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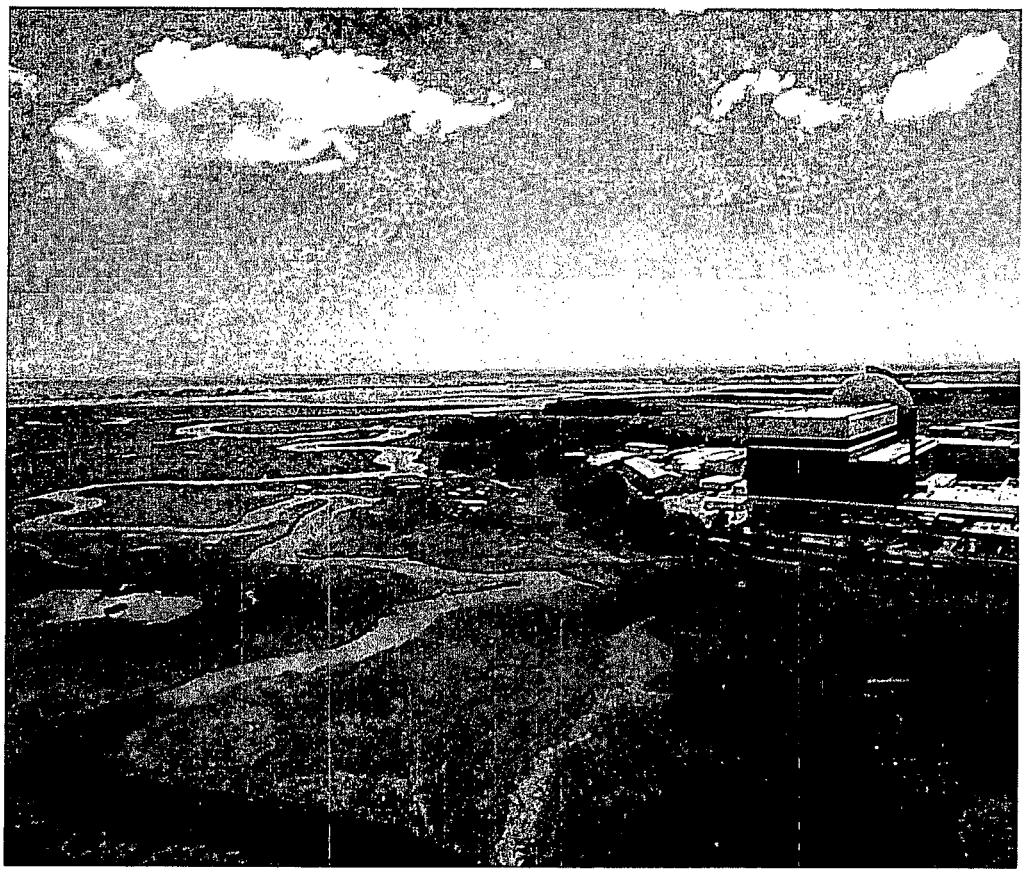

Attachment 2

Vol. 2

SEABROOK ENVIRONMENTAL STUDIES, 1987.

A CHARACTERIZATION OF BASELINE CONDITIONS IN THE HAMPTON-SEABROOK AREA, 1975-1987.

A PREOPERATIONAL STUDY FOR SEABROOK STATION

TECHNICAL REPORT XIX-II

Prepared for

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TABLE OF CONTENTS

PAGE

PAGE

LIST OF FIGURES

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

LIST OF TABLES

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

LIST OF APPENDIX TABLES

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Seabrook Environmental Studies began in 1969 to monitor the balanced indigenous marine communities in preparation for assessing the effects of Seabrook Station operation. As plant operation has not yet begun, the study is in the preoperational or baseline monitoring phase.

The purpose of the 1987 Seabrook Baseline Report is to define the sources and magnitudes of naturally-occurring variability in the physical and biological environment around Seabrook Station. A previous report (The 1986 Seabrook Baseline Report) summarized information collected through 1986. This report updates those results with one additional year of data.

The optimal design of an impact assessment study ensures that a potential impact is delineated from naturally-occurring variability. The Seabrook Monitoring Program accomplishes this by (1) collecting data before and during operation to provide a "temporal control", and by (2) monitoring areas of potential impact as well as areas outside the influence of the thermal plume to provide a "spatial control". In each biological community, the experimental design of the program focuses on the most variable aspect. For example, the species distributions of plankton and pelagic fish change radically from season to season, but are similar throughout the coastal area. The sampling program collected data at least twice monthly to monitor seasonal trends in abundance at a nearfield and farfield area. For benthic macrofauna and macroalgae, seasonality is less of an issue in comparison to the marked changes in species composition with depth and substrate. Benthic collections were made in the predominant substrate type, horizontal hard bottom ledge, along nearfield and farfield transects at regular depth intervals. The American lobster, soft-shell clam, and certain fish are of particular concern because of their commercial or recreational importance. Data on all life stages of these species were collected. The discussion of variability focuses on the source of potential impact (intake, discharge) and the biological community or physical parameter most likely to be affected.

1.2 INTAKE MONITORING

The goal of intake monitoring is to provide information on the number and type of organisms entrained or impinged by the Seabrook Station cooling water system. Zooplankton, ichthyoplankton, and pelagic fish are the organisms which have the greatest potential for exposure to intake effects. During the study, both the number and type of entrainable organisms varied dramatically among seasons. The microzooplankton community shifted from a community predominated by copepods in spring, to one where bivalve larvae were most abundant in summer, to a low-density tintinnid community in fall and winter. Each year was slightly different from the previous depending on the natural thermal regime. Macrozooplankton assemblages were highly predictable from year to year, reflecting the population dynamics of the dominant copepods and the spring and summer reproductive activities of benthic fauna. Seasonal patterns of the bivalve larvae (including mussel and soft shell clam larvae) and the fish egg and larvae species assemblages were the result of spawning activities of the adults. Species composition reflected the predominance of one or two species which were present during a discrete time period. Fish eggs were most abundant in spring and summer, bivalve larvae in summer and fall, and fish larvae in late winter and summer. Most of the species that were represented in the zooplankton of the study area are widely distributed throughout the Gulf of Maine; thus entrainment losses can be replenished by the nearshore populations. Two species with local adult populations contributing to the larval pool, cunner and soft-shell clam, have widespread nearshore larval populations, which lessens the potential for entrainment impact.

Beginning in June 1986, Seabrook Station operated its cooling water system, although no power or heated discharge were produced. As expected, entrainment samples collected in the last half of 1986 and the first half of 1987 had species compositions of fish eggs, fish larvae, and bivalve larvae that were similar to samples collected offshore. Density levels for most of the entrained fish eggs and larvae were lower because the plant intake is not at the depth where ichthyoplankton are most concentrated. Species diversity

of ichthyoplankton entrainment samples was lower because of the less intensive sampling effort. Density levels of bivalve larvae were similar to those offshore except during peak abundance periods, when entrained densities were lower.

Potential intake effects on the pelagic fish community may be apparent from studying the seasonal and annual movements of the six most abundant species, which together constitute over 90% of the population. Of these, Atlantic herring is the most important; from September to April, it makes up from 60-90% of the total gill net catch. The variability in overall catches was directly related to year-to-year variations in Atlantic herring catches. Another important consideration in intake effects is the depth distribution of the pelagic fish. Atlantic menhaden and occasionally Atlantic mackerel were more abundant in the mid-depth area, where intake structures are located, than they were at the surface or at the bottom. These species may potentially be more susceptible than other pelagic fish to intake effects. Benthic oriented (demersel) fish also may be affected by the intakes if (1) they make excursions off the bottom in search of food and/or (2) they perceive the intake structures as protective or food-bearing habitat. The characteristics of the demersal fish communities in the study area are discussed below.

To evaluate the impact of operation of the Circulating Water System on adult and juvenile pelagic and demersal fish species, impingement samples were obtained and evaluated by Seabrook Station personnel. Monitoring to date has identified that approximately 0.02 fish per million gallons of cooling water flow (1 fish/50 million gallons) will be impinged at Seabrook Station. These studies strongly suggest that the design and operation of the intake structures will protect the balanced indigenous fish population by minimizing the number of individuals entrained within the system and subsequently impinged upon the travelling screens.

1.3 DISCHARGE MONITORING

1.3.1 Discharge Plume Monitoring

As the discharge plume will be concentrated in surface and near-surface waters, impact assessment will focus on parameters and organisms which are located primarily in this zone. Surface water quality, phytoplankton, and lobster larvae have been monitored primarily for determining potential discharge plume effects. Water quality parameters have historically shown distinct seasonal patterns that were important in driving biological cycles. Surface and bottom temperatures reached their lowest points from January through March, then steadily increased from August to October before beginning their fall decline. Dissolved oxygen had a seasonal pattern that was inversely related to temperature, with peak values in late winter and lowest values in fall. Year-to-year differences were low. Salinity values were fairly stable, but highest in winter and lowest in spring, a result of high runoff. Nutrients had somewhat erratic seasonal cycles, but were generally lowest in summer and highest in fall and winter. In general, the predictability of seasonal patterns and low year-to-year variability of most of the water quality parameters enhances their suitability for impact assessment.

The phytoplankton community has shown the most seasonal and annual variability of any of the species assemblages monitored. Species composition during peak periods varied from year to year. However, total phytoplankton abundance and chlorophyll *a* were relatively similar among years and showed a predictable seasonal cycle. Increases in irradiance typically initiated the spring bloom; densities usually decreased upon the decline in nitrogen-nutrients, coincident with thermocline development. Densities usually showed another increase in late-summer or fall. The phytoplankter *Gonyaulax* sp. produces paralytic shellfish poisoning, or red tide in this and other coastal areas. This organism usually reached toxic levels (as measured in *Mytilus edulis* meat) in May or June in Hampton Harbor, closing flats to bivalve shellfish fishing for a period of one to seven weeks each year.

Lobster larvae (Stages I-IV) have a strictly surface orientation. In coastal New Hampshire, successful recruitment of larvae is the single biggest factor in determining the level of adult catches. All stages were rare in the study area, generally occurring from June to October, with highest densities from late June through late August. Evidence suggests that waters off Hampton-Seabrook may be too cold for local production of lobster larvae, and those collected off Hampton-Seabrook actually originate from elsewhere in the Gulf of Maine and from Georges Bank.

Subsurface fouling panels, located three meters below the surface, placed in the discharge plume area show timing, type, and abundances of settling benthic organisms. Benthic recruitment and community development have shown a seasonal pattern that was highly consistent from year to year. Recruitment and settling activity was low in winter and spring but intensified from summer through fall.

The intertidal and shallow subtidal area near Sunk Rocks is outside the immediate plume area but might be exposed to slight elevations in temperature. Species composition of benthic macroalgae and macrofaunal communities in the intertidal and shallow subtidal areas changed with depth and substrate, but was highly similar among years. Individual species showed significant variations in recruitment levels from year to year and among stations. Macrofauna length measurements, however, were a more stable parameter.

1.3.2 Benthic Monitoring

The mid-depth and deep subtidal areas are monitored to determine if, during operation, any discharge impacts result from increased detritus levels. Year-to-year differences in the macroalgae and macrofaunal communities have been small in comparison to variations with depth and substrate. The species composition was highly predictable and distinct for each depth zone. Although individual macrofauna species appeared highly variable in

their annual abundance levels, these differences were usually not significant. Length measurements were not as variable as abundances and showed no differences among years.

Demersal fish which inhabit or feed in the discharge area are important because of their predominance in the food chain as well as for their commercial value. Six taxa constituted over 80% of the total otter trawl catch. Long term trends in total catch were evident, as catches in 1980 and 1981 were almost twice catches during the lowest years, 1977 and 1985. The demersal fish species composition basically changed twice per year, from a winter assemblage, when rainbow smelt were abundant, to an extended summer assemblage (April-November), when hakes and longhorn sculpin were abundant. Other dominants such as yellowtail and winter flounder were present year-round. Most of the fish captured, with the exception of hakes and winter flounder, were juveniles.

Because of its commercial importance, the American lobster was monitored in the discharge area. Seasonal patterns in catches were similar from year to year, and were affected by bottom temperatures, which influenced molting and activity levels. Catches usually increased to a peak in August or September, then declined. Decreases in catches in 1984 and 1985 of legal sized lobsters, a primary concern to lobstermen, were a result of natural variation in combination with the effects of the change in the legal size limit instituted in 1984 by the State of New Hampshire. Lobsters which would have been of legal size under the old law were protected from harvest until their next molt. The catches of lobster in 1987 were the lowest of any year during the 1975-1987 study period, showing a low total catch and low proportion of the catch that was of legal size.

1.3.3 Estuarine Monitoring

Although the likelihood of a cooling water system operational impact on the Hampton-Seabrook estuary is low, temperature, salinity, benthos, fish, and the soft-shell clam were all monitored in this area.

Temperature and salinity both showed regular seasonal cycles. Maximum temperatures usually occurred in August with minima in January or February. Salinity levels had a less distinct pattern, but were usually lowest in spring, a result of increased runoff, and highest in summer. Salinity levels in Brown's River were high from 1980-1982, coincident with low precipitation levels and highest discharge volumes of tunnel dewatering through the Seabrook settling basin. By 1986, salinity levels had returned to pre-1980 levels. The estuarine benthic community was highly variable in species composition and abundance, but predominantly composed of surface and subsurface deposit-feeding polychaetes. The number of species, total abundance, and abundance of some of the dominant species increased during the period when salinity levels were higher than average, but have returned to the levels observed prior to the tunnel dewatering discharge.

Estuarine fish included anadromous species as well as residents. Alewives and blueback herring pass into the estuary in spring, travelling upriver to spawn. Catch levels were affected by year class strength as well as water temperature and water level, which were influenced by rainfall and resulting runoff. Young-of-the-year and yearling rainbow smelt were occasionally and erratically caught in the estuary, but never constituted a substantial portion of the total catch. The predominant resident species was Atlantic silverside, which made up over two-thirds of the total catch and over 90% during their most abundant period, August through November. Variations in abundance of this species was the single most important factor in year-to-year changes in total catch.

The species of greatest concern in the Hampton-Seabrook estuary is the soft-shell clam. Density levels of spat, juveniles, and adults have been monitored in the estuary for 17 years. Densities of harvestable clams depend on a set of complex, interacting conditions. A successful set of spat is crucial, but this factor alone does not ensure high densities of harvestable clams. Once settled, survival of young-of-the-year clams depends on protection from its two main predators, green crabs and humans, as well as from

disease. In 1976, a large spatfall throughout the estuary resulted in high densities of harvestable clams in 1980-1982. Increased levels of predation prevented recruitment of the highly successful spatfalls in 1980 and 1981. Light spatfalls from 1982-1986 in combination with an increase in predation accounted for a precipitous decline in standing stock since 1983 and ensure that densities of harvestable clams will remain low for several more years. In addition, neoplasia, a cell growth disease fatal to clams, has been detected from clams in Hampton estuary. This may also be contributing to the decline of harvestable clams.

2.0 DISCUSSION

2.1 INTRODUCTION

2.1.1 General Perspective

Environmental studies for Seabrook Station began in 1969 and focused on plant design and siting questions. Once these questions were resolved, a monitoring program was designed which has examined the structure of all the major biological communities as well as the distribution, abundance, and size of selected species within each community. The goal has been to assess the temporal (seasonal and yearly) and spatial (nearfield and farfield) variability which has occurred during the baseline period. This report focuses on data collected since 1976 for fisheries studies and since 1978 for plankton and benthos studies as these years have maintained a consistent sampling design.

The purpose of this report is twofold: (1) to update results of the preoperational baseline monitoring program, summarized in NAI (1987b) with one additional year of data, and (2) provide a perspective on the sources and magnitude of naturally-occurring variability against which impact assessment will be made. Variability is important because it is the issue on which sampling design is focused and can be a major impediment to meaningful impact assessment. Therefore it is discussed first.

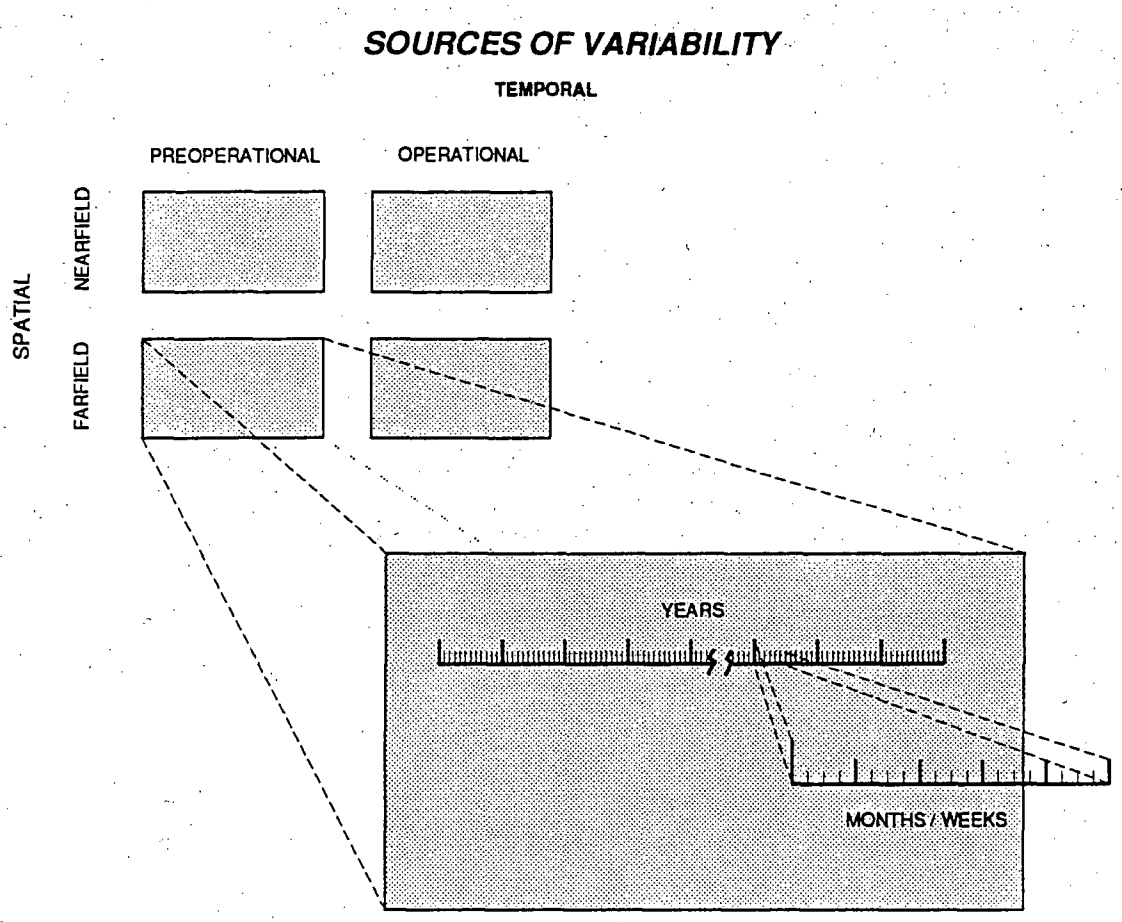
2.1.2 Sources of Baseline Variability

The optimal design of an impact study has four prerequisites that ensure that a potential impact is delineated from any naturally-occurring variability (Green 1979): (1) knowledge of the type, time and place of potential impact; (2) measurement of relevant environmental and biological variables; (3) monitoring before the potential impact occurs to provide a temporal control; (4) monitoring in an area unaffected by impact to serve as

a spatial control. The experimental design of the Seabrook Environmental Program was structured to meet these prerequisites.

A basic assumption was that there are two major sources of naturally-occurring variability: (1) that which occurs among different areas or stations, i.e., spatial, and (2) that which varies in time, from daily to weekly, monthly or annually. In the experimental design and analysis, we focused on the major source of variability in each community type and then determined the magnitude of variability in each community (Figure 2.1-1). In certain communities, particularly planktonic, where circulation patterns provide a similar habitat throughout the area, spatial variability was low in comparison to seasonal. The study design therefore focuses on frequent sampling to monitor seasonal trends at only one nearfield and one farfield station. In other communities, particularly benthic, spatial variability has been higher than seasonal variability. Benthic sampling design has focused on the dominant substrate type in the discharge area, horizontal hard-bottom ledge, with paired nearfield and farfield stations representing the major depth zones. Finfish catches have shown both seasonal and spatial differences. Therefore, these studies make frequent (at least monthly) collections in the area of the discharge as well as farfield areas to the north and south. Because the estuary is an aquatic nursery area and recreationally-important clam flat, baseline collections monitoring seasonal and annual patterns were also made there for operational phase comparison.

Biological variability can be measured on two levels: species and community. A species' abundance, recruitment, size and/or growth are important for understanding operational impact, if any. For this reason, these parameters were monitored for selected species from each community type. Species were chosen for more intensive study based on their commercial or numerical importance, sensitivity to temperature, potential as a nuisance organism, and habitat preference. Overall community structure, e.g., the number and type of species, total abundance and/or the dominance structure, may also be affected by plant operation in a way not detectable by monitoring



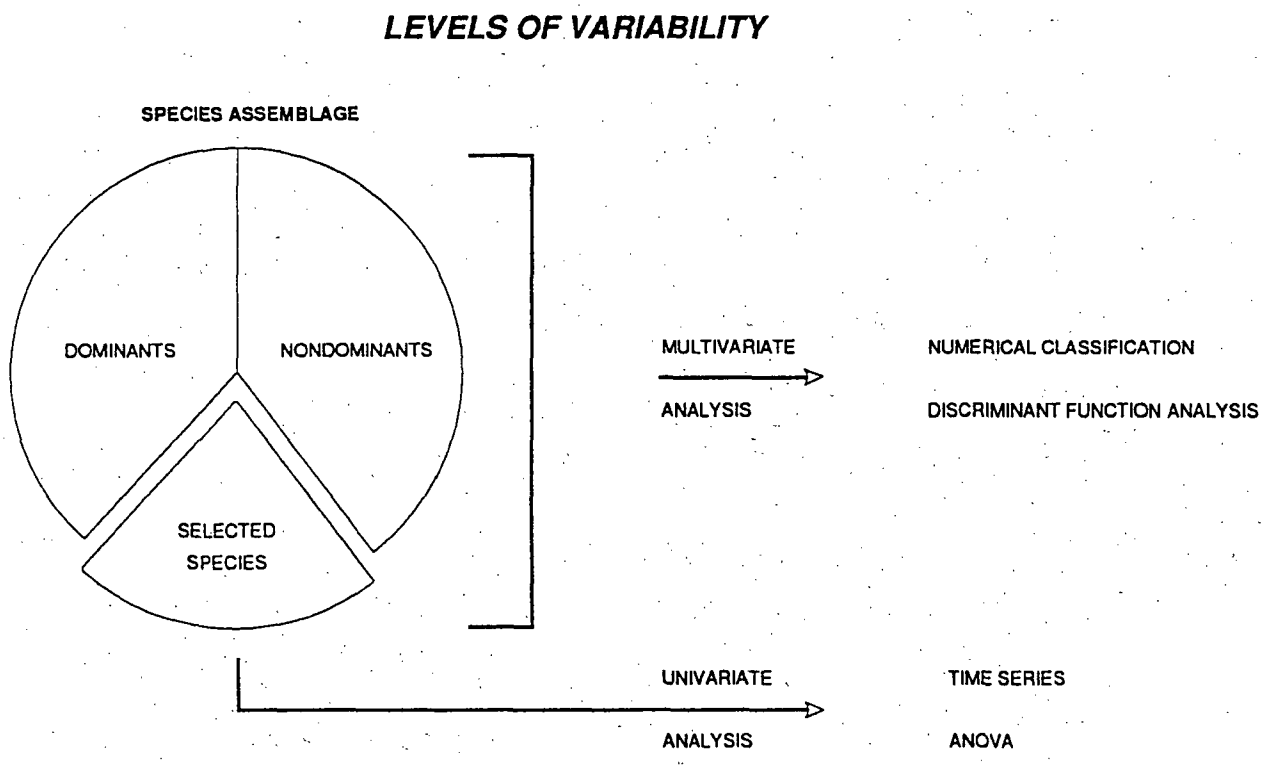


Figure 2.1-1. Schematic of sources and levels of variability in Seabrook Environmental Studies. Seabrook Baseline Report, 1987.

single species; therefore, the natural variation in community structure was monitored at regular time intervals, determined by early studies to be sufficient for this purpose.

Appropriate statistical methods must be used in conjunction with a well-planned experimental design in order to determine the sources and magnitude of variability. Annual and spatial variability in species abundance and size were tested by using analysis of variance or nonparametric analysis which will provide a means of evaluating the statistical significance of changes in the operational period. Spatial, seasonal, and annual variations in community structure were assessed first with numerical classification and then with discriminant analysis. Discriminant analysis provides a set of criteria using the baseline collections against which operational phase collections may be compared.

Identification of the sources and levels of variability utilizing the methods discussed above has its ultimate focus on the sources of potential influence from plant operation, and the sensitivity of a community or parameter to that influence (Table 2.1-1). Naturally, a community or species might be affected by more than one aspect of the cooling water system; however, the focus here is on the aspect of main concern. In general, intake (pumped) entrainment and impingement would potentially affect mainly plankton communities, including fish eggs and larvae, and pelagic fish. If they occur, thermal effects from the discharge (e.g. plume entrainment) would most likely affect nearshore surface water quality, phytoplankton, and intertidal and shallow subtidal benthos. Although no effects are anticipated in the estuary from the offshore discharge, fish and soft-shell clam populations have been monitored in that area to provide a baseline for operational phase comparisons. Bottom-dwelling organisms, including macrofauna, macroalgae, epibenthic crustaceans, and demersal fish, may be influenced by detritus potentially arising from moribund entrained plankton which is discharged with the cooling water. A previous impact assessment (NAI 1977e) has shown that the balanced indigenous community in the Seabrook study area should not be adversely influenced by the above factors. Results from the biological

TABLE 2.1-1. SUMMARY OF BIOLOGICAL COMMUNITIES AND SPECIES MONITORED FOR EACH POTENTIAL IMPACT TYPE. SEABROOK BASELINE REPORT, 1987.

MONITORING AREA	IMPACT TYPE	SAMPLE TYPE	LEVEL MONITORED: COMMUNITY	LEVEL MONITORED: SELECTED SPECIES/ PARAMETERS
Intake	Entrainment	Microzooplankton	x	x
		Macrozooplankton	x	x
		Fish eggs	x	
		Fish larvae	x	x
		Soft-shell clam larvae		x
		Cancer crab larvae		x
	Impingement	Pelagic fish	x	x
Discharge	Thermal Plume	Nearshore water quality		x
		Phytoplankton	x	x
		Lobster larvae		x
		Intertidal/shallow subtidal macroalgae and macrofauna	x	x
		Subsurface fouling community	x	x
	Plume Discharge	Mid-depth/deep macrofauna and macroalgae	x	x
		Bottom fouling community		x
		Demersal fish	x	x
		Lobster adults		x
		Cancer crab adults		x
Estuary	Cumulative Sources	Estuarine temperature		x
		Soft-shell clam spat and adults		x
		Estuarine fish	x	x

communities, species and environmental parameters sampled will be discussed in light of the feature of the cooling water system which would have the greatest potential for affecting them.

2.2 INTAKE AREA MONITORING

2.2.1 Plankton

2.2.1.1 Community Structure

An estimation of the number and type of plankton species affected by plant operation will depend on (1) the time of year, and (2) the degree of yearly variability. Results from the community analysis give an indication of the number and type of species present (and thus entrainable) at any particular time of year. These provide a multivariate "template" against which seasonal assemblages during plant operation may be compared. The selected species analysis enables a more precise estimate of the entrainable density for key species by examining their annual and seasonal variability. Knowledge of the within-year and among-year variability allows for more reliable estimates of impact to be made than if entrainment samples were taken in a single season and year.

All of the planktonic communities had species assemblages that changed with season during the baseline period (Figure 2.2-1). These groups were differentiated primarily on the distribution and abundance of dominant species; however, the relative abundance or even absence of other species was also a factor. The type of species entrained will depend on the seasonal assemblage present at the time. Macrozooplankton assemblages have been distinct and consistent, showing high predictability from year-to-year. Macrozooplankton assemblages reflected mainly the population dynamics of the dominant copepods with reproductive activities of benthic organisms affecting spring and summer species composition. In 1987, each macrozooplankton sample exhibited the same species assemblage that had been present at that time of year during the collections in previous years. There were some shifts in species composition within those assemblages compared to the earlier years. *Centropages typicus* in winter and spring and *Calanus finmarchicus* in summer both showed reduced importance in the macrozooplankton communities sampled in 1987.

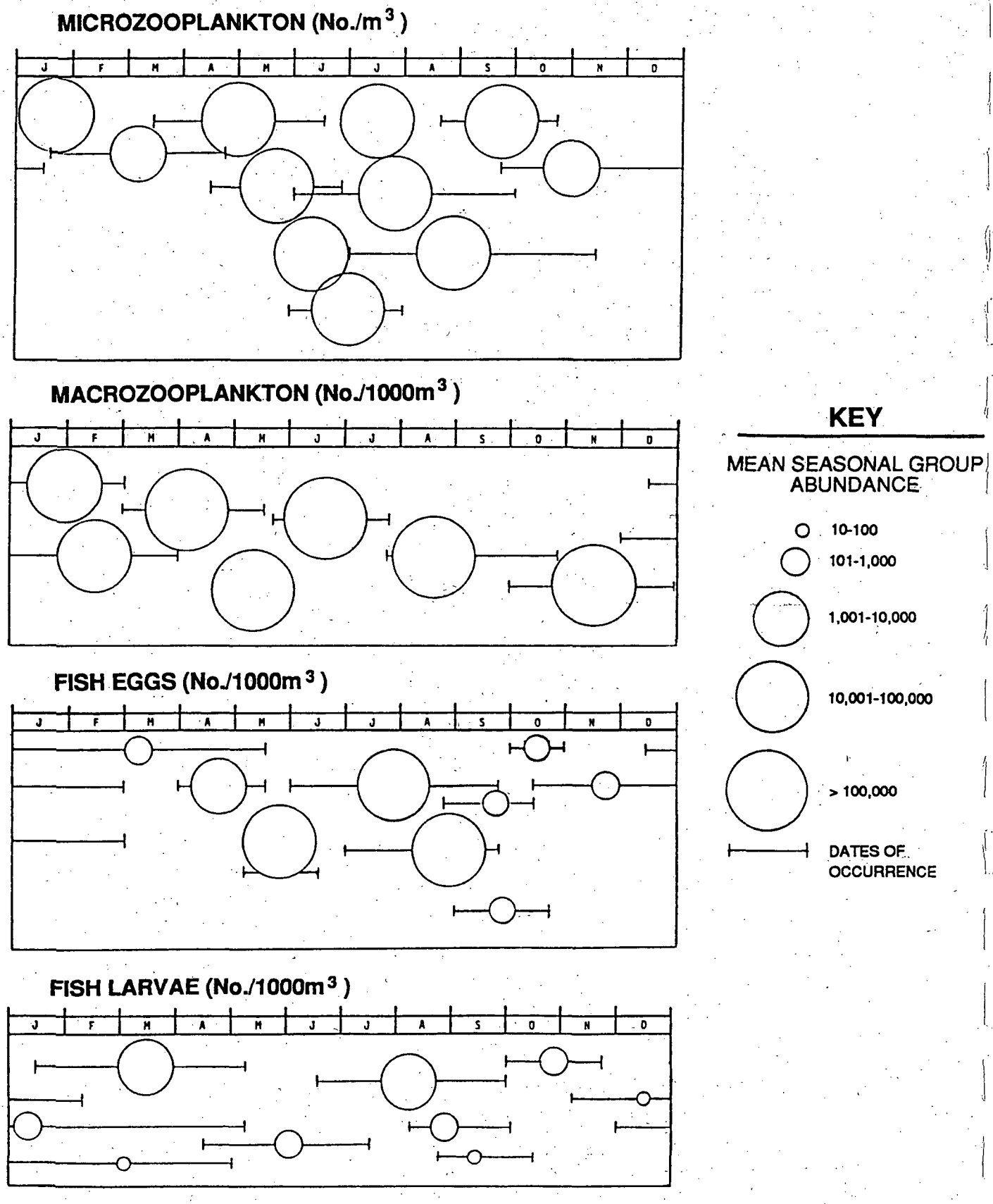


Figure 2.2-1. Historical dates of occurrence and mean abundance (excluding rare taxa) for seasonal groups formed by numerical classification of microzooplankton (No./m , 1978-1984), macrozooplankton (No./1000 m , 1978-1984), fish eggs (No./1000 m , 1976-1984), and fish larvae (No./1000 m ,1976-1984) collections. Seabrook Baseline Report, 1987.

Microzooplankton and planktonic fish eggs had several overlapping groups in spring and summer, indicative of both some year-to-year changes in community structure as well as a variable "transition period" in the late summer assemblage (Figure 2.2-1). The microzooplankton community typically shifted from one characterized rotifers in the spring, bivalve larvae in the summer, copepods in the fall, and tintinnids in the winter (NAI 1987b). Fish egg collections in 1987 were generally similar to previous years in their species composition and density. Exceptions in 1987 to the previously observed pattern were (1) absence of the previously important summer cunner-yellowtail flounder-hake assemblage, and (2) increased importance of two previously minor assemblages of late summer and fall species. The former was due to reduced abundances of two subdominant species in 1987, Atlantic mackerel and Atlantic whiting. The latter exception may have been influenced by the change in classification method from cluster analysis to discriminant analysis. Although species composition and abundances did not appear to differ substantially from past years, discriminant analysis placed greater emphasis on subdominant species in making group assignments, whereas cluster analysis emphasized the most abundant species.

Seasonal assemblages of fish larvae could be divided into four major types based on their dominant taxa: fall-winter (predominated by Atlantic herring), winter-spring (American sand lance), spring (winter flounder, snailfishes, and radiated shanny) and summer-fall (cunner). Variations in density of the major taxa, especially during transition periods, caused small changes in species composition leading to the formation of overlapping "subgroups". Seasonal patterns observed in 1987 were similar to previous years (Figure 2.2-1). There was increased importance in 1987 of a spring sand lance assemblage and a summer cunner assemblage, both characterized by low densities.

The effects of plant operation will also depend on seasonal variations in density. In most months, macrozooplankton densities have historically been over 100,000/1000 m^3 (Figure 2.2-1). The level of entrainment will be fairly consistent, although different species will be involved in each season. Microzooplankton (through 1984) and planktonic fish egg assem-

blages (through 1987), on the other hand, had their greatest concentration in the spring and summer, when bivalve larvae and copepod nauplii (microzooplankton), and cunner eggs (fish eggs), were dominant, and group densities were three orders of magnitude higher than in winter (Figure 2.2-1). Similarly, fish larvae were most abundant in late winter, when sand lance predominated, and summer, when cunner predominated. The level of entrainment for these assemblages will vary more dramatically between seasons in comparison to the macrozooplankton communities. All of the dominant taxa typifying these planktonic assemblages in the vicinity of the Seabrook Station are widely distributed in the Gulf of Maine in either nearshore regions or open water. Two groups, bivalve larvae and cunner larvae, have local adult populations contributing to the larval production; however, these species also have widespread nearshore populations which contribute to the total larval pool along this portion of the western Gulf of Maine.

Beginning in June 1986, Seabrook Station operated its circulating water cooling system; no power or heated discharge were produced. Initial sampling of entrained fish egg, larvae, and bivalve larvae communities revealed them to be similar to those collected offshore, although the smaller sample volumes and less-frequent sample collection in the plant produced some expected differences. The top-ranked entrained fish egg and larvae species were similar to those from offshore collections (Table 2.2-1); however, the total number of taxa was lower, due to the less-intensive sampling effort. Abundances of most of the dominant species were lower in entrainment samples than in offshore samples, in some cases substantially so. This pattern is probably a result of the different depths represented by the two types of samples. Seabrook Station's cooling water entrains organisms at a point five meters above the bottom where the total water depth is 17 m, whereas the oblique offshore tows sample the entire water column. The depth distribution of ichthyoplankton is typically uneven, particularly for eggs of some species, which are heavily concentrated near the surface. Entrained bivalve larvae species were similar to those collected offshore; and, unlike the ichthyoplankton, densities were very similar to those in offshore samples. When samples from the same day were compared, no significant differences in bivalve larvae densities were detected.

TABLE 2.2-1. COMPARISON OF DENSITIES OF TOP-RANKED FISH EGG, FISH LARVAE, AND BIVALVE LARVAE TAXA COLLECTED OFFSHORE AT STATION P2 AND IN ENTRAINMENT SAMPLES AT SEABROOK STATION FROM JULY 1986 THROUGH JUNE 1987. SEABROOK BASELINE REPORT, 1987.

DOMINANT SPECIES	DENSITY[c] ENTRAINED (E1)	DENSITY[c] OFFSHORE (P2)
Fish eggs[a]		
Cunner/yellowtail flounder	169	3390
Atlantic mackerel	107	1790
Rockling/hake	88	142
Atlantic cod/haddock/witch flounder	73	102
American plaice	55	14
Windowpane	43	232
Hake	15	539
Pollock	12	4
Fourbeard rockling	9	228
Fish larvae[a]		
Atlantic herring	127	110
Seasnail	23	33
American sand lance	17	56
Grubby	5	2
Rock gunnel	5	2
Winter flounder	5	20
American plaice	4	5
Bivalve larvae[b]		
Modiolus modiolus	3480	3910
Heteranomia squamula	2520	2930
Mytilus edulis	523	646
Mya arenaria	44	65

[a] No./1000 m^3
[b] No./m^3
[c] Average of monthly averages computed to compensate for unequal numbers of samples

2.2.1.2 Selected Species

Nine species with various lifestages from the pelagic zooplankton communities were designated as selected species. The existence of seven to nine years of preoperational data allows an estimation of seasonal and annual variability. These species exhibited different degrees of numerical importance; their relative contributions to their respective communities are shown in Figures 2.2-2 and 2.2-3.

The zooplankton selected species (including various lifestages) historically have constituted less than 40% of the overall abundances (Figures 2.2-2 and 2.2-3). In both the microzooplankton and macrozooplankton assemblages, other copepods typically have made a large contribution to overall abundances. In the microzooplankton, unidentified copepod nauplii and copepodites have been extremely abundant. In the macrozooplankton, copepods other than the selected species have historically been dominant over the year; however, the noncopepod selected species have been dominants in certain seasons. All of the zooplankton selected species reached peak abundance in spring and summer, with the exception of *Neomysis americana*, which has been most abundant in winter/spring.

Selected species of fish larvae predominated in every season, constituting 79% of the total abundance overall (Figure 2.2-4). Generally, each of the species was present only for a brief time period that was fairly consistent from year to year. Timing of peaks in abundance in 1987 was consistent with previous years, with only minor variations. Sand lance abundance peaked a month earlier than usual. Atlantic cod, unique among these fish larvae in having two peaks per year rather than one, reached its highest abundance during the winter peak, which is usually secondary to the spring-summer peak.

