 21 Sept 82 | 192 | 27887.2 | 42255.1(0) | 1120 |
| | B | 35 C | 21 Sept 82 | 198 | 27887.3 | 42255.0 | 1138 |
| | C | 36 B | 21 Sept 82 | 198 | 27887.3(4) | 42255.1 | 1153 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| Lalt 75 E | A | 37 B | 21 Sept 82 | 75 | 27886.2(1) | 42255.0 | 1200 |
| | B | 38 C | 21 Sept 82 | 74 | 27886.1 | 42254.9 | 1210 |
| | C | 39 B | 21 Sept 82 | 74 | 27886.1 | 42254.9 | 1230 |
| Lalt 50 E | A | 40 B | 21 Sept 82 | 52 | 27885.8(9) | 42255.1 | 1238 |
| | B | 41 C | 21 Sept 82 | 51 | 27885.8 | 42255.1 | 1245 |
| | C | 42 B | 21 Sept 82 | 53 | 27885.9 | 42255.0 | 1250 |
| K-50 E | A | 43 B | 21 Sept 82 | 52 | 27881.2(1) | 42268.9 | 1345 |
| | B | 44 C | 21 Sept 82 | 50 | 27881.2(1) | 42269.0 | 1350 |
| | C | 45 B | 21 Sept 82 | 51 | 27881.2 | 42268.9 | 1358 |
| K-75 E | A | 46 B | 21 Sept 82 | 75 | 27881.5 | 42268.7(8) | 1405 |
| | B | 47 C | 21 Sept 82 | 75 | 27881.5 | 42268.8 | 1410 |
| | C | 48 B | 21 Sept 82 | 75 | 27881.5 | 42268.9 | 1416 |
| K-200 E | A | 49 C | 21 Sept 82 | 216 | 27882.8 | 42269.0 | 1440 |
| | B | 50 B | 21 Sept 82 | 200 | 27882.9 | 42269.0 | 1450 |
| | C | 51 B | 21 Sept 82 | 200 | 27882.9 | 42268.9 | 1500 |
| K-400 E | A | 52 B | 21 Sept 82 | 400 | 27883.5 | 42269.0 | 1515 |
| | B | 53 C | 21 Sept 82 | 408 | 27883.5 | 42268.9 | 1530 |
| | C | 54 B | 21 Sept 82 | 408 | 27883.6 | 42269.0 | 1544 |
| K-570 | A | 55 B | 21 Sept 82 | 567 | 27894.1 | 42265.0 | 1614 |
| | B | 56 C | 21 Sept 82 | 567 | 27894.0 | 42265.0(1) | 1625 |
| | C | 57 B | 21 Sept 82 | 567 | 27894.1 | 42265.0 | 1640 |
| K-75 W | A | 58 B | 21 Sept 82 | 78 | 27907.6 | 42262.7 | 1658 |
| | B | 59 C | 21 Sept 82 | 74 | 27907.4(5) | 42262.7 | 1705 |
| | C | 60 B | 21 Sept 82 | 72 | 27907.5 | 42262.8 | 1710 |
| K-50 W | A | 61 B | 21 Sept 82 | 50 | 27907.5(6) | 42262.7 | 1721 |
| | B | 62 C | 21 Sept 82 | 51 | 27907.5 | 42262.7(8) | 1736 |
| | C | 63 B | 21 Sept 82 | 52 | 27907.5(6) | 42262.7(8) | 1740 |
| PB-1 | A | 64 B | 22 Sept 82 | 180 | 27879.9 | 42277.0 | 0843 |
| | B | 65 C | 22 Sept 82 | 180 | 27879.0 | 42277.0 | 0900 |
| | C | 66 B | 22 Sept 82 | 180 | 27879.0 | 42277.0 | 0908 |
| PB-2 | A | 67 B | 22 Sept 82 | 183 | 27875.7 | 42276.7(8) | 0925 |
| | B | 68 B | 22 Sept 82 | 180 | 27875.7 | 42276.9 | 0940 |
| | C | 69 C | 22 Sept 82 | 176 | 27875.7 | 42276.8 | 0950 |
| PB-3 | A | 70 B | 22 Sept 82 | 180 | 27879.4(3) | 42273.1 | 1007 |
| | B | 71 C | 22 Sept 82 | 178 | 27879.4(3) | 42273.0 | 1012 |
| | C | 72 B | 22 Sept 82 | 183 | 27879.4(3) | 42273.0 | 1020 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| PB-4 | A | 73 B | 22 Sept 82 | 180 | 27880.9(8) | 42270.5 | 1035 |
| | B | 74 C | 22 Sept 82 | 178 | 27880.8 | 42270.4 | 1045 |
| | C | 75 B | 22 Sept 82 | 180 | 27880.9(8) | 42270.4 | 1055 |
| J.5-50 E | A | 76 B | 22 Sept 82 | 53 | 27875.1 | 42274.9 | 1117 |
| | B | 77 C | 22 Sept 82 | 52 | 27875.1 | 42274.8 | 1120 |
| | C | 78 B | 22 Sept 82 | 50 | 27875.1 | 42274.7 | 1135 |
| J.5 75 E | A | 79 C | 22 Sept 82 | 77 | 27875.4 | 42274.9(8) | 1138 |
| | B | 80 B | 22 Sept 82 | 77 | 27875.4 | 42275.0 | 1145 |
| | C | 81 B | 22 Sept 82 | 77 | 27875.4 | 42274.9 | 1148 |
| J.5 250 E | A | 82 C | 22 Sept 82 | 246 | 27876.4(5) | 42275.1 | 1248 |
| | B | 83 B | 22 Sept 82 | 250 | 27876.5 | 42275.2 | 1310 |
| | C | 84 B | 22 Sept 82 | 255 | 27876.4 | 42275.1 | 1317 |
| J.5 400 E | A | 85 B | 22 Sept 82 | 400 | 27877.9 | 42275.0 | 1335 |
| | B | 86 C | 22 Sept 82 | 400 | 27877.8 | 42274.9 | 1342 |
| | C | 87 B | 22 Sept 82 | 396 | 27877.7 | 42275.0 | 1355 |
| J.5 520 E | A | 88 B | 22 Sept 82 | 522 | 27881.6(5) | 42275.4 | 1415 |
| | B | 89 B | 22 Sept 82 | 522 | 27881.6 | 42275.3 | 1425 |
| | C | 90 C | 22 Sept 82 | 522 | 27881.5 | 42275.4 | 1451 |
| J.5 600 | A | 91 B | 22 Sept 82 | 600 | 27892.3 | 42274.0(9) | 1525 |
| | B | 92 B | 22 Sept 82 | 597 | 27892.3 | 42274.1 | 1535 |
| | C | 93 C | 22 Sept 82 | 600 | 27892.3 | 42274.1 | 1550 |
| J.5 75 W | A | 94 B | 22 Sept 82 | 72 | 27906.0 | 42267.0 | 1615 |
| | B | 95 C | 22 Sept 82 | 71 | 27906.0 | 42267.1 | 1620 |
| | C | 96 B | 22 Sept 82 | 74 | 27906.0(1) | 42267.1 | 1630 |
| J-75 W | A | 97 B | 22 Sept 82 | 77 | 27903.9(8) | 42274.0 | 1719 |
| | B | 98 B | 22 Sept 82 | 75 | 27903.9 | 42273.9 | 1727 |
| | C | 99 C | 22 Sept 82 | 77 | 27904.0 | 42273.9 | 1740 |
| J-690 | A | 100 B | 22 Sept 82 | 680 | 27899.1 | 42276.4 | 1800 |
| | B | 101 C | 22 Sept 82 | 684 | 27899.1 | 42276.2 | 1820 |
| | C | 102 B | 22 Sept 82 | 684 | 27899.1 | 42276.3 | 1840 |
| J-50 E | A | 103 B | 23 Sept 82 | 53 | 27894.1 | 42280.8 | 0835 |
| | B | 104 C | 23 Sept 82 | 50 | 27894.0 | 42280.8 | 0840 |
| | C | 105 B | 23 Sept 82 | 53 | 27894.0 | 42280.8 | 0849 |
| J-75 E | A | 106 B | 23 Sept 82 | 75 | 27894.3 | 42280.7 | 0900 |
| | B | 107 C | 23 Sept 82 | 77 | 27894.3 | 42280.6 | 0905 |
| | C | 108 B | 23 Sept 82 | 78 | 27894.4(3) | 42280.6(7) | 0910 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| J-400 E | A | 109 B | 23 Sept 82 | 414 | 27895.2(1) | 42279.7 | 0930 |
| | B | 110 C | 23 Sept 82 | 414 | 27895.2(1) | 42279.7 | 0940 |
| | C | 111 B | 23 Sept 82 | 414 | 27895.2 | 42279.7 | 0957 |
| J-600 E | A | 112 B | 23 Sept 82 | 606 | 27895.8(7) | 42270.3 | 1010 |
| | B | 113 B | 23 Sept 82 | 606 | 27895.9(8) | 42279.3 | 1023 |
| | C | 114 C | 23 Sept 82 | 606 | 27895.9(8) | 42279.3 | 1035 |
| I-200 E | A | 115 B | 23 Sept 82 | 210 | 27911.6 | 42279.8 | 1115 |
| | B | 116 C | 23 Sept 82 | 192 | 27911.7 | 42279.8 | 1121 |
| | C | 117 B | 23 Sept 82 | 207 | 27911.7 | 42279.8 | 1135 |
| I-400 E | A | 118 B | 23 Sept 82 | 408 | 27911.8 | 42279.5 | 1206 |
| | B | 119 C | 23 Sept 82 | 396 | 27911.8 | 42279.5 | 1215 |
| | C | 120 B | 23 Sept 82 | 400 | 27911.7(8) | 42279.5 | 1238 |
| I-600 E | A | 121 B | 23 Sept 82 | 612 | 27911.6 7 | 42279.0 | 1315 |
| | B | 122 C | 23 Sept 82 | 596 | 27911.7 | 42279.0 | 1330 |
| | C | 123 B | 23 Sept 82 | 600 | 27911.8(7) | 42279.0 | 1345 |
| I-690 | A | 124 B | 23 Sept 82 | 684 | 27910.7(8) | 42276.0 | 1400 |
| | B | 125 C | 23 Sept 82 | 684 | 27910.6(7) | 42276.0 | 1415 |
| | C | 126 B | 23 Sept 82 | 684 | 27910.6 | 42276.0 | 1424 |
| I-75 W | A | 127 B | 23 Sept 82 | 73 | 27912.8 | 42271.7 | 1445 |
| | B | 128 C | 23 Sept 82 | 78 | 27912.9 | 42271.7 | 1455 |
| | C | 129 B | 23 Sept 82 | 78 | 27912.8 | 42271.8 | 1500 |
| I-50 W | A | 130 B | 23 Sept 82 | 45 | 27912.8 | 42271.8 | 1510 |
| | B | 131 C | 23 Sept 82 | 48 | 27912.8 | 42271.8 | 1514 |
| | C | 132 B | 23 Sept 82 | 48 | 27912.9 | 42271.8 | 1523 |
| G-50 W | A | 133 B | 23 Sept 82 | 55 | 27931.5 | *42267.9 | 1600 |
| | B | 134 C | 23 Sept 82 | 54 | 27931.4 | *42268.2 | 1615 |
| | C | 135 B | 23 Sept 82 | 50 | 27931.5 | *42267.7 | 1625 |
| G-75 W | A | 136 B | 23 Sept 82 | 74 | 27931.4(5) | *42268.2 | 1632 |
| | B | 137 C | 23 Sept 82 | 74 | 27931.5 | *42267.9 | 1637 |
| | C | 138 B | 23 Sept 82 | 70 | 27931.5 | *42268.3 | 1642 |
| F-50 W | A | 139 B | 23 Sept 82 | 51 | 27940.4(5) | 42267.8 | 1710 |
| | B | 140 C | 23 Sept 82 | 50 | 27040.4 | 42267.8 | 1715 |
| | C | 141 B | 23 Sept 82 | 49 | 27940.5 | 42267.9 | 1725 |
| F-75 | A | 142 B | 23 Sept 82 | 74 | 27940.4(5) | 42268.0 | 1732 |
| | B | 143 C | 23 Sept 82 | 76 | 27940.5(6) | 42268.0 | 1740 |
| | C | 144 B | 23 Sept 82 | 77 | 27940.4(5) | 42268.0 | 1749 |

*Weak signal for this Loran - range fix used

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| H-75 W | A | 145 B | 23 Sept 82 | 73 | 27927.3(4) | 42265.8 | 1805 |
| | B | 146 C | 23 Sept 82 | 73 | 27927.3 | 42266.1 | 1812 |
| | C | 147 B | 23 Sept 82 | 78 | 27927.2 | 42266.0 | 1817 |
| H-50 W | A | 148 B | 23 Sept 82 | 51 | 27927.2 | 42265.6 | 1825 |
| | B | 149 C | 23 Sept 82 | 52 | 27927.3 | 42265.7 | 1829 |
| | C | 150 B | 23 Sept 82 | 52 | 27927.3 | 42265.6 | 1835 |
| H-640 | A | 151 B | 24 Sept 82 | 630 | *27927.7 | 42274.2 | 0915 |
| | B | 152 B | 24 Sept 82 | 630 | *27925.8 | 42274.2 | 0935 |
| | C | 153 B | 24 Sept 82 | 630 | *27925.8 | 42274.3(1) | 0945 |
| | D | 154 C | 24 Sept 82 | 630 | *27925.8(7) | 42274.2 | 0955 |
| | E | 155 B | 24 Sept 82 | 630 | *27925.8(7) | 42274.1 | 1010 |
| | F | 156 B | 24 Sept 82 | 630 | *27925.8 | 42274.1 | 1015 |
| H-600 E | A | 157 B | 24 Sept 82 | 597 | 27923.7(8) | 42276.8 | 1100 |
| | B | 158 B | 24 Sept 82 | 594 | 27923.7 | 42276.9 | 1116 |
| | C | 159 C | 24 Sept 82 | 597 | 27923.8 | 42276.8 | 1122 |
| H-400 E | A | 160 B | 24 Sept 82 | 400 | 27924.0(1) | 42279.8 | 1140 |
| | B | 161 C | 24 Sept 82 | 396 | 27924.0 | 42279.7 | 1150 |
| | C | 162 B | 24 Sept 82 | 390 | 27923.0(1) | 42279.8 | 1158 |
| H-75 E | A | 163 B | 24 Sept 82 | 75 | 27923.2(3) | 42280.7 | 1208 |
| | B | 164 C | 24 Sept 82 | 80 | 27923.2 | 42280.8 | 1215 |
| | C | 165 B | 24 Sept 82 | 76 | 27923.3 | 42280.8 | 1230 |
| H-50 E | A | 166 B | 24 Sept 82 | 52 | 27923.3 | 42280.7 | 1242 |
| | B | 167 C | 24 Sept 82 | 53 | 27923.4 | 42280.8 | 1245 |
| | C | 168 B | 24 Sept 82 | 50 | 27923.3 | 42280.7 | 1251 |
| G-50 E | A | 169 B | 24 Sept 82 | 55 | 27929.2 | 42279.4 | 1312 |
| | B | 170 C | 24 Sept 82 | 55 | 27929.2 | 42279.4 | 1318 |
| | C | 171 B | 24 Sept 82 | 56 | 27929.1(2) | 42279.4 | 1322 |
| G-75 E | A | 172 B | 24 Sept 82 | 72 | 27929.3 | 42279.3(4) | 1347 |
| | B | 173 B | 24 Sept 82 | 76 | 27929.3(4) | 42279.3 | 1352 |
| | C | 174 C | 24 Sept 82 | 70 | 27929.4 | 42279.3 | 1356 |
| G-200 E | A | 175 B | 24 Sept 82 | 200 | 27929.7(8) | 42278.7(6) | 1405 |
| | B | 176 C | 24 Sept 82 | 186 | 27929.8 | 42278.6 | 1423 |
| | C | 177 B | 24 Sept 82 | 192 | 27929.6(7) | 42278.6(5) | 1456 |
| G-400 E | A | 178 B | 4 Oct 82 | 396 | 27928.9 | 42277.6 | 0900 |
| | B | 179 B | 4 Oct 82 | 396 | 27928.9 | 42277.6 | 1045 |
| | C | 180 C | 4 Oct 82 | 417 | 27928.8 | 42277.7 | 1055 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| G-600 E | A | 181 B | 4 Oct 82 | 600 | 27928.5 | 42277.3 | 1120 |
| | B | 182 B | 4 Oct 82 | 588 | 27928.5 | 42277.2 | 1135 |
| | C | 183 C | 4 Oct 82 | 594 | 27928.4 | 42277.1 | 1145 |
| G-780 | A | 184 B | 4 Oct 82 | 696 | 27928.2(1) | 42275.4 | 1230 |
| | B | 185 B | 4 Oct 82 | 684 | 27928.1 | 42275.3 | 1245 |
| | C | 186 C | 4 Oct 82 | 684 | 27928.1 | 42275.3 | 1257 |
| A-200 E | A | 187 B | 4 Oct 82 | 204 | 27975.7 | 42283.8 | 1422 |
| | B | 188 B | 4 Oct 82 | 204 | 27975.7 | 42283.8 | 1435 |
| | C | 189 C | 4 Oct 82 | 195 | 27975.7 | 42283.8 | 1447 |
| A-400 E | A | 190 B | 4 Oct 82 | 400 | 27977.1 | 42283.8 | 1455 |
| | B | 191 C | 4 Oct 82 | 396 | 27977.0 | 42283.8 | 1505 |
| | C | 192 B | 4 Oct 82 | 400 | 27977.0 | 42283.8 | 1518 |
| A-600 E | A | 193 B | 4 Oct 82 | 555 | 27977.4 | 42283.2 | 1531 |
| | B | 194 B | 4 Oct 82 | 555 | 27977.4 | 42283.0 | 1544 |
| | C | 195 C | 4 Oct 82 | 555 | 27977.4 | 42283.2 | 1620 |
| A-720 | A | 196 B | 4 Oct 82 | 700 | 27980.1 | 42277.4 | 1650 |
| | B | 197 C | 4 Oct 82 | 708 | 27980.1 | 42277.3 | 1702 |
| | C | 198 B | 4 Oct 82 | 714 | 27980.0 | 42277.3 | 1728 |
| A-400 W | A | 199 B | 4 Oct 82 | 400 | 27982.5 | 42273.9 | 1755 |
| | B | 200 B | 4 Oct 82 | 400 | 27982.4 | 42273.9 | 1805 |
| | C | 201 C | 4 Oct 82 | 393 | 27982.5 | 42273.9 | 1814 |
| A-200 W | A | 202 B | 4 Oct 82 | 207 | 27984.3 | 42271.3 | 1832 |
| | B | 203 C | 4 Oct 82 | 200 | 27984.3 | 42271.1 | 1837 |
| | C | 204 B | 4 Oct 82 | 195 | 27984.4 | 42271.2 | 1844 |
| N-50 W | A | 205 B | 5 Oct 82 | 52 | 27981.5 | 42259.0 | 0821 |
| | B | 206 C | 5 Oct 82 | 55 | 27981.5 | 42259.1 | 0832 |
| | C | 207 B | 5 Oct 82 | 55 | 27981.4 | 42259.0 | 0845 |
| N-75 W | A | 208 B | 5 Oct 82 | 73 | 27981.3 | 42259.1 | 0855 |
| | B | 209 B | 5 Oct 82 | 75 | 27981.4 | 42259.1 | 0910 |
| | C | 210 C | 5 Oct 82 | 78 | 27981.3 | 42259.2 | 0917 |
| N-200 E | A | 211 C | 5 Oct 82 | 198 | 27976.1 | 42263.4 | 0945 |
| | B | 212 B | 5 Oct 82 | 204 | 27976.1(2) | 42263.4 | 0953 |
| | C | 213 B | 5 Oct 82 | 204 | 27976.1 | 42263.4(5) | 1005 |
| N-75 E | A | 214 B | 5 Oct 82 | 87 | 27974.9 | 42263.5 | 1030 |
| | B | 215 B | 5 Oct 82 | 85 | 27974.9 | 42263.5 | 1035 |
| | C | 216 C | 5 Oct 82 | 85 | 27974.8(9) | 42263.6 | 1040 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| N-50 E | A | 217 B | 5 Oct 82 | 54 | 27974.1 | 42263.6 | 1045 |
| | B | 218 C | 5 Oct 82 | 56 | 27974.1 | 42263.6(7) | 1049 |
| | C | 219 B | 5 Oct 82 | 54 | 27974.1 | 42263.6 | 1056 |
| A-50 W | A | 220 B | 5 Oct 82 | 49 | 27983.8 | 42269.6 | 1230 |
| | B | 221 B | 5 Oct 82 | 56 | 27983.8 | 42269.6(7) | 1234 |
| | C | 222 C | 5 Oct 82 | 56 | 27983.8 | 42269.7 | 1238 |
| B-50 W | A | 223 B | 5 Oct 82 | 49 | 27974.9 | 42272.3 | 1259 |
| | B | 224 C | 5 Oct 82 | 53 | 27974.9 | 42272.3 | 1304 |
| | C | 225 B | 5 Oct 82 | 54 | 27974.9(0) | 42272.3 | 1309 |
| B-75 W | A | 226 B | 5 Oct 82 | 72 | 27973.8 | 42272.5 | 1323 |
| | B | 227 B | 5 Oct 82 | 72 | 27973.8 | 42272.5 | 1327 |
| | C | 228 C | 5 Oct 82 | 75 | 27973.9 | 42272.4 | 1332 |
| B-660 | A | 229 B | 5 Oct 82 | 630 | 27968.9 | 42277.1 | 1420 |
| | B | 230 C | 5 Oct 82 | 600 | 27968.8 | 42276.9(0) | 1435 |
| | C | 231 B | 5 Oct 82 | 624 | 27968.8(9) | 42277.1 | 1512 |
| B-600 E | A | 232 B | 5 Oct 82 | 591 | 27967.5(4) | 42280.9 | 1543 |
| | B | 233 C | 5 Oct 82 | 560 | 27967.3(4) | 42280.8 | 1555 |
| | C | 234 B | 5 Oct 82 | 600 | 27967.4(3) | 42280.8 | 1618 |
| B-400 E | A | 235 B | 5 Oct 82 | 420 | 27966.7 | 42281.3 | 1635 |
| | B | 236 B | 5 Oct 82 | 402 | 27966.6 | 42281.3 | 1645 |
| | C | 237 C | 5 Oct 82 | 396 | 27966.5 | 42281.3 | 1655 |
| B-50 E | A | 238 B | 5 Oct 82 | 52 | 27965.3 | 42282.1 | 1740 |
| | B | 239 B | 5 Oct 82 | 47 | 27965.3 | 42282.2 | 1747 |
| | C | 240 C | 5 Oct 82 | 48 | 27965.3 | 42282.2 | 1753 |
| B-200 E | A | 241 B | 5 Oct 82 | 198 | 27966.2 | 42281.7 | 1804 |
| | B | 242 B | 5 Oct 82 | 200 | 27966.1 | 42281.6 | 1813 |
| | C | 243 C | 5 Oct 82 | 198 | 27966.2 | 42281.6 | 1820 |
| C-50 E | A | 244 B | 6 Oct 82 | 51 | 27953.1 | 42283.1 | 0910 |
| | B | 245 C | 6 Oct 82 | 51 | 27953.2 | 42283.1 | 0916 |
| | C | 246 B | 6 Oct 82 | 50 | 27953.1 | 42283.0 | 0930 |
| C-75 E | A | 247 B | 6 Oct 82 | 78 | 27953.4(5) | 42282.7 | 0936 |
| | B | 248 B | 6 Oct 82 | 78 | 27953.4(5) | 42282.7 | 0942 |
| | C | 249 C | 6 Oct 82 | 80 | 27953.5 | 42282.8 | 0946 |
| C-200 E | A | 250 C | 6 Oct 82 | 210 | 27954.2 | 42282.1 | 0955 |
| | B | 251 B | 6 Oct 82 | 210 | 27954.2 | 42282.3(4) | 1035 |
| | C | 252 B | 6 Oct 82 | 213 | 27954.1 | 42282.3(4) | 1047 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| C-400 E | A | 253 B | 6 Oct 82 | 390 | 27954.9 | 42282.0 | 1124 |
| | B | 254 B | 6 Oct 82 | 390 | 27954.8 | 42281.7 | 1135 |
| | C | 255 C | 6 Oct 82 | 390 | 27954.8 | 42282.0 | 1145 |
| C-50 W | A | 256 B | 6 Oct 82 | 53 | 27969.4 | 42269.5 | 1330 |
| | B | 257 B | 6 Oct 82 | 46 | 27969.4 | 42269.3 | 1335 |
| | C | 258 C | 6 Oct 82 | 51 | 27969.3 | 42269.4 | 1340 |
| C-75 W | A | 259 B | 6 Oct 82 | 76 | 27969.2 | 42269.5 | 1350 |
| | B | 260 B | 6 Oct 82 | 76 | 27969.2 | 42269.6 (7) | 1355 |
| | C | 261 C | 6 Oct 82 | 77 | 27969.2 (1) | 42269.6 | 1400 |
| D-50 W | A | 262 B | 6 Oct 82 | 46 | 27954.0 | 42271.4 | 1430 |
| | B | 263 C | 6 Oct 82 | 55 | 27953.9 (0) | 42271.4 | 1435 |
| | C | 264 B | 6 Oct 82 | 55 | 27953.9 | 42271.3 (4) | 1440 |
| D-75 W | A | 265 B | 6 Oct 82 | 75 | 27953.8 (7) | 42271.2 | 1445 |
| | B | 266 C | 6 Oct 82 | 79 | 27953.8 | 42271.1 | 1455 |
| | C | 267 B | 6 Oct 82 | 81 | 27953.8 | 42271.5 | 1505 |
| E-50 E | A | 268 B | 6 Oct 82 | 56 | 27934.4 | 42271.1 | 1625 |
| | B | 269 B | 6 Oct 82 | 55 | 27932.4 | 42271.1 | 1635 |
| | C | 270 C | 6 Oct 82 | 51 | 27934.3 | 42271.1 | 1645 |
| C-640 | A | 271 B | 7 Oct 82 | 606 | 27958.0 (1) | 42278.1 | 1147 |
| | B | 272 B | 7 Oct 82 | 606 | 27958.0 | 42278.1 | 1202 |
| | C | 273 C | 7 Oct 82 | 605 | 27958.0 | 42278.1 | 1214 |
| C-600 E | A | 274 B | 7 Oct 82 | 570 | 27955.5 | 42281.0 | 1245 |
| | B | 275 B | 7 Oct 82 | 570 | 27955.5 (6) | 42281.1 | 1256 |
| | C | 276 C | 7 Oct 82 | 576 | 27955.5 (4) | 42281.1 | 1309 |
| OT-1 | A | 277 B | 7 Oct 82 | 588 | 27950.5 | 42280.0 | 1342 |
| | B | 278 C | 7 Oct 82 | 588 | 27950.4 (5) | 42280.0 | 1350 |
| | C | 279 B | 7 Oct 82 | 588 | 27950.5 | 42280.0 | 1414 |
| | D | 280 B | 7 Oct 82 | 588 | 27950.7 (6) | 42279.9 | 1430 |
| | E | 281 B | 7 Oct 82 | 588 | 27950.5 | 42280.0 | 1442 |
| | F | 282 B | 7 Oct 82 | 588 | 27950.4 | 42280.1 | 1451 |
| OT-2 | A | 283 B | 7 Oct 82 | 585 | 27945.8 (7) | 42281.9 | 1518 |
| | B | 284 C | 7 Oct 82 | 582 | 27945.9 | 42281.9 | 1527 |
| | C | 285 B | 7 Oct 82 | 582 | 27945.8 | 42281.9 | 1538 |
| | D | 286 B | 7 Oct 82 | 582 | 27945.8 | 42282.2 | 1555 |
| | E | 287 B | 7 Oct 82 | 582 | 27945.8 | 42281.9 | 1620 |
| | F | 288 B | 7 Oct 82 | 582 | 27945.8 | 42281.8 | 1645 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| D-250 E | A | 289 B | 7 Oct 82 | 234 | 27940.1 (1) | 42281.2 | 1711 |
| | B | 290 C | 7 Oct 82 | 240 | 27940.2 | 42281.3 | 1720 |
| | C | 291 B | 7 Oct 82 | 240 | 27940.3 | 42281.3 | 1732 |
| | D | 292 B | 7 Oct 82 | 243 | 27940.2 | 42281.2 | 1737 |
| | E | 293 B | 7 Oct 82 | 255 | 27940.2 | 42281.2 | 1744 |
| | F | 294 B | 7 Oct 82 | 240 | 27940.2 | 42281.3 | 1752 |
| D-660 | A | 295 B | 7 Oct 82 | 600 | 27948.5 | 42275.6 | 1828 |
| | B | 296 C | 7 Oct 82 | 603 | 27948.4 | 42275.6 | 1838 |
| | C | 297 B | 7 Oct 82 | 600 | 27948.4 (5) | 42275.5 | 1852 |
| E-50 W | A | 298 B | 8 Oct 82 | 48 | 27948.3 (3) | 42269.0 (1) | 0910 |
| | B | 299 B | 8 Oct 82 | 50 | 27949.2 | 42269.0 | 0915 |
| | C | 300 C | 8 Oct 82 | 50 | 27948.3 | 42267.0 | 0918 |
| E-75 W | A | 301 B | 8 Oct 82 | 77 | 27948.4 (2) | 42269.2 | 0925 |
| | B | 302 B | 8 Oct 82 | 74 | 27948.2 | 42269.2 | 0930 |
| | C | 303 C | 8 Oct 82 | 76 | 27948.2 | 42269.1 | 0935 |
| E-750 | A | 304 B | 8 Oct 82 | 744 | 27940.1 | 42276.4 | 0950 |
| | B | 305 B | 8 Oct 82 | 744 | 27940.0 | 42276.4 (3) | 1015 |
| | C | 306 C | 8 Oct 82 | 741 | 27940.0 | 42276.4 | 1035 |
| E-600 E | A | 307 B | 8 Oct 82 | 621 | 27938.0 | 42278.4 | 1100 |
| | B | 308 C | 8 Oct 82 | 624 | 27938.0 | 42278.3 | 1120 |
| | C | 309 B | 8 Oct 82 | 624 | 27938.0 | 42248.4 | 1145 |
| E-200 E | A | 310 B | 8 Oct 82 | 200 | 27935.5 | 42280.2 | 1205 |
| | B | 311 B | 8 Oct 82 | 204 | 27935.5 (6) | 42280.2 (3) | 1215 |
| | C | 312 C | 8 Oct 82 | 204 | 27935.5 | 42290.2 | 1225 |
| E-75 E | A | 313 B | 8 Oct 82 | 70 | 27934.6 | 42281.0 | 1300 |
| | B | 314 C | 8 Oct 82 | 73 | 27934.5 | 42281.1 | 1310 |
| | C | 315 B | 8 Oct 82 | 75 | 27934.6 (7) | 42281.0 | 1315 |
| D-75 E | A | 316 B | 8 Oct 82 | 73 | 27939.6 (5) | 42282.2 | 1340 |
| | B | 317 C | 8 Oct 82 | 75 | 27939.6 | 42282.2 | 1347 |
| | C | 318 B | 8 Oct 82 | 75 | 27939.6 | 42282.2 | 1400 |
| D-50 E | A | 319 B | 8 Oct 82 | 55 | 27939.4 | 42282.2 | 1410 |
| | B | 320 B | 8 Oct 82 | 55 | 27939.5 | 42282.2 | 1415 |
| | C | 321 C | 8 Oct 82 | 55 | 27939.5 | 42282.3 | 1420 |
| F-200 E | A | 322 C | 8 Oct 82 | 200 | 27933.8 | 42277.1 (2) | 1440 |
| | B | 323 B | 8 Oct 82 | 200 | 27933.8 | 42277.3 | 1500 |
| | C | 324 B | 8 Oct 82 | 200 | 27933.8 | 42277.2 | 1515 |

Appendix Table 7.2c. (continued)

| Station | Rep | Code | Date | Depth ft. | Loran 1 | Loran 2 | Time |
|---|---|---|---|---|---|---|---|
| F-600 E | A | 325 B | 8 Oct 82 | 590 | 27935.1(2) | 42276.0 | 1600 |
| | B | 326 C | 8 Oct 82 | 606 | 27935.2 | 42276.0 | 1620 |
| | C | 327 B | 8 Oct 82 | 600 | 27935.2 | 42276.0 | 1640 |
| F-780 | A | 328 C | 8 Oct 82 | 780 | 27932.5 | 42274.9 | 1700 |
| | B | 329 B | 8 Oct 82 | 780 | 27932.5 | 42275.0 | 1730 |
| | C | 330 B | 8 Oct 82 | 780 | 27932.5 | 42275.0 | 1730 |

Code: number = sequence grabs were taken in

B = biological sample
C = chemical sample

Depth - recorded in feet

Loran - A small number to the right of the reading indicates the Loran was reading in between the two values.

An * to the left of the value indicates a poor SNR value - e.g., the signal strength was poor - the Loran value reported may not be accurate.