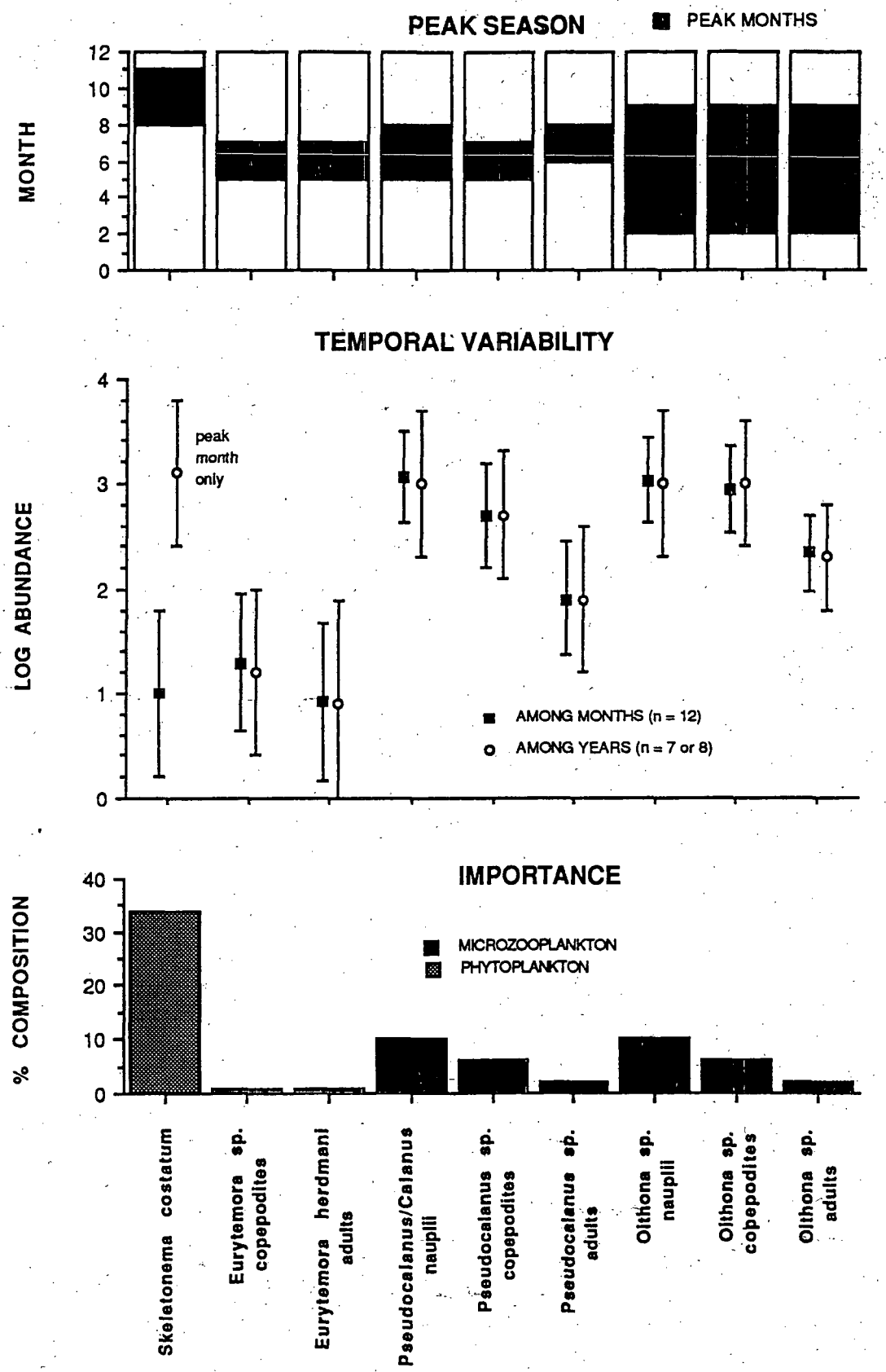


Figure 2.2-2. Percent composition, seasonal vs. annual variability (standard deviation) of log (x+1) abundance, and months of peak abundance for selected species of phytoplankton (thousands of cells/liter) and microzooplankton (No./m^3), 1978-1987. Seabrook Baseline Report, 1987.

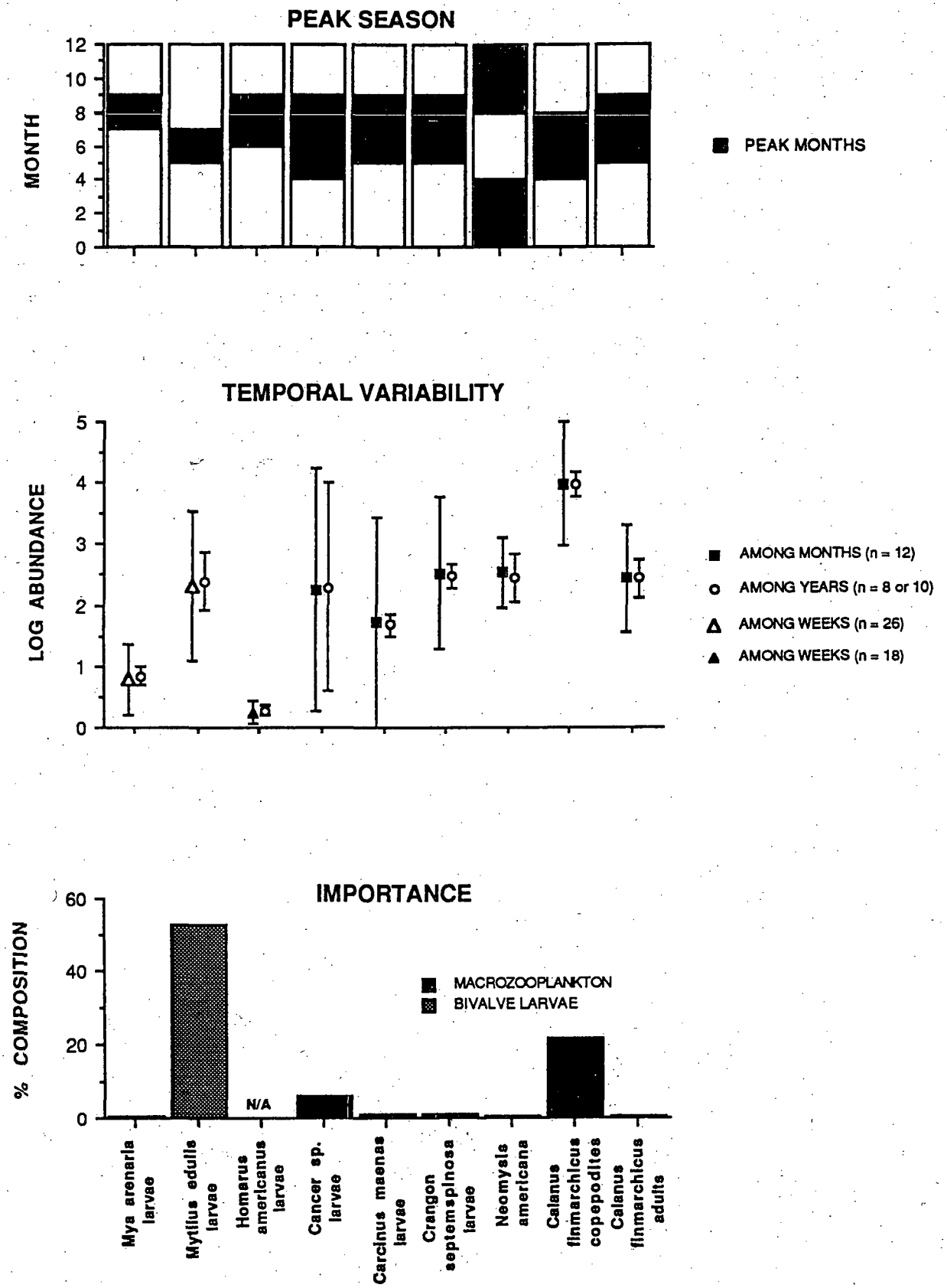


Figure 2.2-3. Percent composition, seasonal vs. annual variability (standard deviation) of log (x+1) abundance, and months of peak abundance for lobster larvae (No./1000 m^2) and selected species of bivalve larvae (No./m^3) and macrozooplankton (No./1000 m^3). Seabrook Baseline Report, 1987.

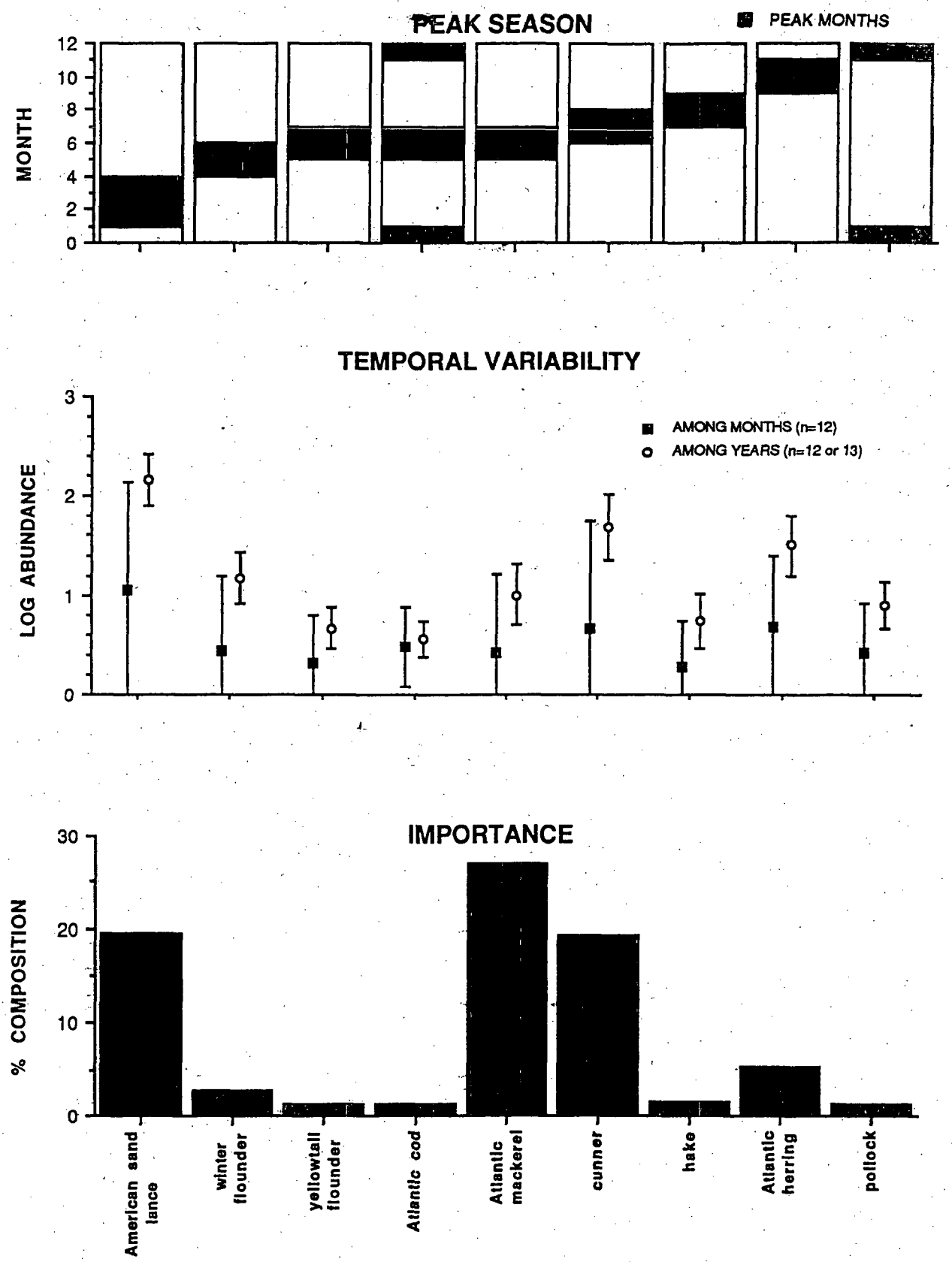


Figure 2.2-4. Percent composition, seasonal vs. annual variability (standard deviation) of log (x + 1) abundance (No./1000 m^3), and months of peak abundance for selected species of fish larvae, 1975-1987. Seabrook Baseline Report, 1987.

The plankton selected species showed varying degrees of year-to-year differences in abundance. For the phytoplankton and microzooplankton, among-year and within-year (seasonal) variations were about the same (Figure 2.2-2). Macrozooplankton, bivalve larvae, and lobster larvae (Figure 2.2-3) and fish larvae (Figure 2.2-4) usually showed higher seasonal variability than among-year variability. *Cancer* sp. larvae were an exception, with very high variation among as well as within years. Only three of the nine selected fish larvae species showed significant differences among years. These analyses indicate the species composition of entrained organisms may be fairly consistent over the years, although the actual number of organisms entrained could vary widely, particularly among seasons.

Bivalve larvae studies were carried out in the intake area to address questions related to the potential reduction in abundances of *Mya arenaria* larvae because of entrainment. Local current regimes and length of time spent in the plankton imply that nearshore *Mya* larvae populations originate from spawning adult populations in local and more southern estuaries, e.g., Hampton-Seabrook, Merrimack River and Essex, Massachusetts (NAI 1982b). Spawning adults have been observed in Hampton Harbor and Plum Island Sound (a farfield site) typically from June through September, but as early as April and as late as the end of October in some years. Although larvae were observed throughout the spawning period, peak densities usually did not occur until August or September (Figure 2.2-3); secondary peaks also occurred in May or June in some years. Therefore, the magnitude of entrainment will depend on the time of year as well as the overall annual abundance in that particular year. Initial entrainment samples collected during the period of peak *Mya* larvae densities were similar in magnitude to those collected offshore (Table 2.2-1). However, because larval densities in the nearshore area have shown no correlation with spat settlement densities (Section 2.3.1.3), entrainment estimates cannot be used to determine the impact of plant operation on the Hampton Harbor adult clam population.

2.2.1.3 Spatial Variability

An optimal impact assessment design (Green 1979) has been used for intake monitoring where comparisons of nearfield and farfield samples in both the preoperational and operational periods will be made. A determination of the similarity of nearfield and farfield plankton communities must be made in order to ascertain the suitability of the farfield station as a "control" area. Previous analyses of the microzooplankton, macrozooplankton, and fish egg and larval communities showed that differences among seasons and even dates within season were greater than those between nearfield and farfield stations (Table 2.2-2). Examination of data collected in 1987 supported these results. The communities in all cases were highly similar among stations. At the species level, some spatial differences were detected. In the macrozooplankton, two taxa, *Pontogeneia inermis*, and *Diastylis* sp., were more abundant at the nearfield intake station. This pattern may be due to a more complex substrate, cobble and sands, at the nearfield station in comparison to the more uniform sandy bottom at the farfield station. Both taxa are tychoplanktonic and are thus closely associated with the substrate. Spatial differences were also observed between intake (P2) and discharge (P5) stations for those two taxa. No station differences occurred among fish eggs or larvae. Thus, with the exception of two macrozooplankton taxa, the farfield plankton station will provide an effective spatial control when examining post-operational plankton communities for possible impacts of Seabrook Station.

2.2.2 Pelagic Fish

2.2.2.1 Temporal

By studying the six dominant species collected in gill nets, which together make up 90% of the population (Figure 2.2-5), any significant effects of plant operations on pelagic fish populations in the study area

TABLE 2.2-2. SUMMARY OF NEARFIELD/FARFIELD (P2 VS. P7) SPATIAL DIFFERENCES IN PLANKTON COMMUNITIES AND SELECTED SPECIES. SEABROOK BASELINE REPORT, 1987.

COMMUNITY	DIFFERENCE BETWEEN P2 AND P7
Microzooplankton	
Community	None
Selected species	None
Bivalve Larvae	
Community	None
Selected species	None
Macrozooplankton	
Community	None
Selected species	Tychoplankters (*Pontogeneia inermis*, *Diastylis* sp.) P2>P7
Ichthyoplankton Egg	
Community	None
Selected species	None
Ichthyoplankton Larvae	
Community	None
Selected species	None

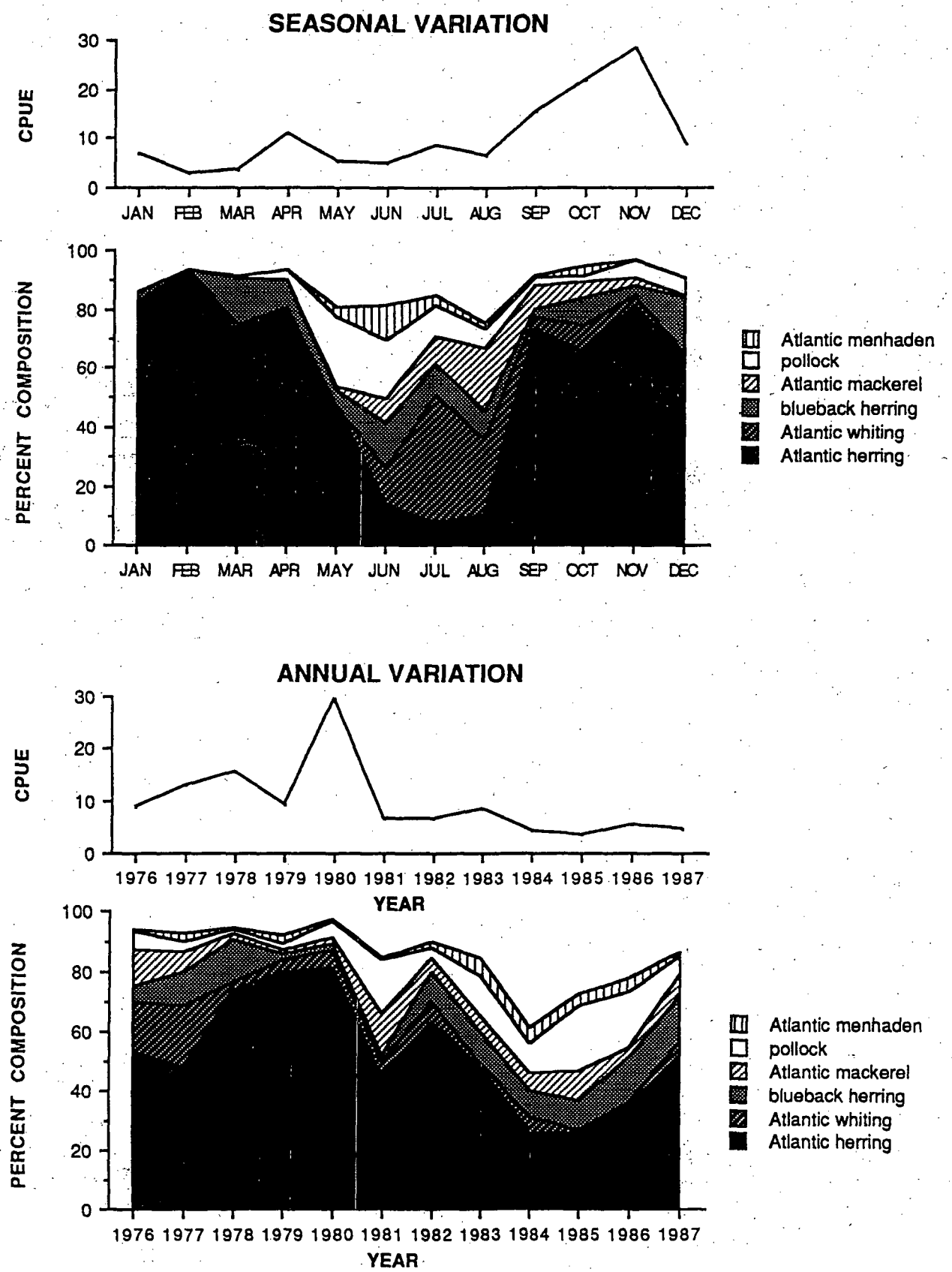


Figure 2.2-5. Seasonal and annual changes in composition and abundance of the pelagic fish community, based on catch per unit effort at gill net stations G1, G2, and G3 combined, 1976-1987. Seabrook Baseline Report, 1987.

should be visible. The distribution of pelagic fish varied seasonally; two main seasonal groups of species, summer and winter, were identified from numerical classification results (NAI 1982c). From September to April, Atlantic herring constituted from 64% to 93% of gill net catches, while in summer months (May-August), other migratory species such as Atlantic whiting (formerly known as silver hake) and Atlantic mackerel predominated (Figure 2.2-5). Pollock (predominantly age-two fish (NAI 1985b)) is a local resident which also made up a greater proportion of the pelagic nearshore community during summer.

In every year, Atlantic herring was the overall dominant pelagic fish in the area; however, it exhibited large annual abundance differences that were reflected in the annual percent composition (Figure 2.2-5). When catch per unit effort (CPUE) peaked in the study area in 1980, Atlantic herring composed 82% of the total catch. From 1984 through 1987, when total catches were at their lowest levels since the inception of the study, Atlantic herring constituted only 26-52% of the total catch (Figure 2.2-5). Atlantic herring are known to show high variability in catches spatially as well as seasonally and annually (Bigelow and Schroeder 1953). Most of the fish collected off Hampton-Seabrook were yearlings, particularly in the spring (NAI 1985b). Little is known about the habits of yearling herring, except that they seek out the warm waters of embayments in spring (Bigelow and Schroeder 1953).

Inconsistency in seasonal patterns adds to the overall variability in pelagic fish distribution. Each of the selected species had its peak abundance during a short but distinct period of time (Figures 2.2-5 and 2.2-6). However, these seasonal fluctuations were variable among years, compounding the high annual variability, as evidenced by high coefficients of variation (approximately 150-250% for the three selected species). This was particularly important for Atlantic herring, whose abundance was the single biggest determinant of overall catch levels (Figure 2.2-5). The number of individuals that will be impinged by the plant intake would therefore be expected to vary substantially among seasons and, to a lesser extent, among

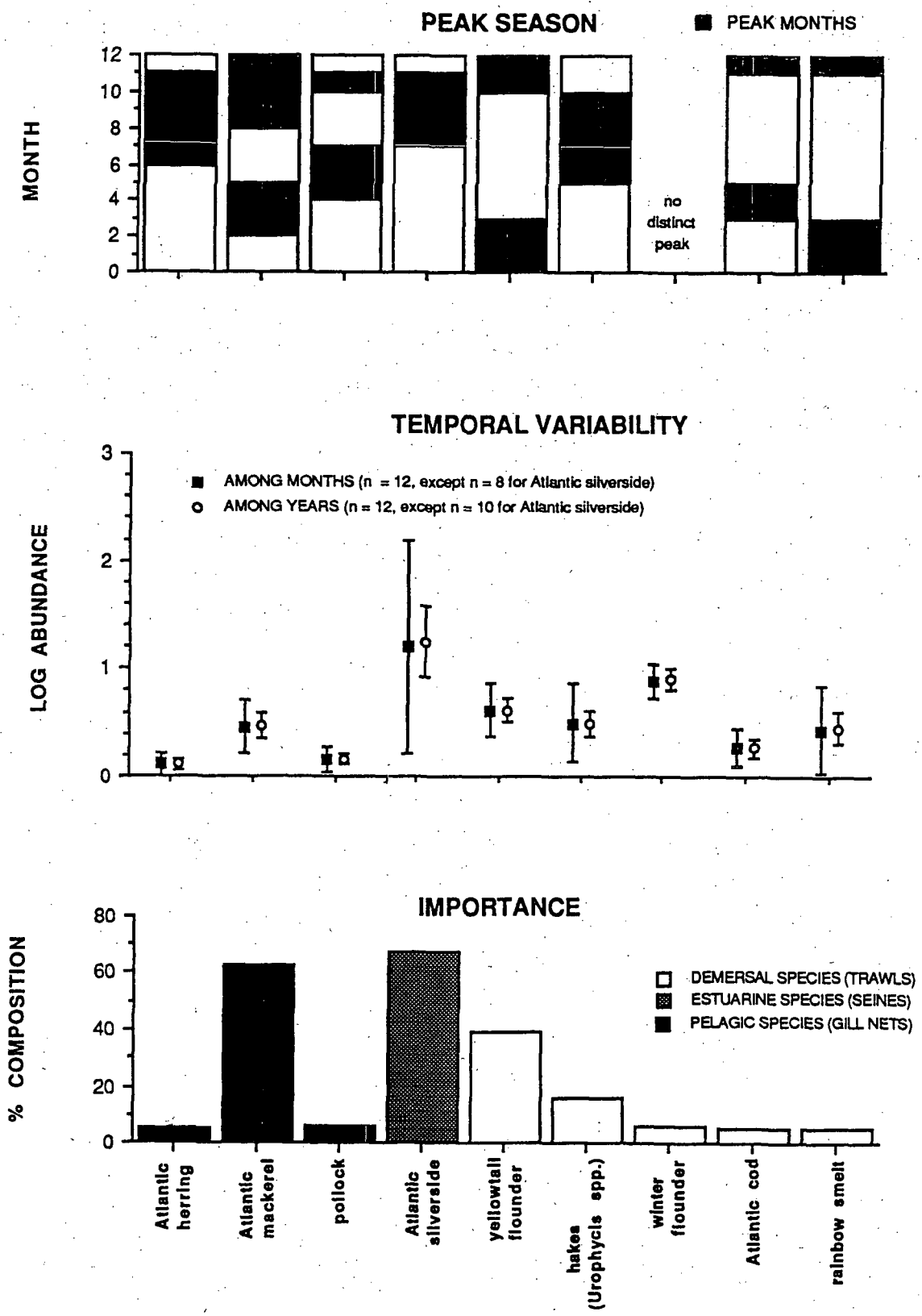


Figure 2.2-6. Percent composition, seasonal vs. annual variability (standard deviation) of log (x+1) abundance (catch per unit effort), and months of peak abundance for selected species of fish, 1976-1987. Seabrook Baseline Report, 1987.

years. Because of this high variability of pelagic fish abundances, predicting abundances with high statistical precision would be difficult.

Since the Circulating Water System began operation in 1981, fish entrained within the system and subsequently impinged upon the travelling screens have been collected by Seabrook Station personnel to determine operational impact. During a five-month period in 1985, 970 individuals, representing 32 species, were collected from the Circulating Water System. These were dominated by grubby (*Myoxocephalus aenaeus*, 21%), snailfishes (*Liparis* sp., 21%), and longhorn sculpin (*Myoxocephalus octodecemspinsus*, 11%). During a seven-month period of Station operation in 1986, 1212 individuals representing 35 species were collected. These were dominated by grubby (21%), windowpane (*Scophthalmus aquosus*, 12%), and longhorn sculpin (9%). Intermittent operation of the Circulating Water System during 1987 resulted in a total of 502 individuals representing 21 species becoming impinged upon the travelling screens. Of these, longhorn sculpin, winter flounder (*Pseudopleuronectes americanus*), and windowpane made up 22%, 14%, and 13%, respectively, of those impinged. Operation of the Circulating Water System, in terms of both the number of pumps and whether the system operated at all, varied throughout the three-year period. Data obtained during full system operation will be reviewed along with these data to determine operational impacts on demersal and pelagic fish species.

2.2.2.2 Spatial

Areal differences will be less important than temporal differences in evaluating potential plant effects on pelagic fishes. Because of their high degree of mobility, pelagic fish were not observed to be associated with any one habitat. As expected, relative abundances of the five most abundant taxa were very similar among stations, although catches were approximately 25% lower at the southern station G1 (NAI 1987b). Differences in the vertical distribution of these species may be important, however, because the intake structures are located at mid-depth, 5 m above bottom in 17 m of

water. Only one of the eight most abundant species, Atlantic menhaden, was more abundant at the intake (mid-water) depth during the months sampled than at surface or bottom (Table 2.2-3). However, this species was only slightly more abundant at mid-depth, and it only accounted for 2% of the pelagic fish in the study area. Two taxa, Atlantic whiting and pollock, were most abundant near the bottom, while Atlantic herring, mackerel and blueback herring were most abundant on the surface (Table 2.2-3). These species may be less vulnerable to intake effects. In 1986, for the first time since 1980, Atlantic mackerel had highest catches in mid-depth nets (NAI 1987b), suggesting that they could occasionally be more prone to intake effects. These results indicated that the most abundant and frequently-occurring pelagic species did not show a preference for mid-depth distribution, verifying earlier results and the rationale for mid-water placement of the intakes (NAI 1975a).

TABLE 2.2-3. CATCH PER UNIT EFFORT[a] BY DEPTH FOR THE DOMINANT GILL NET SPECIES OVER ALL STATIONS AND DATES WHEN SURFACE, MID-DEPTH AND BOTTOM NETS WERE SAMPLED, 1980 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

	CATCH PER UNIT EFFORT		
SPECIES	SURFACE	MID-DEPTH	BOTTOM
Atlantic herring	6.3	3.5	2.3
Atlantic whiting	0.2	0.6	0.8
Atlantic mackerel	0.9	0.4	0.4
Pollock	0.2	0.1	1.1
Alewife	<0.1	<0.1	<0.1
Blueback herring	1.1	0.4	0.3
Atlantic menhaden	0.6	0.7	0.2
Rainbow smelt	<0.1	<0.1	0.1

[a]number per one 24-hour set of one net (surface, mid-depth or bottom)

2.3 DISCHARGE AREA MONITORING

2.3.1 Plume Studies

2.3.1.1 Discharge Plume Zone

Because the discharge plume's largest exposure will be to surface and near-surface waters, the primary focus in this section will be on parameters or organisms in this part of the water column, namely phytoplankton, lobster larvae, and nearfield water quality parameters. Other organisms, such as pelagic fish and ichthyoplankton will, of course, have some exposure to the discharge plume, but it is assumed that entrainment and/or impingement are the more important issues for these organisms.

The water quality parameters measured showed distinct seasonal patterns that were important in driving biological cycles. Surface and bottom temperatures reached their lowest points from January through March, then steadily increased from April to August; temperatures were generally highest from August to October before beginning their fall decline (Figures 2.3-1 and 2.3-2). Surface temperatures had a more exaggerated seasonal cycle in comparison to bottom temperatures, with higher spring and summer temperatures. Temperatures in 1987 were average at the surface and below average at the bottom. Surface temperatures peaked in July in 1987; historically they have typically peaked in August (Figure 2.3-2).

Surface dissolved oxygen had a seasonal pattern inversely related to temperature, with peak values in late winter and lowest values in fall (Figures 2.3-1 and 2.3-2). In 1987, seasonal patterns were similar to previous years, though November values were somewhat higher than the average. Surface salinity values were highest in winter and lowest in spring, a result of increased runoff. In 1987, salinities were generally lower than the average, particularly in April (Figure 2.3-2) as a result of high precipitation during that month (see Section 3.3.1).

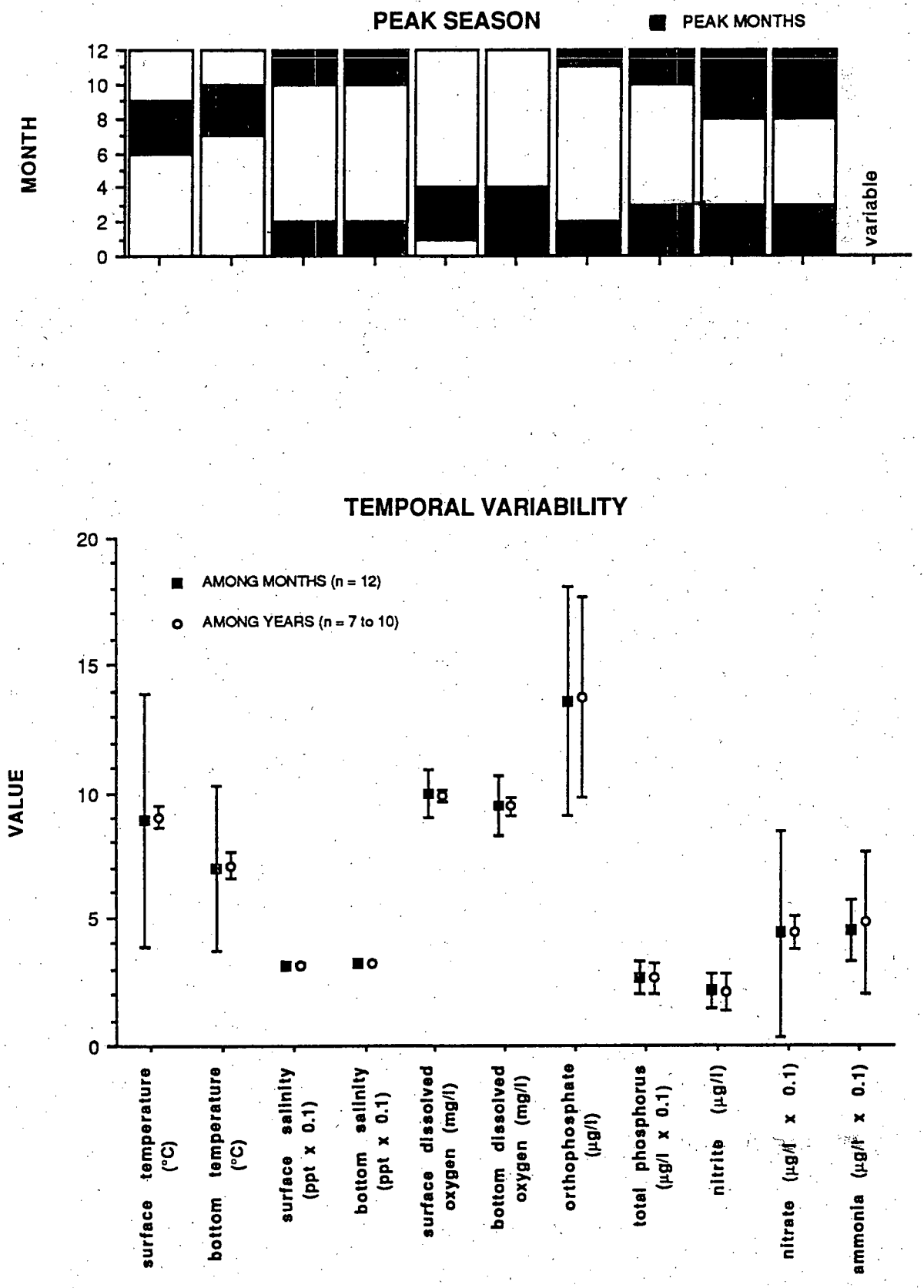


Figure 2.3-1. Seasonal vs. annual variability (standard deviation) and months of peak values for temperature (°C), salinity (ppt), dissolved oxygen (mg/l), and nutrients (µg/l). Seabrook Baseline Report, 1987. (For salinity, total phosphorus, nitrate, and ammonia values, multiply by 10.)

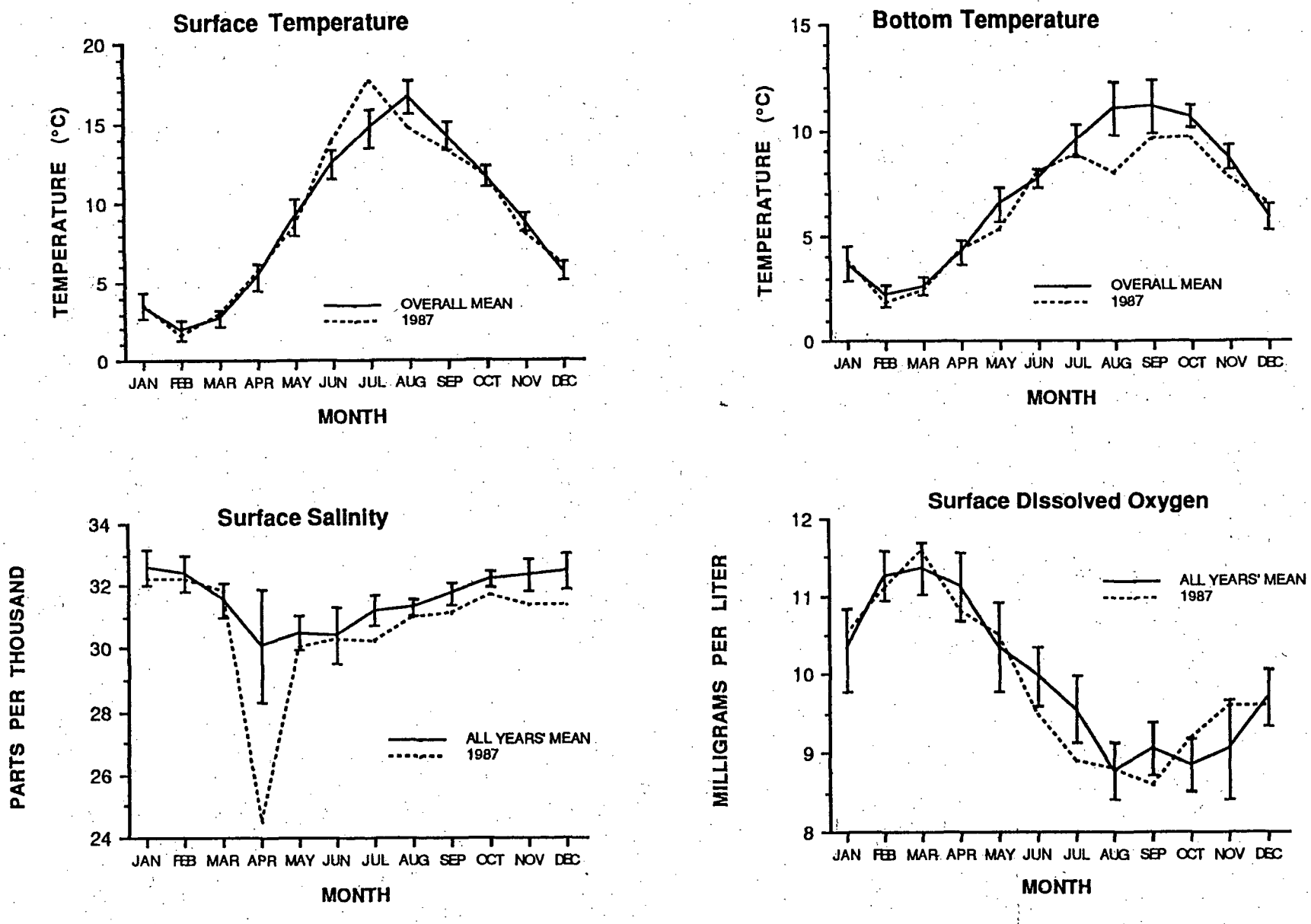


Figure 2.3-2. Monthly mean surface and bottom temperature (°C), surface salinity (ppt), and surface dissolved oxygen (mg/l) at station P2 for each year and over all years. (1978-1987, except temperature, 1978-1984 and August 1986-December 1987). Seabrook Baseline Report, 1987.

Nitrogen and phosphorus nutrients had more erratic cycles than temperature, salinity, and dissolved oxygen, but generally had lowest levels in summer and highest in fall and winter (Figure 2.3-1). Values in 1987 followed the patterns observed in previous years except for unusually high orthophosphate levels in June and July, high levels of total phosphorus in September and October, and low levels (below detection limit) of nitrite in March through June.

The predictability of seasonal patterns and low year-to-year variability of most of the water quality parameters (Figure 2.3-1) enhanced their suitability for impact assessment. Furthermore, they will provide information which can assist in separating natural biological variability from impact.

The phytoplankton community has shown the most seasonal and annual variability of any species assemblage. Seasonal assemblages have changed rapidly and frequently, diminishing the suitability of the community for short-term impact assessment (NAI 1985b). Some elements of the phytoplankton community were relatively stable and predictable. For example, total phytoplankton abundance was generally similar among years, with a predictable seasonal cycle that was closely tracked by biomass (chlorophyll *a*). Increases in irradiance typically initiated the spring bloom, and although the species composition varied from year-to-year, centric diatoms typically were among the first to appear. Densities usually diminished when nitrogen-nutrients declined and the thermocline developed. Thermal stratification prevents the replenishment of nutrients from deeper waters thereby limiting growth of spring dominants. 1986 was unusual in that there was an uncharacteristic July peak caused by bluegreens and *Leptocylindricus*. Phytoplankton assemblages from 1978 to 1980 were similar, based on the predominance of *Skeletonema costatum, Rhizosolenia delicatula,* and *Phaeocystis pouchetti*, while from 1981 through 1984, only *Skeletonema costatum* and *Chaetoceros* spp. were consistent dominants. In the latter half of 1986, *Skeletonema* continued to predominate, along with the above-mentioned bluegreens. No phytoplankton collections were made in 1987; detailed results from previous studies are presented in NAI 1985b and 1987b.

No spatial differences were observed in the phytoplankton community either between intake (P2) and farfield (P7) areas or between intake (P2) and discharge (P5) areas (NAI 1985b, 1987b).

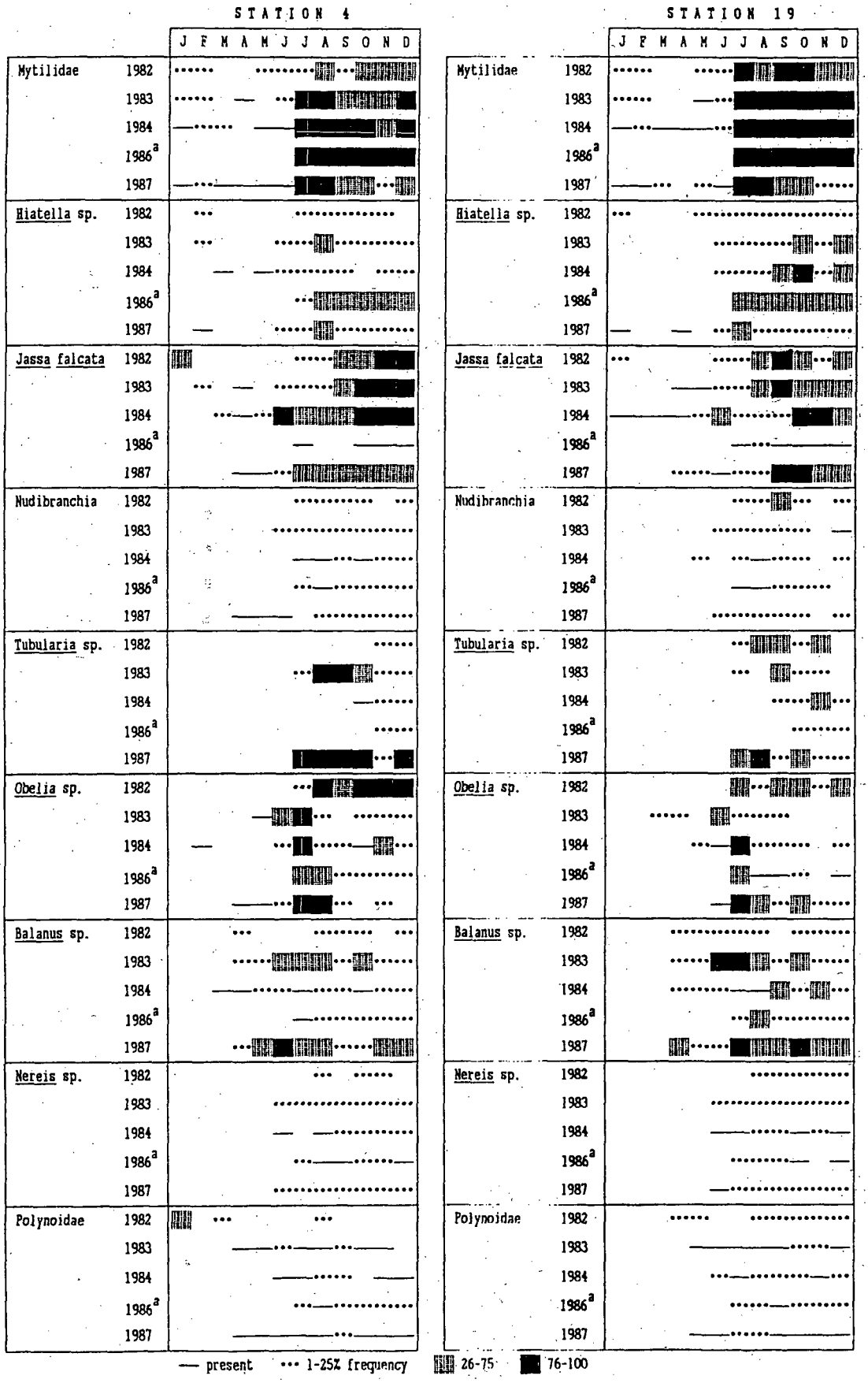
Skeletonema costatum was chosen as the selected phytoplankton species because of its consistent predominance. Generally, there was a major peak in late summer or fall (Figure 2.2-2) and in some years there was also a smaller peak in the spring (NAI 1981f, 1982a) or winter (NAI 1980c, 1983a). Despite highly-variable peak abundances, no significant differences were detected among years (NAI 1987b). Furthermore, intake and discharge densities were statistically similar (NAI 1987b). Simultaneous nearfield/farfield comparisons of total phytoplankton abundances and *Skeletonema costatum* may be the most consistent parameters for monitoring primary producers in the discharge plume area.

Paralytic shellfish poisoning (PSP) levels in *Mytilus edulis*, as measured by the State of New Hampshire and Massachusetts Department of Public Health, has exceeded maximum levels allowable for human consumption every year from 1972 through 1986, usually for a period of 1-7 weeks (NAI 1987b). In 1987, however, PSP toxicity levels in Hampton Harbor mussels were below the detection limit throughout the April-December monitoring season (NAI 1988). In 1972, toxic levels were present in Hampton Harbor for a period of 16 weeks. Although Hampton Harbor flats have been closed each summer since 1976 to soft-shell clam diggers for conservation reasons, high PSP levels caused the closure of the harbor to all bivalve shellfish digging for several weeks each summer as well. Peak values in most years occurred in May or June, coinciding in Hampton Harbor and the farfield area, Essex, MA. The maximum value recorded since 1972 was 8398 μg PSP per 100 g meat.

Of the shellfish in the area with planktonic lifestages (*Cancer* crabs, lobster, and soft-shell clam larvae), only lobster larvae Stages I-IV have strictly a surface orientation, typically found in the top few centimeters of water. The seasonality and variability of *Cancer* sp. larvae and *Mya arenaria* larvae were discussed in the intake area monitoring section. Successful recruitment of lobster larvae is the biggest factor in the deter-

mining the level of adult lobster catches (Harding *et al.* 1983). Lobster larvae collected off Hampton-Seabrook actually originate from warm waters in the Gulf of Maine and Georges Bank (Harding *et al.* 1983) and are driven into the area by a combination of winds and nontidal currents (Grabe *et al.* 1983). Temperatures in the study area are not warm enough to allow planktonic development (Harding *et al.* 1983), reinforcing the fact that this area is probably not important in the production of lobster larvae. Lobster larvae, which were rare throughout the study area, have typically been recorded from the first week in June to the second week in October (Figure 2.2-3). In 1987, lobster larvae first appeared in early June, somewhat earlier than previous years. Maximum densities have occurred over an eight-week period between late June and late August, during the period of maximum surface temperatures. Densities of all life stages were very low, averaging <2 per 1000 square meters (Figure 2.2-3). In 1987 densities were somewhat low in comparison to previous years. Stage I and IV larvae have predominated, and stage II and III were extremely rare. Densities at the farfield station (P7) were consistently higher than at the nearfield station from 1982-1987. Discharge area (P5) densities in the last half of 1986 were intermediate between the nearfield and farfield areas (NAI 1987b).

Subsurface (-3 m) "fouling" panels placed in the projected inner and outer discharge plume area and at farfield areas, show the types, timing and abundances of shallow subtidal organisms which can settle on bare substrates. Short-term panels, exposed for one month, estimate recruitment levels while monthly sequential panels, exposed for 1-12 months (Figure 2.3-3), show the development of the fouling community. Biomass, density, and number of species showed patterns that were highly consistent from year-to-year and between nearfield and farfield areas, reflecting the increase in settling activity in summer and fall. The individual macroinvertebrate taxa also had a predictable seasonal pattern. Only a few showed heavy recruitment before June (*Balanus* sp. in April and *Hiatella* sp. in early summer). In 1987, the overall patterns were similar to previous years, although biomass on September short-term panels was much higher than in most past years. Surface panels should prove to be an effective monitoring tool for benthic settlement activity, particularly when compared to farfield stations.



[a]No fouling panels placed or collected from January 1985 through June 1986.

Figure 2.3-3. Annual settlement periods, abundance and survival of major taxa based on examination of sequentially-exposed panels at nearfield Stations 4 and 19. Seabrook Baseline Report, 1987.

2.3.1.2 Intertidal/Shallow Subtidal Zone

An area outside of the immediate surface plume area that is being monitored for potential plume effects is Sunk Rocks. Intertidal (MSL and MLW) and shallow subtidal (-4.6 m) stations which are representative of the area were monitored on Outer Sunk Rocks (nearfield) and at Rye Ledge (farfield). Benthic algae and macroinvertebrate collections taken annually (August) at Stations 1MLW and 5MLW (intertidal) and Stations 17 and 35 (shallow subtidal) exhibited species assemblages that were consistent and highly similar from year to year at each station (Figure 2.3-4). Each annual collection at a station was grouped (by discriminant analysis) with the majority of those collected in other years at the same station (Sections 3.3.2 and 3.3.3). In 1987, macrofaunal and macroalgal collections were similar to those in previous years (the same species assemblages that were present at each station in previous years were found in 1987). The assemblages identified by this analysis were strongly related to the depths of the stations, particularly for the algae, which exhibited a noticeable difference among depths in which species dominated the algal community (Figure 2.3-5).

Colonial macrofaunal assemblages were somewhat less predictable from year-to-year (NAI 1985b). Intertidal colonial assemblages were distinct in their species composition, but those from shallow subtidal areas in most years were similar to those from mid-depth areas. In several years, assemblages of colonial macrofaunal species were unique and unrelated to any other assemblages.

Fourteen benthic species were selected for more intensive monitoring because of their trophic position, abundance and commercial or recreational value (Table 2.3-1). Parameters monitored included abundance (all taxa), size (fauna only), and reproduction (epibenthic crustaceans). All life stages of the commercially-important species were studied. Some of these taxa were monitored in the Sunk Rocks area while others were examined as part of the discharge or estuarine studies.

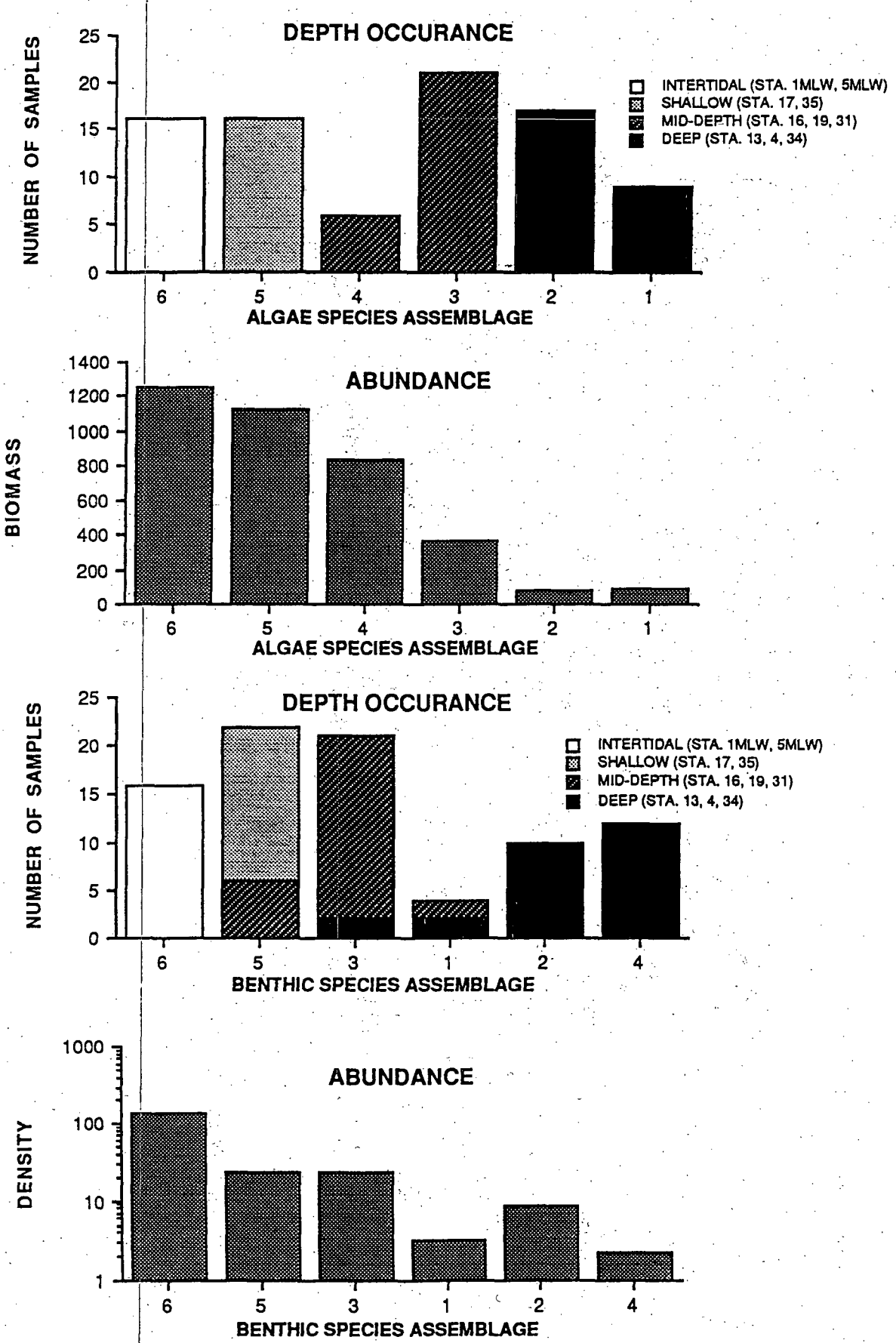


Figure 2.3-4. Depth and abundance characterizations of species assemblages identified by discriminant analysis of August collections of algae (g/m^2 of dominant taxa) and marine benthos (thousands per m^2 of dominant taxa) during 1978-1987. Seabrook Baseline Report, 1987.

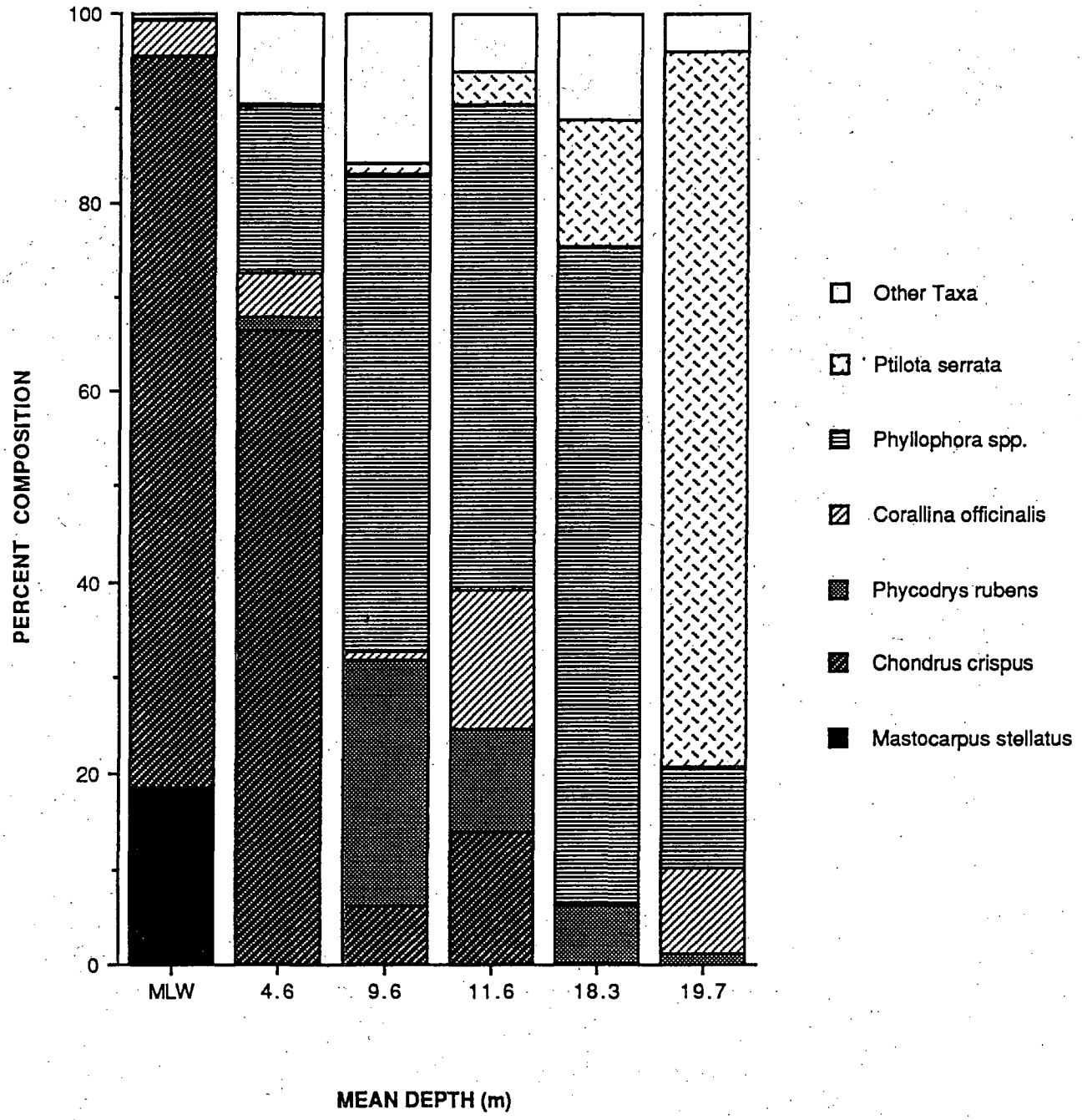


Figure 2.3-5. Percent composition (based on biomass) by depth strata for dominant macroalgae species at marine benthic stations in August, 1978-1987. Seabrook Baseline Report, 1987.

TABLE 2.3-1. SELECTED BENTHIC SPECIES AND RATIONALE FOR SELECTION. SEABROOK BASELINE REPORT, 1987.

SPECIES (COMMON NAME)	LIFESTAGE[a]	RATIONALE
Macroalgae		
Laminaria saccharina (kelp)	A	Habitat (canopy)-forming primary producer
Chondrus crispus (Irish moss)	A	Habitat (understory)-forming primary producer; sporelings may be heat sensitive
Benthic Invertebrates		
Ampithoe rubricata (amphipod)	J,A	Intertidal/shallow subtidal community dominant
Jassa falcata (amphipod)	J,A	Intertidal/shallow subtidal community dominant
Pontogeneia inermis (amphipod)	J,A	Subtidal, ubiquitous community dominant
Nucella lapillus (dog welk)	J,A	A major intertidal predator of *Mytilus edulis*
Asteriidae (starfish)	J	Predator, community dominant
Strongylocentrotus droebrachiensis (green sea urchin)	J,A	Potentially destructive herbivore
Dominant Bivalves		
Mytilus edulis (blue mussel)	L,S,A	Habitat former; spat may be heat sensitive
Mya arenaria (soft-shell clam)	L,S,A	Recreational estuarine species; larvae entrainable
Epibenthic Crustaceans		
Carcinus maenas (green crab)	L,A	A major predator of soft-shell clam spat
Cancer borealis (Jonah crab)	L,J,A	Important predator and prey
Cancer irroratus (rock crab)	L,J,A	Important predator and prey
Homarus americanus (American lobster)	L,J,A	Commercial species; larvae plume entrainable

[a]A = adult; J = Juvenile; L = Larvae; S = Spat

Algal selected species had highly consistent biomass or abundance levels among years, with differences between nearfield and farfield stations observed in the shallow subtidal but not the intertidal. The algal dominant *Chondrus crispus* had low annual variability, with no significant differences in biomass among years from 1982-1987 in the intertidal zone and 1978-1987 in the shallow subtidal zone (Table 2.3-2). Intertidal biomass values of *Chondrus* were significantly different between nearfield and farfield areas in both the intertidal zone and the shallow subtidal zone (Figure 2.3-6, Table 2.3-2). Densities of the dominant kelp, *Laminaria saccharina* showed no differences among years or between nearfield/farfield stations in the shallow subtidal (Figure 2.3-6, Table 2.3-2).

Spatial heterogeneity and variations in recruitment success caused a high degree of variability in abundance of macrofaunal taxa (Figure 2.3-6). Significant differences in annual abundance were found among years for most of the taxa, and nearfield and farfield stations were almost always significantly different (Table 2.3-2). For these species, impact assessment will be most effective when the preoperational period is compared to the operational period within a given station. Few differences in the historically-observed trends were noted in 1987. The amphipod *Ampithoe rubricata*, once one of the intertidal dominants, continued its steady decline in abundance first noticed in 1982; in 1987, no *A. rubricata* were collected at either intertidal station (1MLW or 5MLW). Abundances of other taxa were within the range of previous years.

Length measurements of macroinvertebrates were a more stable and predictable parameter. In most cases, annual mean lengths were statistically similar among years and between stations. Specimens of the gastropod *Nucella lapillus* were unusually large compared to previous years at the nearfield station (1MLW), but they were smaller than usual at the farfield station (5MLW). Sea stars (Asteriidae) were smaller in 1987 than in any of the previous five years when measurements were recorded, indicating successful recruitment of young-of-the-year.

TABLE 2.3-2. SUMMARY OF SIMILARITIES[a] IN ABUNDANCE, BIOMASS, FREQUENCY, OR LENGTH AMONG YEARS AND BETWEEN STATIONS FOR SELECTED MACROFAUNAL AND MACROALGAL SPECIES AT INTERTIDAL AND SHALLOW SUBTIDAL DEPTHS. SEABROOK BASELINE REPORT, 1987.

	AMONG YEARS	
NEARFIELD VS. FARFIELD	SIMILAR	DISSIMILAR
Similar	*Nucella lapillus* (L)	*Ampithoe rubricata* (L)
	Jassa falcata (shallow subtidal, panels) (L)	Mytilidae (shallow subtidal panels) (A)
	Mytilidae (MLW, shallow tidal)(L)	Mytilidae (panels)(L)
	Laminaria saccharina (A)	*Jassa falcata* (panels) (A)
Dissimilar	Asteriidae (L)	*Jassa falcata* (shallow subtidal) (A)
	Chondrus crispus (B) (MLW, shallow subtidal)	*Ampithoe rubricata* (A)
		Nucella lapillus (A)
		Asteriidae (A)
		Mytilidae (MLW) (A)

[a]Results from ANOVAs, paired t-tests, or Wilcoxon's summed ranks tests
(A) = abundance
(L) = length
(B) = biomass

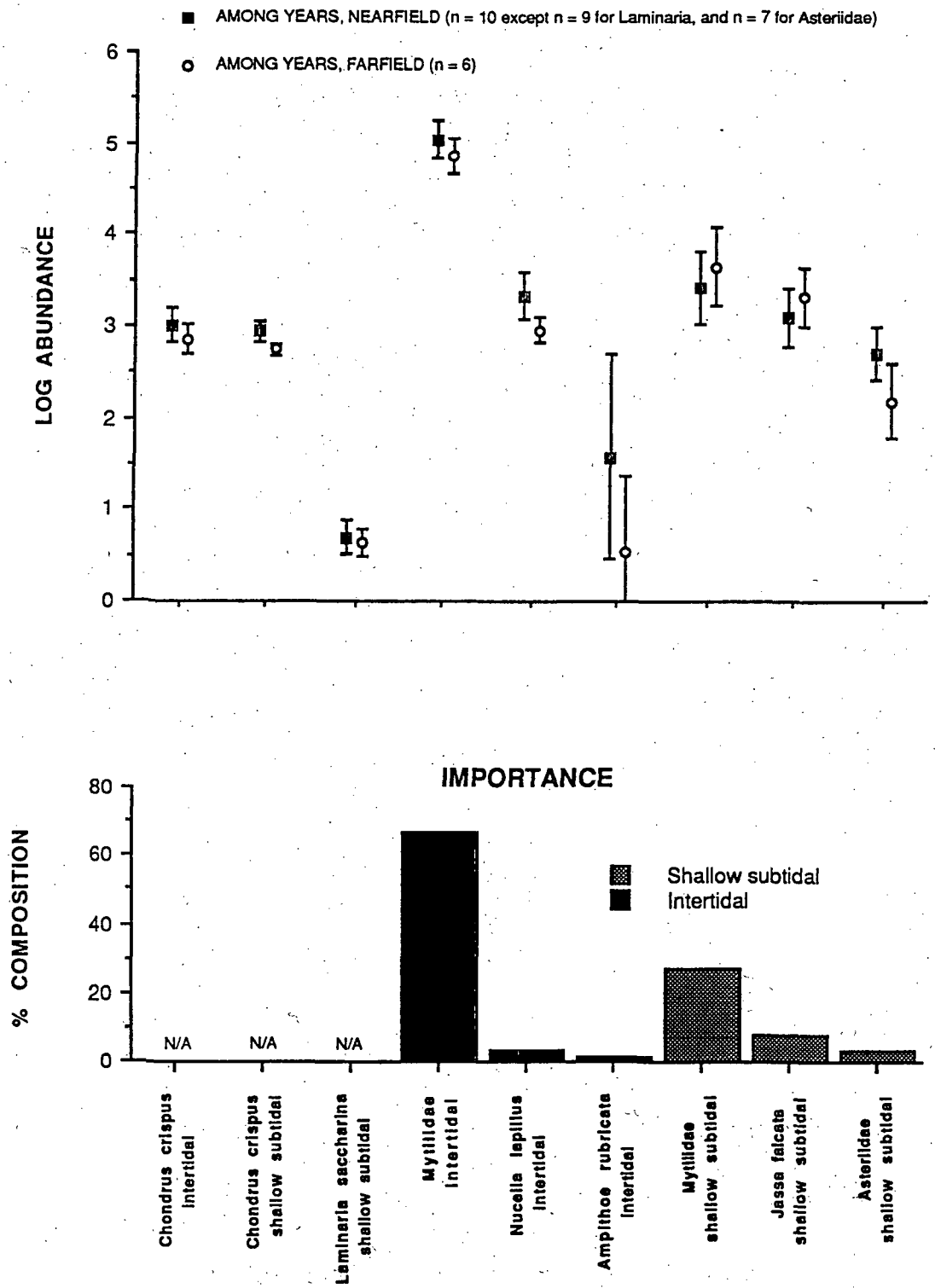


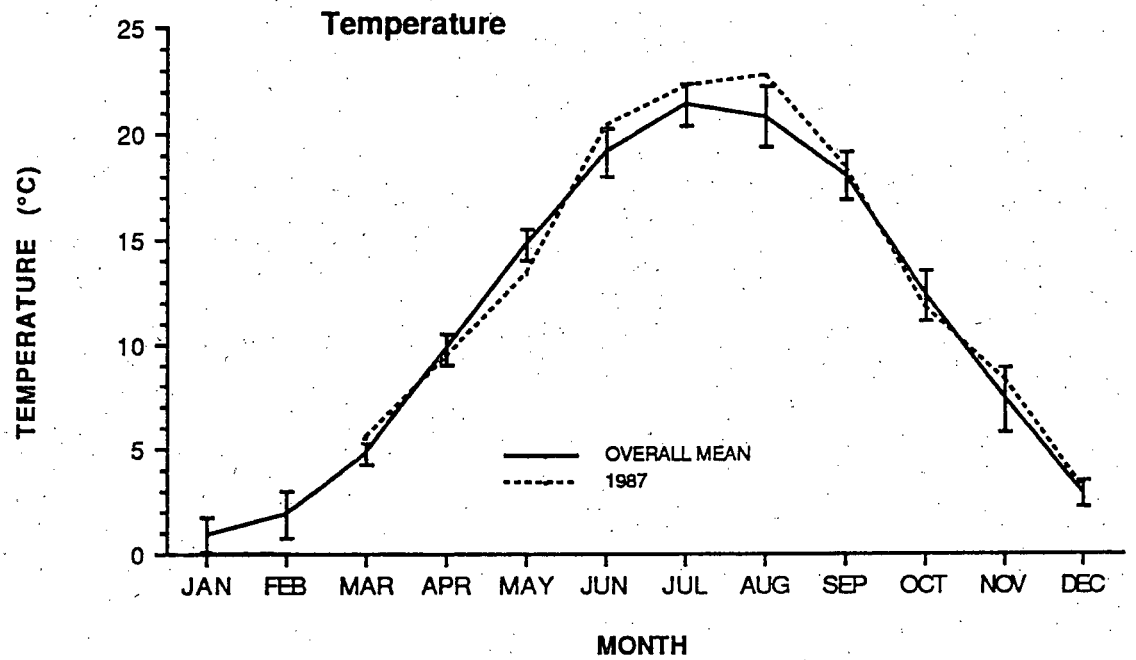
Figure 2.3-6. Percent composition and nearfield (Sta. 1MLW & 17) vs. farfield (Sta. 5MLW & 35) annual variability (standard deviation) of log (x+1) abundance for selected intertidal and shallow subtidal species of algae and benthos. Seabrook Baseline Report, 1987. Abundance is No./m^2 except for *Chondrus*, which is g/m^2.

2.3.1.3 Estuarine Zone

Environmental studies in Hampton Harbor estuary include monitoring physical parameters (temperature and salinity), fish populations, benthic macrofauna, and juvenile and adult soft-shell clams (*Mya arenaria*). One of the main environmental issues in the Hampton-Seabrook estuary related to plant operation is whether the offshore intake and discharge will impact the adult clam population in Hampton Harbor. The probability of impact from the most-likely source, entrainment of *Mya* larvae, is small (NAI 1977e); this is discussed in Section 2.2.2. Natural variability of juvenile and adult *Mya arenaria* will be discussed in this section.

Temperature and salinity, monitored in Hampton Harbor and Brown's River since 1978, provide valuable information for interpreting biological phenomena. Maximum temperatures usually occurred in August, with minima in January or February (Figure 2.3-7); 1987 was no exception to this pattern. Salinity levels had a less distinct seasonal cycle than temperatures, but were usually lowest in spring, coincident with increased runoff. This was particularly true in April of 1987, when heavy rainfall, in addition to melting snow, caused severe flooding in New Hampshire and Maine. In Brown's River, average annual salinity values remained high for a three-year period from 1980-1982, coinciding with low precipitation and highest discharge volumes from the settling basin. This was the period when the maximum dewatering of the cooling tunnels took place, and the salinity of the settling pond's discharge water was relatively high. Salinity levels dropped, with fewer fluctuations, from 1983-1987, when discharge volumes decreased and precipitation returned to pre-1980 levels. Hampton Harbor salinities, which were not as susceptible to these influences because of the influx of a large volume of offshore waters, showed higher salinity and lower year-to-year variability than Brown's River.

The benthic macrofaunal community in Mill Creek (Station 9) and Brown's River (Station 3) was typical of New England estuaries. The species composition was also consistent with that from other estuaries on the East Coast (McCall 1977; Watling 1975; Santos and Simon 1980; Whitlatch 1977).



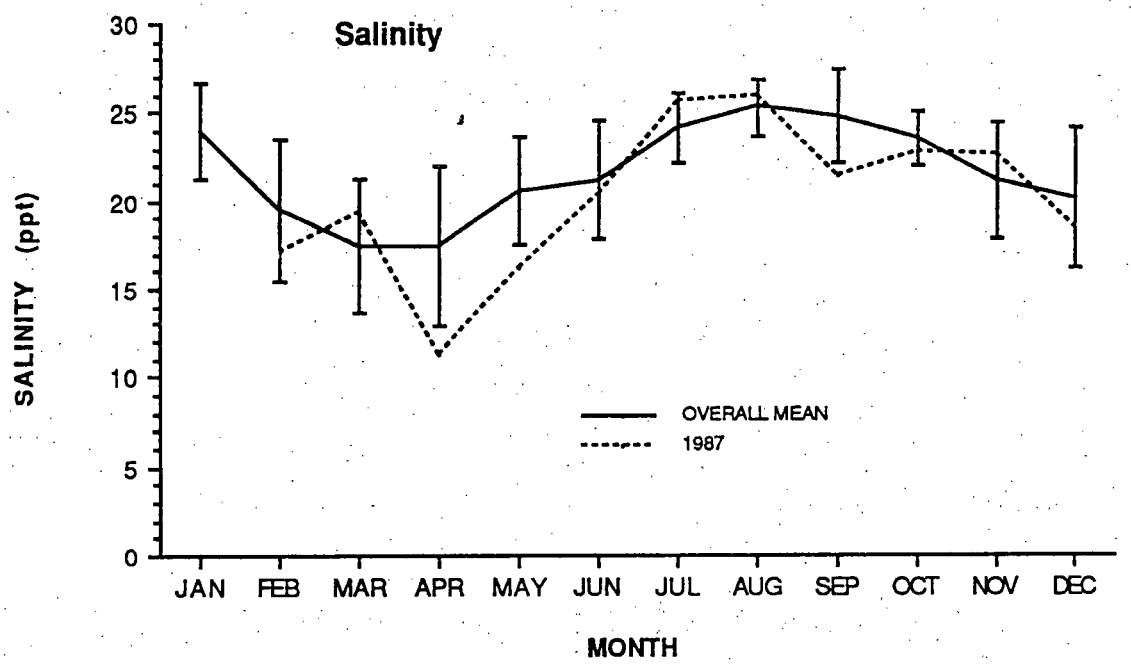
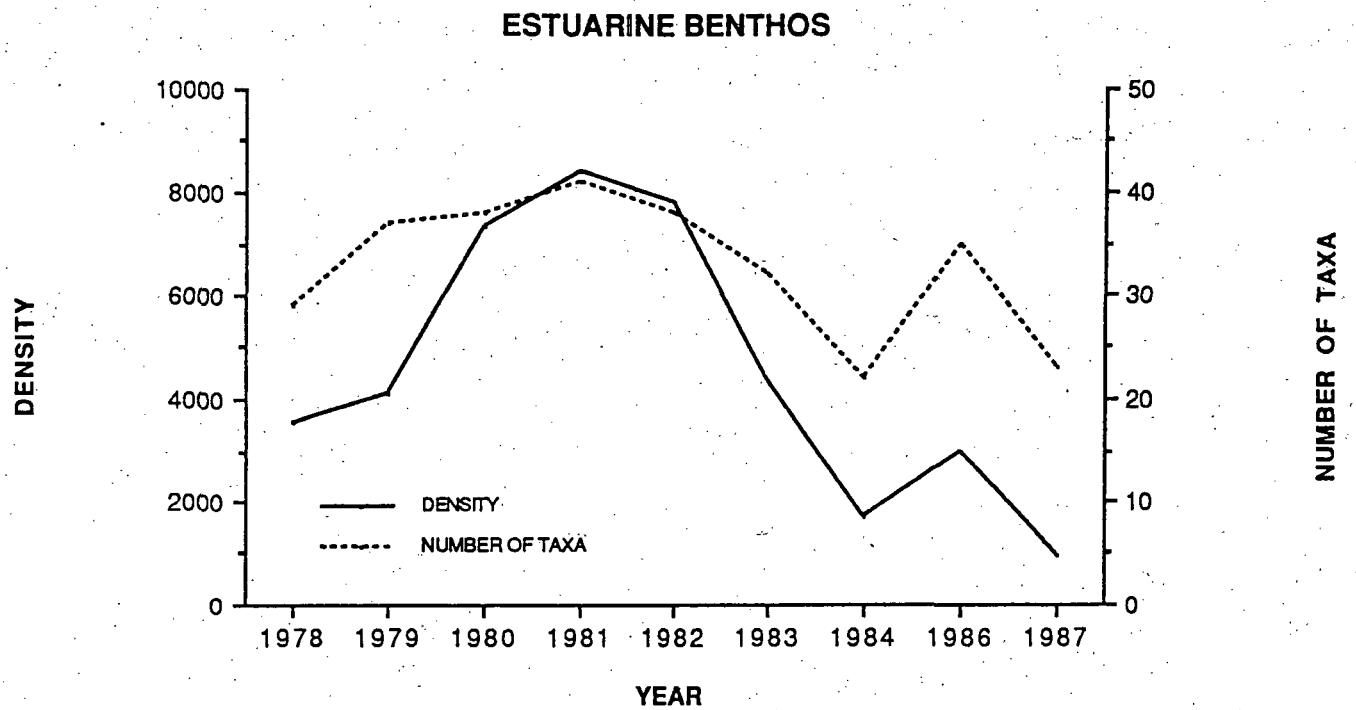


Figure 2.3-7. Mean monthly seawater surface temperature and salinity with 95% confidence limits taken at low tide in Brown's River (Sta. 3) in 1987 and over the entire study period (May 1979 - December 1987). Seabrook Baseline Report, 1987.

Surface and subsurface deposit feeders predominated, including opportunistic polychaetes such as *Streblospio benedicti* and *Capitella capitata*, with suspension feeders and omnivores forming an important component (NAI 1985b). The most numerous species inhabiting estuaries are those which are resistant and resilient to the natural changes in the physical environment, such as fluctuating temperature, salinity, dissolved oxygen, and sediment grain size.

In Mill Creek and Brown's River, the biological parameters measured were highly variable seasonally and annually which is typical of this physically heterogeneous habitat; total density, numbers of taxa, and all of the dominant species tested showed significant differences among years and between stations. Some of this variability was related to changes in salinity. The combination of lower precipitation and higher levels of discharge from the settling basin from 1980 to 1982 apparently caused higher and less-variable salinities in Brown's River. At the same time, total abundance and number of taxa increased (Figure 2.3-8), along with densities of *Streblospio benedicti* and *Capitella capitata* at that site. Higher salinity levels probably enhanced the habitat for more stenohaline species, and at the same time, opportunistic polychaetes invaded the changing habitat. Following an increase in precipitation and decrease in discharge volumes, these parameters dropped to their lowest point in 1984; however, they had returned to pre-1980 levels by 1987.