# APPENDIX 7.3

November/December 1982

Appendix Table 7.3a.
Renton Baseline Study Chemistry Data
Subtidal Biology/Cruise Report November/December Cruise

| CODE NUMBER | STATION DESIGNATION | DATE SAMPLED | CHEMISTRY REQUIRI |
|---|---|---|---|
| 210 | L alt 50 W | 29 NOV. 82 | (VCS), G |
| 211 | L alt 75 W | 29 NOV. 82 | (VCS), G |
| 212 | L alt 570 | 29 NOV. 82 | (VCS), G |
| 213 | L alt 400 | 29 nov. 82 | (VCS), G |
| 214 | L alt 200 | 29 NOV. 82 | (VCS), G |
| 215 | L alt 75 E | 29 NOV. 82 | (VCS), G |
| 216 | L alt 50 E | 29 NOV. 82 | (VCS), G |
| 217 | L.5 200 E | 29 NOV. 82 | (VCS), G |
| 218 | L.5 400 E | 29 NOV. 82 | (VCS), G |
| 219 | L.5 550 | 29 NOV. 82 | (VCS), G |
| 220 | L.5 400 W | 29 NOV. 82 | (VCS), G |
| 221 | M 200 | 30 NOV. 82 | (VCS), G |
| 222 | QM 1 | 30 NOV. 82 | (VCS), G |
| 223 | QM 2 | 30 NOV. 82 | (VCS), G |
| 224 | K 50 W | 30 NOV. 82 | (VCS), G |
| 225 | K 75 W | 30 NOV. 82 | (VCS), G |
| 226 | K 570 | 30 NOV. 82 | (VCS), G |
| 227 | K 400 | 30 NOV. 82 | (VCS), G |
| 228 | K 200 | 30 NOV. 82 | (VCS), G |
| 229 | K 75 E | 30 NOV. 82 | (VCS), G |
| 230 | K 50 E | 30 NOV. 82 | (VCS), G |
| 231 | PB 4 | 30 NOV. 82 | (VCS), G |
| 232 | J.5 75 W | 30 NOV. 82 | (VCS), G |
| 233 | J.5 600 | 30 NOV. 82 | (VCS), G |
| 234 | J.5 520 E | 30 NOV. 82 | (VCS), G |
| 235 | J.5 400 E | 30 NOV. 82 | (VCS), G |
| 236 | J.5 250 | 1 DEC. 82 | (VCS), G |
| 237 | J.5 75 E | 1 DEC. 82 | (VCS), G |
| 238 | J.5 50 E | 1 DEC. 82 | (VCS), G |
| 239 | PB 3 | 1 DEC. 82 | (VCS), G |
| 240 | PB 2 | 1 DEC. 82 | (VCS), G |
| 241 | PB 1 | 1 DEC. 82 | (VCS), G |
| 242 | J 50 E | 1 DEC. 82 | (VCS), G |
| 243 | J 75 E | 1 DEC. 82 | (VCS), G |
| 244 | J 400 E | 1 DEC. 82 | (VCS), G |
| 245 | J 600 E | 1 DEC. 82 | (VCS), G |
| 246 | J 690 | 1 DEC. 82 | (VCS), G |
| 247 | J 75 W | 1 DEC. 82 | (VCS), G |
| 248 | I 50 W | 1 DEC. 82 | (VCS), G |
| 249 | I 75 W | 1 DEC. 82 | (VCS), G |

V= volatile solids and B.O.D. (frozen)
C= organic carbon and nitrogen (frozen)
S= sulfides (frozen)
G= grain size and metals (not frozen)

Appendix Table 7.3a. (continued)

| CODE NUMBER | STATION DESIGNATION | DATE SAMPLED | CHEMISTRY REQUIRED |
|---|---|---|---|
| 250 | I 690 | 1 DEC. 82 | (VCS), G |
| 251 | I 600 E | 1 DEC. 82 | (VCS), G |
| 252 | I 400 E | 1 DEC. 82 | (VCS), G |
| 253 | I 200 E | 2 DEC. 82 | (VCS), G |
| 254 | H 50 E | 2 DEC. 82 | (VCS), G |
| 255 | H 75 E | 2 DEC. 82 | (VCS), G |
| 256 | H 400 E | 2 DEC. 82 | (VCS), G |
| 257 | H 600 E | 2 DEC. 82 | (VCS), G |
| 258 | G 50 E | 2 DEC. 82 | (VCS), G |
| 259 | G 75 E | 2 DEC. 82 | (VCS), G |
| 260 | G 200 E | 2 DEC. 82 | (VCS), G |
| 261 | F 200 E | 2 DEC. 82 | (VCS), G |
| 262 | F 600 E | 2 DEC. 82 | (VCS), G |
| 263 | G 400 E | 2 DEC. 82 | (VCS), G |
| 264 | G 600 E | 2 DEC. 82 | (VCS), G |
| 265 | H 640 | 2 DEC. 82 | (VCS), G |
| 266 | B 50 W | 6 DEC. 82 | (VCS), G |
| 267 | B 75 W | 6 DEC. 82 | (VCS), G |
| 268 | B 660 | 6 DEC. 82 | (VCS), G |
| 269 | B 600 E | 6 DEC. 82 | (VCS), G |
| 270 | B 400 E | 6 DEC. 82 | (VCS), G |
| 271 | B 200 E | 6 DEC. 82 | (VCS), G |
| 272 | B 50 E | 6 DEC. 82 | (VCS), G |
| 273 | A 200 E | 6 DEC. 82 | (VCS), G |
| 274 | A 400 E | 6 DEC. 82 | (VCS), G |
| 275 | A 600 E | 6 DEC. 82 | (VCS), G |
| 276 | A 720 | 6 DEC. 82 | (VCS), G |
| 277 | N 50 W | 7 DEC. 82 | (VCS), G |
| 278 | N 75 W | 7 DEC. 82 | (VCS), G |
| 279 | N 50 E | 7 DEC. 82 | (VCS), G |
| 280 | N 75 E | 7 DEC. 82 | (VCS), G |
| 281 | N 200 E | 7 DEC. 82 | (VCS), G |
| 282 | A 50 W | 7 DEC. 82 | (VCS), G |
| 283 | A 200 W | 7 DEC. 82 | (VCS), G |
| 284 | A 400 W | 7 DEC. 82 | (VCS), G |
| 285 | C 50 W | 7 DEC. 82 | (VCS), G |
| 286 | C 75 W | 7 DEC. 82 | (VCS), G |
| 287 | C 640 | 7 DEC. 82 | (VCS), G |
| 288 | C 600 | 7 DEC. 82 | (VCS), G |
| 289 | C 400 E | 7 DEC. 82 | (VCS), G |
| 290 | C 200 E | 8 DEC. 82 | (VCS), G |
| 291 | C 75 E | 8 DEC. 82 | (VCS), G |
| 292 | C 50 E | 8 DEC. 82 | (VCS), G |
| 293 | OT 1 | 8 DEC. 82 | (VCS), G |
| 294 | OT 2 | 8 DEC. 82 | (VCS), G |
| 295 | D 50 E | 8 DEC. 82 | (VCS), G |
| 296 | D 75 E | 8 DEC. 82 | (VCS), G |
| 297 | D 250 E | 8 DEC. 82 | (VCS), G |
| 298 | D 660 | 9 DEC. 82 | (VCS), G |

V= volatile solids and B.O.D. (frozen)
C= organic carbon and nitrogen (frozen)
S= sulfides (frozen)
G= grain size and metals (not frozen)

Appendix Table 7.3a. (continued)

| CODE NUMBER | STATION DESIGNATION | DATE SAMPLED | CHEMISTRY REQUIRI |
|---|---|---|---|
| 299 | E 50 W | 9 DEC. 82 | (VCS), G |
| 300 | E 75 W | 9 DEC. 82 | (VCS), G |
| 301 | E 750 | 9 DEC. 82 | (VCS), G |
| 302 | G 780 | 11 DEC. 82 | (VCS), G |
| 303 | F 780 | 11 DEC. 82 | (VCS), G |
| 304 | E 600 E | 11 DEC. 82 | (VCS), G |
| 305 | E 200 E | 11 DEC. 82 | (VCS), G |
| 306 | E 75 E | 11 DEC. 82 | (VCS), G |
| 307 | E 50 E | 11 DEC. 82 | (VCS), G |
| 308 | D 75 W | 11 DEC. 82 | (VCS), G |
| 309 | D 50 W | 11 DEC. 82 | (VCS), G |
| 310 | F 75 W | 11 DEC. 82 | (VCS), G |
| 311 | F 50 W | 11 DEC. 82 | (VCS), G |
| 312 | G 75 W | 11 DEC. 82 | (VCS), G |
| 313 | G 50 W | 11 DEC. 82 | (VCS), G |
| 314 | H 50 W | 11 DEC. 82 | (VCS), G |
| 315 | H 75 W | 11 DEC. 82 | (VCS), G |
| V= volatile solids and B.O.D. (frozen) | C= organic carbon and nitrogen (frozen) | S= sulfides (frozen) | G= grain size and metals (not frozen) |

Appendix Table 7.3b.
Descriptive Information/Subtidal Grab Samples

CODE COLUMN:

Number = sequences sample taken
B = biological
C = chemical

SEDIMENT TYPE:

1 = rock
2 = cobble
3 = gravel
4 = sand
5 = silt
6 = clay
7 = wood chips
C = coarse sand
M = medium sand
F = fine sand

COLOR (of sediment):

DO = drab olive
DOS = drab olive surface
G = green
GY = grey
B = black
BWN = brown

ODOR

1 = $H_2S$ smell
2 = petroleum smell
3 = no smell

A = slight odor
B = moderate odor
C = strong odor
D = overwhelming odor

When a slash separates two or more sediment or color types, the last number is the dominant type, the first being modifiers. A dash separating two types indicates equal amounts of each. Examples:

| | |
|---|---|
| 4/5 C | Sandy silt with coarse sand. |
| 3/4 C/-F | Sand with some gravel; equal amounts of medium and fine sand, with a small fraction of coarse sand. |
| GY-G | Grey-green color. |

Appendix Table 7.3c.
Renton Baseline Study
Summary of Descriptive Information /Grab Samples
November/December 82 Cruise

| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| L alt 50 W | A | 1 B | 7/4 F | GY | 3 | 10.0 | |
| | B | 2 C | 7/4 F | GY | 3 | 8.0 | Slight leakage |
| | C | 3 B | 4 F | DO | 3 | 10.0 | Shell fragments |
| L alt 75 W | A | 4 B | 3/4 C | GY | 3 | 10.0 | Diopatra tubes |
| | B | 5 B | 2/3/4 C | DO | 3 | 8.0 | Chaetopteridae |
| | C | 6 C | 2/3/4 C | DO | 3 | 6.0 | |
| L alt 570 | A | 7 B | 4/5 F | DO | 3 | 17.0 | (B) Speckled surface |
| | B | 8 B | 4/5 F | DO | 3 | 13.0 | 1 molpadidae |
| | C | 9 C | 4/5 F | DO | 3 | 17.0 | Lt Bwn surface |
| L alt 400 E | A | 10 B | 4/5 F | DO | 3 | 17.0 | |
| | B | 11 C | 4/5 F | DO | 3 | 17.0 | |
| | C | 12 B | 4/5 F | DO | 3 | 17.0 | |
| L alt 200 E | A | 13 B | 4/5 F | DO | 3 | 16.0 | |
| | B | 14 C | 4/5 F | DO | 3 | 16.0 | |
| | C | 15 B | 4/5 F | DO | 3 | 14.0 | |
| L alt 75 E | A | 16 C | 4 C | DO | 3 | 8.0 | Chaetopteridae |
| | B | 17 B | 4 C | DO-BWN | 3 | 6.5 | " |
| | C | 18 B | 4 C | DO | 3 | 7.5 | |
| L alt 50 E | A | 19 C | 4 C | DO | 3 | 5.0 | |
| | B | 20 B | 2/3/4 C | BWN | 3 | 7.5 | Shell fragments |
| | C | 21 B | 4 C-M | BWN | 3 | 7.0 | |
| L.5 200 E | A | 22 B | 4-5 C | GY | 3 | 16.0 | |
| | B | 23 C | 3/4-5 M | BWN | 3 | 12.0 | DO surface |
| | C | 24 B | 3/4-5 M | DO | 3 | 16.0 | |
| L.5 400 E | A | 25 B | 4-5 M | DO | 3 | 17.0 | Lt Bwn surface |
| | B | 26 C | 4-5 M | DO | 3 | 14.0 | 5cm Bwn surface |
| | C | 27 B | 4-5 M | DO | 3 | 14.0 | |
| L.5 550 | A | 28 B | 4/5 M | DO | 3 | 17.0 | |
| | B | 29 B | 4/5 M | DO | 3 | 17.0 | |
| | C | 30 C | 4/5 M | DO | 3 | 17.0 | |
| L.5 400 W | A | 31 B | 4/5 M | DO | 3 | 17.0 | |
| | B | 32 B | 4/5 M | DO | 3 | 14.0 | |
| | C | 33 C | 4/5 M | DO | 3 | 14.0 | |
| M-200 | A | 34 B | 2/3/4 C | BWN | 3 | 7.5 | Shell fragments |
| | B | 35 B | 2/3/4 C | BWN | 3 | 8.0 | |
| | C | 36 C | 2/3/4 C | BWN | 3 | 6.0 | |
| QM-1 | A | 37 B | 5 | DO | 1 B | 17.0 | Lt Bwn surface |
| | B | 38 C | 5 | DO | 1 B | 17.0 | " " " |
| | C | 39 B | 5 | DO | 1 B | 17.0 | " " " |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| QM-2 | A | 40 B | 5 | DO | 1 A | 17.0 | Shell fragments |
| | B | 41 C | 5 | DO | 1 A | 15.0 | |
| | C | 42 B | 5 | DO | 1 A | 15.0 | |
| K-50 W | A | 43 B | 4 M | G-GY | 1 A | 12.0 | |
| | B | 44 C | 4 M-F | G-GY | 1 A | 7.0 | |
| | C | 45 B | 4 M-F | G-GY | 3 | 8.0 | |
| K-75 W | A | 46 B | 4 M-F | GY | 3 | 7.5 | |
| | B | 47 C | 4 M-F | GY | 3 | 8.0 | Chaetopteridae |
| | C | 48 B | 4 M-F | DO | 3 | 9.0 | " & Onuphidae |
| K-570 | A | 49 B | 5 | DO | 3 | 15.0 | Lt Bwn surface |
| | B | 50 B | 5 | DO | 3 | 15.0 | Brisaster/Molpedidae |
| | C | 51 C | 5 | DO | 3 | 17.0 | |
| K-400 E | A | 52 B | 4/5 F | DO | 3 | 17.0 | |
| | B | 53 B | 4/5 F | DO | 3 | 15.0 | Travisia/Brisaster |
| | C | 54 C | 4/5 F | DO | 3 | 14.0 | |
| K-200 E | A | 55 B | 4-F | GY-BWN | 3 | 12.0 | |
| | B | 56 B | 6/4 F | GY-BWN | 3 | 9.0 | |
| | C | 57 C | 4-F | GY-BWM | 3 | 9.0 | |
| K-75 E | A | 58 C | 4-F | BWM | 3 | 6.0 | |
| | B | 59 B | 4-M | BWN | 3 | 10.5 | |
| | C | 60 B | 4-M | BWN | 3 | 10.5 | |
| K-50 E | A | 61 B | 4-M | GY | 3 | 8.5 | |
| | B | 62 C | 4-M | GY | 3 | 8.0 | |
| | C | 63 B | 4-M | GY | 3 | 9.0 | |
| PB-4 | A | 64 C | 4-M | DO | 3 | 5.0 | |
| | B | 65 B | 4-5 M | DO | 3 | 10.0 | |
| | C | 66 B | 4-5 M | DO | 3 | 15.5 | |
| J.5 75 W | A | 67 B | 5/4 M | BWN | 3 | 9.0 | |
| | B | 68 B | 4 C-M-F | BWN | 3 | 8.0 | |
| | C | 69 C | 4 C-M-F | BWN | 3 | 6.0 | |
| J.5 600 | A | 70 B | 5 | DO | 3 | 17.0 | |
| | B | 71 B | 5 | DO | 3 | 17.0 | |
| | C | 72 C | 5 | DO | 3 | 17.0 | Lt Bwn surface |
| J.5 520 | A | 73 B | 5 | DO | 3 | 14.0 | |
| | B | 74 B | 5 | DO | 3 | 17.0 | |
| | C | 75 C | 5 | DO | 3 | 17.0 | |
| J.5 400 E | A | 76 B | 2/4 C-M | DO | 3 | 12.0 | |
| | B | 77 C | 3/4 C | G-GY | 3 | 17.0 | |
| | C | 78 B | 3/4 C-M | G-GY | 3 | 17.0 | |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| J.5 250 E | A | 79 B | 4 M-F | DO | 3 | 11.0 | |
| | B | 80 B | 4 M-F | DO | 3 | 12.0 | |
| | C | 81 C | 4 M-F | DO | 3 | 12.0 | |
| J.5 75 E | A | 82 B | 4-F | DO | 3 | 11.0 | |
| | B | 83 B | 4-F | DO | 3 | 12.0 | |
| | C | 84 C | 4-M | DO | 3 | 11.0 | |
| J.5 50 E | A | 85 B | 4-F | DO | 3 | 7.0 | |
| | B | 86 B | 4-F | DO | 1 A | 11.0 | |
| | C | 87 C | 4-F | DO | 3 | 8.0 | |
| PB-3 | A | 88 B | 4-F | DO | 3 | 11.0 | |
| | B | 89 B | 4-F | DO | 3 | 10.0 | |
| | C | 90 C | 4-F | DO | 3 | 11.0 | |
| PB-2 | A | 91 C | 4-F | DO | 3 | 5.0 | |
| | B | 92 B | 4-F | DO | 3 | 13.0 | |
| | C | 93 B | 4-F | DO | 3 | 10.0 | |
| PB-1 | A | 94 B | 5/4 M-F | DO | 3 | 11.0 | |
| | B | 95 B | 5/4 M-F | DO | 3 | 12.0 | |
| | C | 96 C | 5/4 M-F | DO | 3 | 13.0 | |
| J-50 E | A | 97 B | 4 M-F | DO | 3 | 10.0 | |
| | B | 98 B | 4 M-F | DO | 3 | 11.0 | |
| | C | 99 C | 4 M-F | DO | 3 | 10.0 | |
| J-75 E | A | 100 B | 4 M-F | DO | 3 | 12.5 | |
| | B | 101 B | 4 M-F | DO | 3 | 11.5 | |
| | C | 102 C | 4 M-F | DO | 3 | 12.0 | |
| J-400 E | A | 103 B | 2/5/6/4 C-M | DO | 3 | 15.0 | Lt Bwn surface |
| | B | 104 B | 5/6/4 C-M | DO | 3 | 11.0 | |
| | C | 105 C | 5/6/4 M-F | DO | 3 | 12.0 | |
| J-600 E | A | 106 B | 5 | DO | 3 | 15.0 | Travisia |
| | B | 107 B | 5 | DO | 3 | 17.0 | |
| | C | 108 C | 5 | DO | 3 | 17.0 | |
| J-690 | A | 109 B | 5 | DO | 3 | 10.0 | |
| | B | 110 C | 5 | DO | 3 | 17.0 | |
| | C | 111 B | 5 | DO | 3 | 17.0 | 3 Molpadidae |
| J-75 W | A | 112 B | 3/4 C-M-F | GY | 3 | 7.0 | |
| | B | 113 B | 4 C | GY | 3 | 8.0 | |
| | C | 114 C | 4 C | GY | 3 | 7.0 | |
| I-50 W | A | 115 B | 4 F | GY | 3 | 9.5 | |
| | B | 116 B | 4 C-M-F | DO | 3 | 11.0 | |
| | C | 117 C | 4 F | DO | 3 | 6.0 | |
| I-75 W | A | 118 B | 4 M-F | DO | 3 | 7.5 | |
| | B | 119 C | 4 M-F | DO | 3 | 7.0 | |
| | C | 120 B | 4 M-F | G-GY | 3 | 12.0 | |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| I-690 | A | 121 B | 5 | DO | 3 | 17.0 | |
| | B | 122 B | 5 | DO | 3 | 13.0 | |
| | C | 123 C | 5 | DO | 3 | 15.0 | |
| I-600 | A | 124 B | 3/4 C-M | DO | 3 | 12.0 | |
| | B | 125 B | 3/4 C-M | DO | 3 | 17.0 | |
| | C | 126 C | 3/4 C-M | DO | 3 | 16.0 | |
| I-400 E | A | 127 C | 3/4/5 C-M-F | GY-BWN | 3 | 11.5 | |
| | B | 128 B | 3/5 | DO | 3 | 9.0 | |
| | C | 129 B | 3/5 | DO | 3 | 12.0 | |
| I-200 E | A | 130 B | 2/3/4/5 C-M-F | DO | 3 | 12.0 | Lt Bwn surface |
| | B | 131 C | 2/3/4/5 C-M-F | DO | 3 | 10.5 | " " " |
| | C | 132 B | 2/3/4/5 C-M-F | DO | 3 | 9.0 | " " " |
| H-50 E | A | 133 B | 3/4 C/M-F | DO | 3 | 12.0 | |
| | B | 134 C | 4 M | DO | 3 | 9.0 | |
| | C | 135 B | 4 C-M | DO | 3 | 12.0 | |
| H-75 E | A | 136 B | 4 C-M | DO | 3 | 9.0 | |
| | B | 137 C | 4 C-M | DO | 3 | 17.0 | |
| | C | 138 B | 4 C-M | DO | 3 | 10.5 | |
| H-400 | A | 139 B | 3/4/6/5 C | DO | 3 | 14.5 | Lt Bwn surface |
| | B | 140 C | 3/4/6/5 C | DO | 3 | 17.0 | " " " |
| | C | 141 B | 4/6/5 C | DO | 3 | 17.0 | " " " |
| H-600 E | A | 142 B | 5 | DO | 3 | 17.0 | Lt Bwn surface |
| | B | 143 B | 5 | DO | 3 | 17.0 | " " " |
| | C | 144 C | 5 | DO | 3 | 17.0 | " " " |
| G-50 E | A | 145 B | 4 M-F | DO | 3 | 12.0 | Lt Bwn surface |
| | B | 146 B | 4 M-F | DO | 3 | 11.0 | " " " |
| | C | 147 C | 4 M-F | DO | 3 | 8.0 | " " " |
| G-75 E | A | 148 B | 4 C | DO | 3 | 12.5 | |
| | B | 149 B | 4 C-M | DO | 3 | 10.5 | |
| | C | 150 C | 4 M-F | DO | 3 | 10.0 | |
| G-200 E | A | 151 B | 2/4 F | DO | 3 | 9.5 | |
| | B | 152 C | 4 F | DO | 3 | 8.0 | |
| | C | 153 B | 2/3/4 M-F | DO | 3 | 12.0 | |
| F-200 E | A | 154 B | 7/4 M-F | DO | 3 | 5.0 | Chaetopteridae |
| | B | 155 C | 2/3/4 C-M-F | DO | 3 | 10.0 | |
| | C | 156 B | 2/3/5/4 M-F | DO | 3 | 10.0 | |
| F-600 E | A | 157 B | 2/5 | DO | 3 | 11.0 | |
| | B | 158 B | 2/5 | DO | 1 A | 13.0 | |
| | C | 159 C | 2/3/5 | DO | 3 | 10.5 | |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| G-400 E | A | 160 C | 2/3/4 /6/5 | M-F | DO | 3 | 5.5 | |
| | B | 161 B | 4/6/5 | M-F | DO | 3 | 14.0 | |
| | C | 162 B | 3/6/5 | | DO | 3 | 14.4 | |
| G-600 E | A | 163 B | 5/4 | C-M-F | DO | 3 | 16.0 | |
| | B | 164 B | 5/6/4 | C-M-F | DO | 3 | 16.0 | |
| | C | 165 C | 5/6/4 | C-M-F | DO | 3 | 16.0 | |
| H-640 | A | 166 B | 5 | | DO | 3 | 15.0 | |
| | B | 167 C | 5 | | DO | 3 | 17.0 | |
| | C | 168 B | 5 | | DO | 3 | 17.0 | 3 Molpadidae |
| | D | 169 B | 5 | | DO | 3 | 17.0 | " " |
| | E | 170 B | 5 | | DO | 3 | 17.0 | 1 Molpadidae |
| | F | 171 B | 5 | | DO | 3 | 17.0 | 2 Molpadidae |
| B-50 W | A | 172 B | 4 | M-F | DO | 3 | 8.0 | Chaetopteridae |
| | B | 173 B | 4 | M-F | DO | 3 | 7.0 | |
| | C | 174 C | 4 | M-F | DO | 3 | 8.0 | Chaetopteridae |
| B-75 W | A | 175 B | 3/4 | C-M | DO | 3 | 7.0 | Lt Bwn surface |
| | B | 176 C | 3/4 | C-M | DO | 3 | 7.0 | " " " |
| | C | 177 B | 2/3/4 | C-M | DO | 3 | 5.0 | " " " |
| B-660 | A | 178 B | 5 | | DO | 3 | 17.0 | Lt Bwn surface |
| | B | 179 B | 5 | | DO | 3 | 17.0 | " " " |
| | C | 180 C | 5 | | DO | 3 | 17.0 | " " " |
| B-600 E | A | 181 C | 5 | | DO | 3 | 17.0 | 3 Molpadidae |
| | B | 182 B | 5 | | DO | 3 | 17.0 | 1 Molpadidae |
| | C | 183 B | 5 | | DO | 3 | 17.0 | " " |
| B-400 E | A | 184 B | 2/3/4 /5/6 | M-F | DO | 3 | 15.0 | |
| | B | 185 C | 2/3/4 /5/6 | M-F | DO | 3 | 15.0 | Lt Bwn surface |
| | C | 186 B | 2/3/4 /5/6 | M-F | DO | 3 | 15.0 | " " " |
| B-200 E | A | 187 B | 2/3/4 | C-M-F | DO | 3 | 7.0 | |
| | B | 188 C | 2/3/4 | C-M-F | DO | 3 | 6.5 | |
| | C | 189 B | 2/3/5/4 | C-M-F | DO | 3 | 6.5 | Lt Bwn surface |
| B-50 E | A | 190 B | 4 | F | DO | 3 | 7.0 | |
| | B | 191 C | 4 | F | DO | 3 | 7.0 | |
| | C | 192 B | 4 | F | DO | 3 | 6.5 | |
| A-200 E | A | 193 C | 3/7/4 | C-M-F | DO | 1 A | 6.0 | Diopatra |
| | B | 194 B | 6/5/4 | C-M-F | DO | 3 | 8.0 | " |
| | C | 195 B | 2/3/4 | C-M-F | DO | 3 | 6.5 | |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| A-400 E | A | 196 C | 3/4/5 M-F | DO | 3 | 14.0 | Lt Bwn surface |
| | B | 197 B | 3/4/6 /7/5 M-F | DO | 3 | 12.0 | " " " |
| | C | 198 B | 3/4/6 /7/5 M-F | DO | 3 | 17.0 | |
| A-600 E | A | 199 B | 5 | DO | 3 | 15.0 | 1 Molpadidae |
| | B | 200 B | 5 | DO | 3 | 15.0 | |
| | C | 201 C | 5 | DO | 3 | 15.0 | |
| A-720 | A | 202 B | 5 | DO | 3 | 17.0 | |
| | B | 203 B | 5 | DO | 3 | 17.0 | |
| | C | 204 C | 5 | DO | 3 | 17.0 | Shell fragments |
| N-50 W | A | 205 B | 4 C-M | DO | 3 | 9.0 | |
| | B | 206 C | 4 C-M | DO | 3 | 6.0 | |
| | C | 207 B | 4 C-M | DO | 3 | 9.0 | |
| N-75 W | A | 208 B | 4 C-M | DO | 3 | 9.0 | Onuphidae |
| | B | 209 B | 4 C-M | DO | 3 | 10.5 | " |
| | C | 210 C | 4 C-M | DO | 3 | 6.0 | |
| N-50 E | A | 211 B | 4 C-M | DO | 3 | 8.5 | |
| | B | 212 B | 3/4 C-M | DO | 3 | 9.0 | Chaetopteridae |
| | C | 213 C | 4 C-M | DO | 3 | 9.0 | |
| N-75 E | A | 214 B | 3/4 M-F | DO | 3 | 5.5 | Shell fragments |
| | B | 215 B | 3/4 M-F | DO | 3 | 9.5 | Chaetopteridae |
| | C | 216 C | 4 C-M | DO | 3 | 6.0 | |
| N-200 E | A | 217 B | 3/4 M | DO | 3 | 6.5 | Shell fragments |
| | B | 218 B | 4 M | DO | 3 | 6.5 | |
| | C | 219 C | 4 M | DO | 3 | 6.0 | Shell fragments |
| A-50 W | A | 220 B | 4 C | DO | 3 | 12.0 | Shell fragments |
| | B | 221 C | 4 C | DO | 3 | 12.0 | |
| | C | 222 B | 4 C | DO | 3 | 12.0 | |
| A-200 W | A | 223 B | 3/4 C | GY-B | 3 | 8.0 | Shell fragments |
| | B | 224 B | 4 C | GY-B | 3 | 5.5 | " " |
| | C | 225 C | 4 C | GY-B | 3 | 6.0 | " " |
| A-400 W | A | 226 B | 4/5 F | DO | 3 | 13.0 | |
| | B | 227 B | 4/5 F | DO | 3 | 11.0 | |
| | C | 228 C | 4/5 F | DO | 3 | 12.0 | |
| C-50 W | A | 229 B | 3/7/4 M-F | DO | 3 | 11.0 | |
| | B | 230 B | 3/7/4 M-F | DO | 3 | 10.0 | Onuphidae |
| | C | 231 C | 4 M-F | DO | 3 | 9.0 | |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| C-75 W | A | 232 B | 4 M-F | DO | 3 | 8.0 | Onuphidae |
| | B | 232 B | 4 M-F | DO | 3 | 8.0 | " & Chacto's |
| | C | 234 C | 4 M-F | DO | 3 | 8.0 | " " |
| C-640 | A | 235 B | 5 | DO | 3 | 17.0 | |
| | B | 236 B | 5 | DO | 3 | 17.0 | |
| | C | 237 C | 5 | DO | 3 | 17.0 | |
| C-600 E | A | 238 C | 5 | DO | 3 | 17.0 | |
| | B | 239 B | 5 | DO | 3 | 12.0 | |
| | C | 240 B | 5 | DO | 3 | 17.0 | |
| C-400 E | A | 241 B | 3/5 | DO | 3 | 17.0 | Shell fragments |
| | B | 242 B | 2/7/5 | DO | 3 | 14.0 | " " |
| | C | 243 C | 2/7/5 | DO | 3 | 15.0 | |
| C-200 E | A | 244 B | 4 M-F | BWN | 3 | 5.0 | |
| | B | 245 B | 3/4 M-F | DO | 3 | 5.5 | Lt Bwn surface |
| | C | 246 C | 4 M-F | DO | 3 | 5.0 | " " " |
| C-75 E | A | 247 B | 4 M-F | DO | 3 | 9.5 | Ptilosarcus |
| | B | 248 B | 4 M-F | DO | 3 | 9.5 | |
| | C | 249 C | 4 M-F | DO | 3 | 8.5 | |
| C-50 E | A | 250 B | 4 M-F | GY | 3 | 11.5 | |
| | B | 251 B | 4 M-F | GY | 3 | 12.0 | 2 Ptilosarcus |
| | C | 252 C | 4 C-M-F | GY | 3 | 12.0 | |
| OT-1 | A | 253 B | 5 | BWN | 3 | 17.0 | 1 Molpadidae |
| | B | 254 B | 5 | BWN | 3 | 17.0 | " " |
| | C | 255 B | 5 | BWN | 3 | 17.0 | 2 " |
| | D | 256 B | 5 | BWN | 3 | 17.0 | 5 " |
| | E | 257 B | 5 | BWN | 3 | 17.0 | 1 " |
| | F | 258 C | 5 | BWN | 3 | 17.0 | |
| OT-2 | A | 259 B | 5 | DO | 3 | 17.0 | Lt Bwn surface |
| | B | 260 B | 5 | DO | 3 | 17.0 | " " " |
| | C | 261 B | 5 | DO | 3 | 17.0 | " " " |
| | D | 262 B | 5 | DO | 3 | 17.0 | " " " |
| | E | 263 B | 5 | DO | 3 | 17.0 | " " " |
| | F | 264 C | 5 | DO | 3 | 17.0 | " " " |
| D-50 E | A | 265 C | 4 M-F | GY | 3 | 6.0 | |
| | B | 266 B | 4 M-F | GY | 3 | 11.0 | |
| | C | 267 B | 4 M-F | GY | 3 | 9.0 | |
| D-75 E | A | 268 B | 4 M-F | GY | 3 | 11.5 | |
| | B | 269 B | 4 M-F | GY | 3 | 11.0 | |
| | C | 270 C | 4 M-F | GY | 3 | 11.0 | |
| D-250 E | A | 271 B | 5/4 M | GY | 3 | 6.5 | |
| | B | 272 B | 5/4 M | GY | 3 | 12.0 | |
| | C | 273 C | 5/4 M | GY | 3 | 7.0 | Lt Bwn surface |