Important estuarine fish include both diadromous species as well as residents. Three anadromous fish pass into the estuary: rainbow smelt in winter and alewives and blueback herring ("river herring") in spring, travelling to upper reaches of local rivers to spawn. Rainbow smelt were caught at the entrance to the estuary (Station T2) from December through March or April (see adult fish section 3.2.2). Abundances were significantly different among years, causing moderate baseline variability, making the detection of minor population changes unlikely. In spring and summer, sparse and erratic numbers of young-of-the-year and yearling smelt have been caught in beach seines (Figure 2.3-9), but no one age group (based on length-frequency) has been consistently dominant (NAI 1985b). Rainbow smelt have



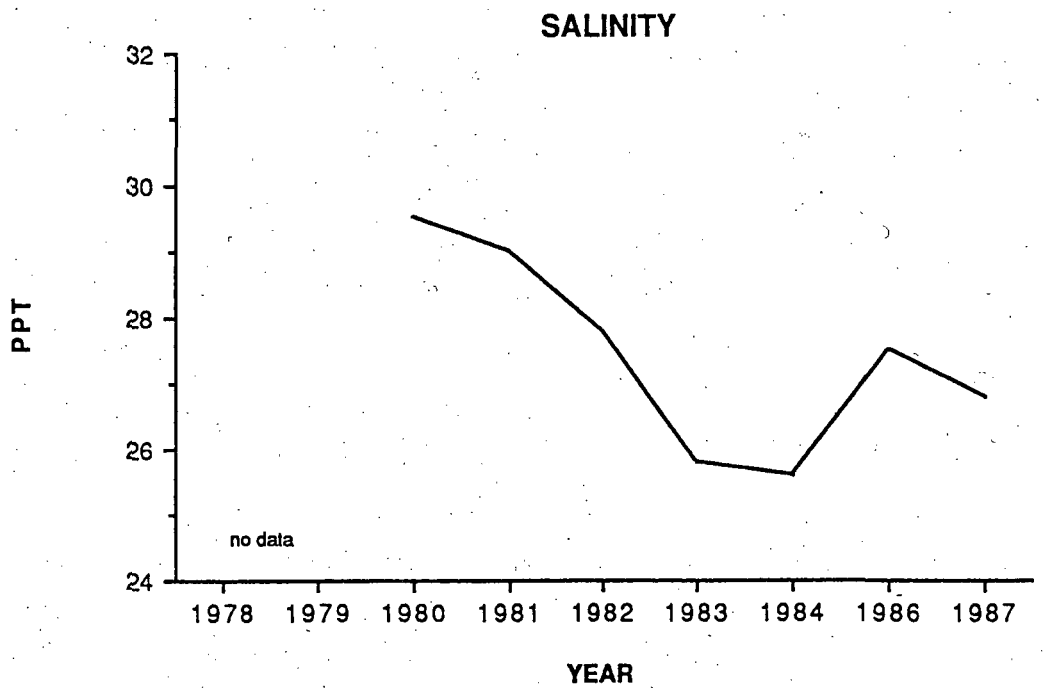


Figure 2.3-8. Annual geometric mean density (No./m^2) and mean number of taxa per station of estuarine benthos, and annual mean salinity, at Browns River and Hampton Harbor. Seabrook Baseline Report, 1987. No data were collected in 1985.

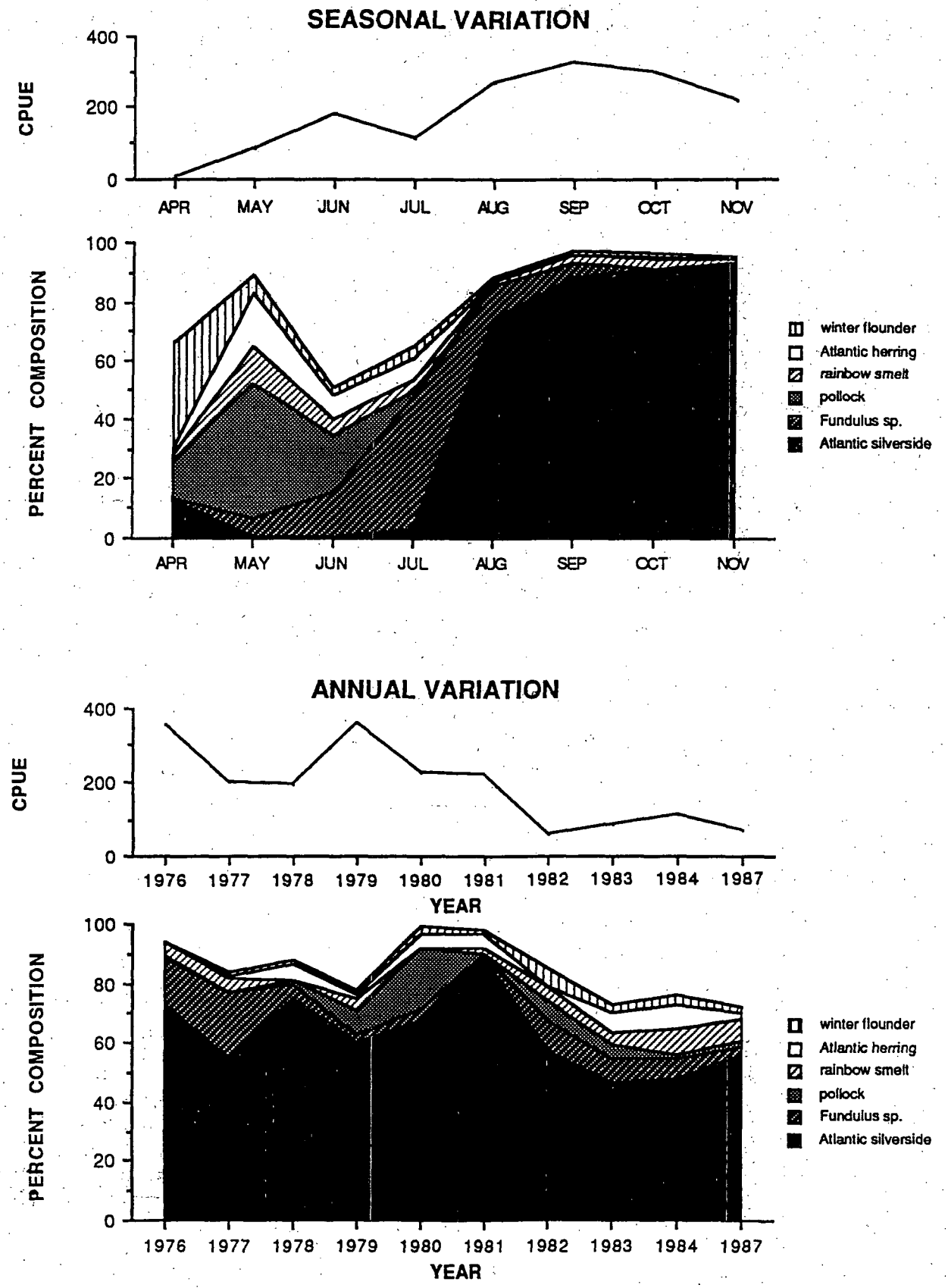


Figure 2.3-9. Seasonal and annual changes in composition and abundance of the estuarine fish community, based on catch per unit effort at beach seine stations S1, S2 and S3 combined 1976-1984 and 1987. Seabrook Baseline Report, 1987.

never comprised a substantial portion of annual seine catches, and over all years (1976-1984 and 1987) averaged only 3% of the total catch. Data were not collected in 1985 and part of 1986. Catches in 1987 (April through November) were lower than average.

River herring, which includes alewife and blueback herring, were monitored both in the Taylor River and in Hampton Harbor from 1980 to 1984. The size and length of the river herring "run" was shown to be variable, with the number of days that fish were observed passing the Taylor River ladder ranging from 31 (1982) to 47 (1981) (NAI 1985b). New Hampshire Fish and Game has estimated run totals to range from 94,000 (1981) to 205,000 (1980) during the 1978-84 period (NAI 1985b). Their staff removed fish from the ladder during peak periods to stock other water bodies. Changes in the run size were affected by year class strength. Periodicity of the run was affected by water temperature and level which were in turn influenced by rainfall and the resulting runoff. Alewives and bluebacks were the third most abundant species caught in beach seines in the Browns River (S2) and Hampton River (S1), respectively (Figure 2.3-10); however, this was caused by large but infrequent catches at these stations. In the estuary as a whole, these species constituted only about 6% of the total catch (1978-1987).

Another species which uses the estuary is winter flounder. This species undergoes onshore/offshore migration, depending on the time of year (Bigelow and Schroeder 1953). Juveniles (age one and two, based on length-frequency analysis) were the main constituent in the estuary, primarily collected during the spring and summer (NAI 1985b). Recruitment was evident by the occurrence of young-of-the-year size classes. Total catches were somewhat variable, and catches in 1987 were much lower than average in all months but June and August (see Section 3.2.2).

The dominant resident species in the estuary was Atlantic silverside, which typically comprised 67% of seine catches during the baseline period (1976-1987) and 90% within their abundant period, August to November (Figure 2.3-9). The population was composed primarily of yearling fish but the occurrence of young-of-the-year size classes in spring indicated recruit-

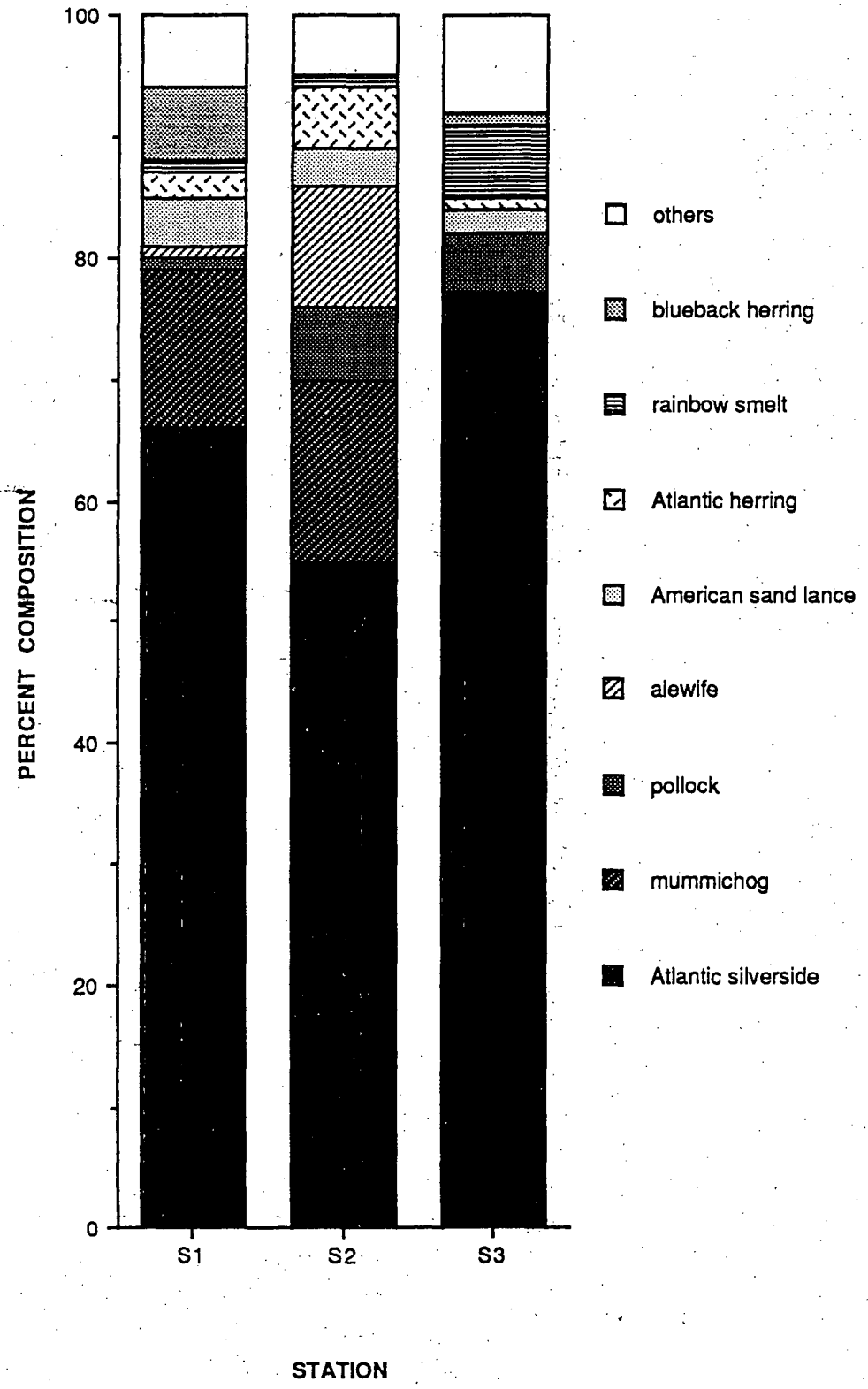
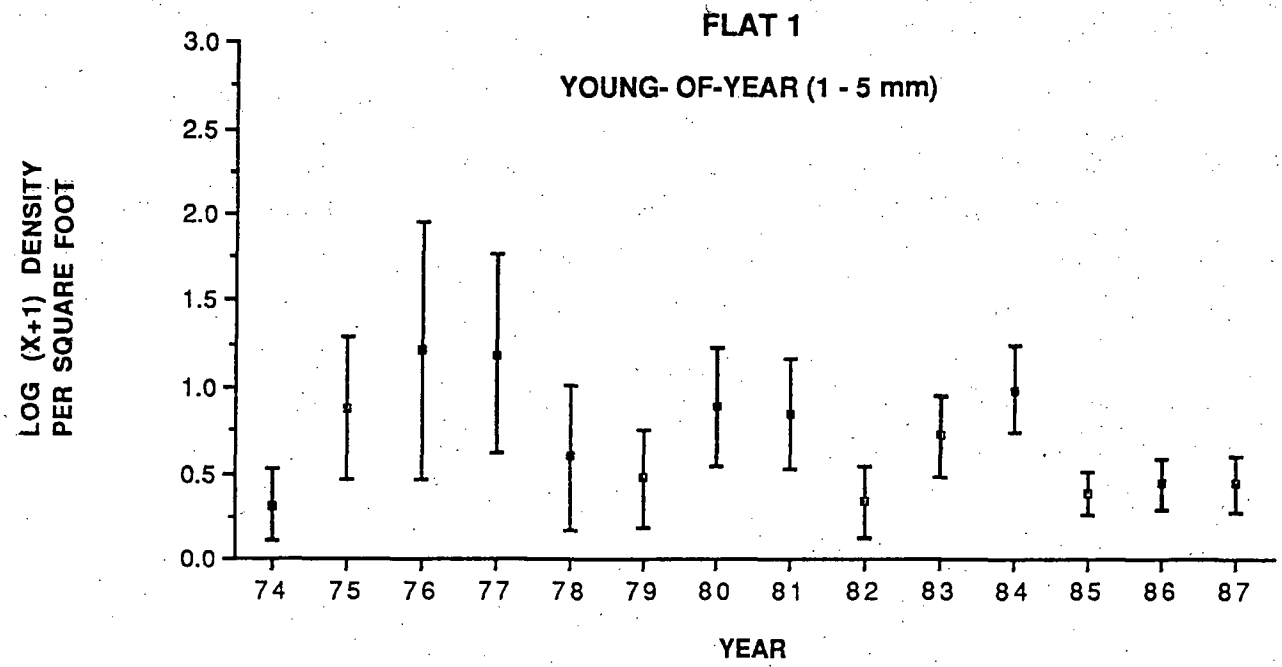


Figure 2.3-10. Percent composition by station for abundant species of fish collected in beach seines, all years combined, 1976-1984 and 1987. Seabrook Baseline Report, 1987.

ment (NAI 1985b). Variability in total seine catch has been the result of high variability in catches of Atlantic silverside; catches were high from 1976-1981 (200-360 fish/haul) and much lower from 1982 - 1987 (60-100 fish/haul) (Figure 2.3-9).

Since the Hampton-Seabrook estuary contains the majority of New Hampshire's stock of the recreationally-important species, *Mya arenaria*, an extensive sampling program (over 13 years) was undertaken in order to characterize the natural variability in densities of all lifestages. Of the potential impact types, larval stages will be most susceptible to intake effects and therefore are discussed in that section (Section 2.2.1). Spat settlement densities appear to bear no relationship to the abundance or periodicity of *Mya* larvae in the nearshore waters (NAI 1982c). It would appear that *Mya* veliger behavior (i.e. their "readiness" or competency to settle) combined with the timing of favorable currents may be more important to settlement success than sheer numbers of larvae in the water column. Such conditions apparently existed in 1976, 1977, 1980, 1981 and 1984 when young-of-the-year spat densities were highest at flat 1 (Figure 2.3-11) and other flats. The 1976 year class in particular provided an important and rejuvenating recruitment to the local population as shown by the high densities of 13-25 mm clams in 1977 and 1978 (Figure 2.3-11). Continued low densities of spat from 1983 through 1987 at flat 1 (Figure 2.3-11) and other flats suggest that the standing crop of adults will remain low for at least another three to four years.

Once settled, survival of young-of-the year *Mya* depends on both the level of predation from its two main predators, the green crab and human clam diggers, and the absence of diseases such as neoplasia. Despite relatively heavy densities of young-of-the year in 1980, 1981, and 1984 on Flat 1, recruitment to yearling clams was minimal (Figure 2.3-11). This pattern was replicated throughout the estuary. Predation by green crabs, whose densities began to increase in 1980 and from 1983-1987 remained much higher than previous years, may have virtually eliminated the first and second year-class. Human predation is also an important factor in the level of harves-



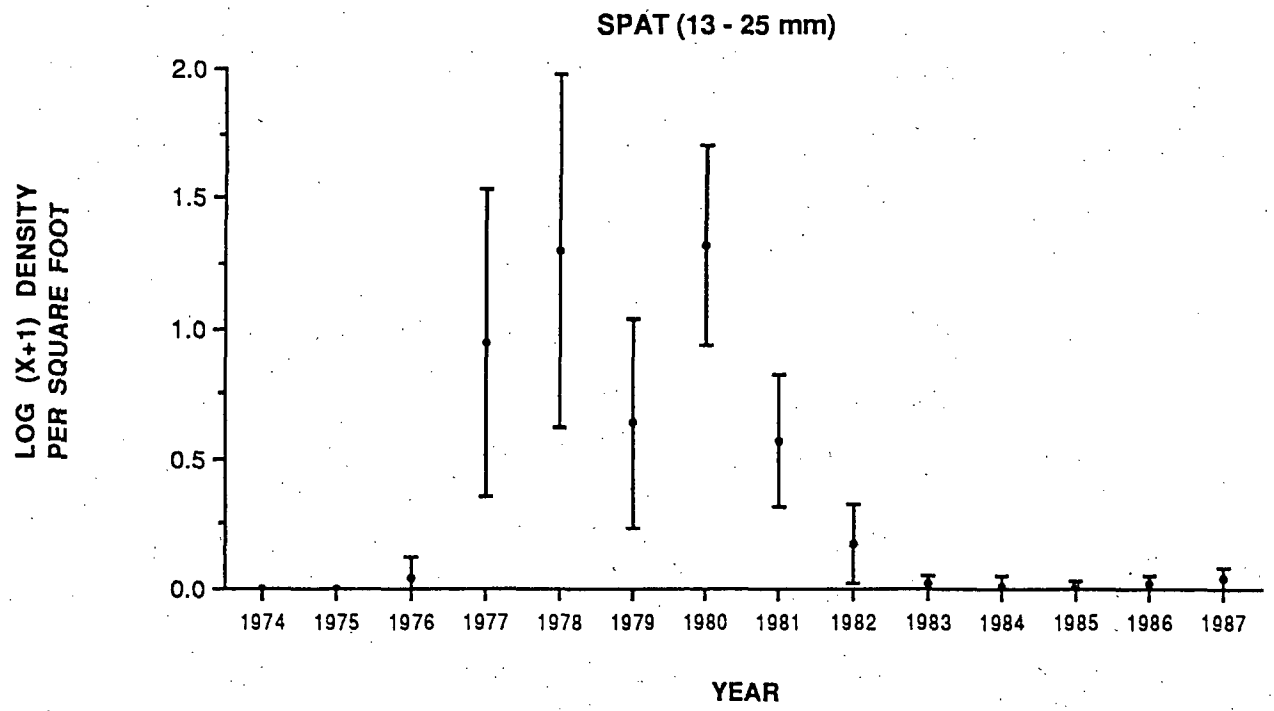


Figure 2.3-11. Annual means and 95% confidence limits of densities (No./ft^2) of *Mya arenaria* young-of-the-year and spat in Hampton-Seabrook on Flat 1. Seabrook Baseline Report, 1987.

table clams, causing mortality to adults as well as spat and juveniles by disturbance. Digging activity has declined sharply from 1982 to 1985 with a small increase in 1986 as clam diggers switched to other flats in an effort to harvest clams. Digging activity resumed its decline in 1987 (Figure 2.3-12). The standing stock has declined precipitously since 1983, lagging trends in digging activity by one year (Figure 2.3-12). Finally, the presence of disease may add to the effects of predation. Neoplasia, a cell growth disease fatal to *Mya*, has been detected in 3-27% of the *Mya* from Hampton Harbor flats 1 and 2; no incidence of this disease was found at flat 4 (Hillman 1986, 1987).

The ability to assess impact in adult clams in Hampton estuary will depend on close monitoring of all of the factors important to recruitment and predation. Clam seeding by the State of New Hampshire during 1987 in tidal creeks running into Hampton Harbor may enhance spat densities, but the ultimate effect on harvestable clams depends on predation levels and disease.

2.3.2 Benthic Monitoring

2.3.2.1 Macroalgae and Macrofauna

Monitoring of the benthic organisms (macroinvertebrates, algae, demersal fish, and epibenthic crustaceans) was established to determine the extent of change (if any) to the community structure in this zone as a result of plant operation. Changes could be manifested by (1) the enhancement of detritivores and suspension feeders, (2) the increased attraction of benthic feeders caused by locally-increased food supply, and/or (3) impact on organisms sensitive to the increased detritus resulting from moribund entrained organisms.

Mid-depth and deep (10-20 m) benthic communities, including macroalgae, macrofauna, and bottom panels, were sampled to monitor the preoperational benthic community. Year-to-year variations in community structure

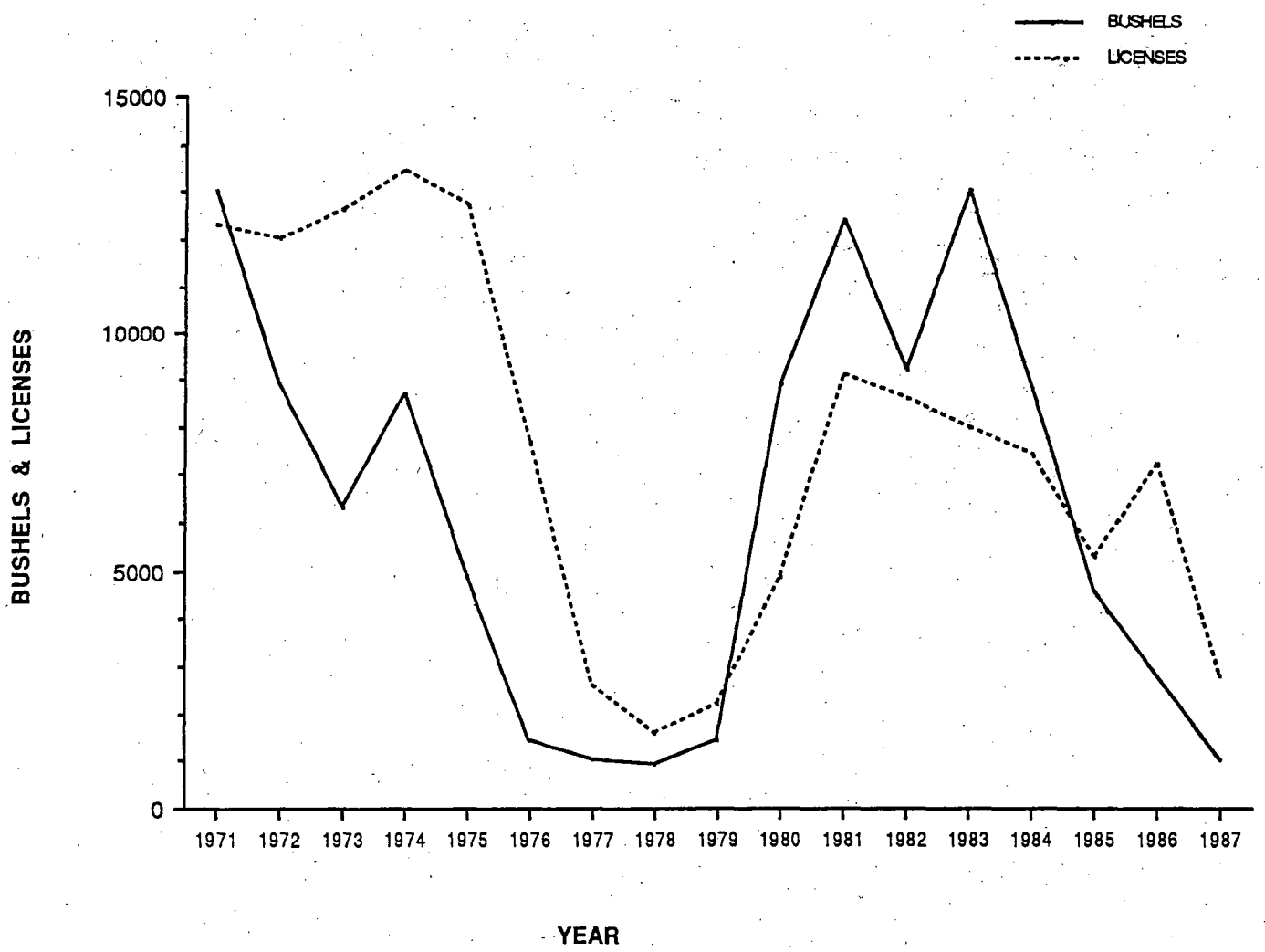


Figure 2.3-12. Number of adult clam licenses issued and the adult clam standing crop (bushels), Hampton-Seabrook Harbor, 1971-1987. Seabrook Baseline Report, 1987.

were small in comparison to variations related to depth and substrate. The macroalgae community was highly similar among years, although less so than in the intertidal and shallow subtidal areas. Species composition of sample collections in the mid-depth and deep subtidal areas during 1987 were similar to those taken at the same station in previous years (Figure 2.3-4 and Section 3.3.2). The same was true for macrofauna, where all collections at the six mid-depth and deep stations had species assemblages which resembled those in previous years (Figure 2.3-4 and Section 3.3.3). Colonial macrofaunal assemblages in the mid-depth and deep areas differed from year-to-year, and did not show a distinct association with depth (NAI 1985b).

Patterns in abundance and size distribution in selected benthic species were only slightly less predictable than species assemblage characteristics. The green sea urchin and the amphipod *Pontogeneia inermis* did not vary significantly in abundance among years, but mussels (Mytilidae) did (Table 2.3-3). There was relatively low variance in abundance among years for most of the species (Figure 2.3-13), compared to some of the more variable communities such as zooplankton and ichthyoplankton. Length measurements were a stable parameter; no differences among years were detected (Table 2.3-3).

Few nearfield/farfield differences were noted in the mid-depth/deep region. In the macrofaunal and macroalgae community, all farfield stations were more similar to their nearfield counterparts than any other areas, indicating their suitability as "control" areas (NAI 1987b). Collections made in 1987 in all cases were most similar to the majority of collections from previous years at the same depth stratum (Figure 2.3-4). Most nearfield annual abundances and all nearfield lengths were statistically similar to those from the farfield area (Table 2.3-3). The only irregularity in spatial distributions was in the macroalgae and macrofaunal community structure at mid-depth Station 16, which was more similar to shallow subtidal stations than those in its own depth zone. The predominance of algae-covered ledge at this station caused increased amounts of algae and correspondingly higher abundances of herbivores.

TABLE 2.3-3. SUMMARY OF SIMILARITIES[a] IN ABUNDANCE OR LENGTH AMONG YEARS AND BETWEEN STATIONS FOR SELECTED SPECIES IN THE MID-DEPTH ZONE. SEABROOK BASELINE REPORT, 1987.

	AMONG YEARS	
NEARFIELD VS. FARFIELD	SIMILAR	DISSIMILAR
Similar	*S. droebachiensis* (A, L) *Pontogeneia inermis* (L) Mytilidae (L)	Jonah crab *Modiolus modiolus*
Dissimilar	*Pontogeneia inermis* (A) Lobster Hakes Rainbow smelt	Rock crab Winter flounder Yellowtail flounder Atlantic cod Mytilidae (A)

[a]Results of ANOVAs, paired t-tests, or Wilcoxon's summed ranks tests. Abundance or catch unless otherwise noted.
(L) = length
(A) = abundance

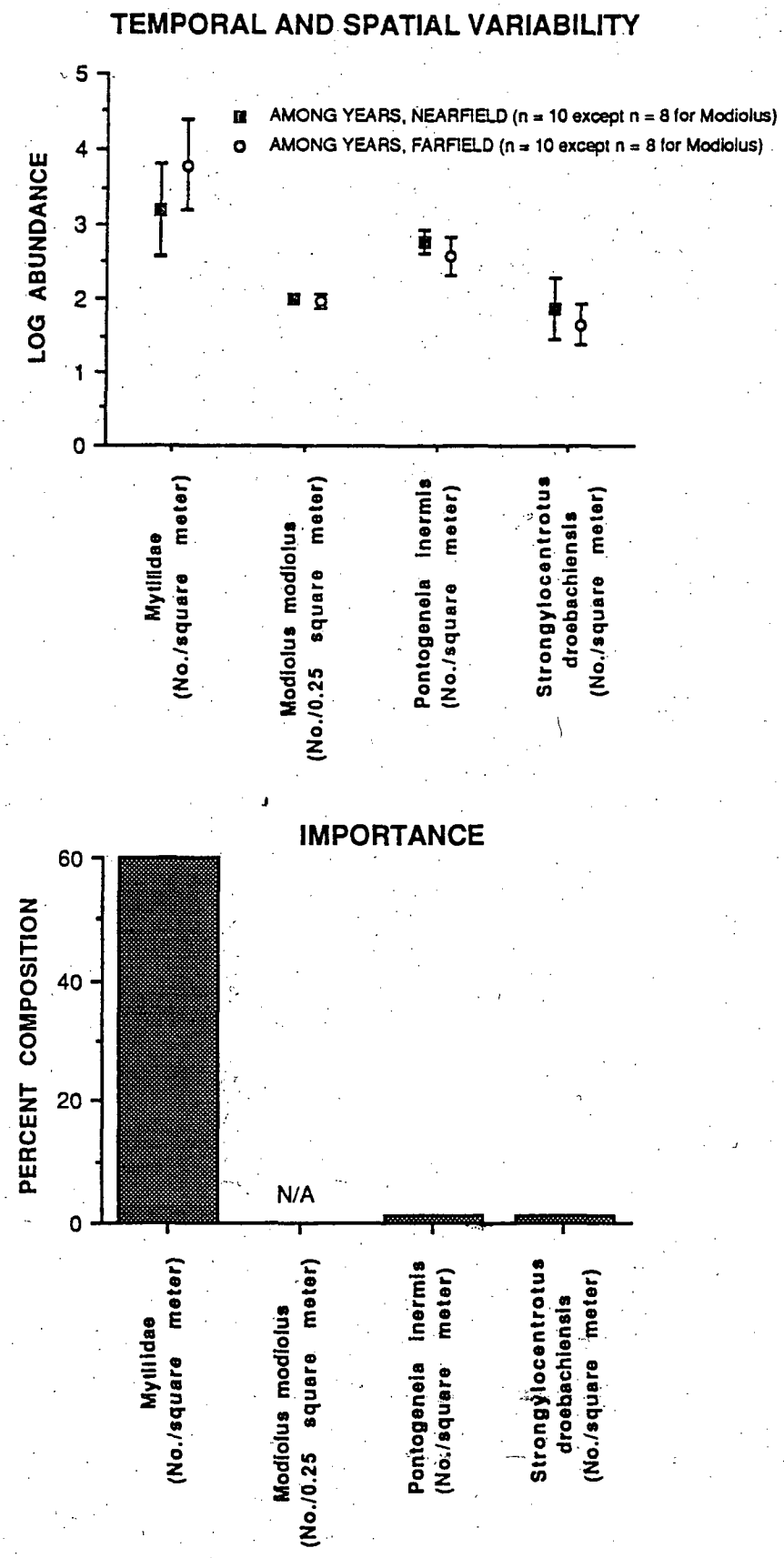


Figure 2.3-13. Percent composition and nearfield (Sta. 19) vs. farfield (Sta. 31) annual variability (standard deviation) of log (x+1) abundance for selected mid-depth benthic species, 1978-1987. Seabrook Baseline Report, 1987.

Because of apparent year-to-year stability in the annual community structure demonstrated above, the once-per-year August sampling provides a good baseline for monitoring potential changes in total numbers of taxa or individuals. Community structure analysis provides a simultaneous view of species numbers, abundance, diversity and dominance, and if changes occur at a particular place or time. Results also indicate that certain species in the study area, because their abundance or size patterns, are predictable and changes, if they occur, could be evaluated with these taxa.

2.3.2.2 Demersal Fish

Demersal fish which inhabit or feed in the discharge area are important not only because of their predominance in the food chain but also because of their commercial value. Six taxa comprised close to 80% of total otter trawl catches both across months and years (Figure 2.3-14). Effects, or lack thereof, should be evident from following the distribution of these six taxa, although the total number of taxa as well as rare and infrequently-occurring species have also been monitored. Numerical classification of 1978-1982 data identified two basic seasonal groups: "winter" (December-March) and an extended "summer" period (April-November) (NAI 1983b). These two periods were evident from monthly relative abundances (Figure 2.3-14) which show rainbow smelt were prominent mainly in winter, and hakes (red, white and spotted) and longhorn sculpin composed a greater proportion of the demersal population in summer. The overall community dominants, yellowtail and winter flounder, provided some temporal stability to this demersal community (Figure 2.3-14). Long-term trends were also evident; total catches were highest in 1980 and 1981 when catch per unit effort was almost twice as high as the CPUE in 1977 and 1985 (Figure 2.3-14), the two lowest years. Total catches steadily declined from 1981 through 1985, then increased slightly in 1986 and 1987. Variations in catch from year to year are lower than seasonal variations (Figure 2.2-6), even for winter flounder, which usually doesn't show a strong seasonal peak. Longhorn sculpin once accounted for an much as 27% of the total catch in 1984, but in 1986 and 1987 accounted for less than 10% (Figure 2.3-14).

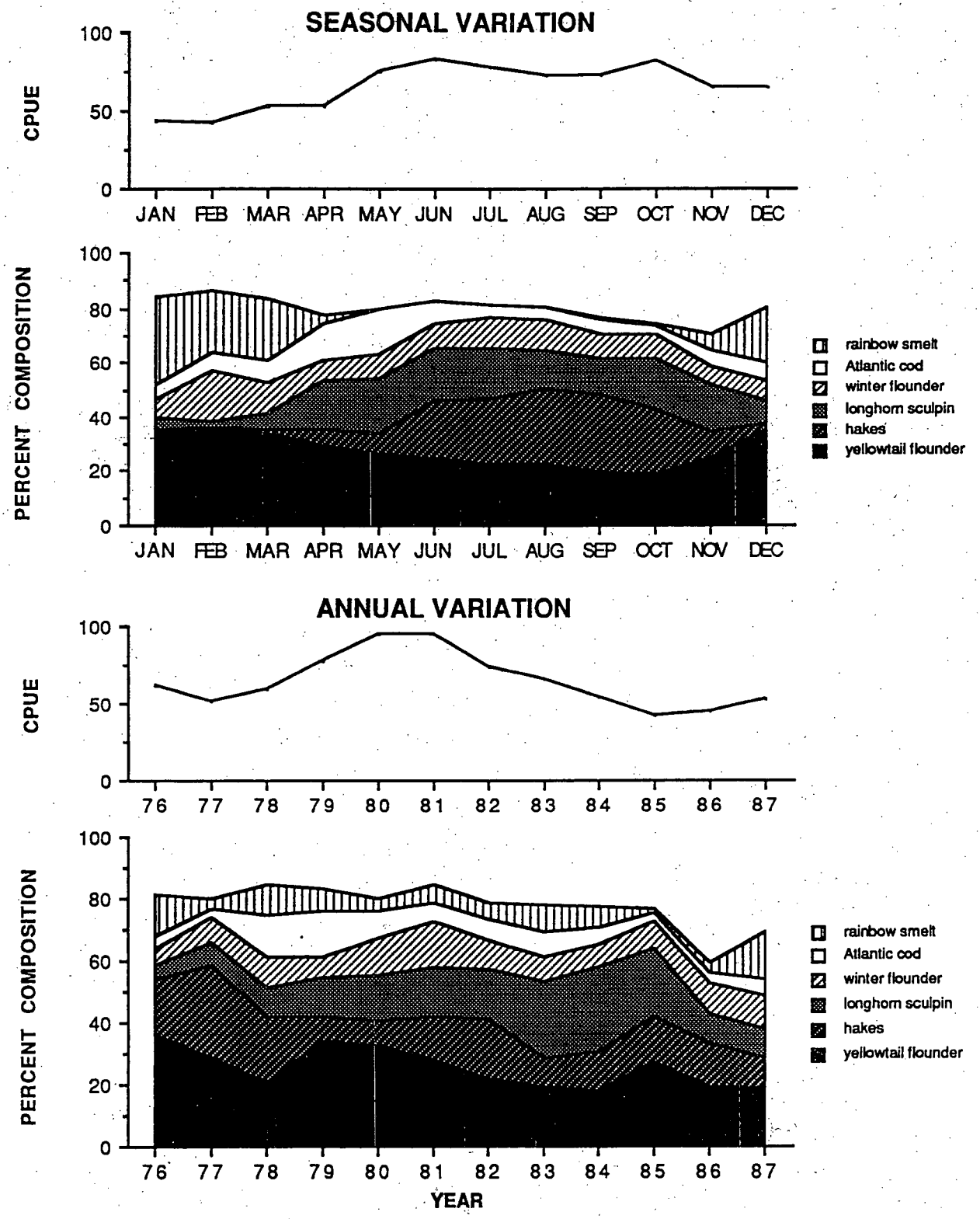


Figure 2.3-14. Seasonal and annual changes in composition and abundance of the demersal fish community, based on catch per unit effort at otter trawl stations T1, T2 and T3 combined, 1976-1987. Seabrook Baseline Report, 1987.

The age structure of the fish populations is also a factor contributing to abundance variability. Based on 1983 and 1984 length-frequency data and age-size information from the literature, the dominant age group collected at the nearfield trawl station (T2) was as follows:

SPECIES	DOMINANT AGE GROUP	RECRUITMENT EVIDENT?[a]
Atlantic cod	Age one and two	yes
Hakes	Several	yes
Yellowtail flounder	Young-of-the-year	yes
Winter flounder	Several	yes
Rainbow smelt	Young-of-the-year	yes

[a]From presence of young-of-the-year or yearlings during certain seasons (NAI 1985b)

As with most of the fish sampled in this study, the majority of fish collected with otter trawls were juveniles. Only hakes and winter flounder had no one age class dominant, although presence of young-of-the-year for these as well as the other taxa indicated the timing of recruitment.

Spatial differences are another important consideration with demersal fish. Farfield stations T1 and T3 were similar in overall catch per unit effort and relatively similar in species percent composition, although the relative contribution of sculpins and yellowtail flounder was reversed at the two stations (Figure 2.3-15). The nearfield station was most unique, with total CPUE (averaged over all years) being 40% lower than at farfield stations. This station also had a noticeable number of dates on which samples could not be collected due to the presence of commercial lobster traps. While CPUE calculations take this into account, the unavailability of data during certain fall months has likely affected catch statistics. Winter flounder and rainbow smelt (together) comprised 43% of the overall catch at T2, compared with 8-11% at the farfield stations. Most of the differences in total catch and species composition can be attributable to local habitat differences. T1 has a sandy bottom, T3 has sand mixed with cobble and shell

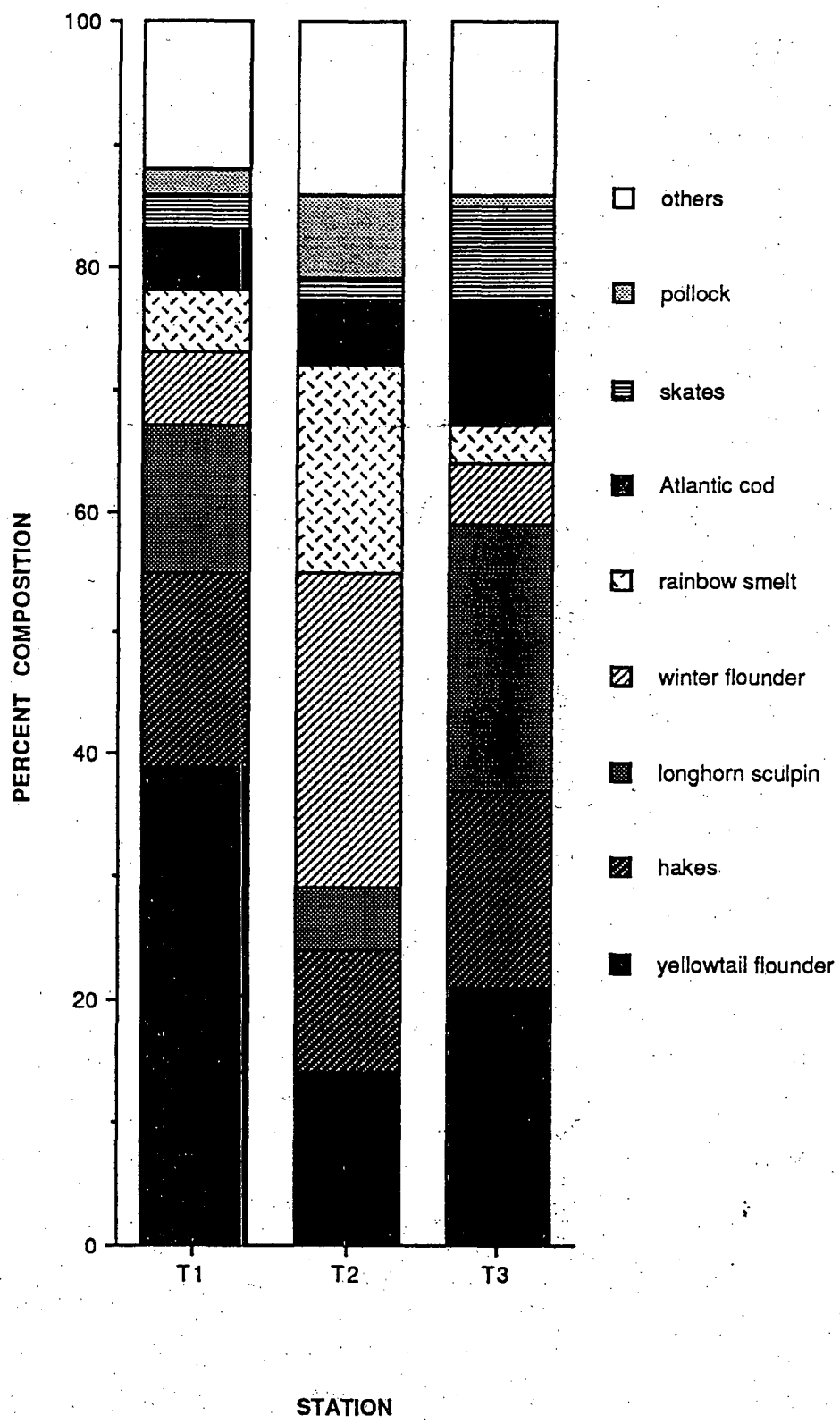


Figure 2.3-15. Percent composition by station for abundant species of fish collected in otter trawls, all years combined, 1976-1987. Seabrook Baseline Report, 1987.

debris, and T2, although mainly sand, has high currents, often resulting in a great deal of drift algae. The nearfield station is also located off the mouth of Hampton inlet and is influenced by tidal flow from the estuary. Thus, operational comparisons will have to focus on relative changes at a given station in species composition and the absolute abundance of selected species.

All of the selected demersal fish monitored have shown significantly different abundances (CPUE) among stations, and three of the five species have also differed significantly among years (Table 2.3-3), implying that determination of "control" conditions is difficult. For almost all of these taxa, precision in impact assessment is only moderate because of among-year variability. Knowledge of the age-structure of the population and use of age and growth parameters (NAI 1985b) can improve the ability to detect impacts.

Age and growth parameters for two species, cunner (1983-1984) and winter flounder (1982-1984), abundant in the nearfield discharge area were measured to provide additional precision to the catch estimates and a view of potential sublethal effects. Results for the first three years of life, when impact effects would be most pronounced, can be summarized as follows:

	SPECIES	
GROWTH	CUNNER	WINTER FLOUNDER
Sexes different?	yes	no
Year classes different?	yes	yes (age 1 & 2 only)
Percent change detectable	2-5%	3 - 4%

Thus, depending on the species, sex and year class differences will have to be considered if measuring age and growth during impact assessment. However, variability of age and growth statistics was low, giving better precision than abundance estimates.

2.3.2.3 Epibenthic Crustacea

Because of its commercial importance, the American lobster has been studied in all of its life stages for 10-14 years. Average annual catches of all lobsters was fairly stable, varying less than the average monthly catch (Figure 2.3-16). Catches did not differ significantly among years (Table 2.3-3). Variations in catches of legal-sized lobsters, a primary concern to lobstermen, were a result of natural variation combined with the effects of the change in the legal size limit. Catches ranged from 7 to 10 per 15-trap effort during 1975-1986, then dropped to three/15 traps in 1987. Although the variability was lower than that for total catches (Figure 2.3-16), this represented a substantial difference to commercial lobstermen. Catches in the 67-79 mm size class (2-5/8 to 3-1/8 inches carapace length), lobsters which are approximately two years old, have been steadily increasing through 1985 despite decreased catches in the smaller size classes (one-year old lobsters) (Figure 2.3-17). In 1984, the legal size limit was increased by the State of New Hampshire from 3-1/8" (79.4 mm) to 3-3/16" (81.0 mm), and catches of legal-sized lobsters decreased to their lowest point in 1984 and 1985. A number of adults which would have been of legal size under the old law were not harvested, causing increased catches through 1985 in the 79-92 mm size class (3-5/8 to 4-1/8 inches), which now contained both legal and sublegal sizes. A decrease in catches in 1986 in the 79-92 mm size class may have been linked to lower catches in the 54-67 mm size class in 1985.

Lobsters have shown consistent seasonal patterns, with catches highest from August through October. Catches to the north (L7) have been consistently (and significantly) higher than at the discharge (L1).

Annual catches of other epibenthic crustaceans, Jonah crab and rock crab, were more variable (Figure 2.3-16). Both species had increasing catches from 1982 through 1985, then slight decreases in 1986 and in 1987 (nearfield station only). Catches of Jonah crab were generally highest in August (Figure 2.3-16), with no differences detected between nearfield and farfield stations. Rock crab catches, much lower than those of its sibling species, usually peaked in July or August, and were significantly greater at the nearfield station than at the farfield station.

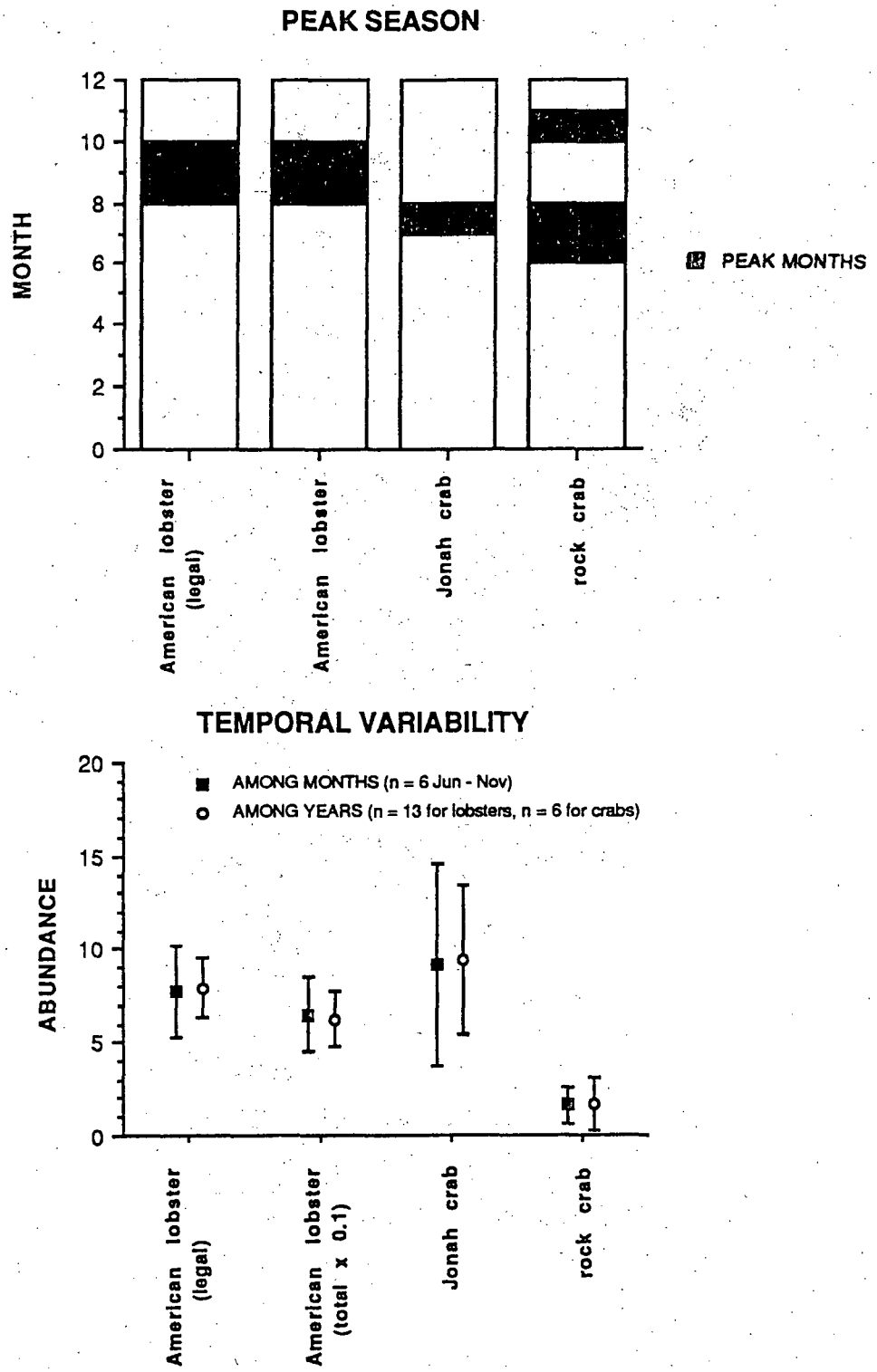


Figure 2.3-16. Seasonal vs. annual variability (standard deviation) and months of peak abundance (catch per 15-trap effort) for adult lobsters and crabs. Seabrook Baseline Report, 1987. (For CPUE of total lobsters, multiply by 10.)

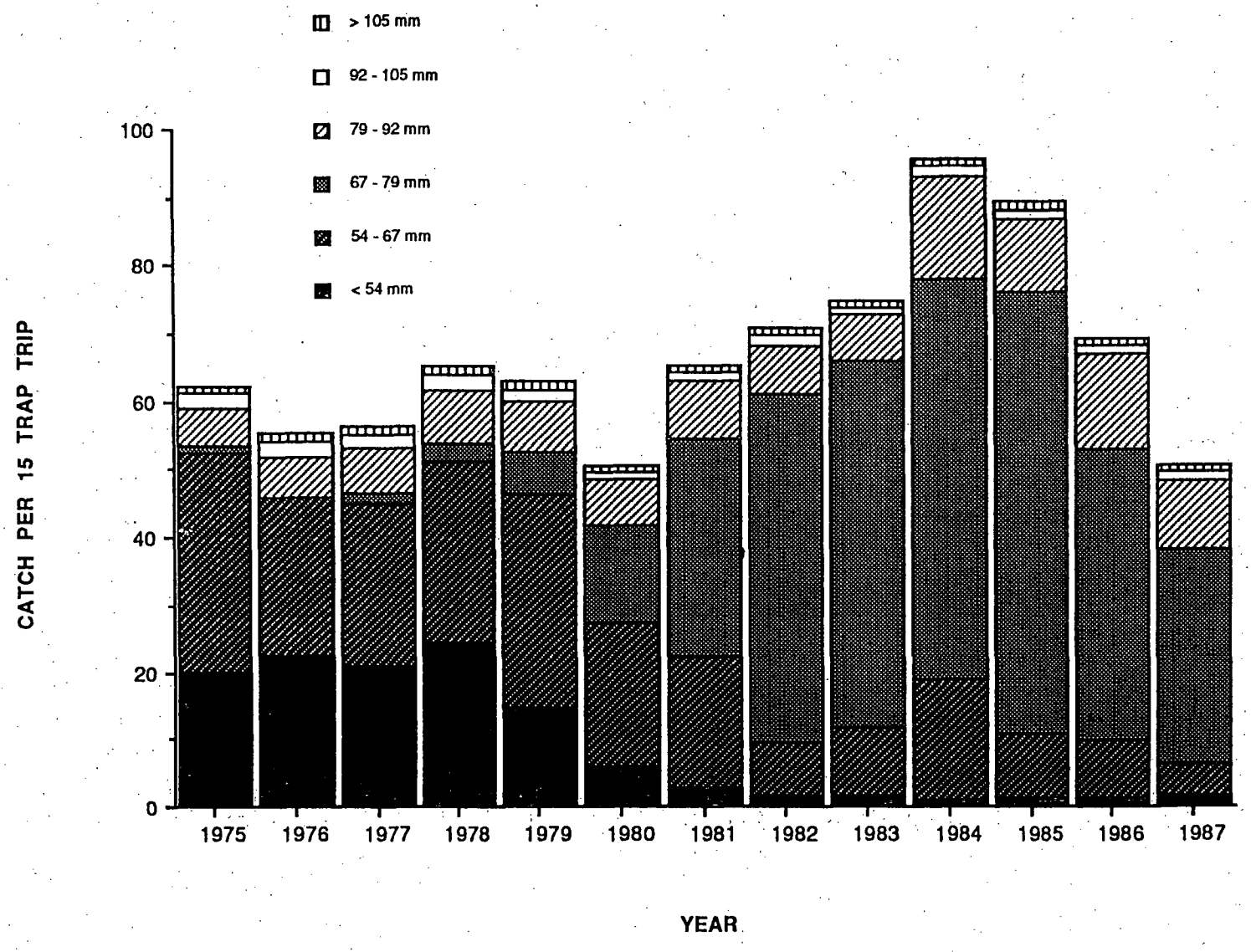


Figure 2.3-17. Size-class distribution (carapace length) of *Homarus americanus* at the discharge site, 1975-1987. Seabrook Baseline Report, 1987.

3.0 RESULTS

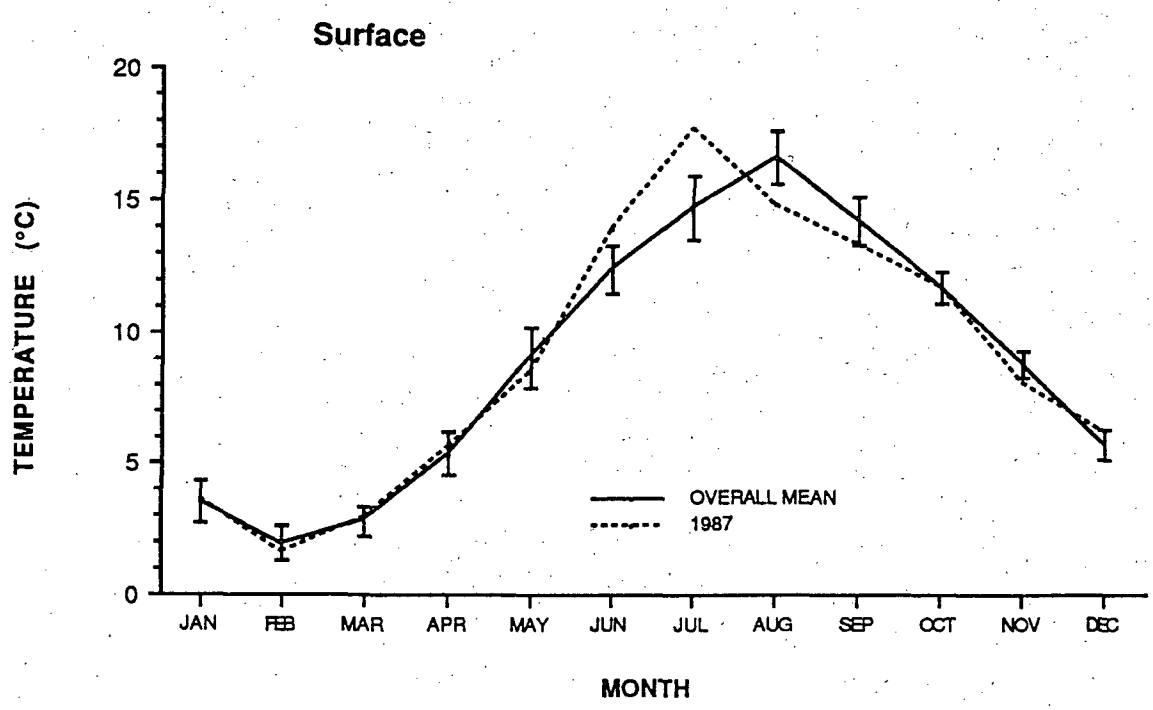
3.1 PLANKTON AND WATER QUALITY PARAMETERS

Plankton and water quality programs of the Seabrook baseline period have included water quality sampling, phytoplankton, microzooplankton, and macrozooplankton. During 1987 there was no additional sampling for phytoplankton or microzooplankton. Results of those two programs were updated and presented in detail in last year's baseline report (NAI 1987b) and are not repeated here. The plankton and water quality programs presented in this 1987 baseline report are those for which sampling was conducted during 1987: water quality (Section 3.1.1), bivalve larvae (3.1.2), and macrozooplankton (3.1.3). The cummulative results for all plankton programs, including phytoplankton and microzooplankton, are discussed in Section 2.0.

3.1.1 Water Quality Parameters-Seasonal Cycles and Trends

Three physical (temperature, salinity and dissolved oxygen) and five chemical (orthophosphate, total phosphorus, nitrite, nitrate and ammonia) parameters were examined over a 10-year period to assess their temporal variability. Generally, parameters exhibited annual cycles with one or two peaks; ammonia showed no distinct pattern (Figures 3.1.1-1 through 3.1.1-7).

Water temperature was monitored in the nearfield both continuously (Station ID, 1978-1986, NAI 1987B) and periodically during the semimonthly plankton cruises (Station P2, 1978-1987). Monthly mean values derived from both sampling methods were similar (NAI 1980c, 1980d, 1981f, 1982a, 1984a, 1985a). Continuous temperature data were not available for January 1985 through July 1986. Irradiance values, collected 1979-1984, and surface temperatures followed the same general annual cycle, with temperature peaks lagging irradiance peaks by one month (NAI 1985b). Bottom temperatures (depth 16 meters at MLW) showed truncated peaks which lagged one to three



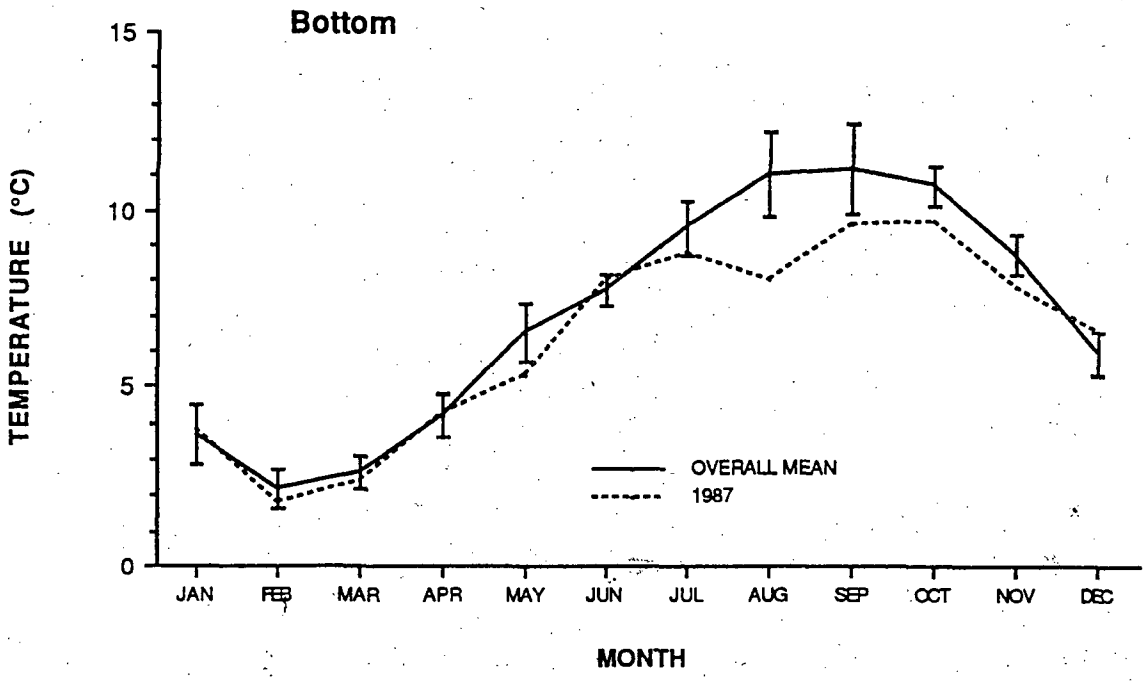


Figure 3.1.1-1. Monthly mean temperature at station P2, all years' mean and 95% confidence interval for 1978-1987 and monthly mean for 1987 for surface and bottom. Seabrook Baseline Report, 1987.

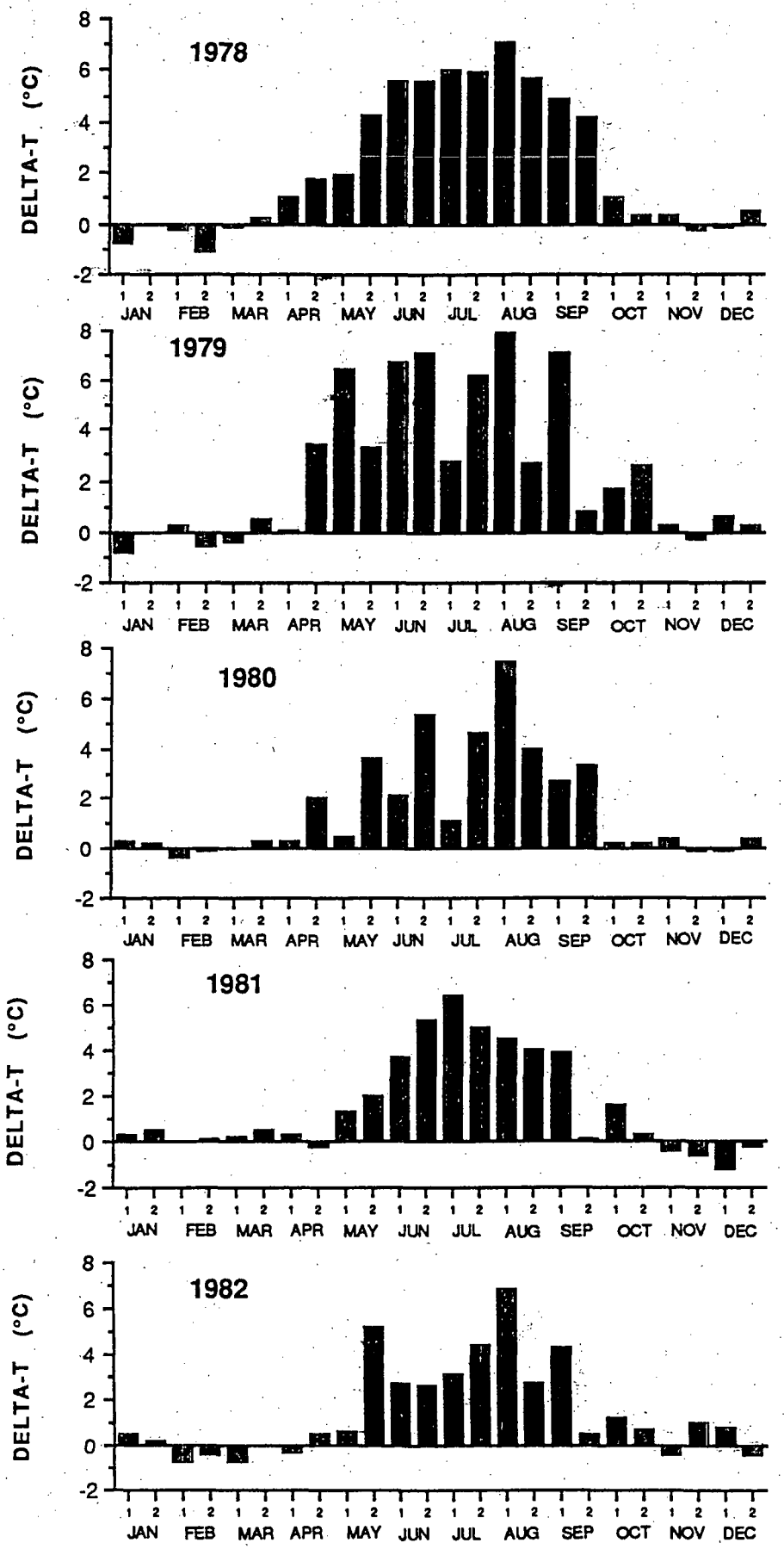


Figure 3.1.1-2. Differences between surface and bottom temperatures taken semi-monthly at station P2, 1978-1987. Seabrook Baseline Report, 1987.

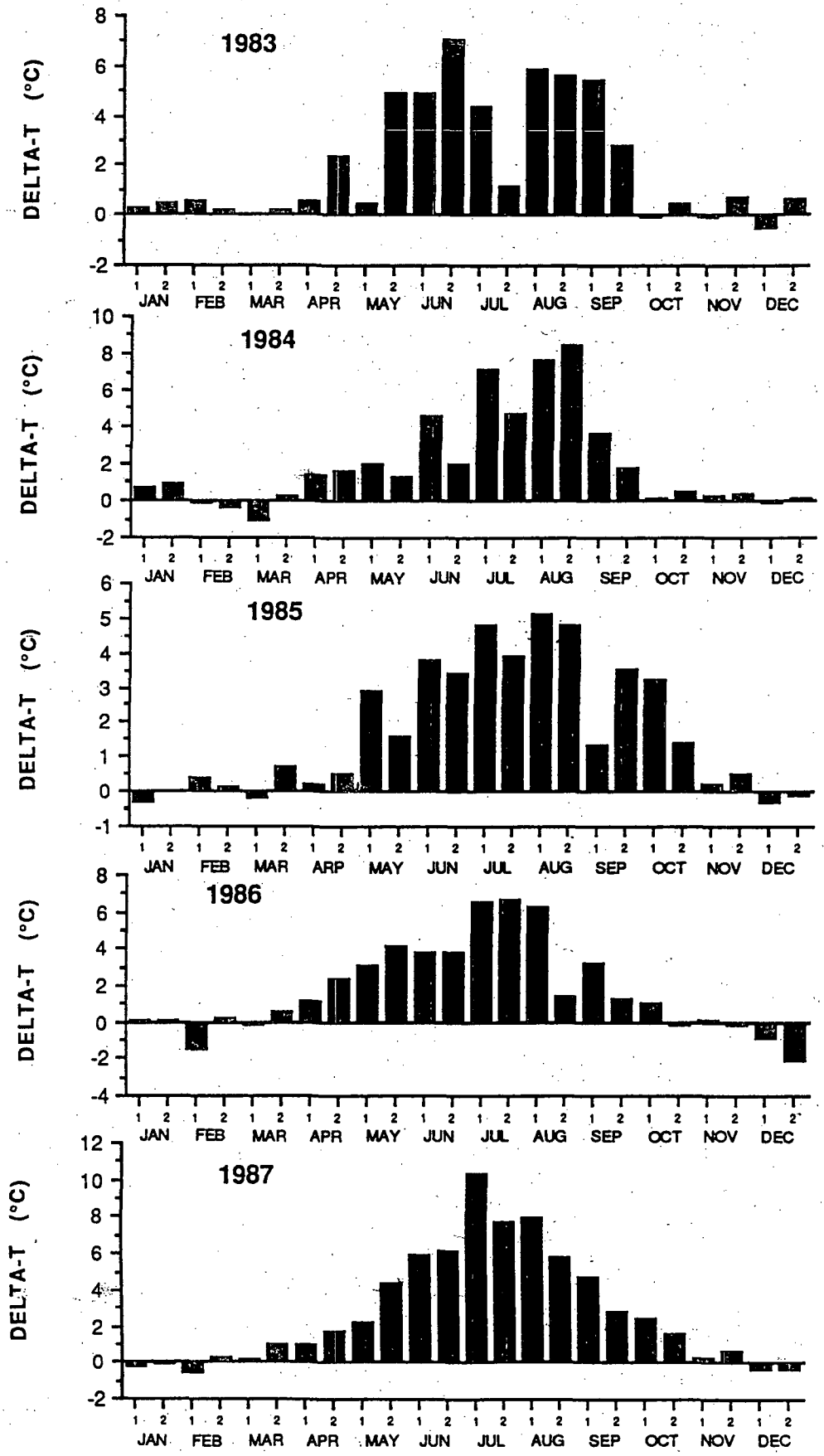
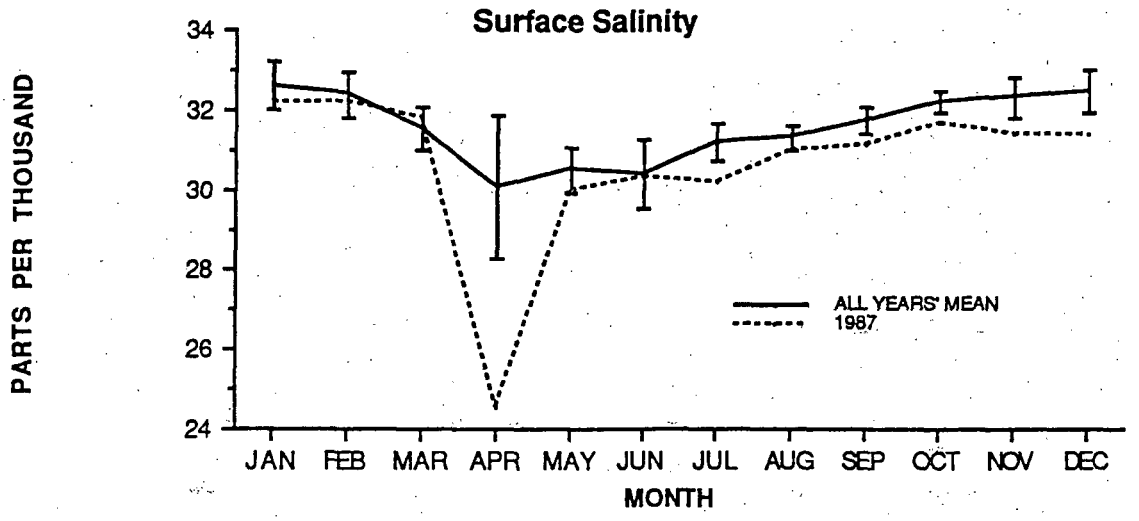


Figure 3.1.1-2. (Continued)



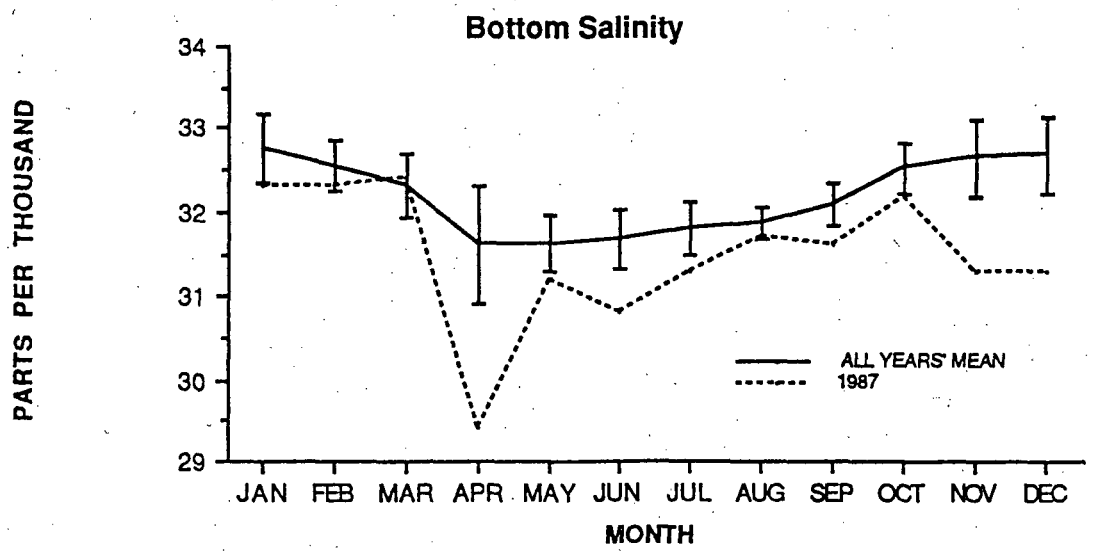
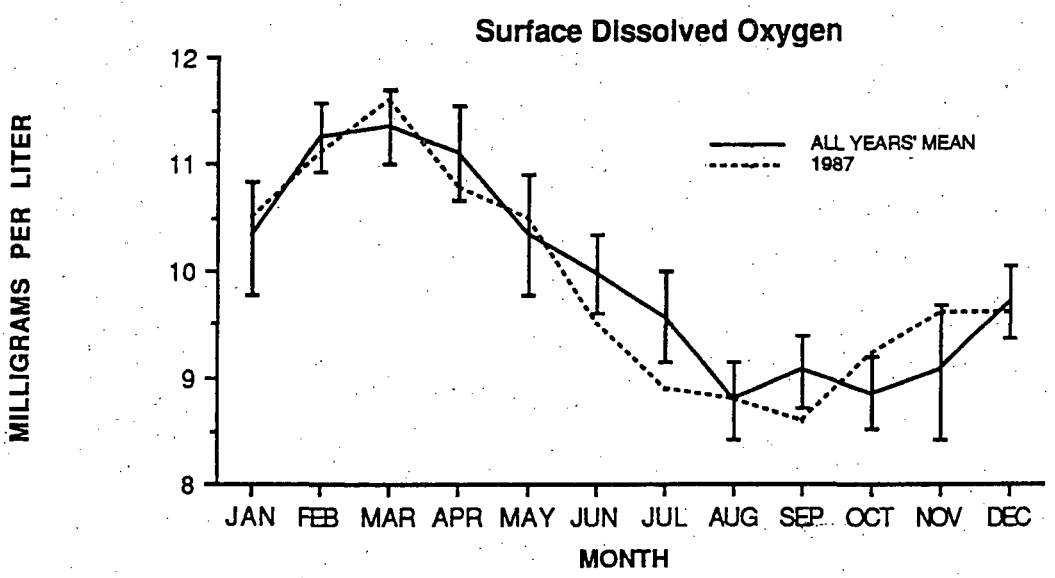


Figure 3.1.1-3. Surface salinity and bottom salinity at nearfield station P2, monthly means and 95% confidence intervals over all years, 1978-1987, and monthly means for 1987. Seabrook Baseline Report, 1987.