Appendix Table 7.3c. (continued)
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| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| D-250 E | D | 274 B | 5/4 M-F | GY | 3 | 7.0 | Lt Bwn surface |
| | E | 275 B | 5/4 M-F | GY | 3 | 7.0 | " " " |
| | F | 276 B | 5/4 M-F | GY | 3 | 13.0 | " " " |
| D-660 | A | 277 B | 5 | BWN | 3 | 15.0 | Lt Bwn surface |
| | B | 278 B | 5 | BWN | 3 | 17.0 | " " " |
| | C | 279 C | 5 | BWN | 3 | 17.0 | " " " |
| D-75 W | A | 280 B | 4 M-F | DO | 3 | 8.0 | Chaetopteridae |
| E-50 W | A | 281 B | 4 M-F | DO | 3 | 9.5 | Sea pen |
| | B | 282 B | 4 M-F | DO | 3 | 8.5 | " " |
| | C | 283 C | 4 M-F | DO | 3 | 8.5 | " " |
| E-75 W | A | 284 B | 4 M-F | DO | 3 | 6.0 | Chaetopteridae |
| | B | 285 C | 5/4 M-F | DO | 3 | 4.5 | " |
| | C | 286 B | 4 M-F | DO | 3 | 6.5 | " |
| E-750 | A | 287 B | 5 | DO | 3 | 10.0 | Lt Bwn surface |
| | B | 288 B | 5 | DO | 3 | 15.0 | " " " |
| | C | 289 C | 5 | DO | 3 | 15.0 | " " " |
| G-780 | A | 290 B | 5 | DO | 3 | 17.0 | Lt Bwn surface |
| | B | 291 B | 5 | DO | 3 | 17.0 | " " " |
| | C | 292 C | 5 | DO | 3 | 17.0 | " " " |
| F-780 | A | 293 B | 3/4/6/7/5 M-F | DO | 3 | 17.0 | Lt Brwn surface |
| | B | 294 B | 3/4/6/5 M-F | DO | 3 | 17.0 | " " " |
| | C | 295 C | 3/4/6/5 M-F | DO | 3 | 17.0 | " " " |
| E-600 E | A | 296 B | 5 | DO | 3 | 17.0 | Lt Bwn surface |
| | B | 297 B | 5 | DO | 3 | 17.0 | " " " |
| | C | 298 C | 5 | DO | 3 | 17.0 | " " " |
| E-200 E | A | 299 B | 5/4 F | GY | 3 | 3.0 | |
| | B | 300 B | 5/4 F | GY | 3 | 10.0 | |
| | C | 301 C | 5/4 F | GY | 3 | 10.0 | |
| E-75 E | A | 302 B | 4 M | BWN | 3 | 10.0 | Chacto's |
| | B | 303 B | 4 M | BWN | 3 | 11.5 | " |
| | C | 304 C | 4 M | BWN | 3 | 10.0 | " |
| E-50 E | A | 305 B | 4 M-F | GY | 3 | 7.5 | |
| | B | 306 B | 4 M-F | GY | 3 | 8.5 | Ptilosarcus |
| | C | 307 C | 4 M-F | GY-B | 3 | 10.0 | " |
| D-75 W | B | 308 B | 5/4 C-M | DO | 3 | 5.0 | Lt Bwn surface |
| | C | 309 C | 5/4 C-M | DO | 3 | 5.0 | " " " |
| D-50 W | A | 310 B | 4 C-M | GY | 3 | 7.0 | |
| | B | 311 B | 4 C-M | GY | 3 | 10.5 | |
| | C | 312 C | 4 C-M | GY | 3 | 10.0 | |

Appendix Table 7.3c. (continued)
Page 9

| Station | Rep | Code | Sediment Type | Color | Odor | Pen Depth Cm. | Comments |
|---|---|---|---|---|---|---|---|
| F-75 W | A | 313 B | 5/4 C-M-F | DO | 3 | 7.5 | |
| | B | 314 B | 5/4 M-F | DO | 3 | 7.5 | |
| | C | 315 C | 5/4 M-F | DO | 3 | 7.5 | |
| F-50 W | A | 316 B | 4 C-M | DO | 3 | 11.0 | |
| | B | 317 B | 4 C-M | DO | 3 | 8.5 | |
| | C | 318 C | 4 C-M | DO | 3 | 10.0 | |
| G-75 W | A | 319 B | | | | | |
| | B | 320 C | 4 M-F | DO | 2 | 8.0 | Chaetopteridae |
| | C | 321 B | 4 M-F | DO | 3 | 8.0 | " |
| G-50 W | A | 322 B | 4 M-F | GY | 3 | 11.0 | Chaetopteridae |
| | B | 323 C | 4 M-F | GY | 3 | 11.0 | |
| | C | 324 B | 4 M-F | GY | 3 | 9.5 | |
| H-50 W | A | 325 B | 4 M/F | GY | 3 | 11.5 | |
| | B | 326 B | 4 M/F | GY | 3 | 10.0 | |
| | C | 327 C | 4 M/F | DO | 3 | 10.0 | |
| H-75 W | A | 328 B | 4 F | DO | 3 | 9.0 | |
| | B | 329 B | 4 F | DO | 3 | 8.5 | |
| | C | 330 C | 4 F | DO | 3 | 10.0 | |

Appendix Table 7.3d.
Loran Info/Depth/Time/Date
November/ December 82 Cruise

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| A-50 W | A | 983.8 | 269.5 | 55 | 1015 | 7 Dec 82 |
| | B | 983.9 | 269.5 | 55 | 1024 | " |
| | C | 983.8 | 269.5 | 55 | 1030 | " |
| A-200 W | A | 984.3(4) | 271.2 | 200 | 1041 | " |
| | B | 984.3 | 271.2 | 195 | 1050 | " |
| | C | 984.4 | 271.3(3) | 186 | 1100 | " |
| A-400 W | A | 982.5 | 274.0 | 396 | 1125 | " |
| | B | 982.5 | 273.9 | 402 | 1136 | " |
| | C | 982.5 | 273.9 | 400 | 1145 | " |
| A-720 | A | 980.1 | 277.3 | 702 | 1650 | 6 Dec 82 |
| | B | 980.1 | 277.3 | 711 | 1705 | " |
| | C | 980.1 | 277.3 | 711 | 1715 | " |
| A-600 E | A | 977.4 | 283.0 | 555 | 1600 | " |
| | B | 977.4 | 283.1 | 555 | 1615 | " |
| | C | 977.4 | 283.0 | 555 | 1620 | " |
| A-400 E | A | 977.0 | 283.9 | 384 | 1511 | " |
| | B | 977.0 | 283.9 | 390 | 1536 | " |
| | C | 976.9 | 283.8 | 390 | 1545 | " |
| A-200 E | A | 975.8 | 283.9 | 207 | 1411 | " |
| | B | 975.7 | 283.9 | 200 | 1418 | " |
| | C | 975.7 | 283.9 | 200 | 1444 | " |
| B-50 W | A | 974.9 | 272.3 | 55 | 0927 | " |
| | B | 974.9 | 272.2 | 52 | 0939 | " |
| | C | 974.8 | 272.3 | 53 | 0945 | " |
| B-75 W | A | 973.8 | 272.4 | 75 | 0958 | " |
| | B | 973.8 | 272.5 | 77 | 1002 | " |
| | C | 973.8 | 272.5 | 77 | 1010 | " |
| B-660 | A | 968.8 | 277.0 | 630 | 1030 | " |
| | B | 968.8 | 277.1 | 630 | 1040 | " |
| | C | 968.9 | 277.1 | 621 | 1110 | " |
| B-400 E | A | 966.6 | 281.2 | 400 | 1207 | " |
| | B | 966.6 | 281.2 | 400 | 1216 | " |
| | C | 966.3 | 281.6 | 210 | 1300 | " |
| B-50 E | A | 965.2 | 282.2 | 56 | 1305 | " |
| | B | 965.2 | 282.2 | 56 | 1314 | " |
| | C | 965.2 | 282.2 | 56 | 1316 | " |
| B-600 E | A | 967.4 | 280.8 | 596 | 1128 | 6 Dec. 82 |
| | B | 967.3 | 280.8 | 596 | 1140 | " |
| | C | 967.3 | 280.8 | 596 | 1155 | " |
| B-200 E | A | 966.2 | 281.6 | 186 | 1235 | 6 Dec. 82 |
| | B | 966.2 | 281.6 | 195 | 1245 | " |
| | C | 966.3 | 281.6 | 210 | 1300 | " |

Appendix Table 7.3d. (continued)
Page 2

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| C-50 W | A | 969.4 | 269.4 | 48 | 1221 | 7 Dec 82 |
| | B | 969.4 | 269.4 | 50 | 1225 | " |
| | C | 969.4 | 269.5 | 46 | 1230 | " |
| C-75 W | A | 969.2 | 269.6 | 73 | 1243 | " |
| | B | 969.2 | 269.6 | 70 | 1243 | " |
| | C | 969.2 | 269.6 | 75 | 1249 | " |
| C-640 | A | 958.1 | 278.1 | 609 | 1410 | " |
| | B | 958.0 | 278.2 | 609 | 1425 | " |
| | C | 958.0 | 278.1 | 609 | 1440 | " |
| C-600 E | A | 955.5 | 281.1 | 570 | 1500 | " |
| | B | 955.6 | 281.0 | 570 | 1510 | " |
| | C | 955.5 | 281.1 | 570 | 1525 | " |
| C-400 E | A | 954.9 | 281.9 | 408 | 1550 | " |
| | B | 955.0 | 281.9 | 400 | 1601 | " |
| | C | 955.0 | 281.9 | 400 | 1615 | " |
| C-200 E | A | 954.2 | 282.4(3) | 198 | 0820 | 8 Dec 82 |
| | B | 954.2 | 282.4(3) | 210 | 0835 | " |
| | C | 954.2 | 282.4 | 195 | 0910 | " |
| C-75 E | A | 953.5 | 282.8 | 75 | 0934 | " |
| | B | 953.3 | 282.8 | 80 | 0938 | " |
| | C | 953.5 | 282.7 | 75 | 0949 | " |
| C-50 E | A | 953.1 | 283.0 | 53 | 1010 | " |
| | B | 953.1(2) | 283.1 | 55 | 1014 | " |
| | C | 953.2 | 283.1 | 52 | 1019 | " |
| D-50 W | A | 953.9 | 271.5 | 50 | 1037 | 11 Dec 82 |
| | B | 953.8 | 271.4 | 55 | 1040 | " |
| | C | 953.9 | 271.5 | 52 | 1050 | " |
| D-75 W | A | 953.7 | 271.6 | 75 | 1034 | 9 Dec 82 |
| | B | 953.8 | 271.6 | 75 | 1030 | 11 Dec 82 |
| | C | 953.8 | 271.6 | 76 | 1032 | " |
| D-660 | A | 948.5 | 275.6 | 600 | 0934 | 9 Dec 82 |
| | B | 948.4 | 275.6 | 600 | 0945 | " |
| | C | 948.5 | 275.6 | 600 | 1000 | " |
| D-250 | A | 940.2 | 281.3 | 246 | 1428 | 8 Dec 82 |
| | B | 940.1 | 281.2 | 246 | 1435 | " |
| | C | 940.2 | 281.2 | 240 | 1440 | " |
| | D | 940.2 | 281.2 | 243 | 1452 | " |
| | E | 940.2 | 281.2 | 240 | 1518 | " |
| | F | 940.2 | 281.2 | 249 | 1612 | " |

Appendix Table 7.3d. (continued)
Page 3

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| D-75 E | A | 939.5 | 282.2 | 76 | 1332 | 8 Dec 82 |
| | B | 939.5 | 282.2 | 75 | 1335 | " |
| | C | 939.5 | 282.3 | 75 | 1338 | " |
| D-50 E | A | 939.5 | 282.2 | 50 | 1313 | " |
| | B | 939.4 | 282.3 | 50 | 1318 | " |
| | C | 939.5 | 282.2 | 50 | 1324 | " |
| E-50 W | A | 948.2 | 269.0 | 52 | 1100 | 9 Dec 82 |
| | B | 948.2 | 269.0 | 51 | 1106 | " |
| | C | 948.2 | 269.0 | 50 | 1110 | " |
| E-75 W | A | 948.1 | 269.2 | 75 | 1120 | 9 Dec. 82 |
| | B | 948.2 | 269.2 | 75 | 1126 | " |
| | C | 946.2 | 269.2 | 75 | 1131 | " |
| E-750 | A | 940.0 | 276.5 | 738 | 1224 | " |
| | B | 939.9 | 276.5 | 738 | 1235 | " |
| | C | 939.9 | 276.5 | 738 | 1255 | " |
| E-600 E | A | 938.0 | 278.3 | 630 | 0830 | 11 Dec 82 |
| | B | 938.0 | 278.3 | 640 | 0853 | " |
| | C | 938.0 | 273.3 | 632 | 0905 | " |
| E-200 E | A | 935.5 | 280.2 | 207 | 0918 | " |
| | B | 935.5 | 280.2 | 207 | 0925 | " |
| | C | 935.6 | 280.2 | 210 | 0930 | " |
| E-75 E | A | 934.5 | 281.1 | 71 | 0934 | " |
| | B | 934.6 | 281.0 | 70 | 0948 | " |
| | C | 934.6 | 281.1 | 71 | 0952 | " |
| E-50 E | A | 934.4 | 281.2 | 50 | 0956 | " |
| | B | 934.4 | 281.2 | 55 | 1000 | " |
| | C | 934.4 | 281.1 | 55 | 1003 | " |
| F-50 W | A | 940.4 | 268.8 | 50 | 1120 | " |
| | B | 940.5 | 268.8 | 53 | 1126 | " |
| | C | 940.4 | 268.8 | 54 | 1130 | " |
| F-75 W | A | 940.5 | 268.0 | 72 | 1105 | " |
| | B | 940.5 | 268.1 | 76 | 1110 | " |
| | C | 940.4 | 268.0 | 76 | 1115 | " |
| F-780 | A | 932.4 | 275.0 | 780' | 0745 | " |
| | B | 932.5 | 274.9 | 774' | 0800 | " |
| | C | 932.4 | 275.0 | 774' | 0812 | " |
| F-600 E | A | 935.1 | 276.0 | 606 | 1405 | 2 Dec 82 |
| | B | 935.1 | 276.0 | 600 | 1420 | " |
| | C | 935.2 | 276.0 | 594 | 1430 | " |
| F-200 E | A | 933.7 | 277.2 | 198 | 1240 | " |
| | B | 933.8 | 277.2 | 200 | 1250 | " |
| | C | 933.7 | 277.2 | 203 | 1320 | " |

Appendix Table 7.3d. (continued)
Page 4

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| G-50 W | A | 931.4 | 268.2 | 51 | 1205 | 11 Dec 82 |
| | B | 931.4 | 268.2 | 55 | 1208 | " |
| | C | 931.5 | 268.2 | 48' | 1214 | " |
| G-75 W | A | 931.4 | 268.2 (SNR on) | 75' | 1150 | " |
| | B | 931.4 | 268.3 " | 75 | 1155 | " |
| | C | 931.5 | 267.9 " | 76' | 1200 | " |
| G-780 | A | 928.0 | 275.3 | 696 | 0658 | " |
| | B | 928.1 | 275.3 | 696 | 0712 | " |
| | C | 928.1 | 275.3 | 702 | 0725 | " |
| G-600 E | A | 928.5 | 277.2 | 600' | 1525 | 2 Dec 82 |
| | B | 928.5 | 277.2 | 600 | 1545 | " |
| | C | 928.5 | 277.2 | 606 | 1600 | " |
| G-400 E | A | 928.9 | 277.6 | 400' | 1445 | " |
| | B | 928.9 | 277.7 | 400' | 1455 | " |
| | C | 928.9 | 277.8 | 400' | 1505 | " |
| G-200 E | A | 929.3(2) | 278.6 | 200 | 1155 | " |
| | B | 929.3 | 278.6 | 203 | 1205 | " |
| | C | 929.3 | 278.5 | 195 | 1220 | " |
| G-75 E | A | 929.3 | 279.2 | 72' | 1115 | " |
| | B | 929.3 | 279.1 | 72' | 1120 | " |
| | C | 929.4 | 279.1 | 76' | 1125 | " |
| G-50 E | A | 929.2 | 279.3 | 46' | 1100 | " |
| | B | 929.1 | 279.4 | 47' | 1105 | " |
| | C | 929.1 | 279.4 | 50' | 1110 | " |
| H-50 W | A | 927.3 | 265.5 | 51' | 1228 | 11 Dec 82 |
| | B | 927.3 | 265.6 | 46' | 1230 | " |
| | C | 927.3 | 265.6 | 50' | 1233 | " |
| H-75 W | A | 926.9 | 266.0 (SNR on) | 77' | 1240 | " |
| | B | 927.0 | 266.1 | 78' | 1243 | " |
| | C | 927.1 | 265.9 | 73' | 1247 | " |
| H-640 | A | 925.8 | 274.3 | 630 | 1625 | 2 Dec 82 |
| | B | 925.8 | 274.3 | 630 | 1630 | " |
| | C | 925.7 | 274.2 | 630 | 1645 | " |
| | D | 925.7 | 274.2 | 630 | 1700 | " |
| | E | 925.7 | 274.1 | 630 | 1710 | " |
| | F | 925.8 | 274.1 | 630 | 1720 | " |
| H-600 E | A | 923.8 | 276.8 | 594' | 1015 | " |
| | B | 923.7 | 276.9 | 591 | 1025 | " |
| | C | 923.7 | 276.8 | 591 | 1035 | " |

Appendix Table 7.3d. (continued)
Page 5

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| H-400 E | A | 924.1 | 279.7 | 411' | 0945 | 2 Dec 82 |
| | B | 924.1 | 279.8 | 390' | 1005 | " |
| | C | 924.1 | 279.7 | 414' | 1005 | " |
| H-75 E | A | 923.2 | 280.7(6) | 82' | 0929 | " |
| | B | 923.1 | 280.7 | 73' | 0925 | " |
| | C | 923.1(2) | 280.6 | 78' | 0930 | " |
| H-50 E | A | 923.3 | 280.7 | 55' | 0905 | " |
| | B | 923.3 | 280.7 | 51' | 0910 | " |
| | C | 923.3 | 280.7 | 53' | 0915 | " |
| I-50 W | A | 912.8 | 271.8 | 45' | 1420 | 1 Dec 82 |
| | B | 912.8 | 271.8 | 48' | 1430 | " |
| | C | 912.8 | 271.8 | 48' | 1440 | " |
| I-75 W | A | 912.7 | 271.7 | 80' | 1445 | " |
| | B | 912.8 | 271.8 | 80' | 1450 | " |
| | C | 912.7 | 271.8 | 75' | 1455 | " |
| I-690 | A | 910.7 | 275.9 | 687' | 1510 | " |
| | B | 910.7 | 276.0 | 684' | 1522 | " |
| | C | 910.6 | 276.0 | 681' | 1535 | " |
| I-600 E | A | 911.8 | 278.9 | 597 | 1555 | " |
| | B | 911.7 | 278.9(8) | 600 | 1605 | " |
| | C | 911.7 | 279.0 | 600 | 1615 | " |
| I-400 E | A | 911.8 | 279.4 | 400' | 1630 | " |
| | B | 911.7 | 279.5 | 405 | | " |
| | C | 911.8 | 279.4 | 397 | 1655 | " |
| I-200 E | A | 911.6 | 279.9 | 200' | 0745 | 2 Dec 82 |
| | B | 911.7(6) | 279.8 | 207' | 0750 | " |
| | C | 911.6 | 279.9 | 200' | 0758 | " |
| J-75 W | A | 903.3 (on range) | 273.8 | 77' | 1348 | 1 Dec 82 |
| | B | 903.5 | 273.8 | 78' | 1400 | " |
| | C | 903.4 | 273.9 | 81' | 1405 | " |
| J-690 | A | 899.0 | 276.2 | 681' | 1305 | " |
| | B | 899.1 | 276.3 | 678' | 1320 | " |
| | C | 899.1 | 276.3 | 678' | 1330 | " |
| J-600 E | A | 895.8 | 279.2(3) | 612' | 1225 | " |
| | B | 895.9 | 279.3 | 606' | 1235 | " |
| | C | 895.9 | 279.2 | 606' | 1245 | " |
| J-400 E | A | 895.1 | 279.8 | 396' | 1135 | " |
| | B | 895.2 | 279.7 | 403 | 1200 | " |
| | C | 895.1 | 279.8 | 403 | 1210 | " |

Appendix Table 7.3d. (continued)
Page 6

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| J-75 E | A | 894.4 | 280.7 | 80' | 1110 | 1 Dec 82 |
| | B | 894.5(4) | 280.8(7) | 80' | 1115 | " |
| | C | 894.4 | 280.7 | 75' | 1120 | " |
| J-50 E | A | 894.0 | 280.8 | 50' | 1050 | " |
| | B | 894.0 | 280.9 | 54' | 1100 | " |
| | C | 894.1 | 280.8 | 56 | 1105 | " |
| J.5-75 W | A | 906.1 | 267.2 | 72' | 1350 | 30 Nov 82 |
| | B | 906.1 | 267.1 | 73' | 1405 | " |
| | C | 906.0 | 267.1 | 77' | 1410 | " |
| J.5-600 | A | 892.4 | 274.1 | 600' | 1440 | " |
| | B | 892.4 | 274.1 | 606 | 1450 | " |
| | C | 892.3 | 274.1 | 600 | 1505 | " |
| J.5-520 E | A | 881.6 | 275.3 | 534 | 1535 | " |
| | B | 881.6 | 275.4 | 531 | 1540 | " |
| | C | 881.6 | 275.3 | 531 | 1525 | " |
| J.5-400 E | A | 877.7 | 275.0 | 400 | 1610 | " |
| | B | 877.9 | 274.9 | 400 | 1630 | " |
| | C | 877.8 | 275.0 | 420 | 1635 | " |
| J.5-250 E | A | 876.4 | 275.1 | 250 | 0750 | 1 Dec 82 |
| | B | 876.4 | 275.2 | 264 | 0800 | " |
| | C | 876.4 | 275.0 | 261 | 0810 | " |
| J.5-75 E | A | 875.4 | 274.9 | 81 | 0815 | " |
| | B | 875.3 | 274.9 | 78 | 0820 | " |
| | C | 875.3 | 274.9 | 80 | 0825 | " |
| J.5-50 E | A | 875.1 | 274.8 | 53 | 0830 | " |
| | B | 875.1 | 274.8 | 52 | 0835 | " |
| | C | 875.1 | 274.8 | 56 | 0840 | " |
| K-50 W | A | 907.5 | 262.7 | 47 | 1010 | 30 Nov 82 |
| | B | 907.4 | 262.7 | 50 | 1015 | " |
| | C | 907.5 | 262.8 | 55 | 1020 | " |
| K-75 W | A | 907.4 | 262.7 | 72 | 1025 | " |
| | B | 907.5 | 262.8 | 70 | 1030 | " |
| | C | 907.5 | 262.7 | 72 | 1035 | " |
| K-570 | A | 894.2 | 265.0 | 564 | 1050 | " |
| | B | 894.2 | 265.0 | 564 | 1110 | " |
| | C | 894.2 | 264.9 | 564 | 1125 | " |
| K-400 E | A | 883.4 | 268.9 | 411 | 1140 | " |
| | B | 883.5 | 269.0 | 400 | 1150 | " |
| | C | 883.5 | 268.9 | 400 | 1200 | " |

Appendix Table 7.3d. (continued)
Page 7

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| K-200 E | A | 882.8 | 269.1 | 200 | 1205 | 30 Nov 82 |
| | B | 882.8 | 269.0 | 200 | 1213 | " |
| | C | 882.7 | 269.1 | 207 | 1218 | " |
| K-75 E | A | 881.4 | 268.9 | 75 | 1226 | " |
| | B | 881.3 | 268.9 | 75 | 1231 | " |
| | C | 881.3 | 268.9 | 72 | 1237 | " |
| K-50 E | A | 881.1 | 268.9 | 53 | 1245 | " |
| | B | 881.1 | 268.9 | 50 | 1250 | " |
| | C | 881.0 | 268.9 | 53 | 1300 | " |
| L alt-50 W | A | 904.4 | 255.9 | 48 | 0920 | 29 Nov 82 |
| | B | 904.3 | 256.0 | 51 | 0935 | " |
| | C | 904.3 | 256.0 | 48 | 0940 | " |
| L alt-75 W | A | 903.9 | 256.0 | 76 | 0945 | " |
| | B | 903.9 | 255.9 | 77 | 1010 | " |
| | C | 903.9 | 256.0 | 76 | 1025 | " |
| L alt-570 | A | 896.0 | 255.5 | 570 | 1045 | " |
| | B | 896.1 | 255.4 | 570 | 1101 | " |
| | C | 896.1 | 255.4 | 570 | 1110 | " |
| L alt 400 E | A | 889.3 | 255.2 | 420 | 1125 | " |
| | B | 889.3 | 255.2 | 402 | 1135 | " |
| | C | 889.3 | 255.3 | 408 | 1155 | " |
| L alt-200 E | A | 887.3 | 255.1 | 192 | 1205 | " |
| | B | 887.2 | 255.0 | 192 | 1212 | " |
| | C | 887.3 | 255.0 | 207 | 1220 | " |
| L alt-75 E | A | 886.0 | 254.9 | 78 | 1255 | " |
| | B | 886.0 | 255.0 | 84 | 1310 | " |
| | C | 886.0 | 255.0 | 75 | 1315 | " |
| L alt-50 E | A | 885.7 | 255.1 | 50 | 1330 | " |
| | B | 885.7 | 255.0 | 53 | 1345 | " |
| | C | 885.6 | 255.0 | 53 | 1400 | " |
| L.5-400 W | A | 893.7 | 244.7 | 420 | 1610 | " |
| | B | 893.7 | 244.7 | 420 | 1620 | " |
| | C | 893.6 | 244.7 | 414 | 1632 | " |
| L.5-550 | A | 891.1 | 249.2 | 546 | 1530 | " |
| | B | 891.0 | 249.2 | 546 | 1545 | " |
| | C | 891.1 | 249.1 | 543 | 1550 | " |
| L.5-440 E | A | 888.3 | 252.1 | 408 | 1445 | " |
| | B | 888.3 | 252.1 | 420 | 1455 | " |
| | C | 888.2 | 252.1 | 400 | 1515 | " |

Appendix Table 7.3d. (continued)
Page 8

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| L.5-200 E | A | 887.0 | 252.9 | 207 | 1420 | 29 Nov 82 |
| | B | 887.1 | 252.8 | 210 | 1430 | " |
| | C | 887.1 | 252.8 | 210 | 1435 | " |
| M-200 | A | 919.1 | 240.5 | 195 | 0710 | 30 Nov 82 |
| | B | 919.1 | 240.5 | 186 | 0720 | " |
| | C | 919.0 | 240.3 | 195 | 0735 | " |
| N-50 W | A | 981.4 | 259.1 | 53 | 0737 | 7 Dec 82 |
| | B | 981.3 | 259.0 | 48 | 0800 | " |
| | C | 981.3 | 259.0 | 50 | 0810 | " |
| N-75 W | A | 981.3 | 259.1 | 82 | 0815 | " |
| | B | 981.3 | 259.0 | 74 | 0820 | " |
| | C | 981.3 | 259.1 | 75 | 0825 | " |
| N-200 E | A | 976.1 | 263.4 | 210 | 0940 | " |
| | B | 976.0 | 263.4 | 200 | 0945 | " |
| | C | 976.1 | 263.4 | 212 | 0950 | " |
| N-75 E | A | 974.9 | 263.5 | 83 | 0915 | " |
| | B | 974.9 | 263.5 | 83 | 0920 | " |
| | C | 975.0 | 263.5 | 83 | 0925 | " |
| N-50 E | A | 974.0 | 263.6 | 55 | 0850 | " |
| | B | 974.0 | 263.6 | 55 | 0855 | " |
| | C | 974.1 | 263.6 | 55 | 0902 | " |
| OT-1 | A | 950.5 | 279.8 | 594 | 1041 | 8 Dec 82 |
| | B | 950.4 | 279.9 | 594 | 1050 | " |
| | C | 950.4 | 279.8 | 594 | 1107 | " |
| | D | 950.5 | 279.9 | 594 | 1115 | " |
| | E | 950.5 | 279.9 | 594 | 1125 | " |
| | F | 950.5 | 279.9 | 594 | 1137 | " |
| OT-2 | A | 945.8 | 282.0 | 585 | 1207 | " |
| | B | 945.8 | 282.0 | 588 | 1219 | " |
| | C | 945.9 | 282.0 | 588 | 1228 | " |
| | D | 945.8 | 281.9 | 588 | 1236 | " |
| | E | 945.8 | 281.9 | 588 | 1245 | " |
| | F | 945.9 | 281.9 | 588 | 1250 | " |
| PB-1 | A | 879.0 | 277.1 | 180 | 1010 | 1 Dec 82 |
| | B | 879.0 | 277.1 | 186 | 1020 | " |
| | C | 879.0 | 277.1 | 186 | 1030 | " |
| PB-2 | A | 875.7 | 276.9 | 189 | 0935 | " |
| | B | 875.7 | 276.8 | 189 | 0945 | " |
| | C | 875.8 | 276.8 | 183 | 0955 | " |

Appendix Table 7.3d. (continued)
Page 9

| Station | Rep | 27 Loran | 42 Loran | Depth Feet | Time | Date Sampled |
|---|---|---|---|---|---|---|
| PB-3 | A | 879.4 | 273.1 | 189 | 0850 | 1 Dec 82 |
| | B | 879.4 | 273.0 | 189 | 0900 | " |
| | C | 879.4 | 273.1 | 183 | 0907 | " |
| PB-4 | A | 880.9 | 270.4 | 186 | 1310 | 30 Nov 82 |
| | B | 880.9 | 270.3 | 190 | 1320 | " |
| | C | 880.9 | 270.4 | 192 | 1330 | " |
| QM-1 | A | 928.2 | 260.0 | 22 | 0830 | " |
| | B | 928.3 | 260.0 | 21 | 0840 | " |
| | C | 928.3 | 260.0 | 21 | 0845 | " |
| QM-2 | A | 923.0 | 255.5 | 53 | 0905 | " |
| | B | 923.0 | 255.4 | 53 | 0915 | " |
| | C | 923.1 | 255.4 | 53 | 0930 | " |

# 8.7 APPENDIX

Appendix 8A. 1982 nearshore and offshore sampling dates.

| Location | Spring | Summer | Autumn |
|---|---|---|---|
| Seahurst | | | |
| Nearshore | 22 June | 18-20 Aug | 4-5 Nov |
| Offshore | 1-2 June | 9 Sept | 21-24 Nov |
| Pt. Pulley | | | |
| Nearshore | 21 June | 12-17 Aug | 3 Nov |
| Offshore | 1-10 June | 10 Sept | 20-21 Nov |
| Tramp Harbor | | | |
| Nearshore | 23 June | 19 Aug | 2 Nov |
| Offshore | 2-10 June | 7-8 Sept | 20-21 Nov |
| Aquarium | | | |
| Nearshore | 24 June | 20 Aug | 1 Nov |
| Offshore | 3-19 June | 8 Sept | 19 Nov |

# APPENDIX 10A

## COLLECTION SITES AND COORDINATES

### Shellfish Collection Sites

Shellfish collections for the virology task have been underway for eight months. A total of ten collection beaches have been established with two collection sites per beach (high and low tide levels). Table 10A.1 summarizes the beach locations indicating the site number, beach name and coordinates. Figure 10A.1 gives an overview of the beach locations for comparative purposes while Figures 10A.2-10A.9 show details of the sites along with descriptions of the individual beaches and the types of fauna to be found at each.

Due to the distance between collection sites (10 miles between farthest points excluding reference site 10) it is not possible to collect all sites during a single low tide cycle. Therefore a three-man team has been collecting opposite sides at East Passage by boat on two different days. By this method each side of the Sound can be covered in approximately four hours if the water is calm. This is sufficient time to get both a high and low tide sample when there is a minus tide (i.e., <0.0 ft.).

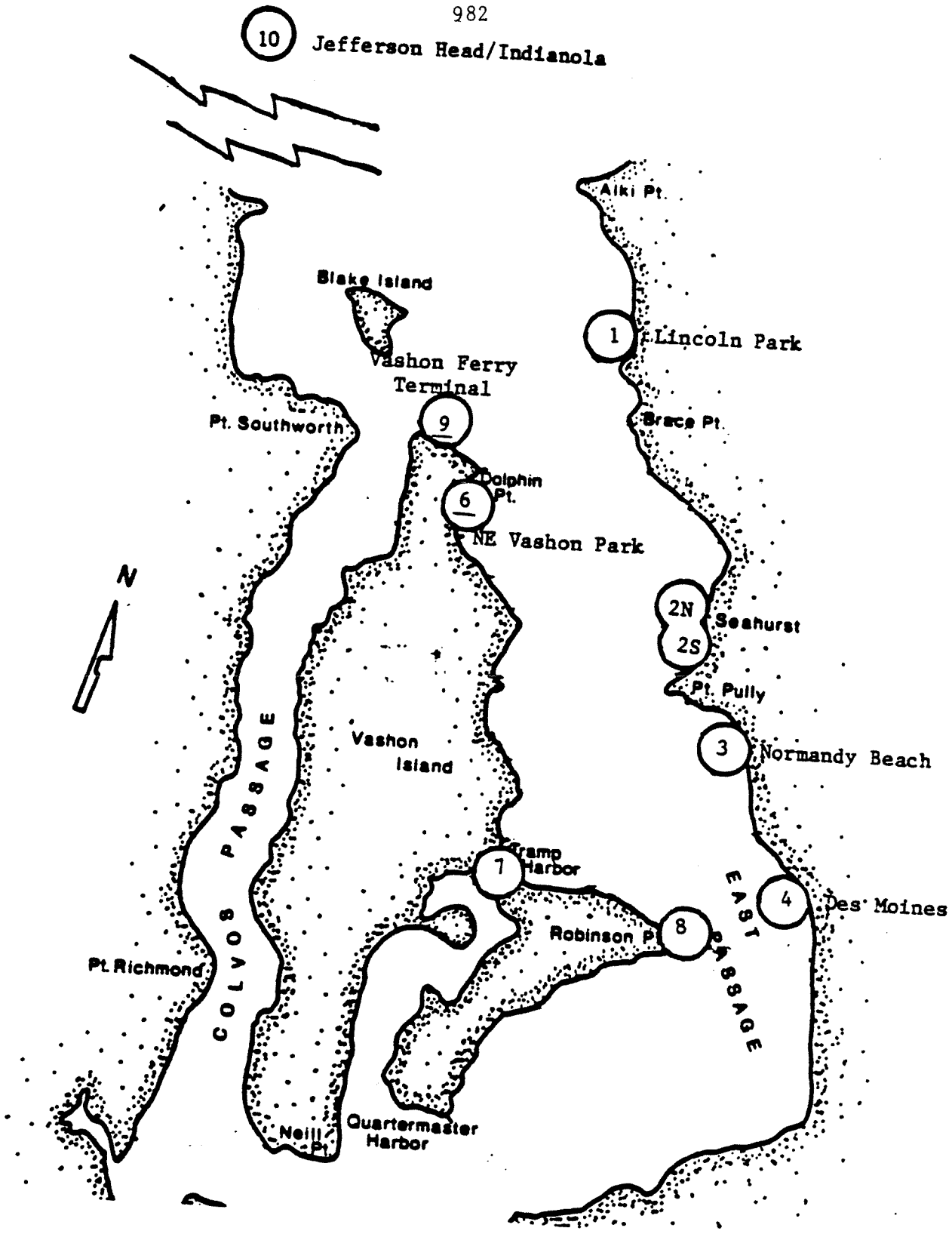



Figure 10A.1. Overview of collection sites being utilized for the METRO Virology study. Sites 1-4 and 10 are collected monthly during a minus tide series, with samples taken from the highest level at which clams occur and the lowest exposed beach for that time and tide cycle. Sites 6-9 are similarly sampled, but on a quarterly basis. Site names and locations are given in Table 10A.1.