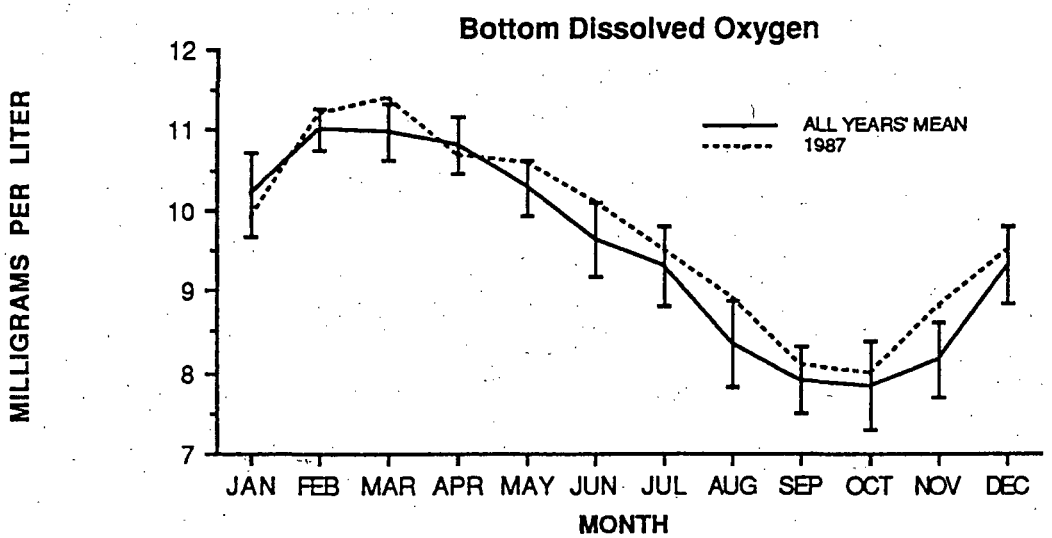
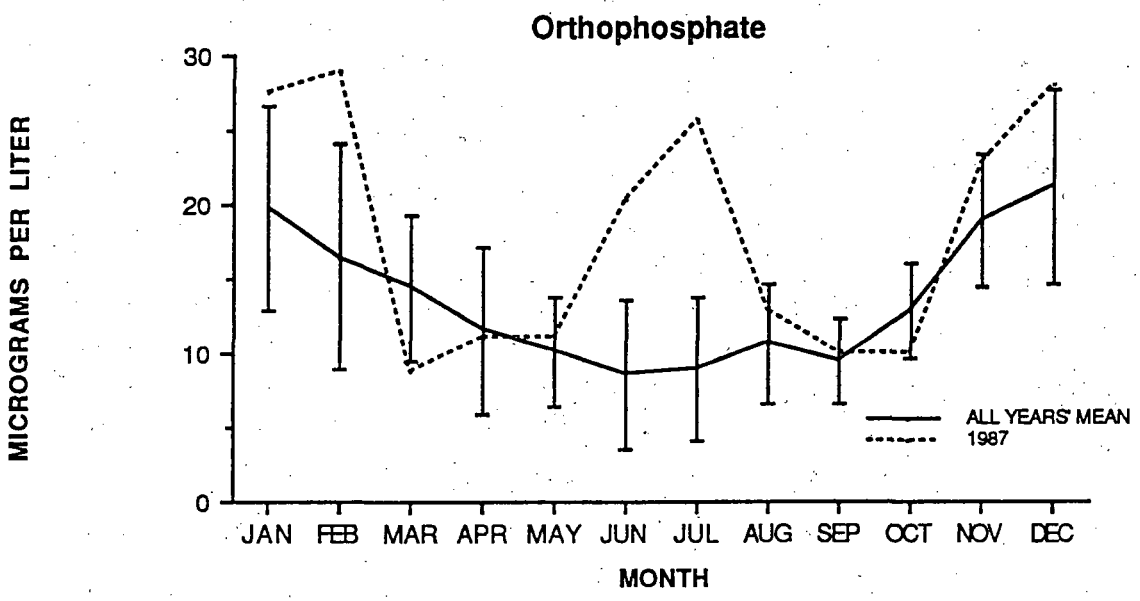


Figure 3.1.1-4. Dissolved oxygen at nearfield station P2, monthly means and 95% confidence intervals over all years, 1978-1987, and monthly means for 1987 for surface and bottom. Seabrook Baseline Report, 1987.



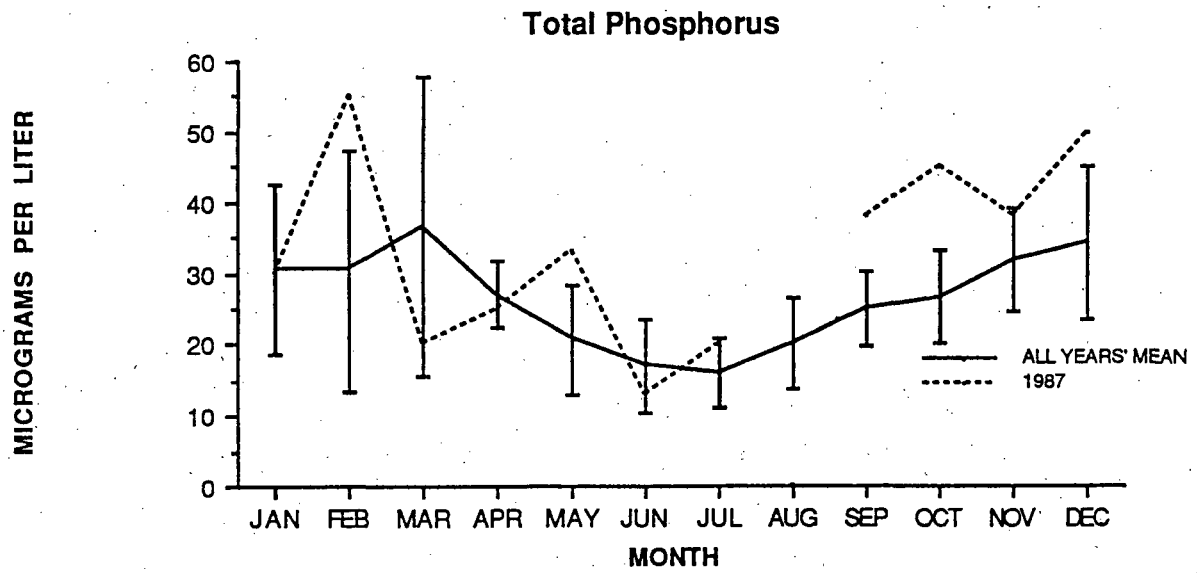
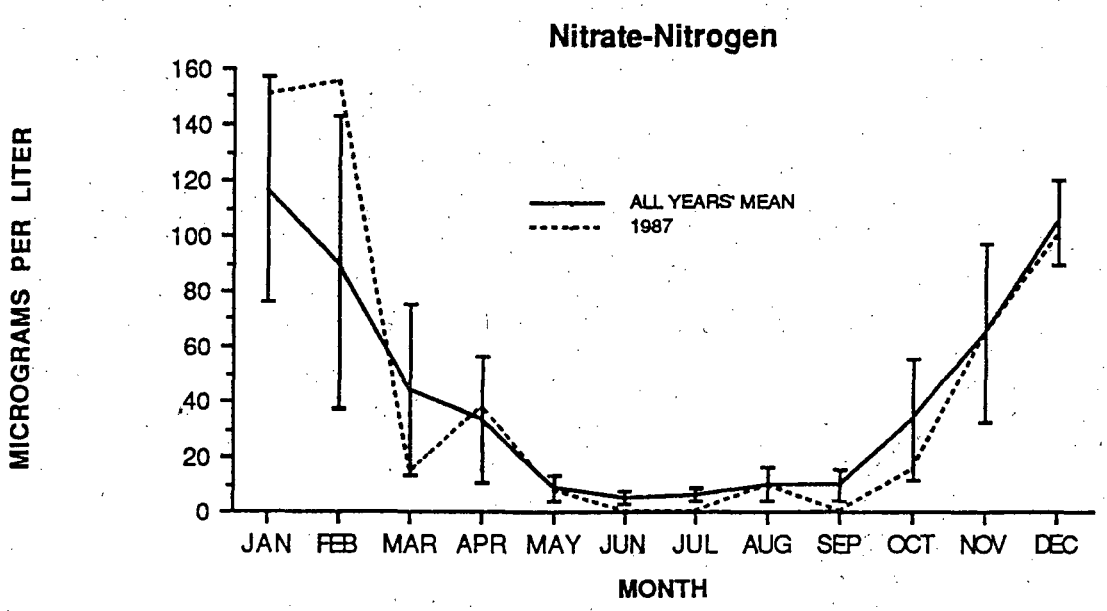


Figure 3.1.1-5. Orthophosphate and total phosphorus at nearfield station P2, monthly means and 95% confidence intervals over all years from 1978-1984 and 1986-1987, and monthly means for 1987. Seabrook Baseline Report, 1987. No data were collected for August in 1987.



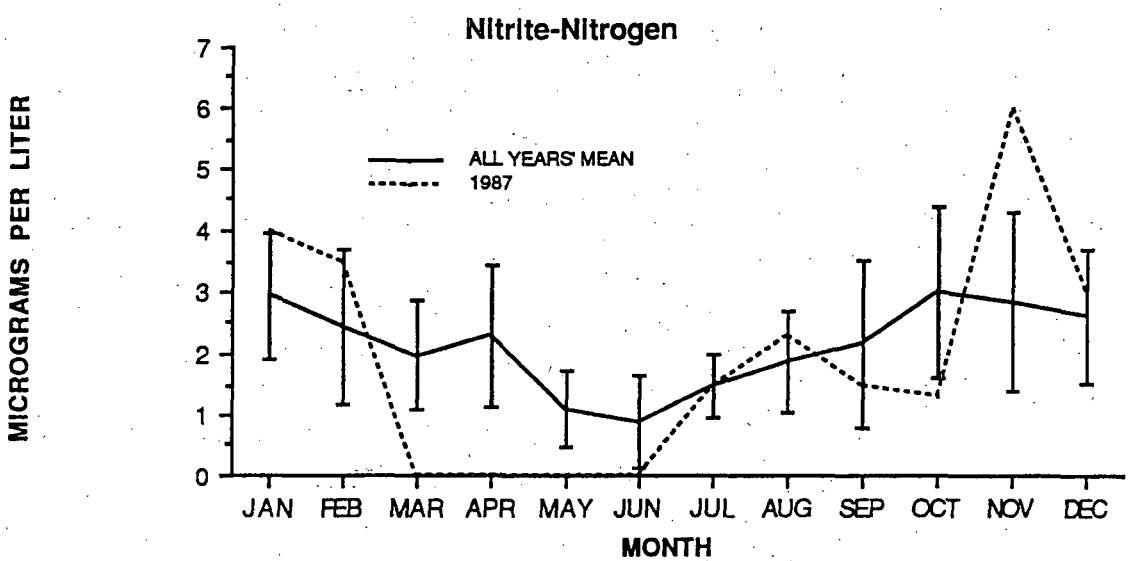


Figure 3.1.1-6. Nitrite-nitrogen and nitrate-nitrogen concentrations at nearfield station P2, monthly means and 95% confidence intervals over all years from 1978-1984 and 1986-1987, and monthly means for 1987. Seabrook Baseline Report, 1987.

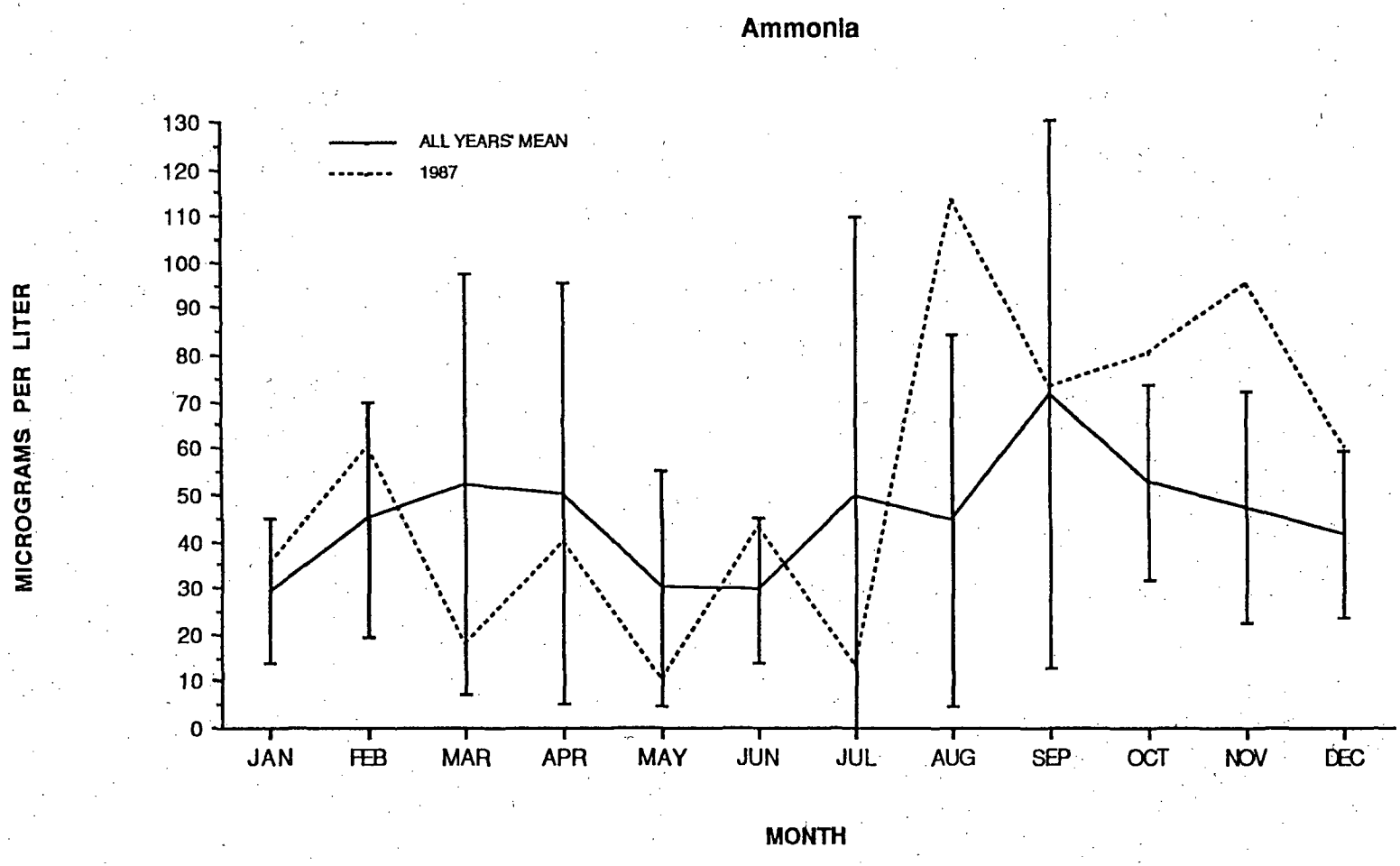


Figure 3.1.1-7. Ammonia concentrations at nearfield station P2, monthly means and 95% confidence intervals over all years from 1978-1984 and 1986-1987, and monthly means for 1987.
Seabrook Baseline Report, 1987.

months behind surface peaks. From 1978 through 1987, the temperature peak occurred in July and August at the surface and from August to October at the bottom at Station P2 (Figure 3.1.1-1). Bottom temperatures were similar to surface temperatures October through April (Figures 3.1.1-1, 3.1.1-2). Minor temperature inversions occurred each year during winter months (Figure 3.1.1-2). Annual mean temperature at Station P2 in 1987 was similar to previous years at the surface (Table 3.1.1-1), though lower than 1985 and 1986, bottom temperatures were the second lowest observed in the past ten years. The thermocline, typically established from May through September, was strongest in August six of the ten years, and in late June and early July the other four years (Figure 3.1.1-2). In 1979, 1980 and 1983, a substantial but temporary breakdown of the thermocline occurred in mid-summer.

Other water quality parameters were monitored at Station P2 and Station P7 during fortnightly plankton cruises. Salinity concentrations were highest in December and January, reaching levels of >33 ppt, though in 1987 peak salinities occurred in March at the bottom (32.4 ppt; Figure 3.1.1-3). Salinities remained fairly uniform throughout the year, dropping only in spring between March and June, depending on the amount of spring runoff and rain. Significant rainfall in April of 1987 resulted in the lowest observed surface salinity for a single date (21.2 ppt). Spring salinity concentrations typically reached lows of 28-31 ppt. Bottom salinity exhibited the same seasonal pattern as the surface, but showed less variation within and among years (Figure 3.1.1-3). Annual mean salinities in 1987 for both surface and bottom were the lowest recorded in this study, reflecting below average salinities throughout the year, especially in April, June (bottom only), November and December (Table 3.1.1-1, Figure 3.1.1-3). Dissolved oxygen peaks occurred February through April in both surface and bottom waters. Dissolved oxygen nadirs varied from August to November near the surface and the bottom (Figure 3.1.1-4). Surface and bottom dissolved oxygen values in 1987 were similar to previous years (Table 3.1.1-1) though November values were somewhat elevated (Figure 3.1.1-4). Maximum orthophosphate and nitrate concentrations occurred in winter (Figures 3.1.1-5 and 3.1.1-6); nitrate was consistently lowest in midsummer. Total phosphorous and nitrite showed fall, winter and occasional spring peaks (Figures 3.1.1-5 and

TABLE 3.1.1-1. ANNUAL MEANS AND COEFFICIENTS OF VARIATION OF WATER QUALITY PARAMETERS MEASURED DURING PLANKTON CRUISES AT NEARFIELD STATION P2, 1978-1984 AND 1986-1987. SEABROOK BASELINE REPORT, 1987.

PARAMETER	ANNUAL MEAN (AND COEFFICIENT OF VARIATION)									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Temperature (°C)										
surface	8.37 (66.93)	8.76 (57.85)	8.76 (57.86)	8.72 (63.34)	8.88 (53.02)	9.58 (53.74)	8.94 (55.72)	9.73 (54.55)	9.31 (49.57)	9.12 (57.80)
bottom	6.61 (55.62)	6.36 (47.96)	7.05 (52.76)	7.37 (59.11)	7.36 (46.03)	7.32 (44.43)	6.93 (45.04)	8.03 (47.81)	7.58 (40.42)	6.39 (45.95)
Salinity (ppt)										
surface	31.68 (3.33)	31.82 (3.84)	32.17 (2.64)	31.89 (2.16)	31.84 (3.47)	31.04 (4.39)	30.68 (4.93)	32.15 (2.26)	31.68 (2.44)	30.65 (6.76)
bottom	32.24 (1.65)	32.47 (2.77)	32.42 (1.52)	32.32 (1.41)	32.41 (2.01)	31.92 (2.12)	31.77 (1.83)	32.50 (1.54)	32.20 (1.77)	31.48 (2.66)
Dissolved Oxygen (mg/l)										
surface	10.28 (10.80)	10.02 (13.39)	10.27 (11.17)	9.90 (12.70)	9.60 (11.15)	9.48 (7.73)	10.01 (12.06)	9.67 (10.42)	9.88 (11.03)	9.89 (9.92)
bottom	10.07 (8.86)	9.69 (14.67)	9.85 (14.28)	9.43 (17.90)	9.25 (16.17)	8.98 (11.99)	9.32 (13.56)	9.17 (15.36)	8.96 (13.52)	9.73 (11.64)
Orthophosphate[d] (µg/l)	9.58 (29.99)	9.75 (52.59)	10.12 (76.10)	11.82 (30.83)	17.02 (55.54)	19.23 (44.47)	14.29 (56.06)	--[b] --	--[c] --	18.08 (45.25)
Total phosphorus[d] (µg/l)	32.50 (40.09)	15.12 (63.09)	31.96 (77.68)	22.50 (33.93)	24.61 (28.66)	25.83 (35.05)	24.17 (40.43)	--[b] --	--[c] --	33.36 (40.30)
Nitrite[d] (µg/l)	2.12 (46.11)	1.71 (66.58)	3.17 (59.59)	2.92 (53.13)	2.30 (68.34)	2.05 (54.34)	1.02 (98.08)	--[b] --	--[c] --	1.48 (98.00)
Nitrate[d] (µg/l)	52.08 (116.61)	38.33 (101.24)	48.33 (111.88)	45.42 (94.41)	37.17 (137.89)	51.83 (106.62)	36.75 (117.47)	--[b] --	--[c] --	44.42 (132.17)
Ammonia[d] (µg/l)	51.46 (120.96)	47.42 (42.93)	104.17 (48.73)	36.25 (64.73)	<30.00[a] --	27.32 (115.96)	16.57 (70.82)	--[b] --	--[c] --	53.33 (61.54)

[a] Below detection limits (30 µg/l) of methods used in 1982.
[b] Not measured in 1985.
[c] Measured July through December 1986 only.
[d] Collected one meter below surface.

3.1.1-6). Ammonia maxima usually occurred in fall or spring. In 1980, when ammonia concentrations were exceptionally high throughout the year, the peak occurred in July (Figure 3.1.1-7).

Orthophosphate and total phosphorus concentrations in 1987 varied somewhat from baseline conditions. Orthophosphate concentrations in 1987 were bimodal with higher than normal values in February, June and July (Figure 3.1.1-5). Total phosphorus concentrations in 1987 were highly variable with higher than normal concentration in February, May, September, October and December. Nitrite concentrations in 1987 were well below normal March through June when no nitrite was detectable (<1.0 µg/l at Station P2; November nitrite levels were above normal (Figure 3.1.1-6). Nitrate levels were typical of past years with somewhat higher than normal concentrations in February (Figure 3.1.1-6). Ammonia concentrations in 1987 were consistent with previous years, with slightly elevated levels in August and October through December (Figure 3.1.1-7).

3.1.2 Bivalvia Veliger Larvae

3.1.2.1 Community

Bivalve veliger larvae were identified and enumerated from oblique tows of 76-µm mesh nets from April through October 1976-1987 at one or more of the Stations P1, P2, and P7 (see Section 3.3.7.1 for *Mya arenaria* results and Figure 4.1-1 for station locations). *Mytilus edulis* was clearly the dominant species, while *Heteranomia squamula, Hiatella* sp., Solenidae and *Modiolus modiolus* were secondary dominants (Table 3.1.2-1).

Hiatella sp. was present April through October, with highest abundances usually occurring in June (Figure 3.1.2-1). *Mytilus edulis*, Solenidae and *Mya truncata* were usually present by mid- to late May. *Mytilus edulis* and *Mya truncata* peaked primarily in June or July. Solenidae peaks were noted in June, late August, September, and October, possibly due to

TABLE 3.1.2-1. OVERALL PERCENT COMPOSITION OF BIVALVE VELIGER LARVAE IN 76-μm NET TOWS AT STATIONS P1, P2 AND P7 FROM MID-APRIL THROUGH OCTOBER, 1982-1987[a]. SEABROOK BASELINE REPORT, 1987.

SPECIES	1982		1983		1984		1986		1987		
	P2	P7	P2	P7	P2	P7	P2	P7	P1	P2	P7
Mytilus edulis	44	54	59	47	77	83	61	54	74	62	56
Heteranomia squamula[b]	21	14	4	17	4	3	12	15	8	8	25
Hiatella sp.	9	8	17	13	8	6	10	9	10	13	8
Modiolus modiolus	9	3	14	18	7	3	13	18	2	3	5
Spisula solidissima	6	8	1	1	1	<1	<1	1	<1	1	1
Solenidae	3	4	3	2	2	2	1	2	4	10	3
Mya arenaria	4	5	1	<1	<1	<1	<1	<1	<1	<1	<1
Other Bivalvia	2	2	1	1	1	1	1	2	2	4	2
Mya truncata	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Macoma balthica	<1	<1	<1	<1	<1	<1	0	0	0	0	0
Placopecten magellanicus	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Teredo navalis	0	0	0	0	0	<1	<1	<1	<1	<1	<1

[a]Only *Mytilus edulis* and *Mya arenaria* were enumerated in 1985.

[b]Formerly referred to as *Anomia* sp.

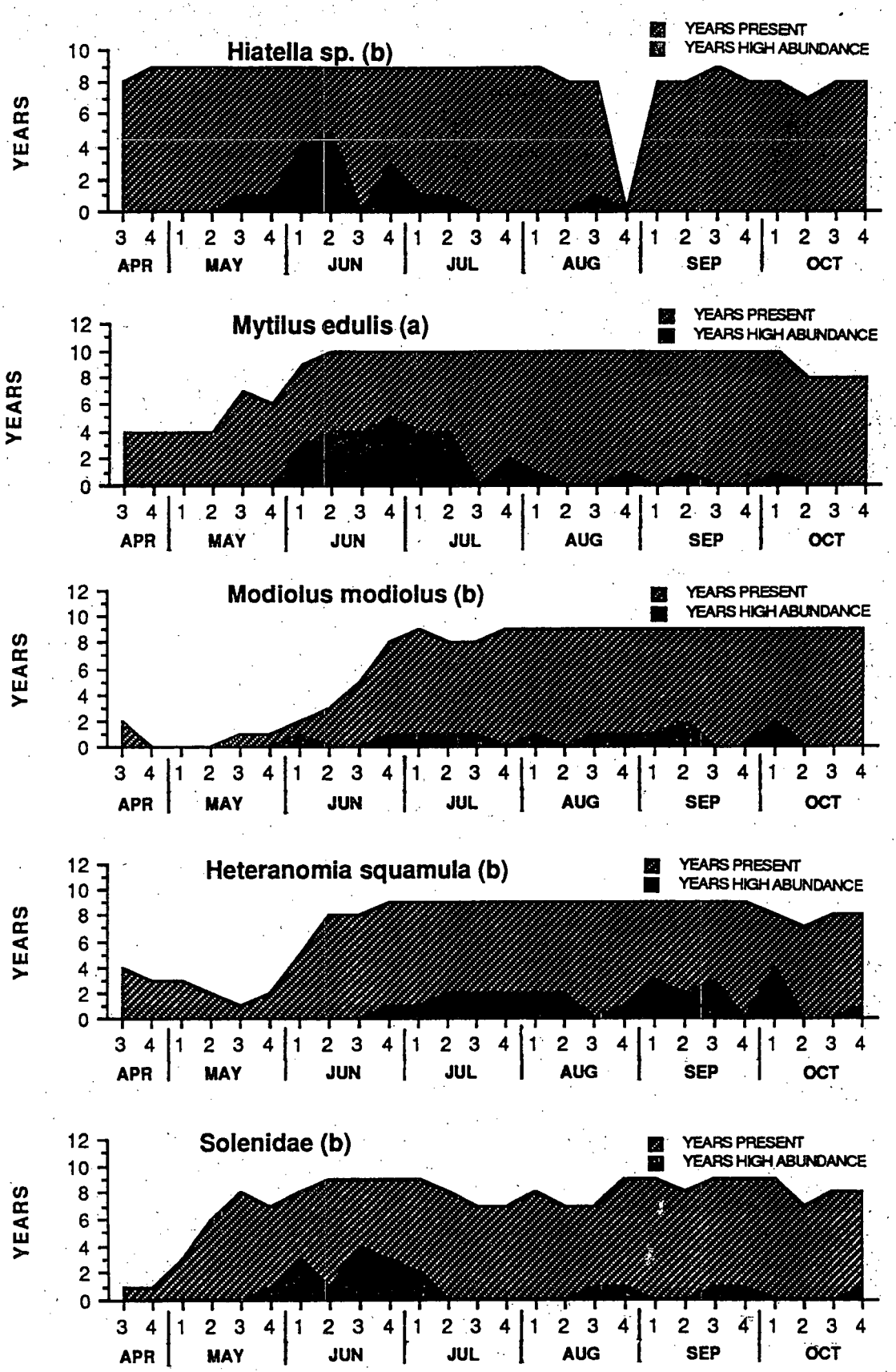


Figure 3.1.2-1. Number of years present and number of years in high abundance (≥ 50% of seasonal peak abundance) of bivalve veliger larvae by week at station P2, 1978-1987. Years enumerated: a. 1976-1987; b. 1978-1984, 1986-1987; c. 1979-1984, 1986-1987. Seabrook Baseline Report, 1987.

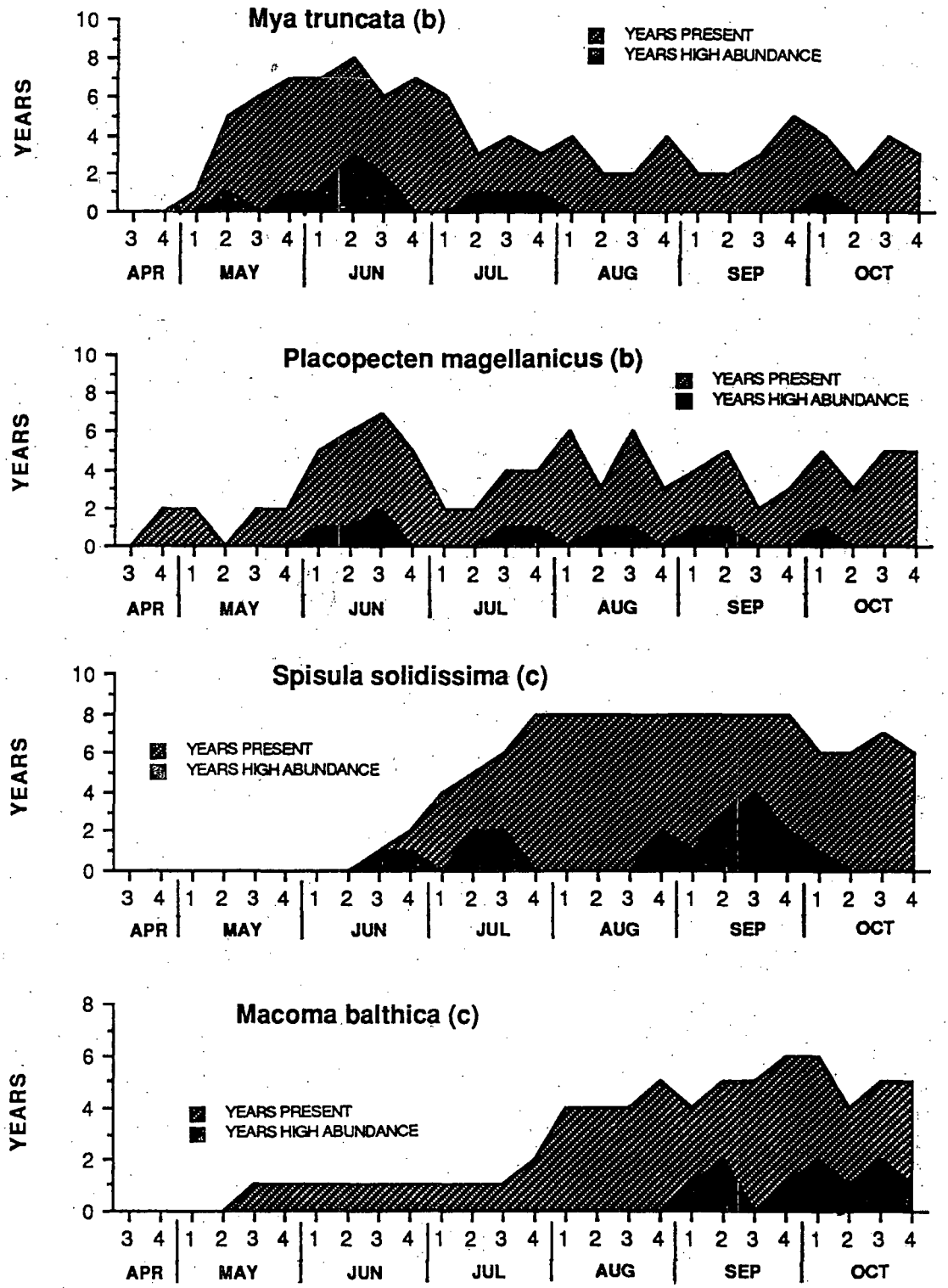


Figure 3.1.2-1. (Continued)

differential spawning of the three component species (*Ensis directus, Siliqua costata, Siliqua squama*). *Heteranomia squamula* was usually present by early June, with highest abundances July through September. *Modiolus modiolus* was usually present by mid-June and has been highly variable in terms of peak abundance, with peaks in early June (1978) and in early October (1986). *Spisula solidissima* and *Macoma balthica* usually were not observed until July and August, respectively; these taxa peaked in late summer or fall. *Placopecten magellanicus* was present sporadically throughout the sampling period, with no clear seasonal peak. In general, larval peak abundances and periods of occurrence in 1987 were comparable to previous years with some exceptions. In 1987, *Spisula solidissima* peaked in early June, slightly earlier than usual and, as in 1986, *Macoma balthica* larvae were not observed (NAI 1987b).

Station P1 (Hampton Harbor), added to the sampling program in 1986, and offshore Stations P2 (nearfield, intake) and P7 (farfield) all displayed similar patterns of species composition and abundance. Entrainment samples were collected within Seabrook Station (E1) July through December 1986 and April through June 1987. In both years, comparison with intake Station P2 demonstrated similar species composition at Station E1 but substantially lower larval densities. In 1987, Station E1 densities for *Hiatella* sp., Solenidae and *Mya arenaria* were substantially lower than densities observed at Station P2 (Table 3.1.2-2).

Differences between Stations E1 and P2 may be attributed to differences in sampling. Station E1 sampled water from the cooling water intake, at a depth of about ten meters, while Station P2 was sampled via oblique net tows which integrated the entire water column. In general, bivalve larvae are found in near-surface waters for the majority of their planktonic existence, thus fewer larvae would be expected at a depth of ten meters, and consequently lower abundances would be expected at Station E1. Additional variation between stations may have been introduced by sampling at different times or different days, allowing small and large scale patchiness to affect the larval densities.

TABLE 3.1.2-2. DENSITIES OF DOMINANT BIVALVE VELIGER LARVAE IN 76-µm MESH NET COLLECTIONS ON OR NEAR THE SAME DATE AT NEARFIELD STATION, P2, AND ENTRAINMENT STATION, E1, APRIL THROUGH JUNE 1987. SEABROOK BASELINE REPORT, 1987.

		APR 21	APR 22	APR 30	MAY 07	MAY 26	JUN 01	JUN 03	JUN 08	ALL
Mytilus edulis	P2	<1	-	0	0	0	4	-	79	14
	E1	-	<1	0	0	0	-	2	61	11
Hiatella Sp.	P2	23	-	1084	1699	866	6433	-	7320	2904
	E1	-	4	<1	363	256	-	856	1237	453
Solenidae	P2	<1	-	0	1	33	328	0	26403	4461
	E1	-	0	0	0	21	0	32	725	130
Mya arenaria	P2	0	-	0	0	0	0	-	82	14
	E1	-	0	0	0	0	-	0	6	<1

- Sample not collected

3.1.2.2 Selected Species

Mya arenaria

This species is discussed in Section 3.3.7.

Mytilus edulis

Umboned veligers of *Mytilus edulis* were usually present by mid- to late May (Figure 3.1.2-1). Once present, they occurred consistently throughout the sampling program. The protracted presence of larvae was due to recruitment patterns and duration of larval lifestages. Major spawning events in Gulf of Maine mussel populations may be limited to temperatures above 10-12°C (Podniesinski and McAlice 1986). Spawning of *M. edulis* in Long Island Sound was found to be asynchronous both within and among local populations and to occur over a two to three month period (Fell and Balsamo 1985). Spawning of some Long Island Sound mussel populations was also restricted by limited food availability for most of the year, resulting in sporadic spawning events (Newell *et al.* 1982). Therefore it is probable, based on the reproductive behavior of *M. edulis*, that recruitment of larvae to the plankton of New Hampshire coastal waters occurred throughout much of the sampling program. Recruitment from non-local sources was probable, as water masses may move large distances over the three to five weeks required for larval development at ambient temperatures (Bayne 1976). Delay of metamorphosis until suitable settlement conditions are encountered can prolong planktonic existence for up to 40 days, depending on temperature (Bayne 1976). These factors suggest that planktonic recruitment to the study area was intermittent and prolonged, and that duration of planktonic life varied over the sampling program as temperature conditions changed.

Highest abundances of *Mytilus edulis* larvae usually occurred between early June and early July (Figure 3.1.2-2), although in 1980-1982 abundances in late August, September or October were as high as in early summer. Peak abundances ranged from $6 \times 10^3/m^3$ in 1982 to $3.3 \times 10^5/m^3$ in 1979 (NAI 1987b). The difficulty in assessing the variability in this

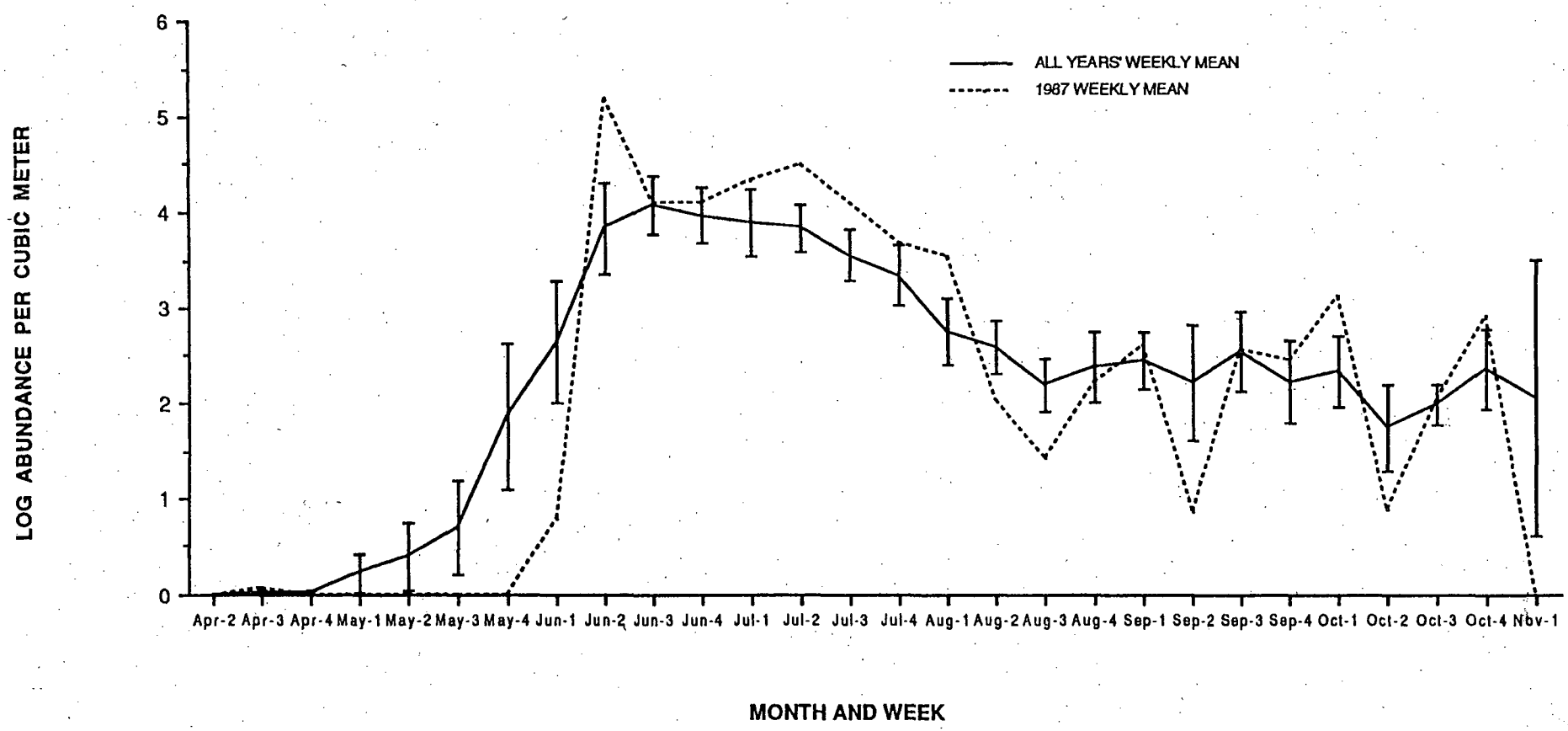


Figure 3.1.2-2. Weekly mean abundance and 95% confidence intervals for Mytilus edulis larvae at nearfield station P2 over all years 1978-1987. Seabrook Baseline Report, 1987.

population is probably compounded by patchiness caused by discontinuous recruitment both spatially and temporally (Bayne 1976; Podniesinski 1986). Collections taken within several days of one another, even during peak months, varied by zero to three orders of magnitude (NAI 1981c, 1984a).

In 1986 and 1987, bivalve larvae were collected within Seabrook Station in order to estimate larval entrainment. In 1987, offshore and entrained *M. edulis* densities over all dates were similar (Table 3.1.2-2). However, in 1986, some weekly densities differed substantially between the two stations, probably a result of small-scale spatial and temporal variations.

Although variability was high among years, overall spatial variability was low. Historically (1982-1984), no significant differences had been found between Stations P2 and P7 when weekly abundances were ranked (NAI 1985b).

3.1.3 Macrozooplankton

3.1.3.1 Community Structure

Temporal Patterns

Historical analysis (1978-1984) of the macrozooplankton assemblage at the nearfield Station P2 showed seasonal changes that were heavily influenced by the population dynamics of dominant copepods *Centropages typicus* and *Calanus finmarchicus*, with other taxa, particularly meroplankton, exerting short-term influences, especially during the spring and summer (NAI 1985b). Historical seasonal assemblages (1978-1984) established by numerical classification on the basis of similarities in species composition were verified by discriminant analysis, and in turn used to evaluate 1986 and 1987 collections. In all cases, new collections were placed in the group with the majority of historical collections from the same time period. This is an indication of the similarity of 1986 and 1987 assemblages with previous years.

Winter abundances have been typically low, with the population composed mainly of copepods *Centropages typicus* (groups 1 and 2) and *Metridia* sp. (group 2 only)(Tables 3.1.3-1, 2). Winter abundances of *C. typicus* in 1987 were an order of magnitude lower than previous years, and 1986 and 1987 winter abundances of copepods *Tortanus discaudatus* and *Temora longicornis* were higher than previous years (Table 3.1.3-2).

The months of March and April were characterized by the beginning of the spring warming trend and initiation of thermocline formation (Section 3.1, Figure 3.1.1-2). Reproductive activities of barnacles at this time result in a tremendous influx of Cirripedia nauplii and cyprids, which distinguish this assemblage (group 3). Copepods *Centropages typicus* and *Calanus finmarchicus* are also dominant components of this assemblage (Tables 3.1.3-1,2). The late winter-early spring assemblage in 1987 was similar to previous years with the exception of *C. typicus* abundance levels, which were two orders of magnitude lower than the 1978-84 average (Table 3.1.3-2). Heavy rainfall in April, 1987 caused salinity to drop to the lowest value observed since the study began in 1978 (21.2 ppt at P2, NAI 1988). This may have affected *C. typicus* densities, as its reported salinity preference is above 30 ppt (Gosner 1971).

In most years, spring collections were marked by a transitional assemblage (group 4), composed mainly of *Calanus finmarchicus* along with other microcrustaceans (*C. typicus, Metridia* sp., *Evadne* sp. and *Temora longicornis*), the holoplanktonic mollusc *Limacina retroversa*, and larvacean *Oikopleura* sp. (Table 3.1.3-2). The transitional period in 1987 consisted only of early May collections, coinciding with continued low surface salinity (Figure 3.1.1-3). Mean group densities of dominant taxa in 1987 were all an order of magnitude lower than those historically (1978-1984)(Table 3.3.1-2).

Late spring-early summer (late May-July) conditions showed rapidly increasing surface temperatures along with stabilization of the thermocline (Figures 3.1.1-1, 3.1.1-2). *Calanus finmarchicus* was typically the dominant organism during this time period, which along with the larval decapods,

TABLE 3.1.3-1. SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF MACROZOOPLANKTON COLLECTIONS FROM NEARFIELD STATION P2, 1978-1984 AND BY DISCRIMINANT ANALYSIS OF COLLECTIONS FROM JULY 1986-DECEMBER 1987. SEABROOK BASELINE REPORT 1987.

SAMPLING PERIOD

GROUP	J[a]				F				M				A			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1 Winter 1978-79, 82-83,83-84,85-86,86-87 Late Fall 1987	B	9 3 4	8 9 B	3 4	2 B	8 3 4	B	9 3	8			8				
2 Winter 1980-1982	0 1 2		0 1 2	0	1	0	1	0								
3 Late Winter-Early Spring								2 4	4 B	1 2 3	9 0 1 2 4 B	3	9 0 1 2 4 B	8 3	9 0 2 4 B	8
4 Spring															1	9 3
5 Late Spring-Early Summer																
6 Summer																
7 Fall																

GROUP	M				J				J				A			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1 Winter 1978-79, 82-83,83-84,85-86,86-87 Late Fall 1987																
2 Winter 1980-1982																
3 Late Winter-Early Spring	4	8 3														
4 Spring	0 1 2 B	9 0	9 1 4	0												
5 Late Spring-Early Summer			2 3 B	8	8 9 1 2 4 B	0 1 2 3	8 9 4 B	0 3	2 4 A B	9 0 1 3	4		9 B			
6 Summer										8	9 0 2 A B	8 1 3	0 3 4 A	8 1 2	8 9 4 A B	0 1 2 3
7 Fall																

GROUP	S				O				N				D			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1 Winter 1978-79, 82-83,83-84,85-86,86-87 Late Fall 1987											B	4	3 A	2 B	3 A	8 2
2 Winter 1980-1982														0	9 0	
3 Late Winter-Early Spring																
4 Spring																
5 Late Spring-Early Summer																
6 Summer	8 0 2 4 A B	9 1 3	9 2 4 A B	1 3	4 A	3 B	A									
7 Fall					8 9 1	0	9 0 1 2 4	2 3 B	8 1 3 4 A B	0 2	9 1 4 A	9 0 3	8 1 4 B	1	4	

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[a] year (1978-1984) represented by last digit; 1986=A; 1987=B.

TABLE 3.1.3-2. MEAN ABUNDANCE AND PERCENT FREQUENCY OF OCCURRENCE OF DOMINANT TAXA OCCURRING IN SEASONAL GROUPS FORMED BY NORMAL CLASSIFICATION OF MACROZOOPLANKTON COLLECTIONS AT NEARFIELD STATION P2, 1978-1984, IN COMPARISON TO 1986 (JULY-DECEMBER) AND 1987 (JANUARY-DECEMBER) AS CLASSIFIED BY DISCRIMINANT ANALYSIS. SEABROOK BASELINE REPORT 1987.

GROUP	SPECIES	1978-1984 MEAN #/1000m^3	1978-1984 % FREQ.	1986 MEAN #/1000m^3	1986 % FREQ.	1987 MEAN #/1000m^3	1987 % FREQ.
1 Winter 1978-1979, 1983, 1984,1986, 1987 Late Fall 1982,1983,1987	*Centropages typicus*	20800	95	10900	100	1700	100
	Cirripedia larva	3700	33	0	0	80	33
	Pseudocalanus sp.	2400	100	700	100	3400	100
	Sagitta elegans	2200	100	1700	100	1400	100
	Neomysis americana	1900	100	37000	100	1300	100
	Tortanus discaudatus	1200	95	10900	100	5060	100
	Temora longicornis	320	90	3960	100	6780	100
2 Winter 1980-1982	*Metridia* sp.	35700	100				
	Centropages typicus	18900	100				
	Limacina retroversa	13600	93				
	Pseudocalanus sp.	7900	93				
	Centropages sp. copepodite	4100	93				
	Temora longicornis	3200	86				
	Calanus finmarchicus	3100	100				
	Neomysis americana	2400	100				
	Sagitta elegans	2300	100				
	Tortanus discaudatus	2100	100				
	Oikopleura sp.	2100	100				
3 Late Winter-Early Spring	Cirripedia larva	292000	100			325000	100
	Centropages typicus	72200	93			900	100
	Calanus finmarchicus	54100	100			124000	100
	Oikopleura sp.	21100	93			11500	100
	Pseudocalanus sp.	9900	100			1100	100
4 Spring	*Calanus finmarchicus*	212000	100			42000	100
	Limacina retroversa	36500	92			500	100
	Oikopleura sp.	29700	100			800	100

(continued)

TABLE 3.1.3-2. (Continued)

GROUP	SPECIES	1978-1984 MEAN #/1000m^3	1978-1984 % FREQ.	1986 MEAN #/1000m^3	1986 % FREQ.	1987 MEAN #/1000m^3	1987 % FREQ.
4 Spring (cont)							
	Centropages typicus	23800	92			600	100
	Metridia sp.	21500	83			0	0
	Evadne sp.	19700	100			4100	100
	Temora longicornis	15000	83			2000	100
5 Late Spring-Early Summer	*Calanus finmarchicus*	101000	100	586000	100	86000	100
	Eualus pusiolus	37000	96	189000	100	12000	100
	Metridia sp.	30900	96	0	0	300	60
	Meganyctiphanes norvegica	29000	88	60200	100	1700	100
	Cancer sp. zoea & megalopa	26600	100	66000	100	24000	100
	Tortanus discaudatus	15300	96	0	0	2500	100
	Centropages typicus	14000	80	43300	100	85000	100
	Oikopleura sp.	13700	72	0	0	2700	100
	Sagitta elegans	9700	96	800	100	1300	80
6 Summer	*Centropages typicus*	263000	100	68000	100	386000	100
	Calanus finmarchicus	206000	100	102000	100	45000	100
	Cancer sp. zoea & megalopa	78700	100	88000	100	66000	100
	Podon sp.	54900	97	100	43	34000	60
	Centropages sp. copepodite	17200	85	5300	86	16000	80
	Eualus pusiolus	13000	100	17000	100	15000	100
	Carcinus maenas zoea & megalopa	11800	100	36000	100	15000	100
	Crangon septemspinosa	9900	100	27000	100	2400	100
	Centropages hamatus	2800	62	2600	86	11400	40
7 Fall	*Centropages typicus*	145000	100	247000	100	38000	100
	Podon sp.	13500	100	700	100	1800	100
	Centropages hamatus	5600	79	2900	100	18800	99

euphausiids and small copepods formed the basis of group 5 (Table 3.1.3-2). 1987 collections in this group extended into August, without a definite transition into the summer assemblage. Average group abundances of several species (*Metridia* sp., *Meganyctiphanes norvegica, Tortanus discaudatus*, and *Oikopleura* sp.) were an order of magnitude lower than 1978-1984 densities, coinciding with higher-than-average surface temperatures and continued lower-than-average salinity (Figures 3.1.1-1,3).

The summer assemblage (mid-July - mid-October, group 6) occurred during the period of peak temperatures and maximum thermocline (Figures 3.1.1-1, 3.1.1-2; Table 3.1.3-1). Historically, populations of *Calanus finmarchicus* and *Centropages typicus* reached peak or near-peak abundances at this time, while abundance levels of other copepods decreased. Meroplanktonic larval stages of decapods *Cancer* sp., *Carcinus maenas* and *Crangon septemspinosa*, and cladoceran *Podon* sp. all reached peak abundance during this period. The summer assemblage in 1987 was similar to previous years, with two exceptions. *Calanus finmarchicus*, an oceanic species (Gosner 1971), mean densities in group 6 were much lower than those observed historically (1978-1984). Estuarine species *Centropages hamatus*, which has a salinity preference of 1-31 ppt (Gosner 1971), had abundance levels that were an order of magnitude higher than historical average (Table 3.1.3-2). Low salinity levels, beginning in spring and continuing throughout the year, may have affected 1987 abundance levels of these two species.

The fall macrozooplankton assemblage (group 7) coincided with declining temperatures and degradation of the thermocline, characterized by fewer species and lower abundance levels than previous assemblages. Historically, copepod *Centropages typicus* has been the only taxon which occurred abundantly, with *Podon* sp. a secondary dominant in the group. 1987 collections in group 7 had a similar species composition, with mean group abundance levels of these two species an order of magnitude lower than those observed historically (Table 3.1.3-2). The estuarine copepod *Centropages hamatus*, historically not an important component of this group, had fall densities in 1987 that were an order of magnitude higher than those observed historically (Table 3.1.3-2).

Spatial Patterns

The spatial distribution of most holo- and meroplanktonic species in the study area are governed primarily by local currents. Hydrographic studies on temperature and salinity have shown that nearfield Station P2, and farfield Station P7 are exposed to the same water mass (NAI 1985a). Furthermore, bivalve larvae studies suggest that areas at similar depths and distances from shore (such as P2 and P5) have similar species composition (NAI 1977a). Thus no spatial differences in the mero- or holo-planktonic macrozooplankton abundances, percent composition, or rank would be expected among Stations P2, P5 or P7. This has been confirmed in examinations of the annual percent composition, percent frequency and rank dominance scores (RDS) of dominant species followed by nonparametric testing of apparent differences (NAI 1985b, 1987b).

Species composition among holoplankton was similar among the three stations in 1987 as well. Percent composition gives an idea of how total annual abundance compares among the three stations. Copepod *Centropages typicus* had highest percent composition at P2 and P7, and Cirripedia had second-highest percentages. At Station P5, Cirripedia were highest in percent composition, followed by *C. typicus* (Table 3.1.3-3). The only other difference noted among stations was a higher percent composition of *Temora longicornis* at P7 in comparison to P2 and P5. These species did not show significant differences among stations in semi-monthly abundances (Table 3.1.3-4). Rank dominance and percent frequency of occurrence give an indication of how frequently a taxon has been a dominant. *C. typicus* and *Calanus finmarchicus* were the top two species in ranks at all three stations (Table 3.1.3-5). Stations were similar in species ranks except for *Pseudocalanus* sp., which had a higher rank at Station P5 (3) than at P2 and P7 (6 and 5, respectively)(Table 3.1.3-5). In addition, *Tortanus discaudatus* had a higher rank (7) at P7 in comparison to P2 (11) and P5 (14)(Table 3.1.3-5). These species did not show significant differences in abundances (Table 3.1.3-4).

TABLE 3.1.3-3. COMPARISON OF PERCENT COMPOSITION (AND PERCENT FREQUENCY OF OCCURRENCE) OF SPECIES IN MACROZOOPLANKTON COLLECTIONS AMONG STATIONS P2, P5 AND P7, JANUARY-DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

	P2	P5	P7
Centropages typicus	33.0 (100)	22.5 (100)	24.3 (100)
Cirripedia	19.6 (42)	34.6 (42)	10.8 (42)
Calanus finmarchicus	16.1 (100)	17.1 (96)	14.3 (100)
Temora longicornis	5.8 (96)	4.5 (96)	16.8 (96)
Cancer sp.	5.7 (62)	4.2 (67)	6.5 (62)
Podon sp.	2.7 (58)	1.2 (67)	1.4 (67)
Pseudocalanus sp.	2.2 (92)	1.5 (100)	3.1 (96)
Centropages hamatus	1.9 (75)	1.3 (50)	1.4 (71)
Eualus pusiolus	1.7 (100)	2.6 (100)	3.9 (100)
Carcinus maenas	1.5 (54)	1.2 (58)	1.9 (54)
Centropages sp.	1.5 (79)	1.5 (83)	1.8 (88)
Tortanus discaudatus	1.1 (83)	0.5 (75)	1.0 (83)
Oikopleura sp.	1.0 (92)	1.4 (83)	1.0 (88)
Evadne sp.	1.0 (58)	1.3 (67)	0.8 (71)
Limacina retroversa	0.3 (67)	0.1 (75)	2.9 (83)
Sagitta elegans	0.6 (96)	0.2 (88)	2.2 (92)
Obelia sp.	0.5 (42)	0.5 (62)	1.9 (58)
Mysis mixta	0.1 (29)	<0.1 (29)	0.4 (25)
Diastylis sp.	<0.1 (92)	<0.1 (79)	<0.1 (62)

TABLE 3.1.3-4. SUMMARY OF 1987 BIWEEKLY ABUNDANCE COMPARISONS BETWEEN STATIONS MADE USING WILCOXON'S TWO SAMPLE TEST. SEABROOK BASELINE REPORT, 1987.

PARAMETER TESTED	TEST		
	P2 v. P5	P2 v. P7	P5 v. P7
Holoplankters			
Calanus finmarchicus	NS	NS	NS
Temora longicornis	NS	NS	NS
Centropages typicus	NS	NS	NS
Limacina retroversa	NS	NS	NS
Tortanus discaudatus	NS	NS	NS
Sagitta elegans	NS	NS	NS
Meroplankters			
Crangon septemspinosa	NS	NS	NS
Carcinus maenas	NS	NS	NS
Cirripedia	NS	NS	NS
Tychoplankters			
Neomysis americana	NS	NS	NS
Pontogeneia inermis	P2>P5*	P2>P7**	NS
Oedicerotidae	NS	NS	NS
Diastylis sp.	P2>P5**	P2>P7***	P5>P7*
Other			
Total Abundance	NS	NS	NS

*significant at $.01<p\leq.05$
**highly significant at $.001<p\leq0.01$
***very highly significant at $p\leq.001$

The probability of a type I error (falsely accepting a difference as significant) is 5% for any single test, but the probability of at least one type I error in this whole table (which contains 52 pairwise comparisons) is much greater than 5%. Therefore, only results that are very highly significant should be viewed as true differences.

TABLE 3.1.3-5. COMPARISON OF RANK[a] (AND PERCENT FREQUENCY OF OCCURRENCE) OF DOMINANT SPECIES IN MACROZOOPLANKTON COLLECTIONS AMONG STATIONS P2, P5 AND P7, JANUARY-DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

	P2	P5	P7
Centropages typicus	1/2 (100)	1 (96)	1 (100)
Calanus finmarchicus	1/2 (100)	2 (96)	2 (100)
Temora longicornis	3 (96)	4 (96)	3 (96)
Eualus pusiolus	4 (100)	5 (100)	4 (100)
Crangon septemspinosa	5 (100)	6 (96)	6 (96)
Pseudocalanus sp.	6 (92)	3 (100)	5 (96)
Neomysis americana	7 (100)	11 (92)	11 (92)
Oikopleura sp.	8 (92)	7 (83)	10 (83)
Pontogeneia inermis	9 (100)	12 (96)	19 (79)
Sagitta elegans	10 (96)	10 (88)	9 (92)
Tortanus discaudatus	11 (83)	14 (75)	7 (88)
Centropages sp.	13 (79)	8 (83)	8 (88)
Oedicerotidae	14 (92)	9 (96)	13 (88)

[a]based on Rank Dominance Score.

Tycho- and hypoplanktonic species, on the other hand, are often strongly associated with particular substrate types. Substrate type and complexity, along with proximity to Hampton-Seabrook estuary, may account for some of the differences observed among tychoplankters. Historically, *Neomysis americana, Pontogeneia inermis,* and *Diastylis* sp. had higher abundances at P2 where substrate is sand and cobble than at P7, the station farthest to the north where the substrate is mainly sand (NAI 1985b). A similar trend was confirmed in 1987, although differences were very highly significant only for *Diastylis* sp. (the number of tests performed necessitates a more stringent significance level to avoid a type I error) (Table 3.3.1-4). At Station P5, where substrate is largely ledge outcrop and cobble, 1987 densities of *P. inermis* and *Diastylis* sp. were lower than at P2 but did not meet significance level criteria. Amphipods in the family Oedicerotidae showed no significant differences in 1987 abundances among the three stations.

3.1.3.2 Selected Species

Calanus finmarchicus

Over the length of this study (1978-1984, 1987) *Calanus finmarchicus* has been a dominant species in the macrozooplankton assemblage (Table 3.1.3-2). Historically, copepodites exhibited greater abundances than adults, a trend which continued in 1987 (Table 3.1.3-6). The major peak in copepodite and adult abundance usually occurred April through September. Low abundances, especially of copepodites, occurred during winter (Figure 3.1.3-1). In 1987 adults were not observed in May and November, though copepodites were still abundant. In general, temporal abundance patterns in 1987 were typical of previous years (Table 3.1.3-7). A more detailed description of the life history of *Calanus finmarchicus* and other selected species is available in the 1984 baseline report (NAI 1984).

TABLE 3.1.3-6. ANNUAL GEOMETRIC MEAN ABUNDANCE (No./1000 m^3) AND UPPER AND LOWER 95% CONFIDENCE LIMITS OF SELECTED SPECIES OF MACROZOOPLANKTON AT SEABROOK NEARFIELD STATION P2, 1978-1984 AND 1987. SEABROOK BASELINE REPORT, 1987.

SPECIES/LIFESTAGES		1978	1979	1980	1981	1982	1983	1984	1987
Calanus finmarchicus	MEAN	8,999	6,614	19,753	13,159	4,756	12,634	8,819	8,555
copepodites	UCL	51,614	29,219	90,884	53,896	33,342	51,566	59,076	44,336
	LCL	1,568	1,496	4,293	3,212	668	3,095	1,316	1,650
Calanus finmarchicus	MEAN	767	129	338	116	186	555	518	160
adults	UCL	4,644	722	898	834	1,366	2,668	1,840	1,370
	LCL	126	22	127	15	25	115	145	18
Carcinus maenas	MEAN	41	22	42	40	40	93	64	62
larvae	UCL	406	276	573	592	512	1,394	722	904
	LCL	3	1	2	2	2	5	5	3
Crangon septemspinosa	MEAN	404	342	152	157	425	547	319	360
Zoeae and postlarvae	UCL	3,002	2,573	1,222	1,464	2,538	2,760	1,595	1,771
	LCL	54	45	18	16	71	108	63	72
Neomysis americana	MEAN	154	40	252	400	651	494	758	258
all lifestages	UCL	521	195	1,288	2,104	2,052	1,688	2,047	783
	LCL	45	8	49	75	206	144	280	84

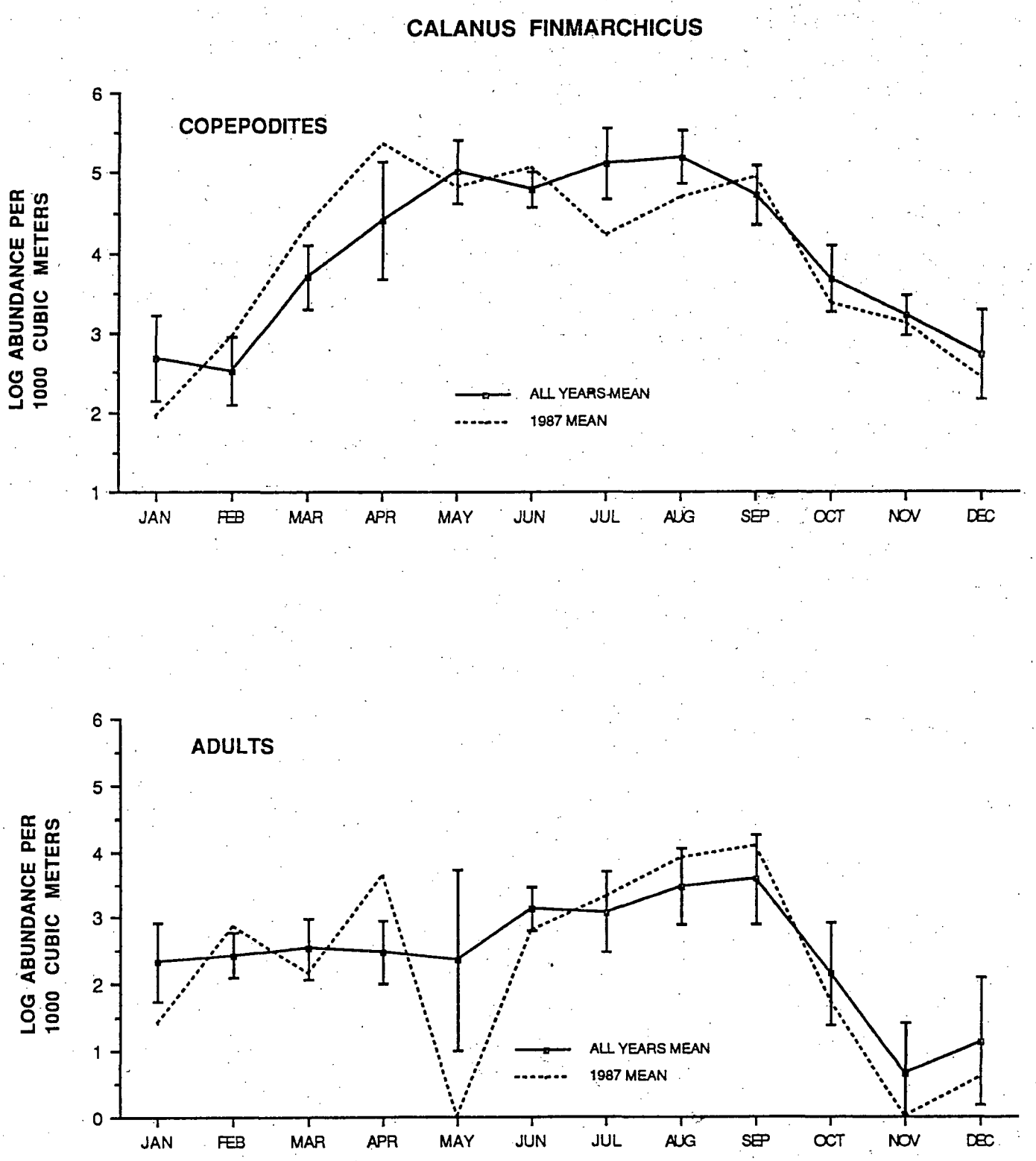


Figure 3.1.3-1. Log (x + 1) abundance per 1,000 cubic meters for *Calanus finmarchicus* copepodites and adults; monthly mean and 95% confidence interval over all years 1978-1984, 1986-1987 and monthly means for 1987. Seabrook Baseline Report, 1987.

TABLE 3.1.3-7. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE[a] AMONG YEARS FOR SELECTED SPECIES OF MACROZOOPLANKTON AT NEARFIELD STATION P2, 1978-1984 AND 1987. SEABROOK BASELINE REPORT, 1987.

SPECIES	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS							
Calanus finmarchicus copepodites	YEARS	7	7.78	0.75NS								
	ERROR	178	262.68									
	TOTAL	185	270.45									
Calanus finmarchicus adults	YEARS	7	21.47	1.65NS								
	ERROR	178	330.96									
	TOTAL	185	352.42									
Carcinus maenas larvae	YEARS	7	4.06	0.21NS								
	ERROR	178	498.27									
	TOTAL	185	502.33									
Crangon septemspinosa Zoeae and postlarvae	YEARS	7	7.08	0.63NS								
	ERROR	178	285.58									
	TOTAL	185	292.66									
Neomysis americana All lifestages	YEARS	7	27.70	3.57**	84	82	83	81	87	80	78	79
	ERROR	178	197.36									
	TOTAL	185	225.06									

[a]Based on semi-monthly sampling periods
NS = Not significant ($p > 0.05$)
* = Significant ($0.05 \geq p > 0.01$)
** = Highly significant ($0.01 \geq p \geq 0.001$)
*** = Very highly significant ($p \leq 0.001$)

3.2 FINFISH

3.2.1 Ichthyoplankton

3.2.1.1 Total Community

Nearfield (P2) ichthyoplankton data collected from 1976 through 1987 were examined for temporal (seasonal and year-to-year) patterns in species assemblages by discriminant analysis. Species composition and frequency of occurrence at the farfield station (P7) and at the discharge station (P5) were compared to data from P2 to detect any differences in ichthyoplankton communities among the sampling areas.

Common names recognized by the American Fisheries Society (Robins *et al.* 1980) are used for fish species in the text. The common and scientific names for every species collected from 1975 to 1987 in the Seabrook ichthyoplankton and adult finfish programs are listed with their relative abundances by gear type in Appendix Table 3.2.1-1. No newly-recorded species were encountered during the 1987 surveys, although fourspot flounder, which previously were only captured as adults, occurred in ichthyoplankton samples for the first time in 1987.

Temporal Patterns of Nearfield Fish Egg Assemblages

Numerical classification of 1976-1984 data had shown that the species composition of fish eggs was highly seasonal in nature, with different species occurring at different times of the year and generally the same seasonal succession repeating each year (NAI 1985b). The basic pattern over the 1976-1984 baseline period was summarized by nine groups of samples, each characterized by a particular assemblage of species occurring at a particular time of year (Table 3.2.1-1).

TABLE 3.2.1-1. DISTRIBUTION AMONG WEEKS[a] AND AMONG SEASONAL ASSEMBLAGES[b] OF SAMPLES OF FISH EGGS COLLECTED AT NEARFIELD STATION P2 DURING JANUARY 1976 THROUGH DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

	DISTRIBUTION OF SAMPLES[c]													
ASSEMBLAGE	JAN 1234	FEB 1234	MAR 1234	APR 1234	MAY 1234	JUN 1234	JUL 1234	AUG 1234	SEP 1234	OCT 1234	NOV 1234	DEC 1234	DOMINANT FISH EGGS[d]	GEOMETRIC MEAN DENSITY[e] (NO./1000 m^3)
1. FALL-WINTER	7917	BA 6								96	7069	8797	Atlantic cod	65
Cod-pollock	2424									12	8390	1033	Pollock	14
	4A4A										1412	3144		
	BBAB										3 33	42AA		
	B										4 44	A4BB		
											B BA	BACC		
											B	CB		
											C	C		
2. WINTER-	03 0	6819	7168	741	3							0	American plaice	56
SPRING	1 3	2342	8283	9A2									Atlantic cod/haddock	43
Plaice-cod		BB3	3394	0 4										
		C4	4A0A	1										
		B	AB1C	2										
			BC2	4										
			C 3	A										
			4											
			B											
			C											
3. SPRING				3868	78								American plaice	627
Plaice-				B399	00								Cunner/yellowtail flounder	160
cunner/				B03	14								Atlantic cod/haddock	113
yellowtail				34	2C									
				AA	3									
				BB	4									
				C	A									
					B									
					C									

continued

TABLE 3.2.1-1. (Continued)

ASSEMBLAGE	DISTRIBUTION OF SAMPLES[c] JAN 1234	FEB 1234	MAR 1234	APR 1234	MAY 1234	JUN 1234	JUL 1234	AUG 1234	SEP 1234	OCT 1234	NOV 1234	DEC 1234	DOMINANT FISH EGGS[d]	GEOMETRIC MEAN DENSITY[e] (NO./1000 m^3)
4. SPRING					967	81C							Cunner/yellowtail flounder	2690
Cunner/					A98	1C							Atlantic mackerel	1210
yellowtail-					B10	2								
mackerel					24	4								
					3A	A								
					3B	B								
					4C	C								
					A									
					B									
					C									
5. SUMMER						9680	7868	7160	7 4				Cunner/yellowtail flounder	8910
Cunner/						3793	3971	9 71					Hake	2830
yellowtail-						034	4093	0 9						
hake						24B	A104	4						
						3A	B33							
						4B	44							
						A	AB							
						B	B							
6. SUMMER						A	2C2B	3882	832				Hake	3390
Hake-cunner/						C	C AC	A233	2A				Cunner/yellowtail flounder	737
yellowtail							A	B34A	A				Windowpane	218
							C	4A						
								AB						
								BC						
								C						

continued

TABLE 3.2.1-1. (Continued)

ASSEMBLAGE	DISTRIBUTION OF SAMPLES[c] JAN 1234	FEB 1234	MAR 1234	APR 1234	MAY 1234	JUN 1234	JUL 1234	AUG 1234	SEP 1234	OCT 1234	NOV 1234	DEC 1234	DOMINANT FISH EGGS[d]	GEOMETRIC MEAN DENSITY[e] (NO./1000 m^3)
7. SUMMER-FALL								C	0996	843			Hake	210
Hake-									3130	9CC			Fourbeard rockling	25
rockling-									4BA1	1			Atlantic whiting	22
whiting									B B3	3				
									C4	4				
									A	C				
									B					
8. SUMMER-FALL								C 4	C4 C	A0			Hake/fourbeard rockling	84
Hake/								B	C	B			Windowpane	18
rockling-														
windowpane														
9. FALL	A	A	A							7343	AAC		Atlantic cod	20
Cod-										BA4	CB		Atlantic whiting	6
whiting-										BA	C		Hake	5
hake										B			Fourbeard rockling	2
										C				

[a] Within each month, Week 1 = dates 1-8, Week 2 = dates 9-15, Week 3 = dates 16-23, and Week 4 = dates 24-31.
[b] Assignment of samples from 1976 through 1984 to assemblages was based on numerical classification. Samples from 1985 through 1987 were classified into the 1976-1984 assemblages by discriminant functions.
[c] Each symbol represents a single sampling date: symbol = last digit of collection year for samples from 1976-1984, A=1985, B=1986, C=1987. For example, samples collected the first week of January (dates 1-8) were classified as containing the Fall-Winter-Cod-Pollock egg assemblage in the years 1977, 1982, 1984, and 1986, and containing the Winter-Spring-Plaice-Cod egg assemblage in the years 1980 and 1981.
[d] Taxa whose geometric mean densities were at least 5% of the total of all taxa analyzed.
[e] Based on 1976-1984 samples.

Two of the groups (8 and 9) had lower within-group similarity values (NAI 1985b) and lower numbrs of samples than the other seven groups. They were characterized by relatively low abundances of a few species that occurred during the fall (NAI 1987b).

Discriminant analysis agreed fairly well with numerical classification analysis in the recognition of the nine seasonal assemblages of eggs. Discriminant analysis assigned 196 of the 219 samples (89.5%) to the same group as that assigned by the cluster analysis. The seasonal groupings of samples recognized by discriminent analysis included late fall-early winter (Group 1), winter-early spring (Group 2), spring (Groups 3 and 4), summer (Groups 5 and 6), late summer-early fall (Groups 7 and 8), and fall (Group 9). Table 3.2.1-1 shows which samples were classified into each group, and what the dominant species and their densities were within each group.

The late fall-early winter cod-pollock assemblage (Group 1) appeared in 1987 from late November through the end of December. The Group 1 assemblage is characterized by moderate numbers of Atlantic cod and pollock eggs (65 and 14 per 1000 m^3, respectively), with very low abundances of other species ($\leq$ 0.3 per 1000 m^3). In previous years most January samples were also classified into Group 1 by both cluster analysis and discriminant analysis. The January samples from 1987 had a species composition similar to that of previous years but these samples were excluded from the analysis because of low densities.

The second seasonal group, a winter-early spring plaice and cod/haddock assemblage, occurred in February and March in 1987, which was typical of the baseline years' pattern. Pollock eggs were replaced by American plaice eggs as a dominant species during this seasonal period.

The spring plaice-cunner/yellowtail assemblage (Group 3) was present in April and May during 1987, similar to previous years. This group was characterized by an increase in the number of abundant species. In 1987, fourbeard rockling was the most abundant species (295 per 1000 m^3), followed by American plaice and cunner/yellowtail flounder, with relatively few

Atlantic cod/haddock eggs (7 per 1000 m^3) compared to 1976-1984 (NAI 1988). Most of the cunner/yellowtail flounder eggs at this time of year, while not identified to species, are assumed to be yellowtail flounder since this species begins spawning in March, while cunner do not typically begin spawning until June (Bigelow and Schroeder 1953).

The spring cunner/yellowtail flounder-mackerel assemblage (Group 4), was present the last two weeks of May and the first three weeks of June in 1987, which was similar to the previous baseline summary period (1976 through 1984). It exhibited high abundances of cunner/yellowtail flounder and mackerel eggs. Fourbeard rockling and windowpane eggs were also abundant.

A very abundant summer cunner-hake assemblage comprised the fifth group of the 1976-1984 baseline period. Generally, the Group 5 assemblage occurred from early June to late August or occasionally into September. Cunner/yellowtail flounder and hake eggs dominated egg collections during this period. Most of the eggs identified as cunner/yellowtail in these summer samples were probably cunner because yellowtail flounders spawn primarily in the spring whereas cunners spawn during the summer (NAI 1983b). Windowpane, Atlantic mackerel, fourbeard rockling, and Atlantic whiting eggs were also abundant in this seasonal group. None of the sample collections in 1987 were classified into this group.

A second summer group (Group 6) was a hake-cunner/yellowtail flounder assemblage. During the 1976-1984 summary baseline period, this assemblage occurred from early July to mid-September. Only four years were represented (1978, 1982, 1983 and 1984), with the majority of samples coming from the latter three years. During 1987, this assemblage first appeared in late June and was present through the end of August. This assemblage, which temporally overlapped the fifth group, usually had lower abundances of cunner/yellowtail eggs and higher abundances of hake eggs compared with Group 5. This assemblage was further characterized by moderate numbers of window-pane eggs. Other species also exhibited a decline from early summer

abundances. In 1987, cunner/yellowtail flounder eggs were very abundant during the late June through late August period, while hake eggs were moderately abundant (NAI 1988). The discriminant function analysis classified these samples with Group 6 rather than Group 5 mainly because of the absence of Atlantic mackerel and Atlantic whiting eggs during this period. These two species are often fairly abundant in July and early August, and are characteristic of the Group 5 assemblage. In 1987, however, mackerel eggs last occurred during the third week of June, and whiting eggs did not appear until the last week in August.

The seventh seasonal group, a late summer-early fall hake-rockling-whiting assemblage, was composed of samples collected from September to mid-October during the 1976-1984 baseline summary period. The only years not represented in this assemblage were 1977 and 1982. During 1987, this assemblage occurred during late August through the third week of October. Hake, although diminished in abundance in comparison to its density in Group 6 samples, still dominated egg collections. During 1987, as in the past, other species continued their gradual seasonal decline (NAI 1988).

A small summer-fall group (8), represented by only three samples during the 1976-1984 baseline period, temporally overlapped Groups 6 and 7. This egg assemblage contained most of the taxa occurring in Groups 6 and 7, but densities were generally lower. Four sampling dates in 1987 were classified with this group.

A small group of fall samples comprised Group 9. This assemblage was characterized by low to moderate densities of Atlantic cod eggs, along with modest numbers of eggs of species that are primarily late summer spawners: hake, Atlantic whiting, and fourbeard rockling. The samples from late October through the third week in November in 1987 were classified with this group.

Overall, the classification of the 1987 samples of fish eggs by discriminant analysis followed a similar seasonal pattern compared with both numerical and discriminant classifications of samples from previous years,

with the exception of increasingly more importance being assigned to two minor groups (8 and 9) consisting of late summer and fall samples, and also the absence in 1987 of the major summer assemblage represented in previous years by Group 5.

Atlantic herring, American sand lance, and winter flounder, which are important components of the larval assemblages discussed below, do not appear in the baseline analysis of fish eggs because these species have demersal rather than buoyant eggs. These eggs are rarely, if ever, collected in oblique tows through the water column.

Temporal Patterns of Nearfield Larval Fish Assemblages

Numerical classification analysis of fish larva abundances at the nearfield station (P2) during the period 1976-1984 revealed the same high degree of seasonality as was observed among eggs (NAI 1985b). The seasonal succession of larval assemblages can be summarized by four major groups, fall-winter, winter-spring, spring, and summer, each containing from one to three subgroups (NAI 1985b). Discriminant analysis placed each of the 1985-1987 samples into one of nine seasonal assemblages (Table 3.2.1-2).

The first major group, fall-winter, consisted of two larval assemblages (Groups 1 and 2). Atlantic herring larvae were the dominant species in Group 1, which occurred from early October to mid-November in the 1976-1984 baseline period (Table 3.2.1-2). Only a few other species were present during this period, all in very low abundances (NAI 1985b, 1986, 1987). During 1987 the Group 1 assemblage extended into the third week of January. Group 2 (late fall-early winter) was dominated by pollock and Atlantic herring, with the latter displaying decreased abundance from the collections earlier in the fall.