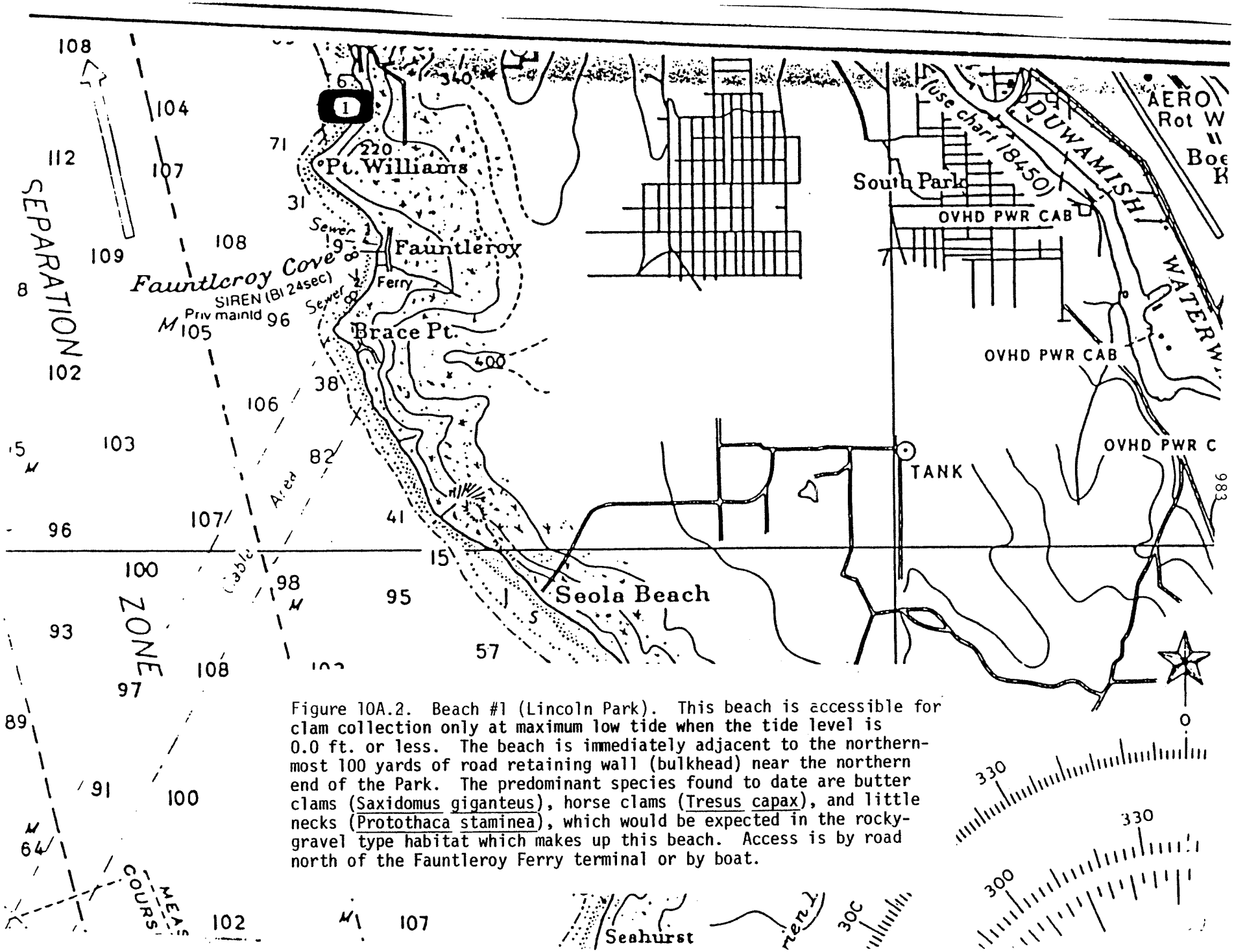



Figure 10A.2. Beach #1 (Lincoln Park). This beach is accessible for clam collection only at maximum low tide when the tide level is 0.0 ft. or less. The beach is immediately adjacent to the northernmost 100 yards of road retaining wall (bulkhead) near the northern end of the Park. The predominant species found to date are butter clams (Saxidomus giganteus), horse clams (Tresus capax), and little necks (Protothaca staminea), which would be expected in the rocky-gravel type habitat which makes up this beach. Access is by road north of the Fauntleroy Ferry terminal or by boat.

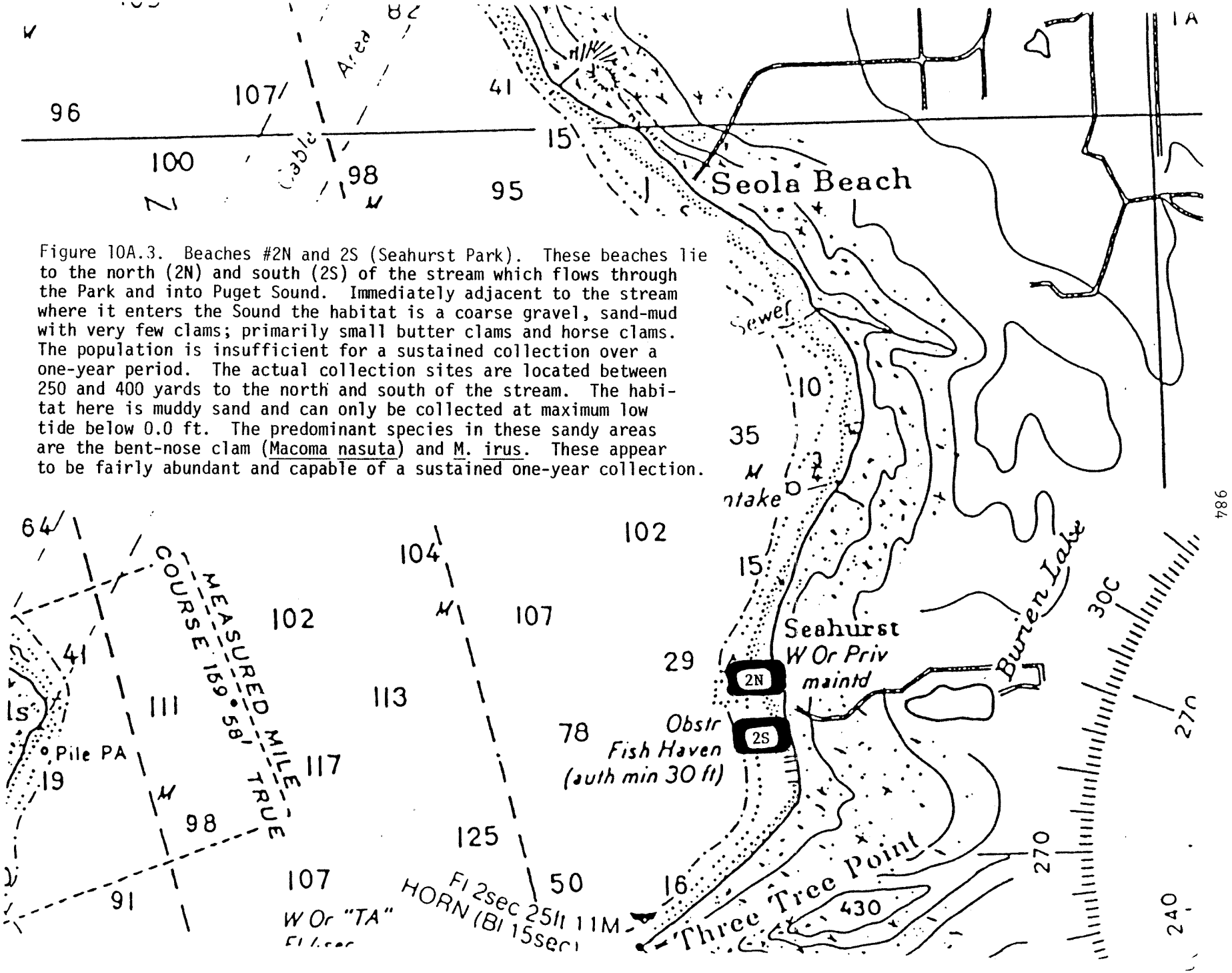



Figure 10A.3. Beaches #2N and 2S (Seahurst Park). These beaches lie to the north (2N) and south (2S) of the stream which flows through the Park and into Puget Sound. Immediately adjacent to the stream where it enters the Sound the habitat is a coarse gravel, sand-mud with very few clams; primarily small butter clams and horse clams. The population is insufficient for a sustained collection over a one-year period. The actual collection sites are located between 250 and 400 yards to the north and south of the stream. The habitat here is muddy sand and can only be collected at maximum low tide below 0.0 ft. The predominant species in these sandy areas are the bent-nose clam (Macoma nasuta) and M. irus. These appear to be fairly abundant and capable of a sustained one-year collection.

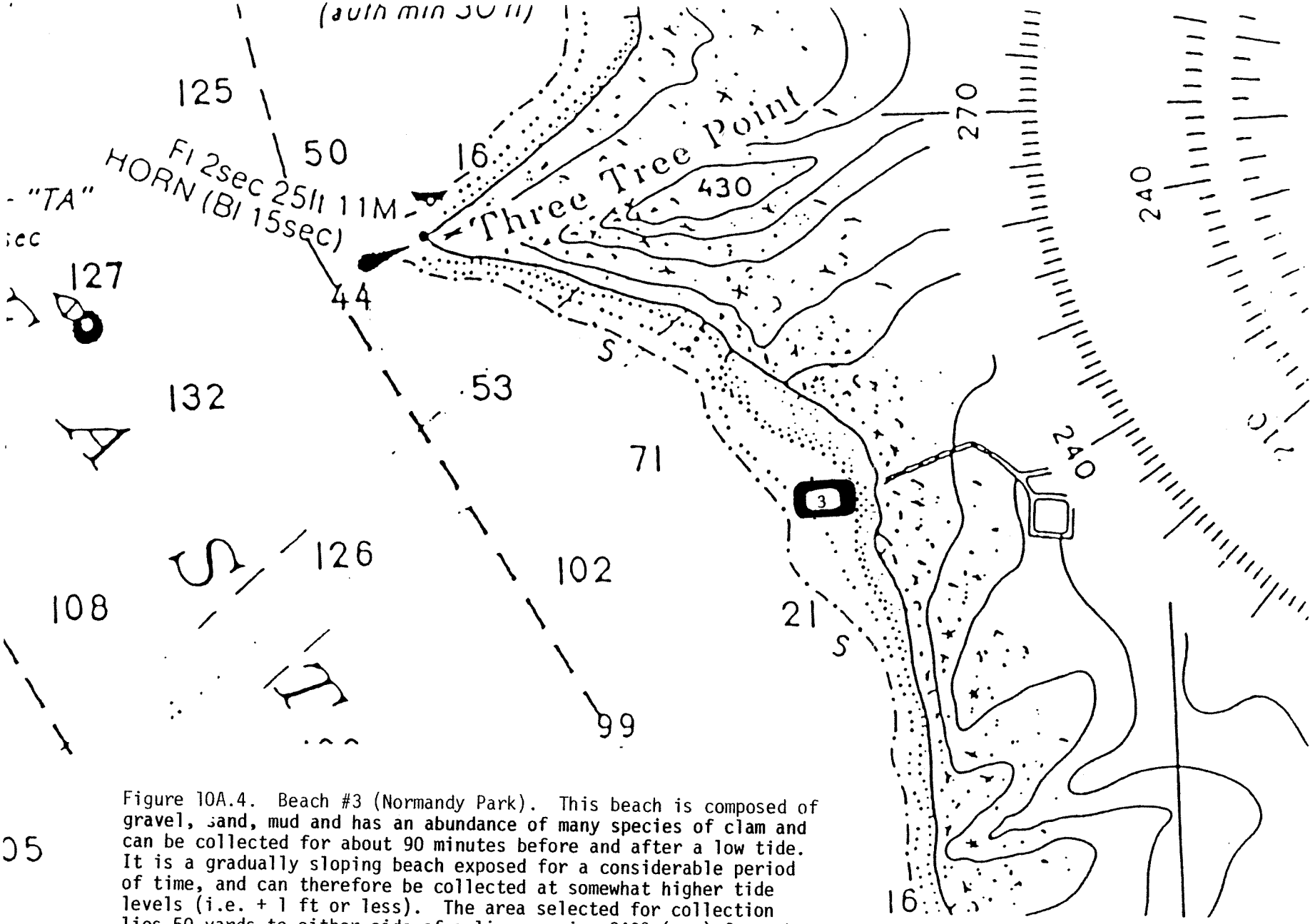



Figure 10A.4. Beach #3 (Normandy Park). This beach is composed of gravel, sand, mud and has an abundance of many species of clam and can be collected for about 90 minutes before and after a low tide. It is a gradually sloping beach exposed for a considerable period of time, and can therefore be collected at somewhat higher tide levels (i.e. + 1 ft or less). The area selected for collection lies 50 yards to either side of a line running 240° (mag) from the parking lot at the end of the beach access road.

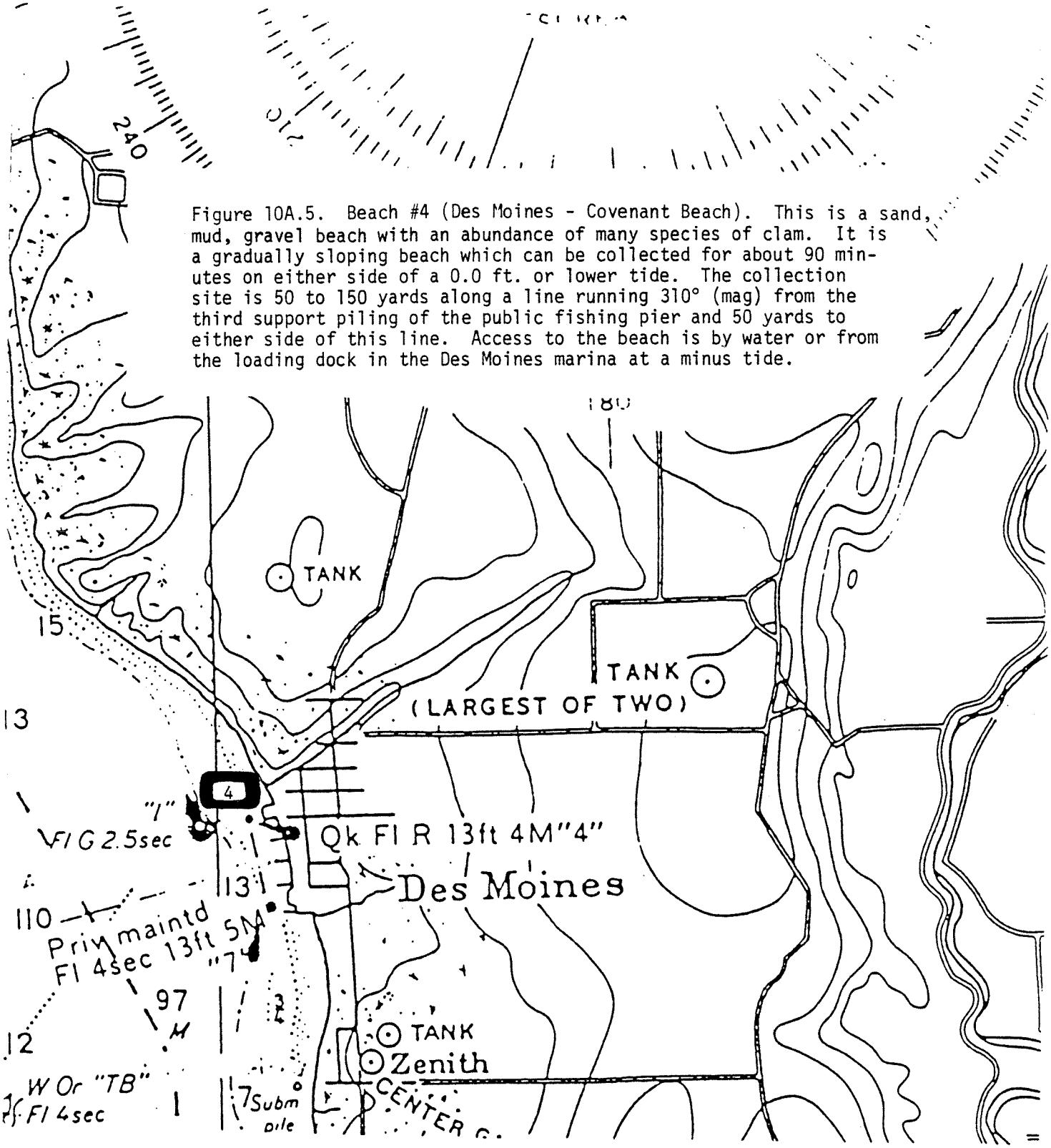



Figure 10A.5. Beach #4 (Des Moines - Covenant Beach). This is a sand, mud, gravel beach with an abundance of many species of clam. It is a gradually sloping beach which can be collected for about 90 minutes on either side of a 0.0 ft. or lower tide. The collection site is 50 to 150 yards along a line running 310° (mag) from the third support piling of the public fishing pier and 50 yards to either side of this line. Access to the beach is by water or from the loading dock in the Des Moines marina at a minus tide.

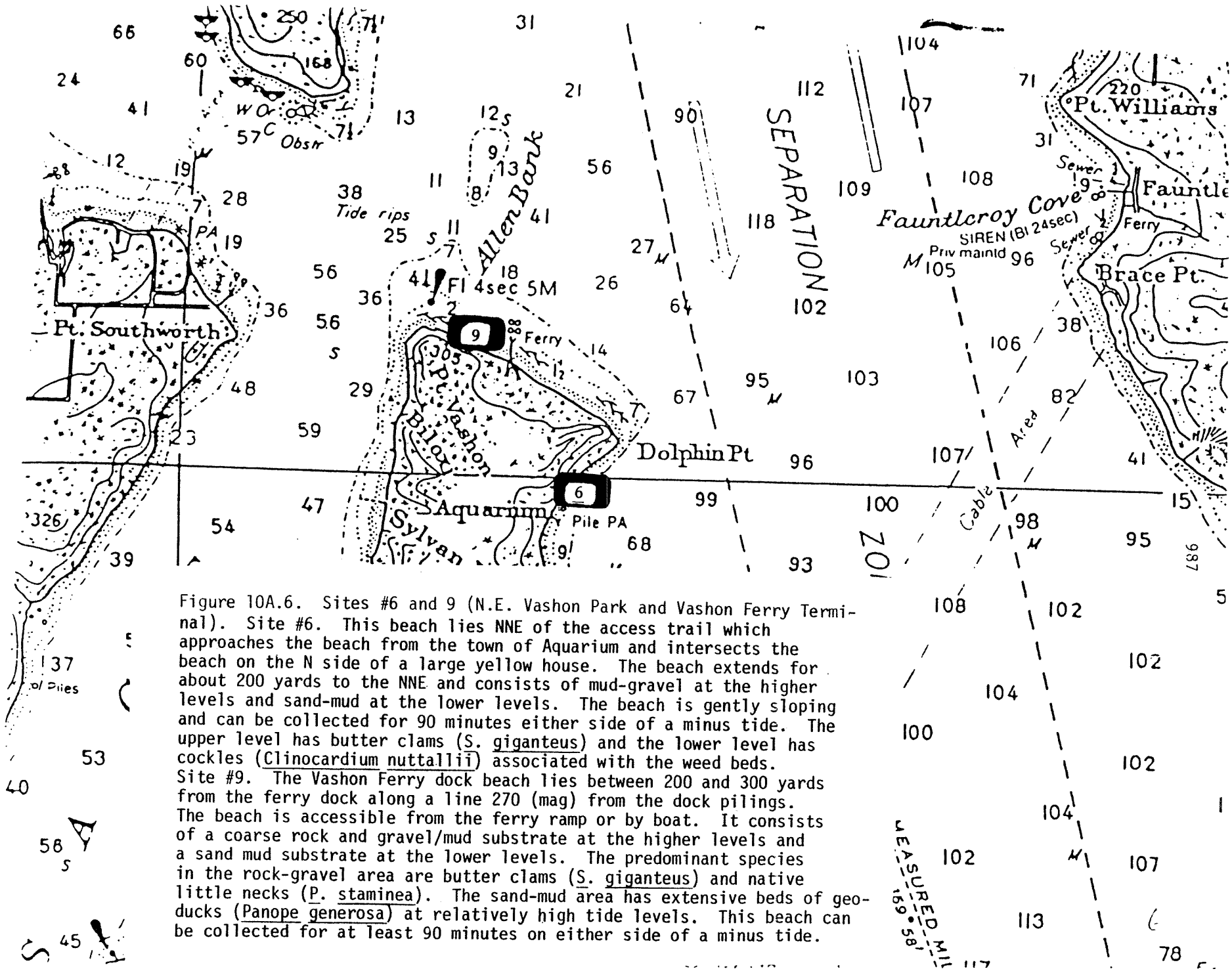



Figure 10A.6. Sites #6 and 9 (N.E. Vashon Park and Vashon Ferry Terminal). Site #6. This beach lies NNE of the access trail which approaches the beach from the town of Aquarium and intersects the beach on the N side of a large yellow house. The beach extends for about 200 yards to the NNE and consists of mud-gravel at the higher levels and sand-mud at the lower levels. The beach is gently sloping and can be collected for 90 minutes either side of a minus tide. The upper level has butter clams (S. giganteus) and the lower level has cockles (Clinocardium nuttallii) associated with the weed beds. Site #9. The Vashon Ferry dock beach lies between 200 and 300 yards from the ferry dock along a line 270 (mag) from the dock pilings. The beach is accessible from the ferry ramp or by boat. It consists of a coarse rock and gravel/mud substrate at the higher levels and a sand mud substrate at the lower levels. The predominant species in the rock-gravel area are butter clams (S. giganteus) and native little necks (P. staminea). The sand-mud area has extensive beds of geoducks (Panope generosa) at relatively high tide levels. This beach can be collected for at least 90 minutes on either side of a minus tide.

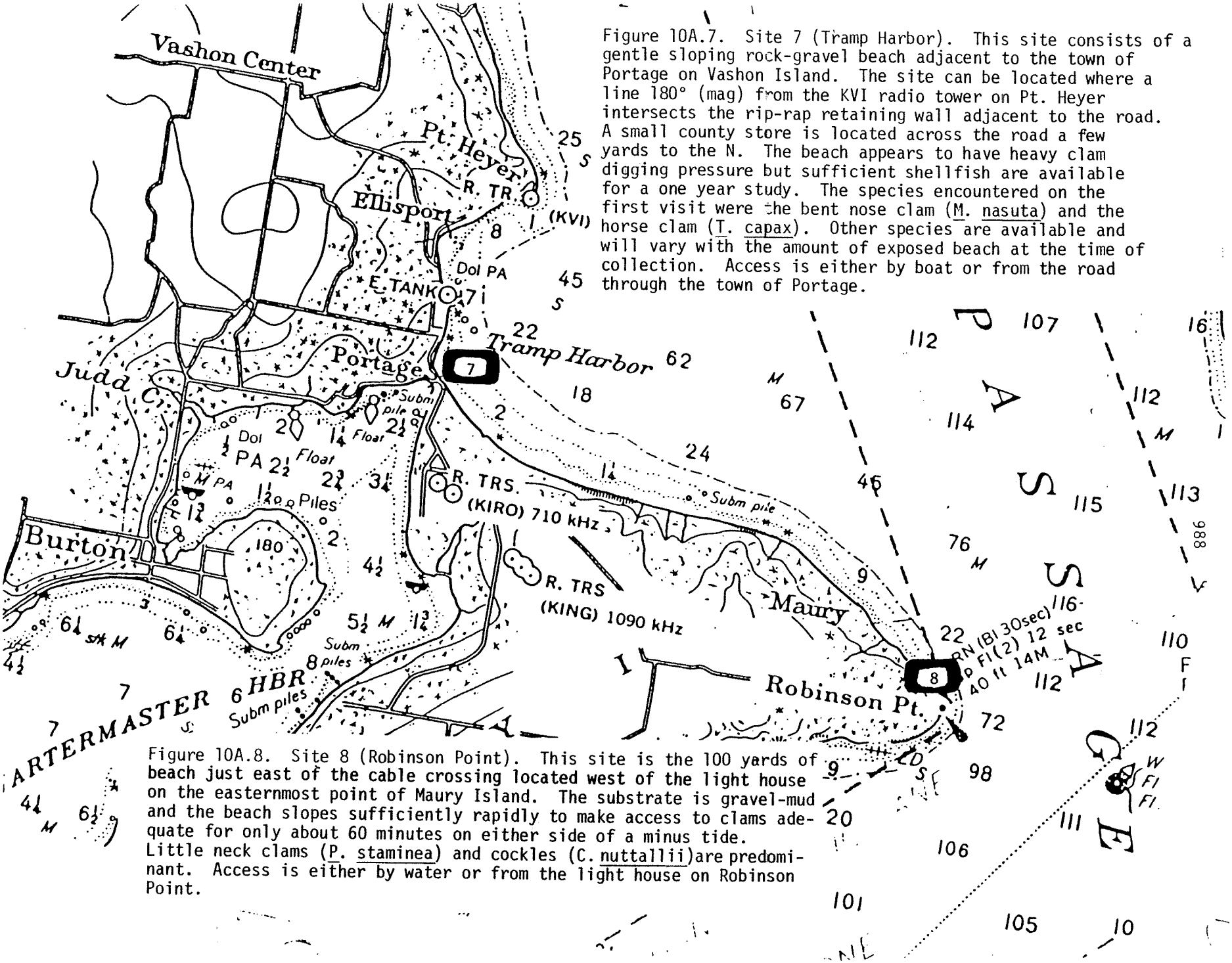



Figure 10A.7. Site 7 (Tramp Harbor). This site consists of a gentle sloping rock-gravel beach adjacent to the town of Portage on Vashon Island. The site can be located where a line 180° (mag) from the KVI radio tower on Pt. Heyer intersects the rip-rap retaining wall adjacent to the road. A small county store is located across the road a few yards to the N. The beach appears to have heavy clam digging pressure but sufficient shellfish are available for a one year study. The species encountered on the first visit were the bent nose clam (M. nasuta) and the horse clam (T. capax). Other species are available and will vary with the amount of exposed beach at the time of collection. Access is either by boat or from the road through the town of Portage.

Figure 10A.8. Site 8 (Robinson Point). This site is the 100 yards of beach just east of the cable crossing located west of the light house on the easternmost point of Maury Island. The substrate is gravel-mud and the beach slopes sufficiently rapidly to make access to clams adequate for only about 60 minutes on either side of a minus tide. Little neck clams (P. staminea) and cockles (C. nuttallii)are predominant. Access is either by water or from the light house on Robinson Point.

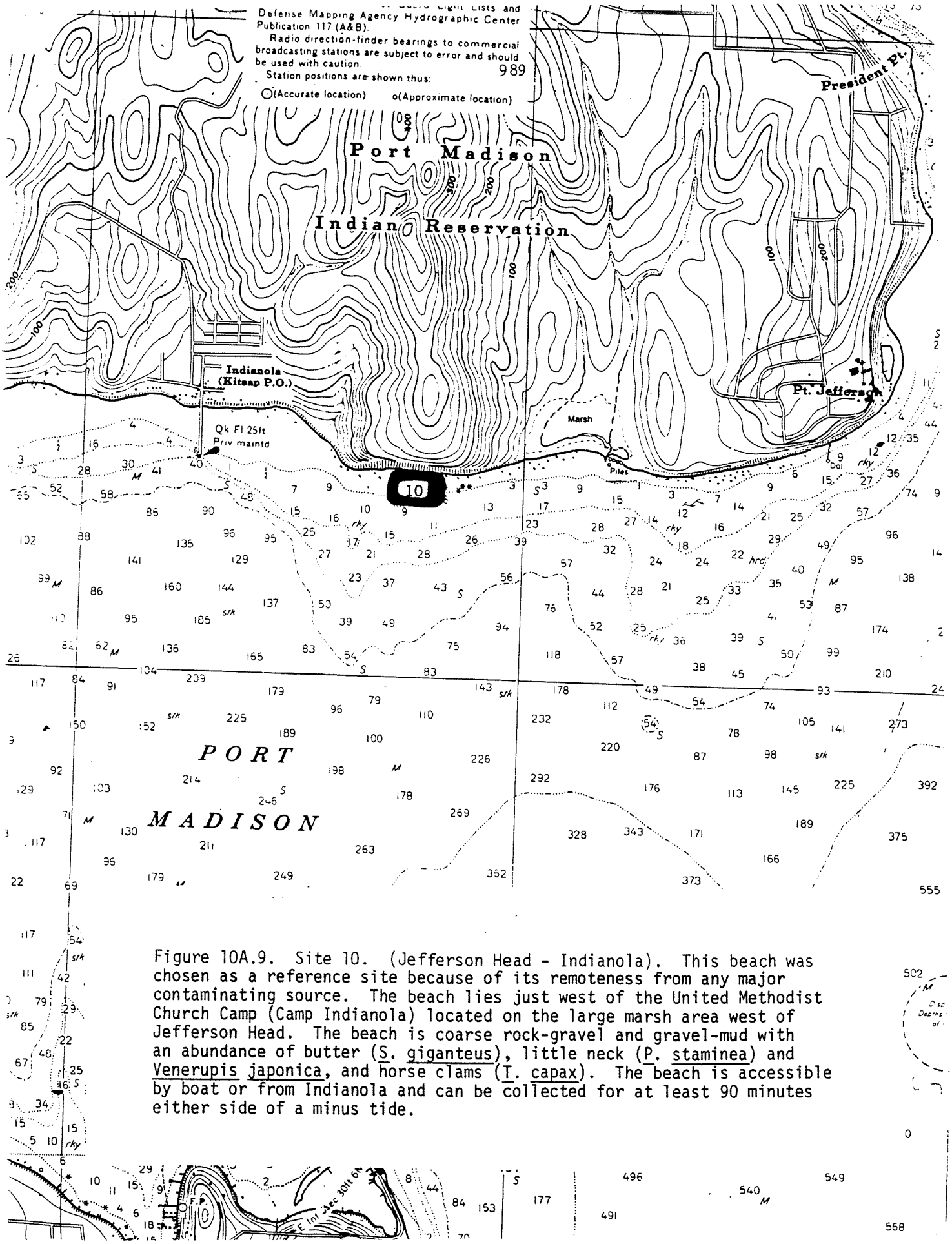



Figure 10A.9. Site 10. (Jefferson Head - Indianola). This beach was chosen as a reference site because of its remoteness from any major contaminating source. The beach lies just west of the United Methodist Church Camp (Camp Indianola) located on the large marsh area west of Jefferson Head. The beach is coarse rock-gravel and gravel-mud with an abundance of butter (S. giganteus), little neck (P. staminea) and Venerupis japonica, and horse clams (T. capax). The beach is accessible by boat or from Indianola and can be collected for at least 90 minutes either side of a minus tide.

APPENDIX 10B

Species and numbers of clams processed from each collection.

| Lincoln Park | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| July | Tresus capax | 6 | Saxidomus giganteus | 7 |
| August | Saxidomus giganteus | 6 | Saxidomus giganteus | 3 |
| September | Saxidomus giganteus | 7 | Tresus capax | 3 |
| October | Tresus capax | 4 | Tresus capax | 2 |
| | Saxidomus giganteus | 1 | Saxidomus giganteus | 2 |
| | | | Protothaca staminea | 2 |
| November | *Saxidomus giganteus | 5 | Saxidomus giganteus | 4 |
| December | Tresus capax | 2 | Tresus capax | 2 |
| | Saxidomus giganteus | 1 | Saxidomus giganteus | 1 |
| January | Saxidomus giganteus | 7 | | |
| February | Saxidomus giganteus | 6 | | |
| | Clinocardium nuttallii | 3 | | |
| | Protothaca staminea | 3 | | |
| March | Saxidomus giganteus | 4 | Saxidomus giganteus | 4 |
| April | Tresus capax | 3 | Tresus capax | 1 |
| | | | Saxidomus giganteus | 1 |
| May | Tresus capax | 2 | Tresus capax | 2 |
| June | Tresus capax | 2 | Tresus capax | 2 |
| **Seahurst (N)** | | | | |
| July | - | - | - | - |
| August | Macoma nasuta | 13 | Macoma nasuta | 12 |
| | | | Clinocardium nuttallii | 1 |
| September | Saxidomus giganteus | 3 | Tresus capax | 1 |
| | Macoma nasuta | 2 | Saxidomus giganteus | 2 |
| | Macoma irus | 2 | | |
| | Protothaca staminea | 2 | | |
| October | Protothaca staminea | 20 | Protothaca staminea | 1 |
| | Macoma nasuta | 4 | Macoma nasuta | 16 |
| | Macoma irus | 10 | | |
| November | Protothaca staminea | 18 | Clinocardium nuttallii | 3 |
| December | Clinocardium nuttallii | 3 | *Tresus capax | 3 |

Appendix 10B (continued).

Seahurst (N)

| | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| January | Tresus capax | 2 | | |
| | Saxidomus giganteus | 6 | | |
| | Protothaca staminea | 1 | | |
| February | Saxidomus giganteus | 1 | | |
| | Protothaca staminea | 7 | | |
| | Maxoma irus | 2 | | |
| | Clinocardium nuttallii | 6 | | |
| March | Saxidomus giganteus | 3 | Saxidomus giganteus | 4 |
| | Clinocardium nuttallii | 3 | | |
| April | Tresus capax | 1 | Tresus capax | 2 |
| | Saxidomus giganteus | 2 | | |
| | Clinocardium nuttallii | 1 | | |
| | Protothaca staminea | 11 | | |
| May | *Tresus capax | 2 | Clinocardium nuttallii | 3 |
| June | Saxidomus giganteus | 5 | Clinocardium nuttallii | 3 |
| | Protothaca staminea | 11 | | |

| Seahurst (S) | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| July | Protothaca staminea | 1 | Macoma irus | 9 |
| | Tresus capax | 1 | | |
| | Saxidomus giganteus | 1 | | |
| August | - | - | Clinocardium nuttallii | 1 |
| | | | Protothaca staminea | 1 |
| | | | Saxidomus giganteus | 1 |
| | | | Macoma irus | 1 |
| September | Saxidomus giganteus | 5 | *Saxidomus giganteus | 5 |
| | Protothaca staminea | 6 | | |
| | Macoma irus | 1 | | |
| October | Macoma irus | 21 | Macoma irus | 5 |
| | Macoma nasuta | 5 | Clinocardium nuttallii | 1 |
| November | Clinocardium nuttallii | 1 | Clinocardium nuttallii | 3 |
| | Tresus capax | 1 | | |
| | Saxidomus giganteus | 1 | | |
| | Protothaca staminea | 1 | | |
| December | Tresus capax | 2 | Clinocardium nuttallii | 3 |
| January | Tresus capax | 3 | | |
| | Clinocardium nuttallii | 2 | | |

Appendix 10B (continued).

Seahurst (S)

| | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| February | Saxidomus giganteus | 1 | | |
| | Protothaca staminea | 1 | | |
| | Macoma irus | 8 | | |
| | Clinocardium nuttallii | 4 | | |
| March | Tresus capax | 1 | Tresus capax | 1 |
| | Saxidomus giganteus | 1 | Macoma nasuta | 2 |
| April | Tresus capax | 2 | Clinocardium nuttallii | 3 |
| May | Tresus capax | 2 | Clinocardium nuttallii | 3 |
| June | *Tresus capax | 2 | Clinocardium nuttallii | 3 |

Normandy Park

| | | | | |
|---|---|---|---|---|
| July | Saxidomus giganteus | 8 | Saxidomus giganteus | 9 |
| August | Saxidomus giganteus | 8 | Tresus capax | 5 |
| September | Saxidomus giganteus | 3 | Saxidomus giganteus | 3 |
| | Venenupis japonica | 10 | Protothaca staminea | 4 |
| October | Saxidomus giganteus | 1 | Saxidomus giganteus | 2 |
| | Mya arenaria | 2 | | |
| November | Saxidomus giganteus | 6 | Saxidomus giganteus | 4 |
| December | Saxidomus giganteus | 5 | Saxidomus giganteus | 5 |
| January | Saxidomus giganteus | 7 | | |
| February | Saxidomus giganteus | 6 | | |
| March | Tresus capax | 1 | *Saxidomus giganteus | 3 |
| | Saxidomus giganteus | 2 | | |
| April | Saxidomus giganteus | 4 | Tresus capax | 1 |
| | | | Saxidomus giganteus | 2 |
| May | Saxidomus giganteus | 4 | Clinocardium nuttallii | 5 |
| June | Tresus capax | 2 | Tresus capax | 2 |

Appendix 10B (continued).

| | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| **Covenent Beach (Des Moines)** | | | | |
| July | Protothaca staminea | 20 | Saxidomus giganteus | 11 |
| August | Saxidomus giganteus | 5 | Tresus capax | 2 |
| September | Protothaca staminea | 2 | Tresus capax | 4 |
| | Saxidomus giganteus | 4 | | |
| | Tresus capax | 1 | | |
| October | Protothaca staminea | 21 | Tresus capax | 2 |
| November | Saxidomus giganteus | 3 | Saxidomus giganteus | 3 |
| December | Tresus capax | 2 | Tresus capax | 2 |
| | Saxidomus giganteus | 1 | Saxidomus giganteus | 3 |
| January | Tresus capax | 4 | | |
| February | Tresus capax | 3 | | |
| | Clinocardium nuttallii | 1 | | |
| March | Tresus capax | 2 | Tresus capax | 2 |
| April | Tresus capax | 2 | Tresus capax | 1 |
| | | | Saxidomus giganteus | 3 |
| May | Tresus capax | 3 | Saxidomus giganteus | 3 |
| June | Tresus capax | 2 | Tresus capax | 1 |
| | | | Saxidomus giganteus | 2 |
| Jefferson Head/ Indianola | | | | |
| July | Protothaca staminea | 10 | Protothaca staminea | 7 |
| August | *Saxidomus giganteus | 4 | Clinocardium nuttallii | 2 |
| September | Saxidomus giganteus | 5 | Saxidomus giganteus | 3 |
| October | Saxidomus giganteus | 4 | Tresus capax | 2 |
| November | Tresus capax | 2 | Saxidomus giganteus | 4 |
| December | Tresus capax | 2 | Saxidomus giganteus | 4 |
| January | Tresus capax | 2 | | |
| | Saxidomus giganteus | 4 | | |
| February | Tresus capax | 2 | | |
| | Saxidomus giganteus | 4 | | |

Appendix 10B (continued).

Jefferson Head/
Indianola

| | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| March | Saxidomus giganteus | 5 | Tresus capax | 2 |
| | Protothaca staminea | 3 | | |
| April | Saxidomus giganteus | 4 | Tresus capax | 2 |
| May | Tresus capax | 2 | Tresus capax | 1 |
| | | | Macoma nasuta | 2 |
| June | Saxidomus giganteus | 1 | | |
| | Clinocardium nuttallii | 2 | | |

Vashon Ferry Dock

| | | | | |
|---|---|---|---|---|
| July | *Saxidomus giganteus | 11 | Saxidomus giganteus | 5 |
| | | | Protothaca staminea | |
| August | | | | |
| September | ---not sampled--- | | | |
| October | Macoma irus | 5 | Macoma irus | 8 |
| November | | | | |
| December | ---not sampled--- | | | |
| January | Macoma irus | 9 | | |
| | Tresus capax | 1 | | |
| February | --not collected-- | | | |
| March | -- | | -- | |
| April | Saxodomus giganteus | 3 | Mya arenaria | 8 |
| | Tresus capax | 1 | | |
| | | | -- | |
| May | -- | | | |
| June | -- | | -- | |

Appendix 10B (continued).

| | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| N.E. Vashon Park | | | | |
| July | Saxidomus giganteus | 5 | Clinocardium nuttallii | 7 |
| August<br>September | ---not sampled--- | | | |
| October | Saxidomus giganteus<br>Tresus capax | 1<br>1 | *Saxidomus giganteus | 2 |
| November<br>December | ---not sampled--- | | | |
| January | Saxidomus giganteus | 6 | | |
| February | --not collected-- | | | |
| March | -- | | -- | |
| April | Saxidomus giganteus | 3 | Saxidomus giganteus | 3 |
| May | -- | | -- | |
| June | -- | | -- | |
| Tramp Harbor | | | | |
| July | Tresus capax | 2 | Macoma nasuta | 19 |
| August<br>September | ---not sampled--- | | | |
| October | Saxidomus giganteus<br>Protothaca staminea | 1<br>14 | Saxidomus giganteus<br>Protothaca staminea<br>Macoma irus | 1<br>9<br>1 |
| November<br>December | ---not sampled--- | | | |
| January | Tresus capax<br>Protothaca staminea<br>Saxidomus giganteus | 1<br>15<br>6 | | |

Appendix 10B (continued).

Tramp Harbor

| | High Tide | # | Low Tide | # |
|---|---|---|---|---|
| March | -- | | -- | |
| April | Saxidomus giganteus | 3 | Clinocardium nuttallii | 3 |
| | Clinocerdium nuttallii | 1 | | |
| May | -- | | -- | |
| June | -- | | -- | |

Point Robinson

| | | | | |
|---|---|---|---|---|
| July | Clinocardium nuttallii | 5 | Protothaca staminea | 14 |
| August | | | | |
| September | ---not sampled--- | | | |
| October | Tresus capax | 2 | Clinocardium nuttallii | 3 |
| November | | | | |
| December | ---not sampled--- | | | |
| January | Tresus capax | 2 | | |
| | Macoma irus | 2 | | |
| | Protothaca staminea | 9 | | |
| February | --not collected-- | | | |
| March | -- | | -- | |
| April | Clinocardium nuttallii | 2 | *Clinocardium nuttallii | 3 |
| | Tresus capax | 1 | | |
| May | -- | | -- | |
| June | -- | | -- | |

*denotes sample injected (spiked) with polio virus to serve as positive control during final virus isolation.

Key to common names of clams used in this study:

Tresus capax . . . . . Horse clam

Saxidomus giganteus. . . . . Butter clam

Clinocardium nuttallii . . . . . Heart cockle

Protothaca staminea. . . . . Native littleneck clam

Venerupes japonica . . . . . Japanense littleneck clam

Macoma nasuta. . . . . Bent nose clam

Macoma irus (inguinata). . . . . none

Mya arenaria . . . . . Eastern soft-shell clam

Appendix 11A.

Media

A-1 Medium, single strength; BAM (A49). (Used in fecal coliform procedure).

A-1 Medium, 1.5 strength; prepare as in BAM (A49) but increase gram amounts by 1.5 times. Use 20 ml broth to 10 ml inoculum.

Brain Heart Infusion (BHI) Broth or Agar; BAM (A11), Difco 0037-01. (Enterococci procedure).

Brain Heart Infusion (BHI) Broth with 40% Bile; EPA (5.4.9). Add 40 ml sterile 10% oxgall to 60 ml BHI. (Enterococci confirmation procedure).

Brilliant Green Agar (BGA); BAM (A12), Difco 0285-01. (Salmonella procedure).

Decarboxylase Control Broth; BAM (A18). (Salmonella and Vibrio procedures).

Decarboxylase Media for Vibrio parahaemolyticus; BAM (A19).

EIA Agar (Levin et al. 1975)

| | |
|---|---|
| Agar | 15.0 gm |
| Esculin | 1.0 gm |
| Ferric citrate | 0.5 gm |
| Distilled water | 1000 ml |

Adjust pH to 7.1 ± 0.1 before autoclaving. Autoclave at 121°C for 15 min. Pour in 3.5 ml amounts to 50 mm plates.

(Enterococci procedure).

Eosin-Methylene Blue (EMB) Agar, Levine's; BAM (A23), Difco 0005-01. (Fecal coliform procedure).

Halophilism Salt Trypticase Broth (STB); BAM (A29). (Vibrio procedure).

Hektoen Agar; BAM (A70), Difco 0853-01. (Salmonella procedure).

Hories Broth; Horie et al. (1964).

| | | | |
|---|---|---|---|
| Peptone | 5.0 gm | Bromthymol Blue, 1.5% | 2.0 ml |
| Beef Extract | 3.0 gm | Ethyl Violet, 0.1% | 1.0 ml |
| Arbinose | 5.0 gm | Calcium Carbonate | 10.0 gm |
| NaCl | 30.0 gm | Distilled Water | 1000 ml |

Dissolve ingredients except arabinose in 900 ml water.
Adjust pH to 9.0 and autoclave at 121°C for 15 min.
Dissolve arabinose in 100 ml water and steam for 15 min. Aseptically add arabinose solution to basal medium. (Vibrio procedure).

Hugh-Leifson Glucose Broth (HLGB); BAM (A30). (Vibrio procedure).

Appendix 11A. (continued)

Media

Iron Milk Medium; St. John et al. 1982.

| | |
|---|---|
| Pasteurized homogenized whole milk | 10 ml/tube |
| Elemental iron powder | 0.2 gm/tube |

Sterilize at 116°C for 10 min. Steam for 5 min and hold at 45°C $\leq$ 1 hour before use. (Clostridium procedure)

Lactate Agar;

| | |
|---|---|
| NaCl | 1.0 gm |
| $MgSO_4 \cdot 7H_2O$ | 0.2 gm |
| $(NH_4)_2 HPO_4$ | 1.0 gm |
| $KH_2PO_4$ | 0.5 gm |
| Lactic acid, Sodium salt | 2.0 gm |
| Phenol red, 0.2% | 4.0 ml |
| Agar | 20.0 gm |
| Distilled water | 1000 ml |

Dissolve agar in 800 ml distilled water and heat to boiling.
Dissolve salts in 200 ml distilled water and adjust pH to 6.9. Add phenol red.
Combine melted agar and salt solution.
Dispense and autoclave at 121°C for 15 min.
Cool tubes in slated position (long slant). (Yersinia procedure)

Lecithovitelline Agar (METRO 1982).

| | |
|---|---|
| Yeast extract | 5 g |
| Bacto-Tryptone | 5 g |
| Proteose Peptone #3 | 20 g |
| NaCl | 5 g |
| Sodium Thioglycollate | 1 g |
| Agar | 20 g |
| Distilled water | 1000 ml |
| Egg yolks | 2 |

Mix all ingredients, except egg yolks, and bring to boil with constant stirring. Autoclave at 118°C/15 minutes, and cool to 50°C. Soak eggs in ethanol. Aseptically separate and discard whites. Place yolks in sterile beaker and add sterile magnet and stir. Add yolks to autoclaved, cooled agar and stir well. Dispense 20 ml/petri plate. (Yersinia procedure).

Lysine Arginine Iron Agar (LAIA); Weagant, 1982. (Yersinia procedure)

Lysine Decarboxylase Broth; BAM (A43). Difco 0215-02. (Salmonella and Vibrio procedures.)

Appendix 11A (continued)

Media

MacConkey Agar; BAM (A45), Difco 0075-01 (Salmonella and Yersinia procedures).

MacConkey Agar CS: Dico 1818-17 (Salmonella and Yersinia procedures).

Malonate Broth; BAM (A47), Difco 0395-02 with the addition of 1.0 gm yeast extract and 0.25 gm flucose per liter. (Salmonella and Yersinia procedures).

Moeller Decarboxylase Broth Base; Difco 0890-01. Supplement individual amino acids at the 0.5% level: (a) Ornithine, or (b) Arginine. (Yersinia and Vibrio procedures).

Motility Test Medium; BAM (A52) with the addition of 5 ml/L 1.0% 2, 3, 5,-triphenyl tetrazolium chloride before autoclaving. When used with Vibrio parahaemolyticus supplement with 3% NaCl. (Yersinia and Vibrio procedures).

MRVP Medium (Buffered Glucose Broth); BAM (A26), Difco 0016-01. (Salmonella and Vibrio procedures).

MSD Agar (Levin et al. 1975).

| | |
|---|---|
| Agar | 15.0 gm |
| Peptone | 10.0 gm |
| NaCl | 15.0 gm |
| Esculin | 1.0 gm |
| Yeast Extract | 30.0 gm |
| Cycloheximide | 0.050 gm |
| Sodium azide | 0.150 gm |
| Distilled water | 1000 ml |

Autoclave at 121°C for 15 min. After autoclaving add:

| | |
|---|---|
| Nalidixic acid | 0.24 gm |
| 2, 3, 5-Triphenyl-tetrazolium chloride | 0.15 gm |

Adjust pH to 7.1 ± 0.1.
Pour in 3.5 ml amounts to 50 mm plates.
(Enterococci procedure)

Nutrient Gelatin; BAM (A60), Difco 0011-01. When used for Vibrio parahaemolyticus supplement with 3% NaCl.

Peptone Sorbitol Broth (PSB); Weagant, 1982. (Yersinia procedure)

Phenylalanine Agar; BAM (A101, Difco 0745-01. (Yersinia procedure)

Appendix 11A (continued)

Media

Purple Carbohydrate Broth; BAM (A66), Difco 0227-01. Supplement individual carbohydrates at the 1.0% level: (a) Lactose, (b) Sucrose, (c) Mannitol, (d) Cellobiose, (e) Sorbitol, (f) Adonitol, (g) Inositol, (h) Raffinose, (i) Rhamnose, (j) Melliobiose, or (k) Dulcitol. When used with Vibrio parahaemolyticus supplement 3% NaCl. (Salmonella, Yersinia, and Vibrio procedures).

Salmonella-Shigella (S-S) Agar; Difco 0074-01. (Salmonella procedure).

Selenite Cystine Broth; BAM (A72, medium 1), Difco 0687-01. (Salmonella procedure).

Simmons' Citrate Agar; BAM (A73), Difco 0091-01. (Salmonella and Yersinia procedures).

Tetrathionate Broth; BAM (A78), Difco 0104-01. (Salmonella procedure).

Thiosulfate-Citrate-Bile salts-Sucrose Agar (TCBS); BAM (A79), Difco 0650-01. (Vibrio procedure).

Triple Sugar Iron (TSI) Agar; BAM (A81), Difco 0265-01. When used for Vibrio parahaemolyticus supplement with 3% NaCl. (Salmonella, Vibrio, and Yersinia procedures).

Tryptic Soy Broth; Difco 0370-01. (Salmonella and Yersinia procedures).

Trypticase Soy Broth; BAM (A84). (Vibrio procedure).

Tryptophane Broth; BAM (A86), Difco 0123-01. When used with Vibrio parahaemolytics supplement with 3% NaCl. (Salmonella, Vibrio, and Yersinia procedures).

Urea Broth; BAM (A89), Difco 0280-61. (Salmonella and Yersinia procedures).

Y-M Agar (Saari et al. 1979).

| | |
|---|---|
| Sodium Thiosulfate (anhydrous) | 2 g |
| Peptone | 4 g |
| Tryptone | 4 g |
| Mannitol | 8 g |
| Beef extract | 3 g |
| Sodium citrate | 16 g |
| Deoxycholic acid sodium salt | 1 g |
| Ferric ammonium citrate | 2 g |
| Potassium phosphate-dibasic | 2 g |
| Agar | 15 g |
| 0.33% solution of neutral acid | 10 ml |
| Deionized water | 1000 ml |

Heat to boiling with constant stirring; let boil for few seconds; do not overheat; pH 7.4-7.5; cool to 50°C in water bath. Dispense 20 ml/plate (thick pour). (Yersinia procedure).

Appendix 11B.

Reagents

Brom Cresol Purple, 0.2%

Catalase reagent; 3.0% hydrogen peroxide

Ferric chloride, 10%

Glycerol.
Add 10% glycerol to TSB cultures prior to freezing for preservation.

Gram stain reagents; Difco 3328-32

Kovacs reagent; BAM (B13)

Methyl Red Indicator; BAM (B18)

Oxidase reagent; 1.0% solution of N,N,N',N'-Tetramethyl-p-phenylenediamine Dihydrochloride. May be stored indefinitely frozen.

Paraffin oil; autoclave 100 ml or less at 121°C for 30 minutes.

Voges-Proskauer Test Reagents; BAM (B36).

Appendix 11C.

Shellfish bacteria per 100 g

| 1982 Date | Sample Location | Lab No. | Fecal coli-forms | 22°C/4°C Yersinia entero-colitica | Vibrio parahaem-olyticus | Salmonella |
|---|---|---|---|---|---|---|
| 7-8 | Lincoln Pk. Low | 001 | 110 | <30 | <30 | Neg |
| 7-8 | Lincoln Pk. High | 002 | 1300 | <30 | <30 | Neg |
| 7-8 | Normandy Beach High | 003 | 50 | <30 | <30 | Neg |
| 7-8 | Normandy Beach Low | 004 | 230 | <30 | <30 | Neg |
| 7-8 | Seahurst South | 005 | 1300 | <30 | <30 | Neg |
| 7-8 | Seahurst Creek | 006 | 70 | <30 | <30 | Neg |
| 7-21 | Tramp Harbor | 014 | 50 | <20 | <30 | Neg |
| 7-21 | Point Robinson | 015 | 230 | <20 | <30 | Neg |
| 7-21 | Des Moines | 016 | 230 | <20 | <30 | Neg |
| 7-21 | Vashon Pk. N.E. | 017 | 1300 | <20 | <30 | Neg |
| 8-4 | Normandy Beach | 018 | 1300 | <30 | <30 | Neg |
| 8-4 | Des Moines | 019 | 80 | <30 | <30 | Neg |
| 8-4 | Seahurst North | 020 | 130 | <30 | <30 | Neg |
| 8-4 | Vashon Ferry | 021 | 330 | <30 | <30 | Neg |
| 8-4 | Lincoln Park Low | 022 | 330 | <30 | <30 | Neg |
| 8-4 | Seahurst So. Low | 023 | 330 | <30 | <30 | Neg |
| 8-31 | Lincoln Central | 031 | 230 | <30 | <30 | Neg |
| 8-31 | Lincoln Park Low | 032 | 330 | <30 | <30 | Neg |
| 8-31 | Seahurst South | 033 | 79 | <30 | <30 | Neg |
| 8-31 | Seahurst Creek | 034 | 700 | <30 | <30 | Neg |
| 8-31 | Normandy Central High | 035 | 490 | <30 | <30 | Neg |
| 8-31 | Normandy North High | 036 | 790 | <30 | <30 | Neg |
| 9-14 | Seahurst North Low | 037 | 50 | <30 | <30 | Neg |
| 9-14 | Normandy High | 038 | 330 | <30 | <30 | Neg |
| 9-14 | Seahurst South Low | 039 | 130 | <30 | <30 | Neg |
| 9-14 | Normandy Low | 040 | 460 | <30 | <30 | Neg |
| 9-14 | Lincoln Low | 041 | 460 | <30 | <30 | Neg |
| 9-15 | Des Moines Low | 042 | 230 | <30 | 70 | Neg |
| 9-15 | Des Moines High | 043 | 80 | <30 | 40 | Neg |
| 10-6 | Lincoln Park Low | 051 | 4900 | <30 | <30 | Neg |
| 10-6 | Seahurst North Low | 052 | 92,000 | | <30 | Neg |
| 10-6 | Normandy Low | 053 | 2300 | <30 | <30 | Neg |
| 10-6 | Seahurst South Low | 054 | 490 | <30 | 30 | Neg |
| 10-6 | Des Moines Low | 055 | 2800 | <30 | 40 | Neg |
| 10-6 | Normandy High | 056 | 2300 | <30 | <30 | Neg |
| 10-6 | Des Moines High | 057 | 4600 | <30 | <30 | Neg |

Appendix 11C. (continued)

Shellfish bacteria per 100 g

| 1982 Date | Sample Location | Lab No. | Fecal coli-forms | 22°C/4°C Yersinia enterio-colitica | Vibrio parahaem-olyticus | Salmonella |
|---|---|---|---|---|---|---|
| 11-16 | Seahurst So. | 068 | 130 | 90 | <30 | Neg |
| 11-16 | Seahurst No. | 069 | 230 | 70 | <30 | Neg |
| 11-16 | Lincoln Park Low | 070 | 20 | 40 | <30 | Neg |
| 11-16 | Lincoln Park High | 071 | 50 | <30 | <30 | Neg |
| 11-18 | Normandy Low | 072 | 330 | 70 | <30 | Neg |
| 11-18 | Normandy High | 073 | 790 | 2400 | <30 | Neg |
| 11-18 | Des Moines High | 074 | 490 | | 30 | Neg |
| 11-18 | Des Moines Low | 075 | 230 | 930 | <30 | Neg |
| 12-2 | Seahurst No. | 077 | 490 | 230 | <30 | Neg |
| 12-2 | Seahurst So. | 078 | 230 | 40 | <30 | Neg |
| 12-2 | Lincoln Park High | 079 | 490 | 30 | <30 | Neg |
| 12-2 | Lincoln Park Low | 080 | 230 | <30 | <30 | Neg |
| 12-4 | Des Moines High | 081 | 460 | 200 | <30 | Neg |
| 12-4 | Des Moines Low | 082 | 490 | 90 | <30 | Neg |
| 12-4 | Normandy | 083 | 230 | 90 | <30 | Neg |
| 1983 | | | | | | |
| 1-27 | Vashon Ferry | 094 | 50 | 40 | | Neg |
| 1-27 | N.E. Vashon Park | 095 | 80 | 70 | | Positive |
| 1-27 | Tramp Harbor | 096 | 230 | 40 | | Neg |
| 1-28 | Lincoln Park | 097 | 330 | 150 | | Neg |
| 1-28 | Seahurst North | 098 | 80 | 1500 | | Neg |
| 1-28 | Seahurst South | 099 | 330 | 930 | | Neg |
| 1-28 | Normandy Low | 100 | 230 | 1500 | | Neg |
| 1-28 | Normandy High | 101 | 230 | 1500 | | Neg |
| 1-28 | Des Moines High | 102 | 1300 | 9300 | | Neg |
| 1-28 | Des Moines Low | 103 | 40 | 4600 | | Neg |
| 2-26 | Des Moines Low | 104 | 330 | 430 | | Neg |
| 2-26 | Des Moines High | 105 | 490 | 150 | | Neg |
| 2-26 | Seahurst North | 106 | 700 | 930 | | Neg |
| 2-26 | Seahurst South | 107 | 1400 | 150 | | Neg |
| 2-26 | Lincoln Park Low | 108 | 230 | <30 | | Neg |
| 2-26 | Normandy Park High | 109 | 490 | 230 | | Neg |
| 2-26 | Normandy Park Low | 110 | 330 | 70 | | |

Appendix 11D.

Intertidal water bacteria per 100 ml saltwater

| 1982 Date | Sample Location | Lab No. | Fecal coli-forms | Enterococci | Salmonella |
|---|---|---|---|---|---|
| 7-8 | Lincoln Pk. Low | 001 | <20 | 3 | Neg |
| 7-8 | Lincoln Pk. High | 002 | <20 | 0 | Neg |
| 7-8 | Normandy Beach Low | 003 | <20 | 1 | Neg |
| 7-8 | Normandy Beach High | 004 | <20 | 0 | Neg |
| 7-8 | Seahurst South | 005 | 20 | 0 | Neg |
| 7-8 | Seahurst Creek | 006 | <20 | 0 | Neg |
| 7-21 | Tramp Harbor | 014 | <20 | 0 | Neg |
| 7-21 | Point Robinson | 015 | <20 | 0 | Neg |
| 7-21 | Des Moines | 016 | 20 | 0 | Neg |
| 7-21 | Vashon Pk. N.E. | 017 | 130 | 18 | Neg |
| 8-4 | Normandy Beach | 018 | 170 | 20 | Neg |
| 8-4 | Des Moines | 019 | <20 | 2 | Neg |
| 8-4 | Seahurst North | 020 | 20 | 3 | Neg |
| 8-4 | Vashon Ferry | 021 | 230 | 12 | Positive |
| 8-4 | Lincoln Park Low | 022 | 50 | 1 | Neg |
| 8-4 | Seahurst So. Low | 023 | <20 | 3 | Neg |
| 8-31 | Lincoln Pk. Central | 031 | 7 | 14 | Neg |
| 8-31 | Lincoln Park North | 032 | 7 | 3 | Neg |
| 8-31 | Seahurst South | 033 | 8 | 1 | Neg |
| 8-31 | Seahurst Creek | 034 | 17 | 12 | Neg |
| 8-31 | Normandy Central High | 035 | 13 | 0 | Neg |
| 8-31 | Normandy North High | 036 | 170 | 1 | Neg |
| 9-14 | Seahurst North Low | 037 | 2300 | 26 | Neg |
| 9-14 | Seahurst South Low | 039 | 5 | TNTC | Neg |
| 9-14 | Normandy Low | 040 | 140 | 33 | Neg |
| 9-14 | Lincoln Low | 041 | 49 | 4 | Neg |
| 9-15 | Des Moines High | 043 | <20 | 29 | Neg |
| 10-6 | Lincoln Park Low | 051 | 540 | TNTC | Neg |
| 10-6 | Seahurst North Low | 052 | 130 | TNTC | Neg |
| 10-6 | Normandy Low | 053 | 540 | TNTC | Neg |
| 10-6 | Seahurst South Low | 054 | 79 | 24 | Neg |
| 10-6 | Des Moines Low | 055 | 130 | 12 | Neg |
| 10-6 | Normandy High | 056 | 33 | 18 | Neg |
| 10-6 | Des Moines High | 057 | 130 | 0 | Neg |
| 11-16 | Seahurst South | 068 | 5 | 11 | Neg |
| 11-16 | Seahurst North | 069 | 13 | 15 | Neg |
| 11-16 | Lincoln Park Low | 070 | 2 | 1 | Neg |

Appendix 11D. (continued)

Intertidal water bacteria per 100 ml saltwater

| 1982 Date | Sample Location | Lab No. | Fecal coli-forms | Enterococci | Salmonella |
|---|---|---|---|---|---|
| 11-18 | Normandy Low | 072 | 17 | 15 | Neg |
| 11-18 | Normandy High | 073 | 23 | 10 | Neg |
| 11-18 | Des Moines High | 074 | 180 | 32 | Neg |
| 11-18 | Des Moines Low | 075 | 130 | 30 | Neg |
| 11-18 | Lincoln Park High | 076 | 240 | 59 | Neg |
| 12-2 | Seahurst North | 077 | 79 | 60 | Neg |
| 12-2 | Seahurst South | 078 | 11 | 5 | Neg |
| 12-2 | Lincoln Park High | 079 | 11 | 19 | Neg |
| 12-2 | Lincoln Park Low | 080 | 23 | 5 | Neg |
| 12-4 | Des Moines High | 081 | 230 | 41 | Neg |
| 12-4 | Des Moines Low | 082 | 220 | 74 | Neg |
| 12-4 | Normandy | 083 | 330 | TNTC | Neg |
| 1983 | | | | | |
| 1-27 | Vashon Ferry | 094 | 170 | 64 | Neg |
| 1-27 | N.E. Vashon Park | 095 | 49 | 5 | Neg |
| 1-27 | Tramp Harbor | 096 | <2 | 5 | Neg |
| 1-28 | Lincoln Park | 097 | 22 | 26 | Neg |
| 1-28 | Seahurst North | 098 | 13 | 16 | Neg |
| 1-28 | Seahurst South | 099 | 13 | 10 | |
| 1-28 | Normandy Low | 100 | 33 | 21 | Neg |
| 1-28 | Normandy High | 101 | 33 | 27 | Neg |
| 1-28 | Des Moines High | 102 | 110 | 32 | Neg |
| 1-28 | Des Moines Low | 103 | 33 | 40 | Neg |
| 2-26 | Des Moines Low | 104 | 790 | 123 | Neg |
| 2-26 | Des Moines High | 105 | 490 | 129 | Neg |
| 2-26 | Seahurst North | 106 | 8 | 2 | Neg |
| 2-26 | Seahurst South | 107 | 23 | 8 | Neg |
| 2-26 | Lincoln Park Low | 108 | 5 | 8 | Neg |
| 2-26 | Normandy Park High | 109 | 490 | 163 | Neg |
| 2-26 | Normandy Park Low | 110 | 490 | 182 | Neg |

Appendix 11E.

Water column bacteria per 100 ml saltwater
(1 meter depth)

| 1982 Date | Sample Location | Lab No. | Fecal coli-forms | 22°-26°C Yersinia entero-colitica | Salmonella |
|---|---|---|---|---|---|
| 7-15 | Site #4 | 007 | <20 | <30 | Neg |
| 7-15 | Site #5 | 008 | <20 | <30 | Neg |
| 7-15 | Site #6 | 009 | <20 | <30 | Neg |
| 7-15 | Site #7 | 010 | <20 | <30 | Neg |
| 7-15 | Site #8 | 011 | <20 | <30 | Neg |
| 7-15 | Site #9 | 012 | <20 | <30 | Neg |
| 7-15 | Site #10 | 013 | <20 | <30 | Neg |
| 8-16 | Site #4 | 024 | <2 | <30 | Neg |
| 8-16 | Site #5 | 025 | <2 | <30 | Neg |
| 8-16 | Site #6 | 026 | <2 | <30 | Neg |
| 8-16 | Site #7 | 027 | <2 | <30 | Neg |
| 8-16 | Site #8 | 028 | <2 | <30 | Neg |
| 8-16 | Site #9 | 029 | <2 | <30 | Neg |
| 8-16 | Site #10 | 030 | <2 | <30 | Neg |
| 9-27 | Site #4 | 044 | <2 | <30 | Neg |
| 9-27 | Site #5 | 045 | <2 | <30 | Neg |
| 9-27 | Site #6 | 046 | <2 | <30 | Neg |
| 9-27 | Site #7 | 047 | <2 | <30 | Neg |
| 9-27 | Site #8 | 048 | <2 | <30 | Neg |
| 9-27 | Site #9 | 049 | 9 | <30 | Neg |
| 9-27 | Site #10 | 050 | 4 | <30 | Neg |
| 10-28 | Site #4 | 058 | 2 | <30 | Neg |
| 10-28 | Site #5 | 059 | 2 | <30 | Neg |
| 10-28 | Site #6 | 060 | 7 | <30 | Neg |
| 10-28 | Site #7 | 061 | 2 | <30 | Neg |
| 10-28 | Site #9 | 062 | 13 | <30 | Neg |
| 11-15 | Site #4 | 063 | <2 | <30 | Neg |
| 11-15 | Site #5 | 064 | <2 | <30 | Neg |
| 11-15 | Site #6 | 065 | 2 | <30 | Neg |
| 11-15 | Site #7 | 066 | <2 | <30 | Neg |
| 11-15 | Site #8 | 067 | <2 | <30 | Neg |
| 12-6 | Site #4 | 084 | 79 | 40 | Neg |
| 12-6 | Site #5 | 085 | 13 | 40 | Neg |
| 12-6 | Site #6 | 086 | 330 | <30 | Neg |
| 12-6 | Site #7 | 087 | 33 | <30 | Neg |
| 12-6 | Site #8 | 088 | 49 | <30 | Neg |

Appendix 11E. (continued)

Water column bacteria per 100 ml saltwater
(1 meter depth)

| 1983 Date | Sample Location | Lab No. | Fecal coli-forms | 22°-26°C Yersinia entero-colitica | Salmonella |
|---|---|---|---|---|---|
| 1-3 | Site #4 | 089 | 2 | <30 | Neg |
| 1-3 | Site #5 | 090 | 5 | <30 | Neg |
| 1-3 | Site #6 | 091 | 11 | 40 | Neg |
| 1-3 | Site #7 | 092 | 8 | <30 | Neg |
| 1-3 | Site #8 | 093 | 2 | <30 | Neg |
| 2-28 | Site #4 | 111 | 5 | <30 | Neg |
| 2-28 | Site #5 | 112 | <2 | <30 | Neg |
| 2-28 | Site #6 | 113 | 2 | <30 | Neg |
| 2-28 | Site #7 | 114 | 5 | <30 | Neg |
| 2-28 | Site #8 | 115 | 5 | <30 | Neg |

Appendix 11F.

Sediment bacteria per gram

| 1982 Date | Sample Location | Lab No. | Clostridium perfringens |
|---|---|---|---|
| 7-8 | Lincoln Park Low | 001 | 93 |
| 7-8 | Lincoln Park High | 002 | 43 |
| 7-8 | Normandy Beach High | 003 | 240 |
| 7-8 | Normandy Beach Low | 004 | 75 |
| 7-8 | Seahurst South | 005 | 93 |
| 7-8 | Seahurst Creek | 006 | 240 |
| 7-21 | Tramp Harbor | 014 | 23 |
| 7-21 | Point Robinson | 015 | 1100 |
| 7-21 | Des Moines | 016 | 23 |
| 7-21 | Vashon Park N.E. | 017 | 46 |
| 8-4 | Normandy Beach | 018 | 93 |
| 8-4 | Des Moines | 019 | 75 |
| 8-4 | Seahurst North | 020 | 4.3 |
| 8-4 | Vashon Ferry | 021 | 4.3 |
| 8-4 | Lincoln Park Low | 022 | 750 |
| 8-4 | Seahurst South Low | 023 | 43 |
| 8-31 | Lincoln Central | 031 | 43 |
| 8-31 | Lincoln Park Low | 032 | 2.3 |
| 8-31 | Seahurst South | 033 | 9 |
| 8-31 | Seahurst Creek | 034 | 9 |
| 8-31 | Normandy Central High | 035 | 93 |
| 8-31 | Normandy North High | 036 | 230 |
| 9-14 | Seahurst North Low | 037 | 43 |
| 9-14 | Normandy High | 038 | 23 |
| 9-14 | Seahurst South Low | 039 | 43 |
| 9-14 | Normandy Low | 040 | 75 |
| 9-14 | Lincoln Park Low | 041 | 4.3 |
| 9-15 | Des Moines Low | 042 | 240 |
| 9-15 | Des Moines High | 043 | 4.3 |
| 10-6 | Lincoln Park Low | 051 | 4.3 |
| 10-6 | Seahurst North Low | 052 | 75 |
| 10-6 | Normandy Low | 053 | 9.3 |
| 10-6 | Seahurst South Low | 054 | 21 |
| 10-6 | Des Moines Low | 055 | 15 |
| 10-6 | Normandy High | 056 | 9.3 |
| 10-6 | Des Moines High | 057 | 93 |

Appendix 11F. (continued)

Sediment bacteria per gram

| 1982 Date | Sample Location | Lab No. | Clostridium perfringens |
|---|---|---|---|
| 11-16 | Seahurst South | 068 | 23 |
| 11-16 | Seahurst North | 069 | 23 |
| 11-16 | Lincoln Park Low | 070 | 9.3 |
| 11-18 | Normandy Low | 072 | 150 |
| 11-18 | Normandy High | 073 | 23 |
| 11-18 | Des Moines High | 074 | 43 |
| 11-18 | Des Moines Low | 075 | 93 |
| 12-2 | Seahurst North | 077 | 1.1 |
| 12-2 | Seahurst South | 078 | 9.3 |
| 12-2 | Lincoln Park High | 079 | 21 |
| 12-2 | Lincoln Park Low | 080 | 9.3 |
| 12-4 | Des Moines High | 081 | 21 |
| 12-4 | Des Moines Low | 082 | 93 |
| 12-4 | Normandy | 083 | 9.3 |
| 1983 | | | |
| 1-27 | Vashon Ferry | 094 | 4.3 |
| 1-27 | N.E. Vashon Park | 095 | 24 |
| 1-27 | Tramp Harbor | 096 | 4.3 |
| 1-28 | Lincoln Park | 097 | 4.3 |
| 1-28 | Seahurst North | 098 | 24 |
| 1-28 | Seahurst South | 099 | 24 |
| 1-28 | Normandy Low | 100 | 4.3 |
| 1-28 | Normandy High | 101 | 15 |
| 1-28 | Des Moines High | 102 | 24 |
| 1-28 | Des Moines Low | 103 | 9.3 |
| 2-26 | Des Moines Low | 104 | 430 |
| 2-26 | Des Moines High | 105 | 23 |
| 2-26 | Seahurst North | 106 | 43 |
| 2-26 | Seahurst South | 107 | 23 |
| 2-26 | Lincoln Park Low | 108 | 39 |
| 2-26 | Normandy Park High | 109 | 4.3 |
| 2-26 | Normandy Park Low | 110 | 23 |

# 12.10 APPENDIX

Appendix Table 12.1. Data summary of the biological responses observed in each of the bioassays of water column baseline samples from Stations 1-10 conducted during 1982, together with representative physical/chemical data. (Note: Stations 90, 91, 92, and 93 = Kincaid Lab, Kincaid Carry-Along, West Point, and Friday Harbor control waters, respectively.)

OBV = OBSERVATION NUMBER
YR = YEAR
DAY = JULIAN DAY
ST = STATION NUMBER
DEP = DEPTH IN METERS
O.SUR = UNADJUSTED OYSTER EMBRYO SURVIVAL
O.ABN = UNADJUSTED % OYSTER EMBRYO ABNORMAL
AVMOR = AVERAGE RELATIVE (TO KINCAID LAB CONTROL) % OYSTER MORTALITY
ADABN = ADJUSTED RELATIVE (TO KINCAID LAB CONTROL) % OYSTER ABNORMAL
UNFER = ADJUSTED RELATIVE (TO KINCAID LAB CONTROL)% SAND DOLLAR EGGS UNFER
SAL = SALINITY IN PARTS PER THOUSAND
PH = PH
NH3 = AMMONIA IN µG-ATOMS/LITER
CHL = CHLOROPHYLL A IN µG/LITER
PRIPR = PRIMARY PRODUCTIVITY IN MG CARBON/SQ. M/DAY

99999 = NOT MEASURED

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 82 | 196 | 5 | 1 | 55.7 | 3.0 | 52.3 | -19.3 | 10.3 | 99999 | 99099 | 0.87 | 1.80 | |
| 2 | 82 | 196 | 5 | 50 | 116.3 | 20.3 | 0.4 | -4.0 | -2.1 | 29.60 | 99099 | 1.57 | 0.40 | |
| 3 | 82 | 196 | 5 | 100 | 135.0 | 32.0 | -15.6 | -3.8 | 0.7 | 29.90 | 99099 | 1.79 | 0.14 | |
| 4 | 82 | 196 | 6 | 1 | 87.2 | 12.8 | 25.3 | -7.6 | 7.1 | 99999 | 99099 | 0.61 | 7.83 | |
| 5 | 82 | 196 | 6 | 50 | 109.5 | 27.2 | 6.2 | 5.2 | -1.8 | 29.62 | 99099 | 1.21 | 0.40 | |
| 6 | 82 | 196 | 6 | 100 | 131.0 | 29.2 | -12.2 | 2.0 | -1.9 | 29.89 | 99099 | 0.76 | 0.30 | |
| 7 | 82 | 196 | 7 | 1 | 118.2 | 14.3 | -1.2 | -10.8 | 7.7 | 99999 | 99099 | 0.72 | 11.40 | 516.7 |
| 8 | 82 | 196 | 7 | 50 | 131.8 | 27.9 | -12.8 | 0.6 | 2.3 | 29.36 | 99099 | 3.52 | 0.98 | |
| 9 | 82 | 196 | 7 | 75 | 152.5 | 37.1 | -30.6 | -4.5 | 1.1 | 29.64 | 99099 | 1.66 | 0.62 | |
| 10 | 82 | 196 | 8 | 1 | 77.8 | 8.5 | 33.4 | -12.4 | 8.0 | 28.24 | 99099 | 0.66 | 18.14 | |
| 11 | 82 | 196 | 8 | 50 | 160.5 | 38.8 | -37.4 | 4.4 | -2.4 | 29.40 | 99099 | 2.81 | 0.52 | |
| 12 | 82 | 196 | 9 | 1 | 61.7 | 7.8 | 47.2 | -10.2 | -0.3 | 99999 | 99099 | 0.95 | 11.40 | |
| 13 | 82 | 196 | 9 | 25 | 141.5 | 26.8 | -21.1 | -2.3 | 1.1 | 29.10 | 99099 | 3.20 | 3.11 | |
| 14 | 82 | 196 | 10 | 1 | 128.8 | 21.7 | -10.3 | -4.9 | 3.0 | 99999 | 99099 | 0.97 | 5.54 | 563.5 |
| 15 | 82 | 196 | 10 | 10 | 98.3 | 12.5 | 15.8 | -10.1 | 5.5 | 99999 | 99099 | 1.10 | 9.84 | |
| 16 | 82 | 196 | 90 | | 116.8 | 24.2 | 0.0 | 0.0 | 0.0 | 29.71 | 99099 | | | |
| 17 | 82 | 196 | 91 | | 132.3 | 32.7 | -13.3 | 5.0 | -0.7 | 29.71 | 99099 | | | |
| 18 | 82 | 196 | 92 | | 110.8 | 28.9 | -5.1 | 6.8 | -2.3 | 28.67 | 8.28 | | | |
| 19 | 82 | 196 | 93 | | 146.8 | 29.3 | -25.7 | -0.9 | -1.8 | 29.52 | 99099 | | | |
| 20 | 82 | 197 | 1 | 1 | 160.3 | 0.4 | 25.7 | -0.9 | 3.1 | 28.16 | 99099 | 2.18 | 3.42 | |

Appendix Table 12.1. (continued)

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 82 | 197 | 1 | 100 | 174.7 | 4.0 | 19.0 | 1.2 | -0.3 | 29.86 | 99099 | 2.89 | 0.11 | |
| 22 | 82 | 197 | 1 | 200 | 213.3 | 4.5 | 1.1 | 1.0 | 1.7 | 30.06 | 99999 | 3.16 | 0.12 | |
| 23 | 82 | 197 | 2 | 1 | 160.3 | 1.6 | 25.7 | -0.1 | -0.0 | 29.01 | 99099 | 1.85 | 99999 | |
| 24 | 82 | 197 | 2 | 50 | 182.0 | 2.9 | 15.6 | 0.5 | -0.8 | 29.27 | 99099 | 2.04 | 1.56 | |
| 25 | 82 | 197 | 2 | 100 | 198.7 | 3.3 | 7.9 | 0.6 | -1.1 | 29.41 | 99099 | 1.87 | 0.52 | |
| 26 | 82 | 197 | 3 | 1 | 193.7 | 0.7 | 10.2 | -0.7 | -1.3 | 27.16 | 99099 | 0.82 | 4.66 | |
| 27 | 82 | 197 | 3 | 75 | 186.3 | 16.6 | 13.6 | 7.9 | -0.8 | 29.29 | 99099 | 1.41 | 0.20 | |
| 28 | 82 | 197 | 3 | 150 | 174.7 | 12.3 | 19.0 | 6.0 | -1.3 | 29.68 | 99099 | 1.05 | 0.16 | |
| 29 | 82 | 197 | 4 | 1 | 177.3 | 2.7 | 17.8 | 0.4 | -0.0 | 99999 | 99099 | 1.09 | 7.77 | 99999 |
| 30 | 82 | 197 | 4 | 75 | 162.3 | 9.6 | 24.8 | 4.9 | -0.1 | 29.66 | 99099 | 1.86 | 0.20 | |
| 31 | 82 | 197 | 4 | 150 | 184.3 | 9.4 | 14.6 | 4.0 | -1.0 | 29.97 | 99099 | 2.15 | 0.43 | |
| 32 | 82 | 197 | 90 | | 215.7 | 2.3 | 0.0 | 0.0 | 0.0 | 29.71 | 99099 | | | |
| 33 | 82 | 197 | 91 | | 201.3 | 5.1 | 6.7 | 1.4 | -1.1 | 29.71 | 99099 | | | |
| 34 | 82 | 197 | 92 | | 204.7 | 1.0 | 5.1 | -0.6 | 2.2 | 28.95 | 7.85 | | | |
| 35 | 82 | 197 | 93 | | 199.3 | 3.3 | 7.6 | 0.4 | -0.5 | 29.52 | 99099 | | | |
| 36 | 82 | 200 | 5 | 1 | 52.0 | 3.6 | 63.0 | -2.1 | 1.2 | 99999 | 99999 | 1.32 | 3.63 | |
| 37 | 82 | 200 | 5 | 50 | 140.3 | 10.1 | 0.3 | -1.8 | -0.1 | 29.37 | 99099 | 1.95 | 0.75 | |
| 38 | 82 | 200 | 5 | 100 | 128.3 | 12.3 | 8.8 | 0.9 | 0.2 | 29.91 | 99099 | 1.27 | 0.50 | |
| 39 | 82 | 200 | 6 | 1 | 11.3 | 0.7 | 92.0 | -2.9 | 2.7 | 99999 | 99999 | 1.16 | 5.08 | |
| 40 | 82 | 200 | 6 | 50 | 124.0 | 5.0 | 11.9 | -5.3 | 0.2 | 29.32 | 99099 | 2.07 | 1.04 | |
| 41 | 82 | 200 | 6 | 100 | 132.7 | 13.2 | 5.7 | 1.2 | 0.5 | 29.90 | 99099 | 0.22 | 0.25 | |
| 42 | 82 | 200 | 7 | 1 | 60.0 | 2.7 | 57.4 | -4.7 | 3.5 | 99999 | 99999 | 1.78 | 3.31 | 193.4 |
| 43 | 82 | 200 | 7 | 50 | 128.0 | 12.2 | 9.0 | 0.8 | -0.1 | 29.46 | 99099 | 1.43 | 3.63 | |
| 44 | 82 | 200 | 7 | 75 | 126.0 | 9.0 | 10.4 | -1.9 | 0.0 | 29.76 | 99099 | 0.89 | 1.25 | |
| 45 | 82 | 200 | 8 | 1 | 38.0 | 1.6 | 73.0 | -5.0 | 2.5 | 28.83 | 99099 | 1.54 | 2.76 | |
| 46 | 82 | 200 | 8 | 50 | 34.0 | 0.7 | 75.8 | -7.3 | 2.0 | 29.46 | 99099 | 1.67 | 1.97 | |
| 47 | 82 | 200 | 9 | 1 | 52.7 | 0.4 | 63.5 | -8.8 | 5.1 | 99999 | 99099 | 1.65 | 3.05 | |
| 48 | 82 | 200 | 9 | 25 | 47.3 | 1.7 | 66.4 | -5.7 | 4.5 | 29.21 | 99099 | 1.64 | 2.90 | |
| 49 | 82 | 200 | 10 | 1 | 107.7 | 6.6 | 23.5 | -3.0 | 2.2 | 99999 | 99099 | 1.76 | 3.34 | 198.5 |
| 50 | 82 | 200 | 10 | 10 | 121.7 | 6.0 | 13.5 | -4.3 | 4.8 | 99999 | 99099 | 2.14 | 1.55 | |
| 51 | 82 | 200 | 90 | | 140.7 | 12.4 | 0.0 | 0.0 | 0.0 | 29.71 | 99099 | | | |
| 52 | 82 | 200 | 91 | | 135.0 | 20.0 | 4.1 | 6.6 | 2.2 | 29.71 | 99099 | | | |
| 53 | 82 | 200 | 92 | | 131.7 | 8.4 | 5.4 | -2.6 | 1.7 | 29.07 | 7.89 | | | |
| 54 | 82 | 200 | 93 | | 137.0 | 10.0 | 2.6 | -1.6 | 1.7 | 29.52 | 99099 | | | |
| 55 | 82 | 207 | 1 | 1 | 149.0 | 23.2 | 6.3 | -0.1 | 0.0 | 28.69 | 7.60 | 2.22 | 1.04 | |
| 56 | 82 | 207 | 1 | 100 | 163.7 | 20.5 | -3.0 | -3.8 | 1.0 | 29.74 | 7.59 | 1.74 | 0.18 | |
| 57 | 82 | 207 | 1 | 200 | 156.3 | 23.4 | 1.7 | -0.8 | 1.0 | 29.89 | 7.62 | 1.02 | 0.20 | |
| 58 | 82 | 207 | 2 | 1 | 156.7 | 25.7 | 1.4 | 0.8 | 0.0 | 29.21 | 7.71 | 1.97 | 0.62 | |
| 59 | 82 | 207 | 2 | 50 | 152.0 | 16.9 | 4.4 | -5.5 | 0.6 | 29.26 | 7.69 | 1.76 | 0.62 | |
| 60 | 82 | 207 | 2 | 100 | 138.0 | 19.3 | 13.2 | -2.0 | 0.6 | 29.30 | 7.70 | 1.71 | 0.52 | |
| 61 | 82 | 207 | 3 | 1 | 137.0 | 16.5 | 13.8 | -4.4 | 2.0 | 27.54 | 7.75 | 2.55 | 99999 | |
| 62 | 82 | 207 | 3 | 75 | 145.7 | 17.3 | 8.4 | -4.5 | -0.4 | 29.44 | 7.70 | 0.42 | 0.04 | |
| 63 | 82 | 207 | 3 | 150 | 154.7 | 30.2 | 2.7 | 4.4 | 0.3 | 29.87 | 7.69 | 0.07 | 0.05 | |
| 64 | 82 | 207 | 4 | 1 | 152.0 | 26.5 | 4.4 | 2.0 | -0.4 | 29.33 | 7.78 | 1.92 | 0.43 | 99999 |
| 65 | 82 | 207 | 4 | 75 | 160.7 | 23.6 | -1.1 | -1.2 | -1.0 | 29.60 | 7.70 | 0.79 | 0.14 | |
| 66 | 82 | 207 | 4 | 150 | 157.3 | 25.0 | 1.2 | 0.2 | -1.0 | 29.86 | 7.70 | 0.13 | 0.11 | |
| 67 | 82 | 207 | 90 | | 159.0 | 25.0 | 0.0 | 0.0 | 0.0 | 29.71 | 7.88 | | | |

Appendix Table 12.1. (continued)

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68 | 82 | 207 | 91 | | 136.7 | 20.0 | 14.0 | -1.3 | 1.3 | 29.71 | 8.61 | | | |
| 69 | 82 | 207 | 92 | | 149.3 | 22.6 | 6.1 | -0.7 | -0.4 | 29.21 | 7.67 | | | |
| 70 | 82 | 207 | 93 | | 165.0 | 23.3 | -3.8 | -1.9 | -1.4 | 29.52 | 7.81 | | | |
| 71 | 82 | 209 | 5 | 1 | 117.3 | 4.9 | 20.6 | -11.3 | -7.3 | 29.14 | 7.80 | 1.18 | 1.43 | |
| 72 | 82 | 209 | 5 | 50 | 126.7 | 5.6 | 14.2 | -11.0 | -7.3 | 29.40 | 7.73 | 1.02 | 0.13 | |
| 73 | 82 | 209 | 5 | 100 | 143.3 | 15.6 | 10.6 | -5.0 | -5.0 | 29.78 | 7.81 | 0.27 | 0.13 | |
| 74 | 82 | 209 | 6 | 1 | 124.7 | 7.4 | 15.6 | -9.3 | -7.3 | 29.11 | 7.90 | 1.10 | 1.88 | |
| 75 | 82 | 209 | 6 | 50 | 131.3 | 9.0 | 11.1 | -8.1 | -5.0 | 29.48 | 7.80 | 0.84 | 0.13 | |
| 76 | 82 | 209 | 6 | 100 | 142.0 | 12.7 | 3.9 | -5.8 | -5.8 | 29.74 | 7.79 | 0.27 | 0.09 | |
| 77 | 82 | 209 | 7 | 1 | 136.7 | 7.1 | 7.4 | -10.1 | -3.5 | 29.08 | 7.91 | 1.16 | 1.81 | 74.9 |
| 78 | 82 | 209 | 7 | 50 | 142.7 | 14.3 | 3.4 | -4.5 | -4.7 | 29.38 | 7.88 | 1.44 | 0.23 | |
| 79 | 82 | 209 | 7 | 75 | 144.7 | 20.7 | 11.5 | -1.5 | -0.8 | 29.48 | 99.00 | 0.38 | 0.18 | |
| 80 | 82 | 209 | 8 | 1 | 137.3 | 17.2 | 7.0 | -1.6 | -8.5 | 29.07 | 7.91 | 1.25 | 1.43 | |
| 81 | 82 | 209 | 8 | 50 | 138.0 | 15.0 | 6.6 | -3.5 | -1.2 | 29.37 | 7.89 | 1.45 | 0.30 | |
| 82 | 82 | 209 | 9 | 1 | 130.0 | 8.6 | 12.0 | -6.2 | -8.5 | 29.14 | 7.90 | 1.24 | 0.98 | |
| 83 | 82 | 209 | 9 | 25 | 142.3 | 20.0 | 3.7 | 0.2 | -2.0 | 29.37 | 7.90 | 1.78 | 0.47 | |
| 84 | 82 | 209 | 10 | 1 | 106.3 | 9.0 | 28.0 | -6.3 | -5.8 | 29.13 | 7.93 | 1.36 | 1.97 | 109.1 |
| 85 | 82 | 209 | 10 | 10 | 137.0 | 25.4 | 7.2 | 5.3 | -2.7 | 29.23 | 7.90 | 1.52 | 0.52 | |
| 86 | 82 | 209 | 90 | | 147.7 | 20.6 | 0.0 | 0.0 | 0.0 | 29.71 | 7.67 | | | |
| 87 | 82 | 209 | 91 | | 141.0 | 21.1 | 4.5 | 1.3 | -6.6 | 29.71 | 7.87 | | | |
| 88 | 82 | 209 | 92 | | 116.0 | 21.4 | 21.5 | 5.2 | -1.5 | 29.28 | 7.79 | | | |
| 89 | 82 | 209 | 93 | | 153.7 | 22.3 | -4.1 | 0.7 | -9.3 | 29.52 | 7.95 | | | |
| 90 | 82 | 214 | 4 | 1 | 80.3 | 11.9 | 22.3 | -11.5 | -0.5 | 28.12 | 8.00 | 0.42 | 2.81 | 39.4 |
| 91 | 82 | 214 | 4 | 75 | 81.7 | 17.3 | 20.9 | -3.1 | -0.2 | 29.76 | 7.87 | 0.17 | 0.13 | |
| 92 | 82 | 214 | 4 | 150 | 85.7 | 18.9 | 17.0 | -2.0 | -0.5 | 29.93 | 7.87 | 0.18 | 0.20 | |
| 93 | 82 | 214 | 5 | 1 | 66.7 | 10.4 | 35.4 | -10.5 | 1.5 | 28.33 | 8.05 | 0.27 | 4.44 | |
| 94 | 82 | 214 | 5 | 50 | 84.7 | 14.3 | 13.0 | -8.8 | -2.6 | 29.55 | 7.89 | 0.69 | 0.13 | |
| 95 | 82 | 214 | 5 | 100 | 87.3 | 15.7 | 15.5 | -7.3 | 0.0 | 29.85 | 7.95 | 0.67 | 0.13 | |
| 96 | 82 | 214 | 6 | 1 | 68.3 | 6.7 | 33.9 | -18.1 | 0.1 | 28.12 | 7.95 | 0.27 | 3.19 | |
| 97 | 82 | 214 | 6 | 50 | 76.3 | 7.2 | 26.1 | -18.6 | -0.2 | 29.56 | 7.93 | 0.63 | 0.11 | |
| 98 | 82 | 214 | 6 | 100 | 81.7 | 12.9 | 20.9 | -10.2 | -0.2 | 29.84 | 7.93 | 0.38 | 0.15 | |
| 99 | 82 | 214 | 7 | 1 | 75.3 | 14.4 | 27.1 | -5.9 | -0.7 | 28.43 | 8.10 | 0.49 | 5.32 | 110.2 |
| 100 | 82 | 214 | 7 | 50 | 85.7 | 14.8 | 17.0 | -8.2 | -0.2 | 29.59 | 7.90 | 0.15 | 0.13 | |
| 101 | 82 | 214 | 7 | 75 | 90.7 | 20.3 | 12.2 | -1.6 | -0.5 | 29.76 | 7.90 | 0.17 | 0.09 | |
| 102 | 82 | 214 | 8 | 1 | 81.7 | 17.6 | 20.9 | -2.7 | 16.0 | 28.30 | 8.10 | 0.40 | 2.50 | |
| 103 | 82 | 214 | 8 | 50 | 91.7 | 16.4 | 11.2 | -7.5 | -0.3 | 29.58 | 7.90 | 0.13 | 0.10 | |
| 104 | 82 | 214 | 9 | 1 | 87.7 | 13.0 | 15.1 | -11.5 | -0.5 | 28.23 | 8.10 | 0.38 | 2.77 | |
| 105 | 82 | 214 | 9 | 25 | 92.7 | 12.4 | 10.3 | -13.4 | -0.5 | 29.34 | 8.00 | 0.24 | 0.32 | |
| 106 | 82 | 214 | 10 | 1 | 69.3 | 13.7 | 32.9 | -5.0 | -0.0 | 28.24 | 8.10 | 0.42 | 4.89 | 119.1 |
| 107 | 82 | 214 | 10 | 10 | 90.7 | 19.6 | 12.2 | -2.6 | -0.2 | 29.19 | 7.80 | 0.63 | 0.98 | |
| 108 | 82 | 214 | 90 | | 103.3 | 24.4 | 0.0 | 0.0 | 0.0 | 29.71 | 7.88 | | | |
| 109 | 82 | 214 | 91 | | 88.7 | 22.8 | 14.1 | -2.7 | 1.6 | 29.71 | 7.72 | | | |
| 110 | 82 | 214 | 92 | | 88.7 | 27.9 | 18.7 | 10.3 | 0.0 | 29.07 | 7.84 | | | |
| 111 | 82 | 214 | 93 | | 84.0 | 19.0 | 18.7 | -1.3 | 4.4 | 29.52 | 7.99 | | | |
| 112 | 82 | 221 | 4 | 1 | 99.0 | 34.5 | 19.7 | 26.0 | -2.1 | 29.41 | 7.92 | 0.32 | 3.45 | 232.2 |
| 113 | 82 | 221 | 4 | 75 | 98.3 | 72.4 | 20.3 | 70.0 | -0.6 | 29.83 | 7.89 | 0.08 | 0.26 | |
| 114 | 82 | 221 | 4 | 150 | 132.7 | 84.2 | -7.6 | 58.6 | 20.0 | 30.07 | 7.89 | 0.34 | 0.19 | |
| 115 | 82 | 221 | 5 | 1 | 115.3 | 13.3 | 6.5 | -0.5 | -1.7 | 29.84 | 8.03 | 0.40 | 5.46 | |
| 116 | 82 | 221 | 5 | 50 | 100.0 | 12.2 | 18.9 | 0.3 | -0.3 | 29.55 | 7.96 | 0.30 | 0.71 | |

Appendix Table 12.1. (continued)

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 117 | 82 | 221 | 5 | 100 | 119.5 | 32.2 | 3.1 | 17.0 | 15.4 | 29.93 | 7.94 | 0.19 | 0.19 | |
| 118 | 82 | 221 | 6 | 1 | 96.0 | 18.1 | 22.1 | 7.9 | -3.8 | 29.41 | 8.07 | 0.53 | 2.87 | |
| 119 | 82 | 221 | 6 | 50 | 106.7 | 20.1 | 13.5 | 7.8 | -3.5 | 29.61 | 7.99 | 0.24 | 0.42 | |
| 120 | 82 | 221 | 6 | 100 | 124.0 | 31.5 | -0.6 | 15.3 | 2.1 | 29.88 | 7.97 | 0.19 | 0.20 | |
| 121 | 82 | 221 | 7 | 1 | 96.0 | 22.1 | 22.1 | 12.6 | -1.1 | 29.39 | 8.10 | 0.40 | 1.85 | 288.2 |
| 122 | 82 | 221 | 7 | 50 | 101.3 | 14.2 | 17.8 | 2.4 | 10.4 | 29.66 | 7.98 | 0.15 | 1.15 | |
| 123 | 82 | 221 | 7 | 75 | 208.7 | 89.8 | -69.3 | 35.3 | -2.1 | 29.81 | 7.98 | 0.13 | 0.80 | |
| 124 | 82 | 221 | 8 | 1 | 134.3 | 26.9 | -8.9 | 9.2 | 99.3 | 29.39 | 8.09 | 0.42 | 4.69 | |
| 125 | 82 | 221 | 8 | 50 | 100.7 | 16.4 | 18.3 | 5.0 | 59.1 | 29.60 | 7.98 | 0.18 | 0.61 | |
| 126 | 82 | 221 | 9 | 1 | 120.0 | 21.8 | 2.7 | 7.2 | 37.4 | 29.04 | 8.02 | 0.61 | 4.71 | |
| 127 | 82 | 221 | 9 | 25 | 117.3 | 17.0 | 4.9 | 3.0 | 18.9 | 29.43 | 8.09 | 0.72 | 2.38 | |
| 128 | 82 | 221 | 10 | 1 | 147.5 | 48.8 | -19.6 | 24.1 | 45.3 | 29.34 | 8.00 | 0.39 | 3.39 | 275.8 |
| 129 | 82 | 221 | 10 | 10 | 190.0 | 24.0 | -54.1 | 0.8 | 2.9 | 29.40 | 8.10 | 0.45 | 4.89 | |
| 130 | 82 | 221 | 90 | | 123.3 | 14.7 | 0.0 | 0.0 | 0.0 | 29.71 | 7.80 | | | |
| 131 | 82 | 221 | 91 | | 130.0 | 19.5 | -5.4 | 3.5 | 0.7 | 29.71 | 7.76 | | | |
| 132 | 82 | 221 | 92 | | 93.0 | 16.4 | 24.6 | 6.5 | -0.3 | 29.39 | 7.92 | | | |
| 133 | 82 | 221 | 93 | | 122.7 | 10.8 | 0.5 | -3.5 | -2.1 | 29.52 | 8.09 | | | |
| 134 | 82 | 223 | 1 | 1 | 123.3 | 4.2 | 15.4 | 0.0 | 3.7 | 99999 | 7.89 | 0.65 | 3.57 | |
| 135 | 82 | 223 | 1 | 100 | 149.3 | 2.0 | -2.5 | -2.2 | 31.1 | 99999 | 7.83 | 0.06 | 0.33 | |
| 136 | 82 | 223 | 1 | 200 | 147.0 | 2.3 | -0.9 | -1.9 | 24.3 | 99999 | 7.89 | 1.68 | 0.33 | |
| 137 | 82 | 223 | 2 | 1 | 136.7 | 3.3 | 6.2 | -1.0 | 6.5 | 29.41 | 8.01 | 0.39 | 5.21 | |
| 138 | 82 | 223 | 2 | 50 | 156.0 | 2.5 | -7.1 | -1.9 | 45.4 | 29.49 | 7.98 | 0.75 | 3.20 | |
| 139 | 82 | 223 | 2 | 100 | 153.0 | 3.0 | -5.0 | -1.4 | 52.7 | 29.56 | 7.99 | 0.55 | 2.68 | |
| 140 | 82 | 223 | 3 | 1 | 131.0 | 4.3 | 10.1 | -0.1 | 11.6 | 27.21 | 8.41 | 0.43 | 10.42 | |
| 141 | 82 | 223 | 3 | 75 | 152.7 | 6.0 | -4.8 | 0.5 | 5.1 | 29.80 | 7.93 | 0.10 | 0.35 | |
| 142 | 82 | 223 | 3 | 150 | 145.3 | 2.4 | 0.3 | -1.8 | 5.8 | 29.98 | 7.93 | 0.10 | 0.12 | |
| 143 | 82 | 223 | 90 | | 145.7 | 5.0 | 0.0 | 0.0 | 0.0 | 29.71 | 7.93 | | | |
| 144 | 82 | 223 | 91 | | 154.7 | 4.9 | -6.2 | -0.2 | 0.6 | 29.71 | 7.84 | | | |
| 145 | 82 | 223 | 92 | | 140.0 | 5.4 | 3.9 | 0.5 | -1.4 | 29.29 | 7.90 | | | |
| 146 | 82 | 228 | 4 | 1 | 87.7 | 3.4 | 11.7 | 1.3 | 1.0 | 29.25 | 8.01 | 0.93 | 1.37 | 25.2 |
| 147 | 82 | 228 | 4 | 75 | 83.3 | 3.7 | 16.1 | 1.8 | -0.3 | 29.85 | 7.82 | 0.26 | 0.49 | |
| 148 | 82 | 228 | 4 | 150 | 98.3 | 4.4 | 1.0 | 2.0 | 3.4 | 30.13 | 7.89 | 1.23 | 0.27 | |
| 149 | 82 | 228 | 5 | 1 | 61.7 | 1.8 | 37.9 | 0.3 | 1.8 | 29.16 | 8.17 | 0.05 | 3.04 | |
| 150 | 82 | 228 | 5 | 50 | 101.3 | 3.6 | -2.0 | 1.0 | 3.4 | 29.69 | 7.91 | 0.69 | 0.48 | |
| 151 | 82 | 228 | 5 | 100 | 86.3 | 1.0 | 13.1 | -1.4 | 2.8 | 29.93 | 7.90 | 0.22 | 0.53 | |
| 152 | 82 | 228 | 6 | 1 | 33.5 | 1.3 | 66.3 | 1.3 | 3.1 | 29.07 | 8.20 | 0.85 | 5.80 | |
| 153 | 82 | 228 | 6 | 50 | 97.6 | 1.2 | 1.7 | -1.4 | 2.8 | 29.77 | 7.92 | 0.48 | 0.33 | |
| 154 | 82 | 228 | 6 | 100 | 92.7 | 2.0 | 6.6 | -0.4 | -0.3 | 29.99 | 7.90 | 0.37 | 0.63 | |
| 155 | 82 | 228 | 7 | 1 | 48.7 | 1.8 | 51.0 | 1.1 | -1.0 | 29.19 | 8.21 | 0.91 | 1.40 | 20.5 |
| 156 | 82 | 228 | 7 | 50 | 80.3 | 1.4 | 19.1 | -0.9 | 3.4 | 29.85 | 7.91 | 0.24 | 0.45 | |
| 157 | 82 | 228 | 7 | 75 | 63.7 | 1.4 | 35.9 | -0.4 | -0.3 | 29.98 | 7.96 | 0.34 | 0.36 | |
| 158 | 82 | 228 | 8 | 1 | 59.7 | 2.4 | 39.9 | 1.4 | 86.3 | 29.25 | 8.23 | 1.05 | 1.61 | |
| 159 | 82 | 228 | 8 | 50 | 90.0 | 2.2 | 9.4 | -0.2 | 2.1 | 29.74 | 7.97 | 0.46 | 0.35 | |
| 160 | 82 | 228 | 9 | 1 | 34.3 | 1.4 | 65.5 | 1.5 | 1.8 | 29.21 | 8.24 | 0.98 | 3.27 | |
| 161 | 82 | 228 | 9 | 25 | 98.3 | 3.8 | 1.0 | 1.3 | 2.1 | 29.42 | 8.09 | 1.62 | 0.63 | |
| 162 | 82 | 228 | 10 | 1 | 80.0 | 5.4 | 19.4 | 4.3 | -0.3 | 29.19 | 8.25 | 0.11 | 3.31 | 46.4 |
| 163 | 82 | 228 | 10 | 10 | 56.7 | 2.3 | 42.9 | 1.5 | 2.1 | 29.26 | 8.20 | 0.09 | 5.06 | |
| 164 | 82 | 228 | 90 | | 99.3 | 2.6 | 0.0 | 0.0 | 0.0 | 29.71 | 7.82 | | | |

Appendix Table 12.1. (continued)

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 165 | 82 | 228 | 91 | | 104.3 | 5.6 | -5.0 | 2.9 | 4.4 | 29.71 | 7.63 | | | |
| 166 | 82 | 228 | 92 | | 82.3 | 1.7 | 17.1 | -0.5 | -1.3 | 29.60 | 7.91 | | | |
| 167 | 82 | 228 | 93 | | 85.3 | 2.0 | 14.1 | -0.3 | -0.3 | 29.52 | 8.09 | | | |
| 168 | 82 | 250 | 4 | 1 | 99999 | 99999 | 99999 | 99999 | 27.4 | 29.80 | 8.22 | 0.66 | 4.76 | 90.6 |
| 169 | 82 | 250 | 4 | 75 | 99999 | 99999 | 99999 | 99999 | 2.1 | 30.09 | 8.06 | 99999 | 0.11 | |
| 170 | 82 | 250 | 4 | 150 | 99999 | 99999 | 99999 | 99999 | 1.4 | 30.37 | 8.01 | 1.21 | 0.07 | |
| 171 | 82 | 250 | 5 | 1 | 99999 | 99999 | 99999 | 99999 | 53.9 | 29.73 | 8.33 | 99999 | 20.54 | |
| 172 | 82 | 250 | 5 | 50 | 99999 | 99999 | 99999 | 99999 | 4.9 | 29.97 | 8.03 | 99999 | 0.63 | |
| 173 | 82 | 250 | 5 | 100 | 99999 | 99999 | 99999 | 99999 | 4.2 | 30.25 | 7.98 | 99999 | 0.12 | |
| 174 | 82 | 250 | 6 | 1 | 99999 | 99999 | 99999 | 99999 | 81.4 | 29.70 | 8.43 | 99999 | 25.30 | |
| 175 | 82 | 250 | 6 | 50 | 99999 | 99999 | 99999 | 99999 | -0.3 | 29.94 | 7.99 | 1.51 | 0.29 | |
| 176 | 82 | 250 | 6 | 100 | 99999 | 99999 | 99999 | 99999 | 1.8 | 30.33 | 7.88 | 1.15 | 0.10 | |
| 177 | 82 | 250 | 7 | 1 | 99999 | 99999 | 99999 | 99999 | 75.0 | 29.74 | 8.25 | 99999 | 30.96 | 192.5 |
| 178 | 82 | 250 | 7 | 50 | 99999 | 99999 | 99999 | 99999 | 0.3 | 30.05 | 7.88 | 99999 | 0.08 | |
| 179 | 82 | 250 | 7 | 75 | 99999 | 99999 | 99999 | 99999 | 1.4 | 30.16 | 7.84 | 0.34 | 0.05 | |
| 180 | 82 | 250 | 8 | 1 | 99999 | 99999 | 99999 | 99999 | 90.9 | 29.73 | 8.26 | 0.39 | 12.50 | |
| 181 | 82 | 250 | 8 | 50 | 99999 | 99999 | 99999 | 99999 | 1.4 | 30.04 | 7.88 | 0.43 | 0.26 | |
| 182 | 82 | 250 | 9 | 1 | 99999 | 99999 | 99999 | 99999 | 92.0 | 29.70 | 8.27 | 99999 | 28.58 | |
| 183 | 82 | 250 | 9 | 25 | 99999 | 99999 | 99999 | 99999 | 5.9 | 29.88 | 8.00 | 1.01 | 0.95 | |
| 184 | 82 | 250 | 10 | 1 | 99999 | 99999 | 99999 | 99999 | 48.6 | 99999 | 8.17 | 99999 | 20.54 | 272.9 |
| 185 | 82 | 250 | 10 | 10 | 99999 | 99999 | 99999 | 99999 | 18.8 | 99999 | 8.00 | 99999 | 5.51 | |
| 186 | 82 | 250 | 90 | | 99999 | 99999 | 99999 | 99999 | 0.0 | 29.71 | 7.78 | | | |
| 187 | 82 | 250 | 91 | | 99999 | 99999 | 99999 | 99999 | -1.0 | 29.71 | 7.76 | | | |
| 188 | 82 | 250 | 92 | | 99999 | 99999 | 99999 | 99999 | -0.3 | 29.81 | 7.73 | | | |
| 189 | 82 | 252 | 1 | 1 | 271.7 | 20.4 | 9.1 | 0.1 | 3.8 | 27.97 | 7.84 | 1.43 | 6.55 | |
| 190 | 82 | 252 | 1 | 100 | 240.7 | 20.5 | 19.5 | 1.2 | -1.8 | 28.57 | 7.77 | 1.57 | 0.35 | |
| 191 | 82 | 252 | 1 | 200 | 310.5 | 27.5 | -3.5 | 1.6 | 68.4 | 28.78 | 7.73 | 1.69 | 0.32 | |
| 192 | 82 | 252 | 2 | 1 | 277.0 | 10.8 | 7.4 | -3.8 | -1.5 | 29.74 | 7.83 | 2.10 | 1.13 | |
| 193 | 82 | 252 | 2 | 50 | 232.0 | 14.0 | 22.4 | -1.5 | -1.0 | 29.84 | 7.85 | 1.76 | 1.01 | |
| 194 | 82 | 252 | 2 | 100 | 246.3 | 16.2 | 17.6 | -0.9 | -0.7 | 29.96 | 7.75 | 1.27 | 0.25 | |
| 195 | 82 | 252 | 3 | 1 | 316.0 | 20.4 | -5.7 | -1.0 | 15.0 | 29.36 | 8.06 | 1.11 | 7.06 | |
| 196 | 82 | 252 | 3 | 75 | 271.3 | 13.8 | 9.3 | -2.5 | 0.6 | 30.08 | 7.74 | 0.20 | 0.04 | |
| 197 | 82 | 252 | 3 | 150 | 272.5 | 16.2 | 8.9 | -1.6 | 6.3 | 30.33 | 7.68 | 0.95 | 0.10 | |
| 198 | 82 | 252 | 90 | | 299.0 | 22.0 | 0.0 | 0.0 | 0.0 | 29.71 | 7.38 | | | |
| 199 | 82 | 252 | 91 | | 284.7 | 20.8 | 4.8 | -0.1 | 6.3 | 29.71 | 7.36 | | | |
| 200 | 82 | 252 | 92 | | 219.0 | 14.3 | 26.8 | -0.1 | -0.7 | 29.85 | 7.65 | | | |
| 201 | 82 | 252 | 93 | | 274.0 | 17.4 | 8.4 | -1.1 | -3.9 | 29.52 | 7.82 | | | |
| 202 | 82 | 256 | 4 | 1 | 223.0 | 2.6 | 0.1 | -79.3 | -0.6 | 29.60 | 7.83 | 4.46 | 1.16 | 22.9 |
| 203 | 82 | 256 | 4 | 75 | 201.3 | 147.6 | 9.9 | 51.5 | 1.0 | 30.14 | 7.75 | 1.35 | 0.14 | |
| 204 | 82 | 256 | 4 | 150 | 256.0 | 31.3 | -14.6 | -59.3 | 34.4 | 30.38 | 7.75 | 5.13 | 0.23 | |
| 205 | 82 | 256 | 5 | 1 | 197.3 | 18.3 | 11.6 | -64.6 | 1.0 | 29.49 | 7.97 | 6.84 | 1.55 | |
| 206 | 82 | 256 | 5 | 50 | 201.3 | 91.8 | 9.9 | 1.3 | -1.3 | 30.04 | 7.78 | 1.41 | 0.15 | |
| 207 | 82 | 256 | 5 | 100 | 161.3 | 81.5 | 27.8 | 10.2 | -0.6 | 30.26 | 7.78 | 0.88 | 0.07 | |
| 208 | 82 | 256 | 6 | 1 | 250.3 | 12.6 | -12.1 | -72.4 | 0.0 | 29.48 | 7.97 | 99999 | 2.14 | |
| 209 | 82 | 256 | 6 | 50 | 191.7 | 65.6 | 14.2 | -19.4 | -0.6 | 29.98 | 7.92 | 1.64 | 0.08 | |
| 210 | 82 | 256 | 6 | 100 | 200.0 | 75.6 | 10.4 | -12.9 | -0.6 | 30.24 | 7.79 | 0.76 | 0.03 | |
| 211 | 82 | 256 | 7 | 1 | 232.7 | 9.6 | -4.2 | -74.0 | 0.7 | 29.41 | 7.99 | 7.18 | 1.40 | 35.2 |
| 212 | 82 | 256 | 7 | 50 | 229.0 | 5.3 | -2.6 | -77.3 | -0.3 | 30.02 | 7.80 | 1.62 | 0.20 | |

**Appendix Table 12.1. (continued)**

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 213 | 82 | 256 | 7 | 75 | 267.7 | 3.3 | -19.9 | -79.3 | 0.0 | 30.18 | 7.63 | 1.55 | 0.07 | |
| 214 | 82 | 256 | 8 | 1 | 232.0 | 5.0 | -3.9 | -77.5 | -0.3 | 29.42 | 7.93 | 7.01 | 0.86 | |
| 215 | 82 | 256 | 8 | 50 | 241.0 | 3.0 | -7.9 | -79.3 | 11.4 | 29.99 | 7.73 | 1.63 | 0.02 | |
| 216 | 82 | 256 | 9 | 1 | 203.0 | 3.3 | 9.1 | -78.6 | 0.0 | 29.41 | 7.91 | 8.07 | 0.35 | |
| 217 | 82 | 256 | 9 | 25 | 236.3 | 2.1 | -5.4 | -79.9 | 0.0 | 29.75 | 7.81 | 3.54 | 0.22 | |
| 218 | 82 | 256 | 10 | 1 | 224.0 | 2.9 | -0.3 | -79.1 | 1.0 | 29.41 | 7.90 | 99999 | 0.36 | 42.2 |
| 219 | 82 | 256 | 10 | 10 | 210.3 | 24.0 | 5.8 | -60.8 | 0.0 | 29.68 | 7.80 | 99999 | 0.24 | |
| 220 | 82 | 256 | 90 | | 223.3 | 100.3 | -0.0 | -0.0 | 0.0 | 29.71 | 7.52 | | | |
| 221 | 82 | 256 | 91 | | 215.3 | 65.3 | 3.6 | -26.5 | -0.3 | 29.71 | 7.54 | | | |
| 222 | 82 | 256 | 92 | | 208.0 | 18.9 | 6.9 | -65.0 | -0.6 | 29.67 | 7.61 | | | |
| 223 | 82 | 256 | 93 | | 259.3 | 4.2 | -16.1 | -78.6 | -1.0 | 29.52 | 7.89 | | | |
| 224 | 82 | 264 | 4 | 1 | 93.7 | 7.5 | 16.6 | -26.4 | 0.6 | 29.97 | 99999 | 1.56 | 1.34 | 73.0 |
| 225 | 82 | 264 | 4 | 75 | 52.0 | 7.0 | 53.7 | -18.8 | 1.3 | 30.24 | 99999 | 2.75 | 0.33 | |
| 226 | 82 | 264 | 4 | 150 | 45.7 | 10.0 | 59.3 | -7.3 | 32.9 | 30.44 | 99999 | 3.13 | 0.20 | |
| 227 | 82 | 264 | 5 | 1 | 73.3 | 6.6 | 34.7 | -25.0 | 0.6 | 29.98 | 99999 | 1.36 | 4.44 | |
| 228 | 82 | 264 | 5 | 50 | 102.7 | 5.1 | 8.5 | -30.5 | 1.0 | 30.04 | 99999 | 1.89 | 1.95 | |
| 229 | 82 | 264 | 5 | 100 | 98.0 | 12.0 | 12.7 | -20.6 | 1.6 | 30.32 | 99999 | 1.78 | 0.47 | |
| 230 | 82 | 264 | 6 | 1 | 113.7 | 9.7 | -1.2 | -25.7 | 0.3 | 29.99 | 99999 | 1.54 | 3.77 | |
| 231 | 82 | 264 | 6 | 50 | 88.7 | 75.8 | 21.0 | 80.1 | 1.0 | 30.22 | 99999 | 2.16 | 0.58 | |
| 232 | 82 | 264 | 6 | 100 | 87.0 | 79.9 | 22.5 | 88.7 | 9.1 | 30.37 | 99999 | 1.94 | 0.29 | |
| 233 | 82 | 264 | 7 | 1 | 60.7 | 54.6 | 45.9 | 86.3 | 16.7 | 29.94 | 99999 | 1.10 | 5.88 | 166.0 |
| 234 | 82 | 264 | 7 | 50 | 98.3 | 32.3 | 12.5 | 7.8 | 1.0 | 30.04 | 99999 | 2.04 | 1.23 | |
| 235 | 82 | 264 | 7 | 75 | 94.3 | 47.6 | 16.0 | 32.0 | 0.6 | 30.11 | 99999 | 2.10 | 0.67 | |
| 236 | 82 | 264 | 8 | 1 | 87.0 | 57.6 | 22.5 | 53.6 | 22.2 | 29.99 | 99999 | 1.20 | 5.16 | |
| 237 | 82 | 264 | 8 | 50 | 88.3 | 39.1 | 21.4 | 23.5 | 6.6 | 30.07 | 99999 | 2.03 | 1.00 | |
| 238 | 82 | 264 | 9 | 1 | 72.3 | 59.7 | 35.6 | 76.1 | 0.6 | 29.98 | 99999 | 1.41 | 4.01 | |
| 239 | 82 | 264 | 9 | 25 | 83.3 | 48.2 | 25.8 | 42.2 | 2.0 | 30.00 | 99999 | 1.96 | 1.84 | |
| 240 | 82 | 264 | 10 | 1 | 80.0 | 66.0 | 28.8 | 76.0 | 10.4 | 29.90 | 99999 | 1.15 | 3.98 | 85.1 |
| 241 | 82 | 264 | 10 | 10 | 92.3 | 35.0 | 17.8 | 14.7 | 0.0 | 29.97 | 99999 | 1.71 | 3.24 | |
| 242 | 82 | 264 | 90 | | 112.3 | 30.5 | 0.0 | 0.0 | 0.0 | 29.71 | 99999 | | | |
| 243 | 82 | 264 | 91 | | 91.3 | 10.2 | 18.7 | -22.0 | 3.0 | 29.71 | 99999 | | | |
| 244 | 82 | 264 | 92 | | 54.0 | 23.4 | 51.9 | 22.1 | 0.6 | 29.97 | 99999 | | | |
| 245 | 82 | 264 | 93 | | 129.7 | 12.3 | -15.5 | -24.3 | 0.0 | 29.52 | 99999 | | | |
| 246 | 82 | 265 | 1 | 1 | 161.3 | 11.4 | 27.8 | 1.2 | -1.0 | 29.88 | 99999 | 1.62 | 3.45 | |
| 247 | 82 | 265 | 1 | 100 | 208.7 | 7.2 | 6.5 | -2.8 | 0.7 | 30.32 | 99999 | 3.13 | 0.23 | |
| 248 | 82 | 265 | 1 | 200 | 172.3 | 7.7 | 22.8 | -1.6 | 1.7 | 30.43 | 99999 | 3.47 | 0.42 | |
| 249 | 82 | 265 | 2 | 1 | 184.7 | 15.8 | 17.3 | 2.8 | -0.3 | 29.90 | 99999 | 1.86 | 4.44 | |
| 250 | 82 | 265 | 2 | 50 | 209.3 | 16.4 | 6.3 | 1.9 | -0.3 | 30.01 | 99999 | 2.07 | 2.46 | |
| 251 | 82 | 265 | 2 | 100 | 189.7 | 19.7 | 15.0 | 4.7 | 0.0 | 30.01 | 99999 | 2.06 | 3.14 | |
| 252 | 82 | 265 | 3 | 1 | 168.3 | 10.3 | 24.6 | 0.1 | 0.0 | 29.06 | 99999 | 0.94 | 4.92 | |
| 253 | 82 | 265 | 3 | 75 | 183.7 | 15.1 | 17.7 | 2.3 | 1.7 | 30.20 | 99999 | 1.86 | 1.15 | |
| 254 | 82 | 265 | 3 | 150 | 189.7 | 21.1 | 15.0 | 5.4 | 7.4 | 30.33 | 99999 | 2.45 | 0.53 | |
| 255 | 82 | 265 | 90 | | 223.3 | 13.4 | 0.0 | 0.0 | 0.0 | 29.71 | 99999 | | | |
| 256 | 82 | 265 | 91 | | 226.3 | 16.5 | -1.3 | -1.4 | 0.7 | 29.71 | 99999 | | | |
| 257 | 82 | 265 | 92 | | 216.3 | 12.8 | 3.1 | -0.1 | 0.3 | 29.98 | 99999 | | | |
| 258 | 82 | 265 | 93 | | 199.3 | 12.9 | 10.7 | 0.5 | -0.3 | 29.52 | 99999 | | | |
| 259 | 82 | 270 | 4 | 1 | 131.0 | 3.3 | 24.1 | -3.4 | 0.3 | 29.69 | 8.05 | 0.66 | 4.47 | 71.7 |
| 260 | 82 | 270 | 4 | 75 | 183.3 | 7.4 | -6.1 | -1.8 | 0.6 | 30.32 | 7.85 | 3.08 | 0.24 | |

Appendix Table 12.1. (continued)

| OBV | YR | DAY | ST | DEP | O.SUR | O.ABN | AVMOR | ADABN | UNFER | SAL | PH | NH3 | CHL | PRIPR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 261 | 82 | 270 | 4 | 150 | 187.7 | 3.4 | -8.7 | -4.1 | -0.6 | 30.43 | 7.82 | 3.30 | 0.32 | |
| 262 | 82 | 270 | 5 | 1 | 108.3 | 3.2 | 37.3 | -2.9 | -0.4 | 29.67 | 8.10 | 1.22 | 4.32 | |
| 263 | 82 | 270 | 5 | 50 | 169.0 | 0.4 | 2.1 | -5.8 | 0.3 | 30.10 | 7.88 | 2.84 | 0.95 | |
| 264 | 82 | 270 | 5 | 100 | 173.7 | 20.5 | -0.6 | 6.5 | 1.0 | 30.38 | 7.83 | 3.52 | 0.53 | |
| 265 | 82 | 270 | 6 | 1 | 92.3 | 1.6 | 46.6 | -4.2 | 0.3 | 29.70 | 8.08 | 0.53 | 4.76 | |
| 266 | 82 | 270 | 6 | 50 | 189.0 | 4.3 | -9.4 | -3.6 | 0.0 | 30.15 | 7.85 | 2.51 | 0.62 | |
| 267 | 82 | 270 | 6 | 100 | 194.0 | 0.3 | -12.3 | -5.8 | 0.0 | 30.40 | 7.85 | 3.05 | 0.37 | |
| 268 | 82 | 270 | 7 | 1 | 117.7 | 3.0 | 31.8 | -3.4 | 0.0 | 29.67 | 8.06 | 0.91 | 5.36 | 74.8 |
| 269 | 82 | 270 | 7 | 50 | 176.3 | 1.0 | -2.1 | -5.4 | 0.3 | 30.10 | 7.85 | 2.62 | 0.95 | |
| 270 | 82 | 270 | 7 | 75 | 148.3 | 1.8 | 14.1 | -4.8 | 1.0 | 30.30 | 7.83 | 3.12 | 0.47 | |
| 271 | 82 | 270 | 8 | 1 | 148.3 | 5.8 | 14.1 | -1.9 | 0.0 | 29.65 | 8.03 | 1.07 | 4.91 | |
| 272 | 82 | 270 | 8 | 50 | 182.3 | 2.7 | -5.6 | -4.5 | 0.0 | 30.11 | 7.84 | 2.61 | 0.67 | |
| 273 | 82 | 270 | 9 | 1 | 164.7 | 1.4 | 4.6 | -5.1 | 0.3 | 29.75 | 8.00 | 1.48 | 3.37 | |
| 274 | 82 | 270 | 9 | 25 | 176.3 | 2.6 | -2.1 | -4.5 | 1.3 | 30.04 | 7.89 | 2.69 | 1.43 | |
| 275 | 82 | 270 | 10 | 1 | 125.7 | 1.7 | 27.2 | -4.6 | 0.3 | 29.66 | 8.00 | 1.25 | 5.51 | 73.3 |
| 276 | 82 | 270 | 10 | 10 | 154.3 | 0.3 | 10.7 | -5.8 | 0.6 | 29.94 | 7.95 | 2.05 | 2.82 | |
| 277 | 82 | 270 | 90 | | 172.7 | 9.9 | 0.0 | 0.0 | 0.0 | 29.71 | 7.75 | | | |
| 278 | 82 | 270 | 91 | | 191.7 | 1.7 | -11.0 | -5.1 | 3.3 | 29.71 | 7.55 | | | |
| 279 | 82 | 270 | 92 | | 184.0 | 0.3 | -6.5 | -5.8 | 0.6 | 29.94 | 7.73 | | | |
| 280 | 82 | 270 | 93 | | 185.7 | 0.9 | -7.5 | -5.5 | 0.6 | 29.52 | 7.88 | | | |
| 281 | 82 | 279 | 1 | 1 | 81.0 | 11.0 | 3.2 | -3.1 | 0.3 | 99999 | 7.62 | 3.10 | 1.04 | |
| 282 | 82 | 279 | 1 | 100 | 52.3 | 23.3 | 37.5 | 33.9 | -2.0 | 99999 | 7.58 | 2.49 | 0.23 | |
| 283 | 82 | 279 | 1 | 200 | 81.0 | 14.1 | 3.2 | 1.4 | 2.1 | 99999 | 7.67 | 2.59 | 0.20 | |
| 284 | 82 | 279 | 2 | 1 | 64.3 | 9.3 | 23.2 | -2.0 | -0.7 | 99999 | 7.65 | 2.40 | 1.10 | |
| 285 | 82 | 279 | 2 | 50 | 66.3 | 10.9 | 20.8 | 0.2 | -0.0 | 99999 | 7.65 | 2.52 | 0.89 | |
| 286 | 82 | 279 | 2 | 100 | 69.0 | 6.4 | 17.6 | -2.2 | 0.3 | 99999 | 7.61 | 2.42 | 0.80 | |
| 287 | 82 | 279 | 3 | 1 | 72.3 | 8.6 | 13.6 | -4.8 | -0.4 | 99999 | 7.71 | 1.95 | 3.15 | |
| 288 | 82 | 279 | 3 | 75 | 77.3 | 15.5 | 7.6 | 4.7 | 0.6 | 99999 | 7.61 | 2.41 | 0.28 | |
| 289 | 82 | 279 | 3 | 150 | 96.0 | 15.4 | -14.7 | -0.2 | 0.0 | 99999 | 7.60 | 2.52 | 0.17 | |
| 290 | 82 | 279 | 4 | 1 | 69.3 | 10.0 | 17.2 | -2.1 | -0.4 | 99999 | 7.69 | 1.67 | 1.82 | 99999 |
| 291 | 82 | 279 | 4 | 75 | 81.0 | 15.7 | 3.2 | 3.8 | -0.4 | 99999 | 7.63 | 2.42 | 0.35 | |
| 292 | 82 | 279 | 4 | 150 | 55.0 | 10.3 | 34.3 | 3.0 | 0.0 | 99999 | 7.62 | 2.49 | 0.18 | |
| 293 | 82 | 279 | 90 | | 83.7 | 13.6 | 0.0 | 0.0 | 0.0 | 29.71 | 7.59 | | | |
| 294 | 82 | 279 | 91 | | 81.3 | 9.1 | 2.9 | -6.0 | 0.0 | 29.71 | 7.45 | | | |
| 295 | 82 | 279 | 92 | | 83.7 | 13.2 | 0.0 | -0.5 | 0.0 | 30.09 | 7.52 | | | |
| 296 | 82 | 279 | 93 | | 77.0 | 11.9 | 8.0 | -0.8 | 0.3 | 29.52 | 7.79 | | | |
| 297 | 82 | 300 | 1 | 1 | 205.0 | 9.8 | 1.0 | -0.5 | -2.9 | 99999 | 7.91 | 0.43 | 1.89 | |
| 298 | 82 | 300 | 1 | 100 | 196.3 | 13.1 | 5.2 | 1.5 | -2.6 | 99999 | 7.90 | 0.48 | 0.19 | |
| 299 | 82 | 300 | 1 | 200 | 192.5 | 14.2 | 7.0 | 2.2 | -2.1 | 99999 | 7.88 | 0.73 | 0.27 | |
| 300 | 82 | 300 | 2 | 1 | 216.0 | 15.7 | -4.3 | -2.1 | -4.0 | 99999 | 7.92 | 0.32 | 0.63 | |
| 301 | 82 | 300 | 2 | 50 | 208.3 | 15.0 | -0.6 | 2.0 | -1.1 | 99999 | 7.91 | 0.34 | 0.74 | |
| 302 | 82 | 300 | 2 | 100 | 202.7 | 16.5 | 2.1 | 3.0 | -1.5 | 99999 | 7.90 | 0.24 | 0.67 | |
| 303 | 82 | 300 | 3 | 1 | 215.0 | 30.3 | -3.9 | 9.3 | -3.2 | 99999 | 7.98 | 0.75 | 1.18 | |
| 304 | 82 | 300 | 3 | 75 | 209.7 | 29.2 | -1.3 | 9.1 | -2.1 | 99999 | 7.92 | 0.11 | 0.16 | |
| 305 | 82 | 300 | 3 | 150 | 213.0 | 16.8 | -2.9 | 2.7 | 0.0 | 99999 | 7.89 | 0.36 | 0.09 | |
| 306 | 82 | 300 | 90 | | 207.0 | 10.9 | 0.0 | 0.0 | 0.0 | 29.71 | 7.87 | | | |
| 307 | 82 | 300 | 91 | | 216.0 | 14.4 | -4.3 | 1.5 | 0.3 | 29.71 | 7.81 | | | |
| 308 | 82 | 300 | 92 | | 214.7 | 14.1 | -3.7 | 1.4 | 0.6 | 30.02 | 7.98 | | | |

Appendix Table 12.2. Oyster embryo and sand dollar sperm assay responses observed in dilutions of Renton sewage or freshwater on ten separate test dates. All response values have been adjusted for the control (filtered West Point seawater) responses.

INFLUENT SEWAGE--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 75 | 100 | 100 | 100 | 100 | 62 | 100 | 91.0 |
| 8.4 | 39 | 58 | 100 | 58 | 100 | 23 | 49 | 61.0 |
| 5.5 | 18 | 51 | 100 | -18 | 100 | -2 | 23 | 38.9 |
| 3.6 | -4 | 20 | 86 | -1 | 99 | -12 | 10 | 28.4 |
| 2.3 | -19 | -1 | 34 | -1 | 84 | 1 | 7 | 14.9 |
| 1.5 | 1 | -15 | 4 | -9 | 51 | -3 | 2 | 4.7 |
| 1.0 | 3 | 0 | 16 | -9 | 44 | 6 | 8 | 9.8 |
| 0.64 | -9 | -23 | 3 | -11 | 44 | 0 | 9 | 1.9 |
| 0.41 | 36 | -10 | -5 | -27 | 7 | -11 | 36 | 3.7 |
| 0.27 | 7 | 12 | -11 | 44 | -2 | -12 | 16 | 7.8 |

INFLUENT SEWAGE--OYSTER EMBRYO PERCENT ABNORMAL

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 8.4 | 100 | 100 | 100 | 46 | 100 | 89 | 100 | 90.7 |
| 5.5 | 100 | 100 | 100 | -2 | 100 | 8 | 20 | 60.8 |
| 3.6 | 100 | 37 | 100 | -2 | 100 | 6 | 7 | 49.4 |
| 2.3 | 5 | -4 | 65 | -3 | 20 | -2 | 1 | 11.7 |
| 1.5 | -9 | -3 | -36 | -4 | 17 | -1 | 5 | -4.7 |
| 1.0 | -9 | -3 | -42 | -1 | -4 | -4 | -2 | -9.5 |
| 0.64 | -9 | -5 | -36 | -4 | -4 | 1 | 3 | -7.8 |
| 0.41 | 5 | -7 | -40 | -4 | 7 | 3 | 52 | 2.2 |
| 0.27 | -1 | -5 | -42 | 4 | -7 | 0 | 11 | -5.5 |

INFLUENT SEWAGE--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | 15 SEP | 20 SEP | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 86 | 100 | 100 | 98.6 |
| 13.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 80 | 100 | 100 | 98.0 |
| 8.4 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 75 | 100 | 100 | 97.5 |
| 5.5 | 100 | 96 | 83 | 74 | 96 | 99 | 100 | 48 | 100 | 100 | 89.6 |
| 3.6 | 92 | 93 | 11 | 46 | 93 | 82 | 100 | 10 | 99 | 100 | 72.5 |
| 2.3 | 89 | 24 | 5 | 10 | 46 | 39 | 100 | 6 | 94 | 97 | 50.9 |
| 1.5 | 51 | 12 | -1 | 2 | 17 | 8 | 100 | 2 | 66 | 82 | 34.0 |
| 1.0 | 6 | 6 | -1 | 2 | 1 | 4 | 97 | 2 | 36 | 50 | 20.3 |
| 0.64 | 0 | 0 | -1 | -2 | 0 | 0 | 87 | 10 | 3 | 38 | 13.4 |
| 0.41 | 1 | 4 | -1 | 3 | 1 | 2 | 85 | 0 | 4 | 34 | 13.4 |
| 0.27 | 1 | 0 | 0 | -1 | 0 | 2 | 42 | -1 | -1 | 7 | 4.9 |

Appendix Table 12.2 (Continued).

PRIMARY SEWAGE--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 99.3 |
| 13.0 | 79 | 80 | 100 | 100 | 77 | 86 | 100 | 88.9 |
| 8.4 | 9 | 58 | 100 | 29 | 56 | 39 | 50 | 48.9 |
| 5.5 | 21 | 28 | 82 | -8 | 69 | -1 | 19 | 29.9 |
| 3.6 | -16 | -3 | 24 | 14 | 84 | -5 | 5 | 14.8 |
| 2.3 | -54 | -24 | 11 | -14 | 53 | 3 | -1 | -3.7 |
| 1.5 | 3 | 0 | -10 | -1 | 27 | 7 | 10 | 5.2 |
| 1.0 | -15 | -8 | 4 | 21 | -9 | 11 | 11 | 2.1 |
| 0.64 | -19 | -12 | 2 | -6 | 7 | 19 | 17 | 1.2 |
| 0.41 | -21 | -3 | -1 | 31 | 23 | 11 | 10 | 7.0 |
| 0.27 | 5 | 3 | -6 | 15 | 32 | 10 | 15 | 10.7 |

PRIMARY SEWAGE--OYSTER EMBRYO PERCENT ABNORMALITY

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 8.4 | 100 | 100 | 100 | 40 | 53 | 84 | 100 | 82.6 |
| 5.5 | 96 | 96 | 100 | 2 | 29 | 6 | 2 | 47.3 |
| 3.6 | -1 | 27 | -14 | 0 | 22 | -2 | 0 | 4.5 |
| 2.3 | -11 | -6 | -39 | -2 | 7 | 0 | -3 | -7.5 |
| 1.5 | -9 | -3 | -45 | -3 | -4 | -5 | 4 | -9.2 |
| 1.0 | -11 | -1 | -38 | -1 | -8 | -3 | 9 | -7.7 |
| 0.64 | -10 | -5 | -36 | -4 | -6 | -4 | -1 | -9.4 |
| 0.41 | -6 | -2 | -39 | 10 | -10 | 4 | 8 | -5.2 |
| 0.27 | -6 | -5 | -40 | -3 | -6 | -2 | 2 | -8.6 |

PRIMARY SEWAGE--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | 15 SEP | 20 SEP | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 100 | 96 | 99 | 100 | 100 | 100 | 100 | 100 | 99.5 |
| 8.4 | 100 | 100 | 97 | 85 | 93 | 98 | 100 | 98 | 100 | 100 | 97.1 |
| 5.5 | 99 | 94 | 58 | 59 | 67 | 87 | 100 | 62 | 98 | 100 | 82.4 |
| 3.6 | 98 | 70 | 2 | 17 | 17 | 40 | 98 | 7 | 95 | 100 | 54.5 |
| 2.3 | 74 | 28 | 0 | 3 | 1 | 25 | 77 | -2 | 83 | 96 | 38.5 |
| 1.5 | 6 | 5 | -2 | 2 | 1 | 3 | 36 | 2 | 45 | 55 | 15.4 |
| 1.0 | 16 | 5 | -2 | 2 | -1 | 2 | -12 | 0 | 13 | 31 | 5.5 |
| 0.64 | 9 | 0 | 0 | -1 | 0 | 3 | -2 | 1 | 0 | 20 | 3.1 |
| 0.41 | 2 | 0 | -2 | -2 | 0 | -1 | -30 | 2 | -1 | 8 | -2.3 |
| 0.27 | 1 | 1 | 1 | 1 | 0 | 1 | -15 | 1 | -4 | 2 | -0.9 |

Appendix Table 12.2 (Continued).

SECONDARY SEWAGE--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | -46 | -2 | -2 | -30 | 14 | -5 | -4 | -10.7 |
| 13.0 | -21 | 5 | -14 | -14 | 16 | 6 | -6 | -3.7 |
| 8.4 | -34 | -4 | 1 | 22 | 19 | 0 | -11 | -1.0 |
| 5.5 | -8 | 9 | -12 | -2 | 24 | 12 | -9 | 2.2 |
| 3.6 | -28 | -5 | 1 | 10 | 30 | -13 | -14 | -2.8 |
| 2.3 | -11 | 2 | -52 | 33 | 30 | 14 | -9 | 1.1 |
| 1.5 | -34 | -1 | 5 | 52 | 55 | 20 | -6 | 12.8 |
| 1.0 | 4 | 11 | -8 | 52 | 39 | 30 | 7 | 19.3 |
| 0.64 | -13 | -2 | -11 | -1 | 51 | 27 | 6 | 8.4 |
| 0.41 | 25 | -16 | 0 | -1 | 35 | 20 | 6 | 9.7 |
| 0.27 | -35 | 11 | -4 | -58 | 39 | 23 | 7 | -2.4 |

SECONDARY SEWAGE--OYSTER EMBRYO PERCENT ABNORMAL

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | -4 | 1 | -34 | -4 | -3 | 13 | 6 | -3.4 |
| 13.0 | 1 | 0 | -39 | -4 | -14 | 1 | -1 | -8.2 |
| 8.4 | -2 | -4 | -35 | -4 | -17 | -3 | 0 | -9.3 |
| 5.5 | 1 | 0 | -42 | -1 | -16 | -6 | 2 | -8.9 |
| 3.6 | -5 | -3 | -47 | -5 | -12 | -4 | 2 | -10.7 |
| 2.3 | -6 | 0 | -42 | 0 | -15 | -1 | 0 | -9.2 |
| 1.5 | -5 | -3 | -40 | -1 | 3 | -5 | -5 | -7.9 |
| 1.0 | -3 | -3 | -44 | -1 | -5 | 0 | 19 | 5.2 |
| 0.64 | -8 | -4 | -47 | -2 | -2 | 3 | 4 | -8.1 |
| 0.41 | 3 | -2 | -40 | 1 | 6 | 0 | 0 | -4.7 |
| 0.27 | 4 | 2 | -43 | 0 | 3 | 2 | 9 | -3.3 |

SECONDARY SEWAGE--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | 15 SEP | 20 SEP | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 85 | -2 | 46 | 55 | 82 | 82 | 23 | 27 | 95 | 59.2 |
| 13.0 | 95 | 39 | 3 | 11 | 9 | 69 | 39 | 1 | 4 | 79 | 35.0 |
| 8.4 | 79 | 17 | 8 | 6 | 3 | 49 | 21 | 7 | 1 | 67 | 25.8 |
| 5.5 | 67 | 6 | 3 | 1 | 0 | 19 | 0 | 0 | 0 | 28 | 12.5 |
| 3.6 | 37 | 1 | 2 | 1 | 1 | 6 | -15 | -2 | 0 | 12 | 4.3 |
| 2.3 | 31 | 2 | 14 | 4 | 0 | 6 | -21 | 0 | -4 | 13 | 4.8 |
| 1.5 | 14 | 1 | 3 | 2 | 0 | 3 | -12 | -1 | 0 | 18 | 3.0 |
| 1.0 | 11 | 2 | -2 | 0 | -1 | 1 | -16 | -2 | -2 | -2 | -1.0 |
| 0.64 | 8 | 0 | 6 | -1 | 1 | 1 | -18 | -1 | 0 | -3 | -0.6 |
| 0.41 | 0 | 6 | 0 | 0 | 0 | -1 | -25 | -1 | -4 | 9 | -1.5 |
| 0.27 | -1 | -1 | 1 | 0 | 0 | 0 | -16 | 2 | -1 | 1 | -1.5 |

Appendix Table 12.2 (Continued).

CHLORINATED SECONDARY SEWAGE--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | 86 | 100 | 100 | 100 | 100 | 100 | 100 | 98.0 |
| 13.0 | 71 | 100 | 100 | 100 | 100 | 100 | 100 | 95.9 |
| 8.4 | 60 | 100 | 100 | 100 | 100 | 100 | 95 | 93.6 |
| 5.5 | 27 | 88 | 66 | 100 | 100 | 100 | 82 | 80.5 |
| 3.6 | -14 | 69 | 33 | 88 | 70 | 90 | 51 | 55.3 |
| 2.3 | -6 | 42 | 39 | 74 | 42 | 62 | 23 | 39.3 |
| 1.5 | -21 | 4 | -1 | 37 | 16 | 10 | -2 | 6.2 |
| 1.0 | 0 | -1 | 3 | -2 | 34 | 8 | 2 | 6.3 |
| 0.64 | -25 | 2 | 7 | 6 | 51 | 37 | 2 | 11.5 |
| 0.41 | 10 | 3 | -7 | -62 | 18 | 30 | -6 | -2.0 |
| 0.27 | 6 | 4 | 8 | -30 | 16 | 31 | 18 | 7.4 |

CHLORINATED SECONDARY SEWAGE--OYSTER EMBRYO PERCENT ABNORMAL

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 8.4 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 5.5 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 3.6 | 90 | 100 | 100 | 100 | 97 | 100 | 85 | 95.9 |
| 2.3 | 18 | 76 | 62 | 100 | 46 | 82 | 10 | 56.1 |
| 1.5 | -5 | 4 | -29 | 24 | 24 | 8 | 0 | 3.9 |
| 1.0 | -9 | 1 | -40 | -2 | 25 | 4 | 0 | -3.2 |
| 0.64 | -3 | 1 | -43 | 0 | 29 | 9 | -3 | -1.4 |
| 0.41 | -9 | -4 | -30 | -1 | 27 | 18 | 0 | 0.1 |
| 0.27 | 2 | -6 | -38 | -3 | 6 | 6 | -1 | -4.7 |

CHLORINATED SECONDARY SEWAGE--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT SEWAGE | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | 15 SEP | 20 SEP | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 8.4 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 5.5 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 3.6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 2.3 | 100 | 100 | 96 | 92 | 100 | 100 | 100 | 100 | 100 | 100 | 98.8 |
| 1.5 | 100 | 93 | 83 | 16 | 63 | 92 | 100 | 100 | 99 | 100 | 84.5 |
| 1.0 | 86 | 12 | 4 | 8 | 4 | 27 | 100 | 96 | 96 | 91 | 52.6 |
| 0.64 | 9 | 1 | 8 | -1 | 0 | 12 | 87 | 83 | 19 | 50 | 26.8 |
| 0.41 | 5 | 3 | 0 | 1 | -1 | 2 | 32 | 10 | -1 | 6 | 5.7 |
| 0.27 | 0 | 1 | 10 | -2 | -1 | 1 | -14 | 3 | -1 | 2 | 0.0 |

Appendix Table 12.2 (Continued).

DECHLORINATED SECONDARY EFFLUENT--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT EFFLUENT | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | -59 | -12 | -8 | -18 | -3 | 17 | -11 | -13.3 |
| 13.0 | -47 | 11 | 10 | -8 | -23 | 16 | 4 | -5.1 |
| 8.4 | -62 | -4 | -17 | -21 | 13 | -17 | 7 | -14.5 |
| 5.5 | -39 | 0 | -10 | 0 | 16 | 4 | 5 | -3.4 |
| 3.6 | -59 | 11 | -15 | 17 | 24 | 9 | -9 | -3.1 |
| 2.3 | -26 | 3 | -22 | 8 | 24 | 3 | -6 | -2.6 |
| 1.5 | -26 | -1 | -12 | 31 | 21 | -14 | 3 | 0.3 |
| 1.0 | -26 | 4 | -5 | 18 | 29 | 8 | 1 | 4.3 |
| 0.64 | -35 | -2 | 0 | 9 | 40 | 9 | 0 | 3.1 |
| 0.41 | -44 | 5 | 9 | -4 | 17 | 7 | -10 | -2.8 |
| 0.27 | -15 | 9 | 13 | 9 | 19 | 4 | -5 | 4.9 |

DECHLORINATED SECONDARY EFFLUENT--OYSTER EMBRYO PERCENT ABNORMAL

| PERCENT EFFLUENT | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | -6 | 5 | -20 | 7 | 50 | 21 | 5 | 8.9 |
| 13.0 | -6 | 0 | -22 | 0 | -5 | 5 | -2 | -4.2 |
| 8.4 | -8 | -4 | -44 | -4 | -10 | 9 | 0 | -8.5 |
| 5.5 | -5 | -5 | -45 | -3 | -5 | 7 | -4 | -8.4 |
| 3.6 | -7 | -4 | -38 | -1 | -6 | 7 | 0 | -7.1 |
| 2.3 | 3 | -2 | -41 | -3 | -5 | 4 | -2 | -6.5 |
| 1.5 | -1 | -4 | -47 | 8 | -5 | 1 | 11 | -5.2 |
| 1.0 | 0 | -1 | -34 | 2 | -1 | -2 | 3 | -5.6 |
| 0.64 | -8 | -3 | -39 | -3 | 0 | 2 | 2 | -6.9 |
| 0.41 | -6 | -2 | -16 | -5 | 13 | 14 | -1 | -0.4 |
| 0.27 | 4 | 15 | -33 | -2 | -7 | -1 | 2 | -3.0 |

DECHLORINATED SECONDARY EFFLUENT--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT EFFLUENT | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | 15 SEP | 20 SEP | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 100 | 97 | 91 | 94 | 100 | 99 | 100 | 100 | 99 | 100 | 98.0 |
| 13.0 | 98 | 94 | 63 | 53 | 99 | 74 | 100 | 92 | 87 | 100 | 86.1 |
| 8.4 | 96 | 55 | 14 | 14 | 90 | 69 | 81 | 23 | 47 | 96 | 58.5 |
| 5.5 | 82 | 14 | 10 | 4 | 15 | 28 | 71 | 5 | 30 | 76 | 33.6 |
| 3.6 | 24 | 6 | 10 | 2 | 0 | 9 | 40 | 0 | 1 | 29 | 12.3 |
| 2.3 | 6 | 1 | -1 | 1 | 1 | 2 | -19 | 1 | -2 | 18 | 0.9 |
| 1.5 | 3 | 0 | 2 | 0 | -1 | 1 | -31 | 10 | -4 | 7 | -1.2 |
| 1.0 | 1 | 0 | 0 | 0 | 0 | 4 | -2 | 2 | -1 | 6 | 1.0 |
| 0.64 | 5 | 3 | 12 | 0 | 0 | -1 | -9 | 0 | -2 | 5 | 1.3 |
| 0.41 | -1 | 1 | 1 | 0 | 1 | 0 | -28 | -2 | -4 | 2 | -2.9 |
| 0.27 | 0 | 0 | 0 | 2 | 0 | -1 | -19 | 0 | -2 | -4 | -2.4 |

Appendix Table 12.2 (Continued).

FRESHWATER--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT FRESHWATER | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | -38 | -10 | 6 | 4 | 10 | -25 | 16 | -5.3 |
| 13.0 | -39 | -13 | 26 | 34 | 12 | -12 | 9 | 2.5 |
| 8.4 | -40 | -5 | -4 | 39 | 4 | 1 | -2 | -0.9 |
| 5.5 | -25 | -3 | -8 | 16 | 10 | -8 | 20 | 0.4 |
| 3.6 | -45 | -8 | 1 | 13 | 0 | -8 | 6 | -6.1 |
| 2.3 | -47 | 3 | 2 | 38 | -1 | -12 | -9 | -3.6 |
| 1.5 | -50 | -12 | -5 | -12 | 32 | -22 | -4 | -10.2 |
| 1.0 | -58 | -6 | -17 | 7 | 4 | 12 | 0 | -8.3 |
| 0.64 | -27 | 3 | 16 | 6 | 16 | 14 | 1 | 4.3 |
| 0.41 | -20 | 19 | -11 | 9 | 23 | -3 | 4 | 2.9 |
| 0.27 | -12 | -13 | 57 | 1 | 24 | 18 | 0 | 10.6 |

FRESHWATER--OYSTER EMBRYO PERCENT ABNORMAL

| PERCENT FRESHWATER | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 20.0 | -14 | 5 | -24 | -1 | -3 | 7 | 3 | -3.9 |
| 13.0 | -9 | -2 | -14 | -5 | 9 | -3 | -4 | -4.0 |
| 8.4 | -6 | -1 | -43 | 2 | 4 | 0 | 1 | -6.2 |
| 5.5 | -8 | -3 | -38 | -3 | 11 | 3 | 15 | -4.7 |
| 3.6 | -4 | -4 | -45 | -4 | -7 | -1 | -2 | -9.4 |
| 2.3 | -1 | 6 | -33 | -4 | 2 | -1 | -3 | -4.7 |
| 1.5 | -9 | -1 | -39 | -3 | 9 | 2 | -4 | -6.4 |
| 1.0 | -9 | 1 | -46 | -3 | 3 | -3 | -3 | -8.5 |
| 0.64 | -6 | -2 | -39 | -1 | 6 | 3 | 9 | -4.3 |
| 0.41 | 0 | -4 | -40 | -2 | 16 | -1 | 12 | -2.8 |
| 0.27 | 13 | 0 | 50 | -1 | 3 | -2 | 7 | 10.3 |

FRESHWATER--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT FRESHWATER | 21 JUL | 23 JUL | 30 JUL | 4 AUG | 6 AUG | 13 AUG | 3 SEP | 15 SEP | 20 SEP | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 37 | 3 | 12 | 19 | 16 | 38 | 74 | 82 | 18 | 52 | 35.0 |
| 13.0 | 7 | 2 | 0 | 12 | 3 | 4 | 0 | 2 | 13 | 15 | 6.0 |
| 8.4 | -1 | -1 | 8 | 6 | -1 | 2 | -9 | -1 | -2 | 28 | 2.9 |
| 5.5 | -2 | 3 | 12 | 2 | 0 | 4 | -25 | 0 | 0 | 16 | 1.0 |
| 3.6 | 1 | 5 | 2 | 4 | 0 | 1 | -18 | -1 | 3 | 4 | 0.1 |
| 2.3 | 4 | 3 | 3 | 2 | -1 | 1 | -12 | -1 | 0 | 7 | 0.6 |
| 1.5 | 5 | 8 | 1 | 11 | 1 | 1 | -30 | 0 | -4 | 8 | 0.3 |
| 1.0 | -2 | 1 | 4 | -2 | 0 | 3 | -16 | -2 | 1 | 2 | -1.0 |
| 0.64 | 0 | 0 | 3 | -1 | 1 | 2 | -19 | 4 | -4 | 5 | -0.8 |
| 0.41 | 0 | -1 | 8 | 5 | 0 | 0 | -27 | 0 | -4 | 5 | -1.3 |
| 0.27 | -4 | -1 | 10 | 0 | 0 | 2 | -6 | 0 | 0 | -1 | 0.0 |

Appendix Table 12.3 Sewage bioassay control water salinity, pH, and temperature. Dashes mean not measured.

| | West Point control seawater | | | Kincaid Lab control seawater | |
|---|---|---|---|---|---|
| Date | Salinity °/₀₀ | pH | Temp. °C | Salinity °/₀₀ | pH |
| 21 July | 28.99 | 7.6 | 12.4 | 29.71 | 7.3 |
| 23 July | 29.18 | 8.0 | 12.3 | " | 7.9 |
| 30 July | 29.14 | 7.6 | 13.6 | " | 8.6 |
| 4 Aug | 29.35 | -- | 13.0 | " | 7.8 |
| 6 Aug | 29.37 | 7.6 | 12.3 | " | 7.6 |
| 13 Aug | 29.45 | 7.7 | 12.4 | " | 7.5 |
| 3 Sept | 29.77 | 7.4 | 12.4 | " | 8.7 |
| 15 Sept | 29.86 | 7.5 | 12.8 | " | 7.3 |
| 20 Sept | 29.97 | 7.6 | 12.3 | " | 8.3 |
| 28 Sept | 29.80 | -- | 12.4 | " | 7.4 |
| Average: | 29.49 | 7.62 | 12.59 | 29.71 | 7.84 |
| S.D.: | 0.34 | 0.18 | 0.43 | 0 | 0.53 |
| Range: | 28.99-29.97 | 7.4-8.0 | 12.3-13.6 | 0 | 7.3-8.7 |

Appendix Table 12.4. Oyster embryo and sand dollar sperm assay responses observed in dilutions of West Point unchlorinated primary effluent on five separate test dates (four test dates for the oyster embryo assays). All responses have been adjusted for the control (filtered West Point seawater) responses.

WEST POINT PRIMARY--OYSTER EMBRYO PERCENT MORTALITY

| PERCENT EFFLUENT | 4 AUG | 4 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|
| 20.0 | 100 | 85 | 38 | 100 | 80.7 |
| 13.0 | 100 | 79 | 17 | 100 | 74.0 |
| 8.4 | 67 | 46 | 22 | 67 | 50.7 |
| 5.5 | 53 | 32 | 10 | 40 | 33.7 |
| 3.6 | 53 | 44 | 15 | 10 | 30.2 |
| 2.3 | 54 | 7 | 12 | 17 | 22.4 |
| 1.5 | 23 | 36 | 1 | 57 | 29.4 |
| 1.0 | 19 | 8 | 16 | 65 | 26.8 |
| 0.64 | 18 | 16 | 20 | 19 | 18.4 |
| 0.41 | -8 | 5 | 0 | 28 | 6.4 |
| 0.27 | 15 | 48 | -9 | 48 | 25.6 |

WEST POINT PRIMARY--OYSTER EMBRYO PERCENT ABNORMAL

| PERCENT EFFLUENT | 4 AUG | 6 AUG | 13 AUG | 3 SEP | AVERAGE |
|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 71 | 100 | 92.7 |
| 8.4 | 100 | 51 | 16 | 96 | 66.0 |
| 5.5 | 43 | 18 | 16 | 64 | 35.1 |
| 3.6 | 8 | 8 | 26 | -3 | 9.6 |
| 2.3 | 6 | 0 | 20 | 8 | 8.3 |
| 1.5 | 10 | 7 | 14 | 0 | 7.5 |
| 1.0 | 4 | -2 | 39 | 22 | 18.8 |
| 0.64 | -1 | 1 | 20 | 0 | 5.0 |
| 0.41 | 2 | 1 | 51 | 8 | 15.6 |
| 0.27 | -2 | 5 | 11 | 10 | 6.1 |

WEST POINT PRIMARY--SAND DOLLAR PERCENT EGGS UNFERTILIZED

| PERCENT EFFLUENT | 4 AUG | 6 AUG | 13 AUG | 3 AUG | 28 SEP | AVERAGE |
|---|---|---|---|---|---|---|
| 20.0 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 13.0 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 8.4 | 100 | 100 | 95 | 100 | 100 | 99.0 |
| 5.5 | 100 | 100 | 34 | 100 | 100 | 95.3 |
| 3.6 | 91 | 100 | 34 | 100 | 100 | 84.9 |
| 2.3 | 89 | 92 | 6 | 93 | 99 | 75.6 |
| 1.5 | 68 | 78 | 6 | 87 | 78 | 63.3 |
| 1.0 | 24 | 22 | 0 | 48 | 28 | 24.7 |
| 0.64 | 2 | 3 | 3 | 43 | 9 | 12.0 |
| 0.41 | 4 | 1 | 4 | 64 | 5 | 15.5 |
| 0.27 | 5 | 0 | -1 | 16 | 13 | 6.6 |

Appendix Table 12.5

## RUN 3

| Raw Data | | | Proportions | |
|---|---|---|---|---|
| A400E | | | A400E | |
| 20 | 19 | 1 | 0.95 | 0.05 |
| 20 | 19 | 2 | 0.95 | 0.10 |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 14 | 1 | 0.70 | 0.07 |
| C400E | | | C400E | |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 18 | 1 | 0.90 | 0.05 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 11 | 0 | 0.55 | 0.00 |
| C600E | | | C600E | |
| 20 | 19 | 1 | 0.95 | 0.05 |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 14 | 0 | 0.70 | 0.00 |
| 20 | 13 | 0 | 0.65 | 0.00 |
| C640 | | | C640 | |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 17 | 2 | 0.85 | 0.11 |
| 20 | 14 | 0 | 0.70 | 0.00 |
| 20 | 14 | 0 | 0.70 | 0.00 |
| G780 | | | G780 | |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 17 | 1 | 0.85 | 0.05 |
| G50W | | | G50W | |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 20 | 0 | 1.00 | 0.00 |
| H640 | | | H640 | |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 16 | 0 | 0.80 | 0.00 |
| I690 | | | I690 | |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 16 | 0 | 0.80 | 0.00 |
| 20 | 16 | 0 | 0.80 | 0.00 |
| J600E | | | J600E | |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 18 | 0 | 0.90 | 0.00 |
| **West Beach** | | | **West Beach** | |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 18 | 0 | 0.90 | 0.00 |
| **Duw 2** | | | **Duw 2** | |
| 20 | 15 | 0 | 0.75 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 |
| 20 | 16 | 0 | 0.80 | 0.00 |
| 20 | 13 | 0 | 0.65 | 0.00 |
| **OT-2** | | | **OT-2** | |
| 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 18 | 1 | 0.90 | 0.05 |
| **OT-1** | | | **OT-1** | |
| 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| B75W | | | B75W | |
| 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 |

Raw Data: Column 1 = Total # Amphipods (N)
Column 2 = Total # Survivors ($F_1$)
Column 3 = Number Moribund ($F_2$)

Proportions: Column 1 = Proportion Survivors ($F_1/N$)
Column 2 = Proportion Moribund ($F_2/F_1$)

Appendix Table 12.6. "Methods comparison" sediment bioassay raw data and proportions from comparison Runs A and B. (See footnote, Appendix Table 12.5 for explanation of column entries.)

## RUN A

| Raw Data | | | Proportions | | Raw Data | | | Proportions | |
|---|---|---|---|---|---|---|---|---|---|
| O10E | | | O10E | | O660W | | | O660W | |
| 20 | 14 | 0 | 0.70 | 0.00 | 20 | 8 | 3 | 0.40 | 0.37 |
| 20 | 14 | 0 | 0.70 | 0.00 | 20 | 5 | 1 | 0.25 | 0.20 |
| 20 | 14 | 0 | 0.70 | 0.00 | 20 | 6 | 2 | 0.30 | 0.33 |
| 20 | 16 | 1 | 0.80 | 0.06 | 20 | 12 | 3 | 0.60 | 0.25 |
| 20 | 17 | 0 | 0.85 | 0.00 | 20 | 8 | 3 | 0.40 | 0.37 |
| S10E | | | S10E | | S660W | | | S660W | |
| 20 | 9 | 0 | 0.45 | 0.00 | 20 | 10 | 0 | 0.50 | 0.00 |
| 20 | 2 | 1 | 0.10 | 0.50 | 20 | 0 | 0 | 0.00 | 0.00 |
| 20 | 16 | 5 | 0.80 | 0.31 | 20 | 8 | 1 | 0.40 | 0.12 |
| 20 | 18 | 3 | 0.90 | 0.16 | 20 | 6 | 0 | 0.30 | 0.00 |
| 20 | 14 | 2 | 0.70 | 0.14 | 20 | 12 | 2 | 0.60 | 0.16 |
| P10E | | | P10E | | O88W | | | O88W | |
| 20 | 12 | 0 | 0.60 | 0.00 | 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 11 | 4 | 0.55 | 0.36 | 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 16 | 0 | 0.80 | 0.00 | 20 | 15 | 0 | 0.75 | 0.00 |
| 20 | 17 | 5 | 0.85 | 0.29 | 20 | 18 | 0 | 0.90 | 0.00 |
| O10W | | | O10W | | 20 | 15 | 0 | 0.75 | 0.00 |
| 20 | 9 | 7 | 0.45 | 0.77 | S88W | | | S88W | |
| 20 | 13 | 12 | 0.65 | 0.92 | 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 13 | 12 | 0.65 | 0.92 | 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 12 | 7 | 0.60 | 0.58 | 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 11 | 0 | 0.55 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| S10W | | | S10W | | 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 18 | 4 | 0.90 | 0.22 | O88E | | | O88E | |
| 20 | 18 | 3 | 0.90 | 0.16 | 20 | 6 | 0 | 0.30 | 0.00 |
| 20 | 15 | 5 | 0.75 | 0.33 | 20 | 6 | 0 | 0.30 | 0.00 |
| 20 | 14 | 5 | 0.70 | 0.35 | 20 | 5 | 0 | 0.25 | 0.00 |
| 20 | 16 | 3 | 0.80 | 0.18 | 20 | 4 | 0 | 0.20 | 0.00 |
| O660E | | | O660E | | 20 | 7 | 0 | 0.35 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | S88E | | | S88E | |
| 20 | 16 | 2 | 0.80 | 0.12 | 20 | 0 | 0 | 0.00 | 0.00 |
| 20 | 16 | 1 | 0.80 | 0.06 | 20 | 1 | 0 | 0.05 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | 20 | 0 | 0 | 0.00 | 0.00 |
| 20 | 16 | 1 | 0.80 | 0.06 | 20 | 2 | 0 | 0.10 | 0.00 |
| S660E | | | S660E | | 20 | 2 | 0 | 0.10 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | P88E | | | P88E | |
| 20 | 18 | 0 | 0.90 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 14 | 0 | 0.70 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| P660E | | | P660E | | | | | | |
| 20 | 13 | 0 | 0.65 | 0.00 | | | | | |
| 20 | 19 | 0 | 0.95 | 0.00 | | | | | |
| 20 | 9 | 0 | 0.45 | 0.00 | | | | | |
| 20 | 17 | 0 | 0.85 | 0.00 | | | | | |
| 20 | 17 | 0 | 0.85 | 0.00 | | | | | |

Station Name Key (Run A):
Method = O ("Ott"); S ("Swartz"); P ("Pierson")
Sediment = 10 (Duwamish #2); 660 (D660); 88 (West Beach)
Treatment = E (fresh); W (frozen)

Appendix Table 12.6 (continued).

## RUN B

| Raw Data | | | Proportions | | Raw Data | | | Proportions | |
|---|---|---|---|---|---|---|---|---|---|
| O111W | | | O111W | | S260W | | | S260W | |
| 20 | 18 | 0 | 0.90 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 15 | 4 | 0.75 | 0.26 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 10 | 0 | 0.50 | 0.00 | 20 | 19 | 1 | 0.95 | 0.05 |
| O112W | | | O112W | | 20 | 18 | 1 | 0.90 | 0.05 |
| 20 | 15 | 0 | 0.75 | 0.00 | 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | O180E | | | O180E | |
| 20 | 14 | 0 | 0.70 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| O113W | | | O113W | | 20 | 19 | 1 | 0.95 | 0.05 |
| 20 | 19 | 0 | 0.95 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 15 | 0 | 0.75 | 0.00 | 20 | 18 | 1 | 0.90 | 0.05 |
| 20 | 15 | 3 | 0.75 | 0.20 | 20 | 20 | 0 | 1.00 | 0.00 |
| O114W | | | O114W | | O280E | | | O280E | |
| 20 | 20 | 2 | 1.00 | 0.10 | 20 | 17 | 2 | 0.85 | 0.11 |
| 20 | 19 | 1 | 0.95 | 0.05 | 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 18 | 1 | 0.90 | 0.05 | 20 | 19 | 0 | 0.95 | 0.00 |
| O210W | | | O210W | | 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 19 | 3 | 0.95 | 0.15 | S280E | | | S280E | |
| 20 | 20 | 3 | 1.00 | 0.15 | 20 | 20 | 1 | 1.00 | 0.05 |
| 20 | 18 | 3 | 0.90 | 0.16 | 20 | 20 | 1 | 1.00 | 0.05 |
| 20 | 18 | 1 | 0.90 | 0.05 | 20 | 20 | 2 | 1.00 | 0.10 |
| S210W | | | S210W | | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 18 | 1 | 0.90 | 0.05 | 20 | 20 | 1 | 1.00 | 0.05 |
| 20 | 20 | 0 | 1.00 | 0.00 | O180W | | | O180W | |
| 20 | 20 | 0 | 1.00 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 18 | 3 | 0.90 | 0.16 | 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 17 | 1 | 0.85 | 0.05 | 20 | 18 | 0 | 0.90 | 0.00 |
| O160W | | | O160W | | 20 | 18 | 0 | 0.90 | 0.00 |
| 20 | 17 | 0 | 0.85 | 0.00 | 20 | 17 | 0 | 0.85 | 0.00 |
| 20 | 20 | 0 | 1.00 | 0.00 | O280W | | | O280W | |
| 20 | 18 | 0 | 0.90 | 0.00 | 20 | 18 | 1 | 0.90 | 0.05 |
| 20 | 14 | 0 | 0.70 | 0.00 | 20 | 16 | 0 | 0.80 | 0.00 |
| 20 | 19 | 2 | 0.95 | 0.10 | 20 | 20 | 0 | 1.00 | 0.00 |
| O260W | | | O260W | | 20 | 17 | 3 | 0.85 | 0.17 |
| 20 | 17 | 0 | 0.85 | 0.00 | 20 | 1 | 1 | 0.05 | 1.00 |
| 20 | 20 | 0 | 1.00 | 0.00 | S280W | | | S280W | |
| 20 | 19 | 0 | 0.95 | 0.00 | 20 | 20 | 0 | 1.00 | 0.00 |
| 20 | 19 | 0 | 0.95 | 0.00 | 20 | 19 | 0 | 0.95 | 0.00 |
| 20 | 18 | 1 | 0.90 | 0.05 | 20 | 19 | 0 | 0.95 | 0.00 |
| | | | | | 20 | 18 | 0 | 0.90 | 0.00 |
| | | | | | 20 | 18 | 0 | 0.90 | 0.00 |

Station Key Name (Run B):
Method = 01 ("Ott" flowthrough); 02 ("Ott" static); S2 ("Swartz" static)
Sediment (second two digits) = 11 (Duw #3, juveniles, tank 1); 12 (Duw #3, adults, tank 1); 13 (Duw #3, juveniles, tank 2); 14 (Duw #3, adults, tank 2); 10 (Duw #3); 60 (D660); 80 (West Beach).
Treatment = E (fresh); W (frozen)