TABLE 3.2.1-2 DISTRIBUTION AMONG WEEKS[a] AND AMONG SEASONAL ASSEMBLAGES[b] OF SAMPLES OF FISH LARVAE COLLECTED AT NEARFIELD STATION P2 DURING JANUARY 1976 THROUGH DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

	DISTRIBUTION OF SAMPLES[c]													
ASSEMBLAGE	JAN 1234	FEB 1234	MAR 1234	APR 1234	MAY 1234	JUN 1234	JUL 1234	AUG 1234	SEP 1234	OCT 1234	NOV 1234	DEC 1234	DOMINANT FISH LARVAE[d]	GEOMETRIC MEAN DENSITY[e] (NO./1000 m^3)
1. FALL Herring	C									4496 BA02 B13 24 4A BB CC	724A 13AB 34BC 4 C A C	B B C	Atlantic herring	192
2. FALL-WINTER Pollock-herring	7AA 1BB A B	4A									069 A90 B12 C 3 4	8797 3032 41A3 A4B4 A A B C	Pollock Atlantic herring Atlantic cod	19 12 3
3. WINTER Sand lance	997 300 C 4 A B C	68 14 2 A B	8	4B	2							1208	American sand lance	199
4. WINTER-SPRING Sand lance - cod	2 3 C	CBC C	7	C4	A C								American sand lance Atlantic cod Snailfishes (*Liparis* spp.)	10 1 1

continued

TABLE 3.2.1-2. (Continued)

ASSEMBLAGE	DISTRIBUTION OF SAMPLES[c] JAN 1234	FEB 1234	MAR 1234	APR 1234	MAY 1234	JUN 1234	JUL 1234	AUG 1234	SEP 1234	OCT 1234	NOV 1234	DEC 1234	DOMINANT FISH LARVAE[d]	GEOMETRIC MEAN DENSITY[e] (NO./1000 m^3)
5. WINTER-SPRING Sand lance-rock gunnel	2	C016	8168	7898	4								American sand lance	425
		349	3293	930B									Rock gunnel	47
		BA0	4304	0B1									Snailfishes (Liparis spp.)	25
		2	AA1A	1 2										
		3	BB2B	2 3										
		4	CC3C	3 4										
		A	4	4										
		B	A	B										
			B	C										
			C											
6. SPRING Winter flounder-snailfish				69	7867	8684	29						Winter flounder	55
				3	099B	979A	B4						Snailfishes (Liparis spp.)	45
				A	3010	104B							Radiated shanny	41
					B324	21A							American plaice	33
					43A	32B								
					A3B	43								
					B4C	A4								
					CA	BA								
					B	CB								
					C	C								
7. SUMMER Cunner-rockling						30	7868	7860	79C1				Cunner	414
						C3	3071	9373	33				Fourbeard rockling	77
							4193	049C	4A				Atlantic whiting	29
							A304	3 3	CC					
							A2C	4 4						
							B3	C						
							C4							

continued

TABLE 3.2.1-2. (Continued)

ASSEMBLAGE	DISTRIBUTION OF SAMPLES[c] JAN 1234	FEB 1234	MAR 1234	APR 1234	MAY 1234	JUN 1234	JUL 1234	AUG 1234	SEP 1234	OCT 1234	NOV 1234	DEC 1234	DOMINANT FISH LARVAE[d]	GEOMETRIC MEAN DENSITY[e] (NO./1000 m^3)
8. SUMMER							C	AB	A181	8 40			Cunner	32
Cunner								B	B2AA	A				
								C	AC					
									C					
9. SUMMER-FALL						C		A	B 2	0 96	83A		Fourbeard rockling	22
Rockling									4	2 23	1C		Windowpane	4
										34	3		Witch flounder	3
										AA	C		Hake	2
										C			Cunner	2

[a] Within each month, Week 1 = dates 1-8, Week 2 = dates 9-15, Week 3 = dates 16-23, and Week 4 = dates 24-31.
[b] Assignment of samples from 1976 through 1984 to assemblages was based on numerical classification. Samples from 1985 through 1987 were classified into the 1976-1984 assemblages by discriminant functions.
[c] Each symbol represents a single sampling date: symbol = last digit of collection year for samples from 1976-1984, A=1985, B=1986, C=1987. For example, samples collected in the first week of January (dates 1-8) were classified as containing the Fall-Winter-Pollock-Herring larval assemblage in the years 1977, 1981, 1985, and 1986, and containing the Winter-Sand Lance larval assemblage in the years 1982 and 1987.
[d] Taxa whose geometric mean densities were at least 5% of the total of all taxa analyzed.
[e] Based on 1976-1984 samples.

American sand lance larvae dominated the second major seasonal period, winter-spring, consisting of Groups 3, 4, and 5 (Table 3.2.1-2). Group 3 samples were characterized by moderate abundances of American sand lance (199 per 1000 m^3) and relatively low numbers of a number of other winter species (≤ 6 per 1000 m^3). This assemblage usually occurred from some time in December to about mid-February. Two samples from 1987 were classified with this group. The Group 4 assemblage consisted of four samples in winter and spring of 1976-1984 that had lower densities of larvae and fewer numbers of species than in Group 3, with sand lance still being the dominant species. An unusually large number of samples (six) from 1987 were classified into this group, an indication that densities on those dates in 1987 were lower than typical for most years. Group 5 consisted of a large number of late winter and early spring samples characterized by high densities of American sand lance (425 per 1000 m^3) and moderate densities of rock gunnel (47 per 1000 m^3) and snailfishes (25 per 1000 m^3, primarily *Liparis coheni*). This larval assemblage usually was present approximately from mid-February to late April. Six dates from early February to early April in 1987 were classified with Group 5.

A spring larval assemblage was usually present during May and June in 1976-1984. These samples comprised the third major seasonal group, Group 6. The spring group, as in previous years, was characterized in 1987 by moderate numbers of winter flounder, snailfishes (primarily *Liparis atlanticus*), radiated shanny, and American plaice larvae. This assemblage was present from mid-May to mid-June in 1987.

The fourth major seasonal group, summer-early fall, consisting of Groups 7, 8 and 9, typically lasted from early July to early October. Group 7, the largest of the three groups, was mainly characterized by high densities of cunner larvae and moderate densities of fourbeard rockling and Atlantic whiting. Witch flounder, Atlantic mackerel, windowpane, and hake larvae were also important in these samples, which were primarily from July, August, and early September. Group 8 is distinguished from Group 7 by lower densities and fewer species, with cunner being the only important species.

Group 9 consists of late summer and early fall samples characterized by a fourbeard rockling larval assemblage. Besides modest numbers of rockling, a few other species were occasionally important in these samples (windowpane, witch flounder, hake, cunner), although both densities of larvae and numbers of species were characteristically low. This was also a relatively small group in 1976-1984 (n=14) that received several additions in 1985-1987 (n=10).

In general, the results of the 1987 discriminant analysis for fish larvae agreed with previous seasonal and species groupings determined by numerical classification (NAI 1985b): 94% of the 1976-1984 samples were classified by the discriminant functions into the same groups as by the cluster analysis, and the classification of 1985-1987 samples followed a similar seasonal pattern to those from the earlier years. In most cases where the two methods differed, the samples in question had relatively low numbers of larvae. For example, Group 8 was originally a small group (only seven samples in the nine-year period 1976-1984), but in the last three years an additional 13 samples have been classified here by the discriminant function analysis, including four from 1987. This tendency of discriminant functions to assign greater importance to minor groups compared to the original numerical classification was also noted in the analysis of egg data. The two methods use different procedures to evaluate the similarity of individual samples with each other. Discriminant functions sometimes place greater emphasis on subdominant species in differentiating among groups, whereas the Bray-Curtis similarity index used in the cluster analysis of the 1976-1984 data is strongly influenced by abundance, and thus places greater emphasis on the dominant species.

Spatial Patterns of Fish Eggs and Larvae

Spatial comparison of abundance and species composition from the nearfield and farfield stations was previously done using numerical classification for both fish eggs and larvae. Spatial (station) differences were

found to be less important than short-term temporal differences (NAI 1983b, 1984b). Samples collected on the same date at different stations (nearfield or farfield) more likely resembled each other than if collected one to two weeks apart at the same station. This similarity in species composition and abundance between nearfield and farfield sites was consistent with the known extent of water mass movements in the study area. During 1987, the relative abundance and frequency of occurrence of all taxa in ichthyoplankton samples were very similar among the three areas sampled for both eggs and larvae (Tables 3.2.1-3 and 3.2.1-4).

Tidal currents and longshore (northward and southward) currents in the study area are typically in the range of 0.2 to 0.6 knots about 75% of the time (NAI 1980d). Currents of this magnitude would transport a water mass about two nautical miles during a single tidal excursion, or about 5-15 miles in 24 hours during periods dominated by longshore flow. The distance from Nearfield Station P2 to P5 (1-1/2 miles) or to P7 (3-1/2 miles) is relatively short. Considering that, for example, a water mass sampled at Station P2 could very possibly have been located at Station P7 a few hours before sampling, rigorous treatment of these locations as distinct from each other in terms of plankton is not justified. Since previous baseline reports have confirmed statistically that ichthyoplankton densities and species composition do not differ among stations, and data from 1987 are very similar among stations (Tables 3.2.1-3 and 3.2.1-4) no further analysis was conducted.

Entrainment Species Assemblages

Although Seabrook Station was not generating power or discharging heat in 1987, the circulating water system was operated for the entire year, however, pumps were only operating consistently enough to run the entrainment sampling apparatus from January through June. The flow rates for the sampling dates for the first six months are found on Table 3.2.1-5. Flow rates per month averaged between 240 and 480 million gallons per day. As a preliminary evaluation of entrainment effects, ichthyoplankton samples were

TABLE 3.2.1-3. COMPARISON OF PERCENT ABUNDANCE AND PERCENT FREQUENCY OF FISH EGG COLLECTIONS AT NEARFIELD (P2), FARFIELD (P7) AND DISCHARGE (P5) STATIONS DURING 1987. SEABROOK BASELINE REPORT, 1987.

	NEARFIELD		FARFIELD		DISCHARGE	
	PERCENT ABUN-DANCE	PERCENT FRE-QUENCY	PERCENT ABUN-DANCE	PERCENT FRE-QUENCY	PERCENT ABUN-DANCE	PERCENT FRE-QUENCY
Brevoortia tyrannus	0.00	0.00	<0.01	2.17	<0.01	2.17
Enchelyopus cimbrius	2.34	60.87	3.03	56.52	3.40	52.17
Enchelyopus/Urophycis	2.26	32.61	7.75	30.43	3.93	34.78
Gadidae/*Glyptocephalus*	0.29	36.96	0.55	39.13	0.37	36.96
Gadus morhua	0.26	56.52	0.55	58.70	0.32	58.70
Gadus/Melanogrammus	0.05	17.39	0.11	17.39	0.05	15.22
Glyptocephalus cynoglossus	0.15	28.26	0.43	36.96	0.31	32.61
Hippoglossoides platessoides	0.16	30.43	0.37	34.78	0.29	39.13
Labridae/*Limanda*	65.36	50.00	52.84	54.35	55.34	52.17
Limanda ferruginea	<0.01	2.17	0.06	4.35	<0.01	2.17
Melanogrammus aeglefinus	<0.01	4.35	<0.01	2.17	<0.01	2.17
Merluccius bilinearis	0.34	23.91	1.31	26.09	0.60	28.26
Osteichthyes	0.00	0.00	0.02	2.17	0.00	0.00
Pollachius virens	0.02	19.57	0.04	21.74	0.05	23.91
Scomber scombrus	19.18	13.04	19.57	19.57	26.17	13.04
Scophthalmus aquosus	3.19	43.48	2.82	43.48	2.78	47.83
Tautoga onitis	0.07	8.70	0.10	6.52	0.02	4.35
Tautogolabrus adspersus	3.96	32.61	7.26	28.26	3.16	34.78
Urophycis sp.	2.35	45.65	3.20	43.48	3.21	47.83

TABLE 3.2.1-4. COMPARISON OF PERCENT ABUNDANCE AND PERCENT FREQUENCY OF LARVAL FISH SPECIES AT NEARFIELD (P2), FARFIELD (P7) AND DISCHARGE (P5) STATIONS DURING 1987. ONLY COMMON SPECIES ARE LISTED (PERCENT FREQUENCY AT LEAST 10% AT ONE OR MORE STATIONS). SEABROOK BASELINE REPORT, 1987.

	NEARFIELD		FARFIELD		DISCHARGE	
	PERCENT ABUN-DANCE	PERCENT FRE-QUENCY	PERCENT ABUN-DANCE	PERCENT FRE-QUENCY	PERCENT ABUN-DANCE	PERCENT FRE-QUENCY
Ammodytes americanus	7.70	45.65	5.10	43.48	4.82	45.65
Anguilla rostrata	0.02	13.04	0.02	13.04	<0.01	2.17
Brevoortia tyrannus	1.50	8.70	1.05	10.87	2.23	13.04
Clupea harengus	3.70	54.35	7.17	50.00	4.25	52.17
Enchelyopus cimbrius	5.12	52.17	5.71	41.30	9.18	56.52
Gadus morhua	0.14	39.13	0.06	36.96	0.14	45.65
Glyptocephalus cynoglossus	0.99	26.09	1.58	36.96	1.68	36.96
Hippoglossoides platessoides	0.49	23.91	0.15	23.91	0.19	21.74
Limanda ferruginea	0.29	17.39	1.78	36.96	1.18	28.26
Liparis atlanticus	2.99	21.74	0.53	17.39	0.94	21.74
Liparis coheni	0.39	28.26	0.24	30.43	0.38	36.96
Merluccius bilinearis	2.10	21.74	1.44	19.57	3.62	21.74
Myoxocephalus aenaeus	0.33	23.91	0.44	26.09	0.18	21.74
Myoxocephalus octodecemspinosus	0.18	19.57	0.25	17.39	0.21	26.09
Myoxocephalus scorpius	0.03	6.52	0.06	10.87	0.01	6.52
Pholis gunnellus	2.14	28.26	1.68	28.26	2.07	23.91
Pollachius virens	0.09	19.57	0.12	21.74	0.10	21.74
Pseudopleuronectes americanus	1.89	23.91	1.65	17.39	1.31	23.91
Scomber scombrus	40.82	13.04	48.79	15.22	53.72	15.22
Scophthalmus aquosus	0.24	30.43	0.27	26.09	0.38	36.96
Sebastes sp.	0.20	13.04	0.12	13.04	0.16	15.22
Tautoga onitis	0.40	21.74	0.09	10.87	0.03	13.04
Tautogolabrus adspersus	25.04	36.96	20.22	36.96	10.61	41.30
Ulvaria subbifurcata	2.38	41.30	0.98	43.48	1.96	41.30
Urophycis sp.	0.48	21.74	0.35	21.74	0.33	28.26

TABLE 3.2.1-5. MEAN MONTHLY FLOW (MILLIONS OF GALLONS PER DAY) THROUGH THE SEABROOK CIRCULATING WATER SYSTEM, JANUARY - JUNE 1987. SEABROOK BASELINE REPORT, 1987.

MONTH	NUMBER OF DAYS OPERATING	MEAN FLOW (millions of gallons/day)
JAN	31	367
FEB	28	480
MARCH	31	432
APRIL	30	411
MAY	31	240
JUNE	30	266

collected periodically in the intake pumphouse (Station E1) from January 6 through June 10, 1987. Generally, entrainment samples were collected within hours of the offshore nearfield collections (Station P2), but not necessarily on the same day (Table 3.2.1-6). These two stations were chosen for comparative analysis because P2 is the closest offshore station to the intake structure (Figure 4.1-1). More samples were collected at the nearfield station (18 dates vs. 11), contributing to some differences discussed below. Since there were no samples collected at E1 for the month of March, data from Station P2 for March were not used in any comparisons between stations. Entrainment pump sample volumes averaged 100 m^3 (as designed) as compared to approximately 489 m^3 for offshore towed net samples for the same time period (NAI 1987).

Fish egg taxa in entrainment samples had similar species composition to those in offshore nearfield collections (Table 3.2.1-7). Atlantic mackerel, American plaice, cod/witch flounder, fourbeard rockling/hake, cunner/ yellowtail flounder, and windowpane were the six most abundant taxa in the in-plant samples. In general, mean abundances and the total number of taxa at Station P2 exceeded those observed in entrainment samples. Species such as Atlantic mackerel, windowpane, and fourbeard rockling, which have large oil globules, exhibit characteristics similar to other buoyant species in the middle Atlantic bight (Kendall and Naplin 1981) in that they tend to be found more often at surface depths. Because of this tendency to concentrate near the surface, eggs of these species were less abundant in the entrainment samples than in the oblique offshore tows, because the plant intake draws water from well below the surface. Cunner/yellowtail flounder eggs were two orders of magnitude higher in abundance at Station P2 than at Station E1. Although this species lacks an oil globule, previous studies (NAI 1980, 1981) have shown that this species is present in much greater abundances in middle and surface depths. Species such as American plaice and Atlantic cod/witch flounder, which lack oil, may be less buoyant and therefore more abundant in the bottom portions of the water column, thus accounting for the larger abundances observed in in-plant samples compared with

TABLE 3.2.1-6. ICHTHYOPLANKTON SAMPLING DATES AT ENTRAINMENT (EI) AND NEARFIELD (P2) SAMPLING STATIONS, JANUARY - JUNE 1987. SEABROOK BASELINE REPORT, 1987.

		SAMPLING DATES	
MONTH	WEEK	E1	P2
January	1	6	5
	2	--	12
	3	--	21
	4	--	28
February	1	3	3
	2	--	12
	3	17	18
	4	--	25
March	1	--	5
	2	--	12
	3	--	19
	4	--	25
April	1	2	8
	2	16	--
	3	22	21
	4	30	--
May	1	7	7
	2	--	14
	3	--	19
	4	26	27
June	1	3	3
	2	10	9
	3	--	18
	4	--	29

-- = Not sampled

TABLE 3.2.1-7. MEAN ABUNDANCE (NO./1000 m^3) OF FISH EGGS PER MONTH AT STATIONS E1 AND P2 FROM JULY 1986 - JUNE 1987. SEABROOK BASELINE REPORT, 1987.

	1986													
	JUL		AUG		SEP		OCT		NOV		DEC		JUL-DEC MEAN	
SPECIES	E1	P2	E1	P2	E1	P2	E1	P2	E1	P2	E1	P2	E1	P2
Cunner/Yellowtail flounder	1552	7611	8	862	0	96							260	1428
Rockling/Hake	466	530	58	776	7	400	0	10					88	206
Windowpane	155	177	20	232	26	72	0	2					33	81
Hake	34	4003	70	1415	56	504	5	11	0	<1			28	989
Pollock							0	1	5	15	119	21	21	6
Cunner	121	161	0	133									20	49
Atlantic cod							2	9	37	537	62	205	17	125
Fourbeard rockling	0	52	2	54	43	263	4	18	0	<1			8	65
Atlantic mackerel	17	0											3	0
Cod/Witch flounder			2	2	0	3	2	88					<1	16
Witch flounder			2	4									<1	<1
Atlantic whiting			0	3	2	30	0	6	0	<1			<1	7
Tautog			0	29									0	5
Unidentified species			0	1	0	3			0	<1			0	<1
Yellowtail flounder					0	1							0	<1
Cusk							0	<1					0	<1
Number of Taxa	6	6	7	11	5	9	4	9	2	6	2	2		

continued

TABLE 3.2.1-7. (Continued)

SPECIES	JANUARY E1	JANUARY P2	FEBRUARY E1	FEBRUARY P2	APRIL E1	APRIL P2	MAY E1	MAY P2	JUNE E1	JUNE P2	JAN-JUN MEAN[a] E1	JAN-JUN MEAN[a] P2
	1987											
Atlantic mackerel							46	102	1,114	19,585	232	3937
American plaice	0	<1	2	3	166	26	185	79	254	39	121	30
Cod/witch flounder					0	<1	223	48	396	178	124	45
Rockling/hake							226	6	219	322	89	66
Cunner/yellowtail flounder					15	2	72	533	206	28,201	59	5747
Windowpane							12	147	256	1916	54	413
Fourbeard rockling					55	118	0	747	0	1248	11	423
Cod/haddock			0	7	22	0					4	1
Atlantic cod	27	4	8	2			0	<1	15	40	10	9
Pollock	7	6									1	1
Lumpfish					1	0					<1	0
NUMBER OF TAXA	2	3	2	3	5	4	6	8	7	8		

[a]March excluded because no entrainment samples were taken that month.

offshore samples. Larger sample volumes and greater frequency of collection contributed to the higher number of taxa found in the offshore samples compared to entrainment samples.

Entrained fish larvae also followed trends in species composition similar to those observed in the offshore nearfield station collections (Table 3.2.1-8). Abundance of larvae at both stations was virtually identical for all species, except American sand lance, which was four times higher at the offshore nearfield station than at the entrainment station. American sand lance larvae have been shown to prefer surface depths (Dalley and Winters 1987), which might explain the larger abundances for the offshore oblique tows at Station P2 (the cooling water intake is 5 m above the bottom in 17 m of water). As was the case for fish eggs, offshore collections, which had larger sample volumes and greater sampling frequency, exhibited a higher number of taxa than found at the nearfield station.

3.2.1.2 Selected Species

Larvae of nine fish species were selected for a detailed analysis of their within-year and among-year patterns of abundance because of their numerical dominance or importance as a recreational or commercial species. Analyses were based on a series of monthly means for Nearfield Station P2 samples collected from July 1975 through December 1987. These monthly means were averages of two to four tows on one to four dates within each month.

Each of the nine species displayed distinct seasonal patterns of abundance. While fish larvae were present in every month, the larvae of each species exhibited a sharply defined period of only a few months' duration in which their peak abundance occurred. Values in other months were typically much lower and were often zero. These seasonal fluctuations were the primary reason for the high within-year variances calculated for each species (NAI 1983b). To reduce overall variability and improve statistical power, or ability to detect significant year-to-year differences in abundance, seasonal

TABLE 3.2.1-8. MEAN ABUNDANCE (NO./1000 m^3) OF FISH LARVAE PER MONTH AT STATIONS E1 AND P2. SEABROK BASELINE REPORT, 1987.

	1986													
	JUL		AUG		SEP		OCT		NOV		DEC		JUL-DEC MEAN	
SPECIES	E1	P2	E1	P2	E1	P2	E1	P2	E1	P2	E1	P2	E1	P2
Atlantic herring					0	<1	1039	429	243	695	84	53	228	196
Pollock									7	17	9	3	3	3
Cunner	0	16	4	18	<1	2							<1	6
Fourbeard rockling	0	9	3	2	<1	<1	0	12	0	<1			<1	4
Radiated shanny	0	11	2	4	2	2							<1	3
Northern pipefish	0	2	0	<1	<1	<1	1	1					<1	<1
American sand lance											2	3	<1	<1
Unidentified species			0	<1			1	1			0	<1	<1	<1
Gadidae							0	<1	2	0			<1	<1
Goosefish									2	<1			<1	<1
Seasnail			1	0									<1	0
Atlantic mackerel	0	13											0	2
Witch flounder	0	2	0	8									0	2
Windowpane			0	5	0	1	0	<1					0	1
Atlantic cod			0	<1					0	3	0	<1	0	<1
Atlantic whiting					0	<1	0	2	0	<1			0	<1
Arctic shanny	0	2											0	<1
Hake					0	<1	0	2					0	<1
Yellowtail flounder			0	<1									0	<1
NUMBER OF TAXA	0	7	4	9	4	8	3	8	4	6	3	5		

(continued)

TABLE 3.2.1-8. (Continued)

SPECIES	1987 JANUARY E1	JANUARY P2	FEBRUARY E1	FEBRUARY P2	APRIL E1	APRIL P2	MAY E1	MAY P2	JUNE E1	JUNE P2	JAN-JUN MEAN[a] E1	JAN-JUN MEAN[a] P2
Seasnail					36	22	55	326	156	14	49	72
American sand lance	10	400	140	153	29	42	0	16	0	6	36	123
Grubby	0	<1	3	<1	54	20	2	6			12	5
Rock gunnel	0	1	15	20	37	2	0	<1			10	5
Winter flounder					0	<1	5	141	44	75	10	43
American plaice					1	4	0	13	38	42	8	12
Atlantic herring	23	24	5	6	1	4	0	2			6	7
Atlantic cod	0	<1	0	2	1	<1	0	<1	15	3	3	1
Gulf snailfish	7	10	4	14	2	11	0	3			3	8
Moustache sculpin			5	0							1	0
Sculpin			2	0							<1	0
NUMBER OF TAXA	3	6	7	6	8	9	3	9	4	5		

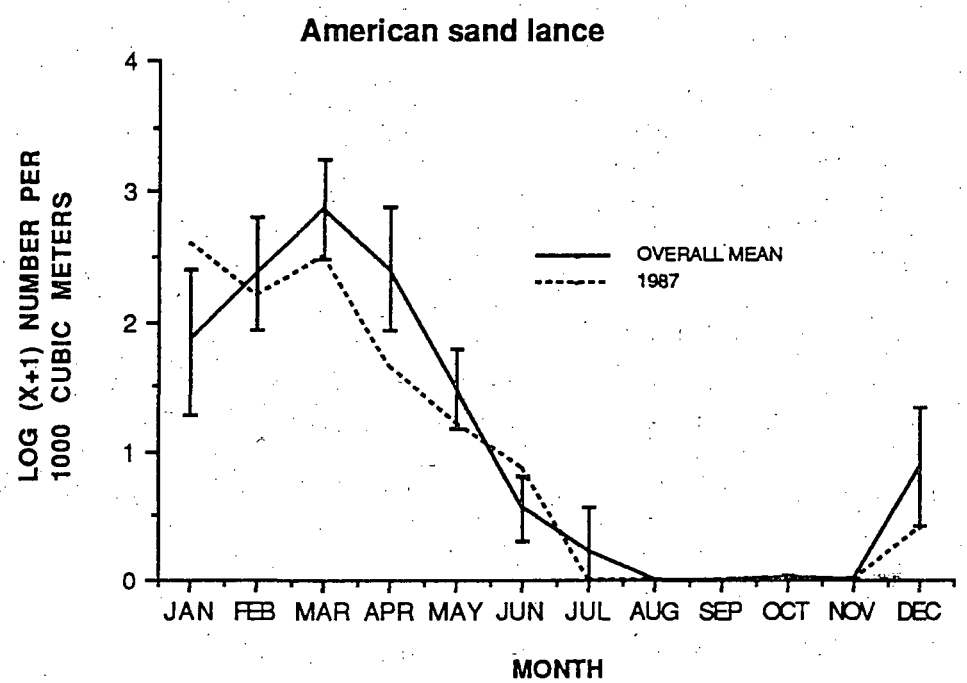
[a]March excluded because no entrainment samples were taken that month.

mean abundances (and upper and lower confidence limits) were calculated using data only from sampling periods which encompassed the seasonal peak in larval abundance. These select periods included the season of maximum yearly abundance and approximately 90% of total yearly catch for each species. Abundances from this subset were used to test for significant differences among years with a one-way analysis of variance and when differences were found to be significant they were subjected to a Waller-Duncan K-ratio t-test for multiple comparisons.

Because 1975 data only include July-December samples, that year was only included in the analysis of variance for those taxa whose peak season does not include months prior to July: hake, Atlantic herring, and pollock. The analysis of pollock data excludes 1987 because each year's peak season for pollock includes January and February of the following year, and 1988 data are not included in this baseline report.

American Sand Lance

American sand lance larvae continued to exhibit a December through July presence with peak abundance occurring from January through April (Figure 3.2.1-1). In 1987, abundances dropped off in April but continued through June, then dropped to zero in July. This broad peak was due primarily to two factors: an extended hatching period and a long planktonic stage for larvae (Bigelow and Schroeder 1953). Sand lance, the most abundant species over all years, has been highly variable (Table 3.2.1-9). Starting in 1976, with 353 larvae per 1000 cubic meters, abundances decreased in 1977 to 35 larvae per 1000 cubic meters, the lowest value for any year of the study. In 1978, the abundances of sand lance increased to 384 larvae per 1000 cubic meters, then in subsequent years alternately decreased then increased. The highest abundance for sand lance larvae was recorded in 1982 (448 larvae/1000 m^3). Abundance for 1987 (87.9 larvae/1000 m^3) was the third lowest abundance during the thirteen years of the study. Using the peak season data, a one-way analysis of variance showed no significant difference among years for log (x + 1) transformed abundances (Table 3.2.1-10).



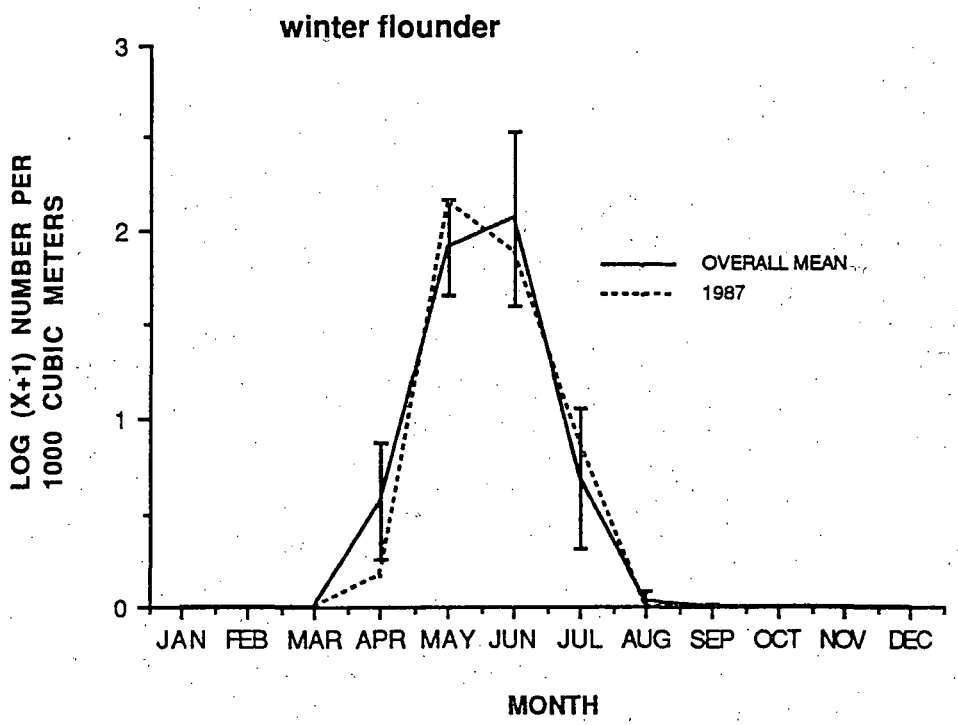


Figure 3.2.1-1. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x+1) transformed abundance (No./1000 m^3) for American sand lance and winter flounder larvae at stations P2 and P3, July 1975 through December 1987. Seabrook Baseline Report, 1987.

TABLE 3.2.1-9. GEOMETRIC MEAN OF SEASON OF PEAK ABUNDANCE (NUMBER PER 1000 M^3) BY YEAR OF SELECTED FISH SPECIES LARVAE AT STATION P2 JULY 1975 THROUGH DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

SPECIES (and months included)	YEAR 1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	OVER-ALL MEAN	CONFIDENCE LIMIT LOWER	CONFIDENCE LIMIT UPPER
American sand lance (Jan-Apr)	-[a]	352.9	35.0	384.0	203.2	219.7	213.7	447.7	95.0	73.8	71.5	314.8	87.9	147.0	99.9	216.0
Winter flounder (Apr-Jul)	-	12.5	10.4	17.6	7.9	9.5	2.9	12.4	14.4	19.7	22.4	19.1	15.4	13.8	9.2	20.7
Yellowtail flounder (May-Aug)	-	3.7	20.2	4.1	12.4	6.5	1.3	0.3	4.3	2.8	2.2	5.3	1.7	3.6	2.4	5.2
Atlantic cod (Apr-Jul)	-	4.7	9.4	16.1	1.2	3.4	9.9	2.8	1.8	2.1	1.3	1.6	0.6	2.5	1.7	3.6
Atlantic mackerel (May-Aug)	-	2.6	5.4	2.3	8.0	24.2	12.4	4.3	12.0	8.4	11.7	12.4	8.5	9.0	5.3	14.7
Cunner (June-Sep)	-	21.1	224.5	30.3	46.2	97.7	29.1	22.6	97.9	22.7	40.7	12.4	255.2	48.4	29.7	78.6
Hake (Jul-Sep)	6.5	0.5	4.2	2.7	8.2	5.4	5.9	2.4	10.4	7.8	10.0	0.1	3.2	4.4	2.6	7.0
Atlantic herring (Oct-Dec)	197.0	144.7	16.1	2.1	7.4	34.0	50.0	62.7	9.3	40.3	21.5	126.7	28.8	30.9	19.8	47.7
Pollock (Nov-Feb)	12.2	27.7	5.1	1.9	49.2	7.3	4.0	2.1	3.4	22.8	13.8	1.2	-[b]	7.0	4.6	10.3

[a] Sampling at P2 began in July 1975, excluding part of annual peak.
[b] Yearly mean not computed for pollock in 1987 because January and February 1988 data were not available.

TABLE 3.2.1-10. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE AMONG YEARS OF LOG (x + 1) TRANSFORMED ABUNDANCES (NO./1000 m^3) OF SELECTED SPECIES DURING SELECTED MONTHS, JULY 1975 THROUGH DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

SPECIES (AND MONTHS INCLUDED)	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS
American sand lance (Jan-Apr)	Years	11	11.43	1.27 NS	
	Error	107	87.55		
	Total	118	98.99		
Winter flounder (Apr-Jul)	Years	11	4.81	0.45 NS	
	Error	118	112.26		
	Total	129	117.07		
Yellowtail flounder (May-Aug)	Years	11	10.02	1.74 NS	
	Error	120	66.63		
	Total	131	76.65		
Atlantic cod (Apr-Jul)	Years	11	10.43	2.35 *	78 81 77 76 80 82 84 83 86 85 79 87
	Error	118	47.49		
	Total	129	57.92		
Atlantic mackerel (May-Aug)	Years	11	5.79	0.38 NS	
	Error	120	168.13		
	Total	131	173.92		
Cunner (Jun-Sep)	Years	11	21.79	1.46 NS	
	Error	117	159.30		
	Total	128	181.10		
Hake (Jul-Sep)	Years	12	10.63	1.21 NS	
	Error	87	63.81		
	Total	99	74.44		
Atlantic herring (Oct-Dec)	Years	12	17.07	1.95 *	75 76 86 82 81 84 80 87 85 77 83 79 78
	Error	82	69.86		
	Total	94	76.93		
Pollock (Nov-Feb)	Years	11	19.76	3.35 ***	79 76 84 85 75 80 77 81 83 82 78 86
	Error	101	54.21		
	Total	112	73.97		

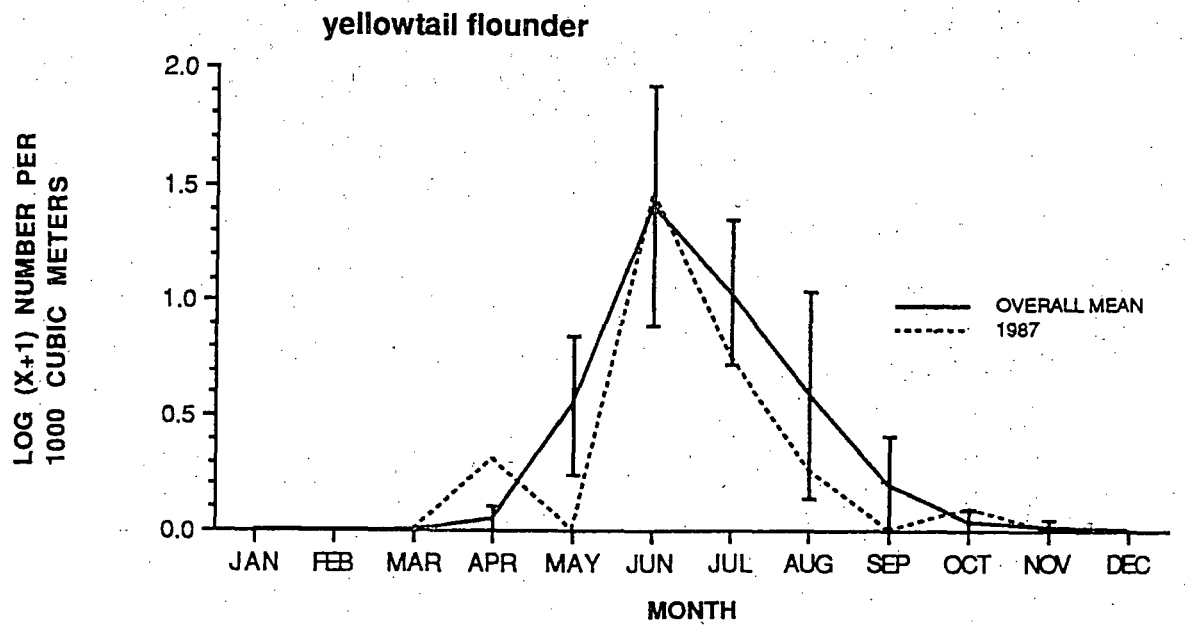
NS = not significant ($p > 0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

Winter Flounder

Winter flounder larvae, the fourth most abundant over all years of the nine selected species, are usually present from March through September, with the highest concentrations occurring in April through July (Figure 3.2.1-1). Very few specimens were encountered in March, August and September. In 1987, abundances followed the same general pattern as in previous years. Winter flounder larvae, highly variable in earlier years, decreased to an all time low in 1981 (2.9 larvae/1000 m^3) then increased during the next four years to the highest abundance (22.4 larvae/1000 m^3) recorded during the study. Since that time, the abundance has decreased in both 1986 and 1987 (Table 3.2.1-9). A one-way analysis of variance of the peak month data showed no significant difference among years (Table 3.2.1-10).

Yellowtail Flounder

Yellowtail flounder larvae normally occur from May through November, with peak abundances occurring from May through August. In recent years there have been an increasing number of larvae present in April, with 1987 recording the highest abundance for that month (Figure 3.2.1-2). In 1987, abundances dropped to zero in May but then increased to normal values in June and followed the general pattern of abundance through November. Yellowtail flounder, like most of the selected species, has been highly variable from year to year (Table 3.2.1-9). Starting with the highest value in 1977 (20.2 larvae/1000 m^3) abundances generally decreased to the lowest value in 1982 (0.3 larvae/1000 m^3) and then varied from year to year through 1987. Abundance in 1987 (1.7 larvae/1000 m^3) was the third lowest abundance observed and was half the overall yearly geometric mean of 3.6 larvae per 1000 cubic meters. The one-way analysis of variance to test overall yearly differences in log-transformed means was not significant.



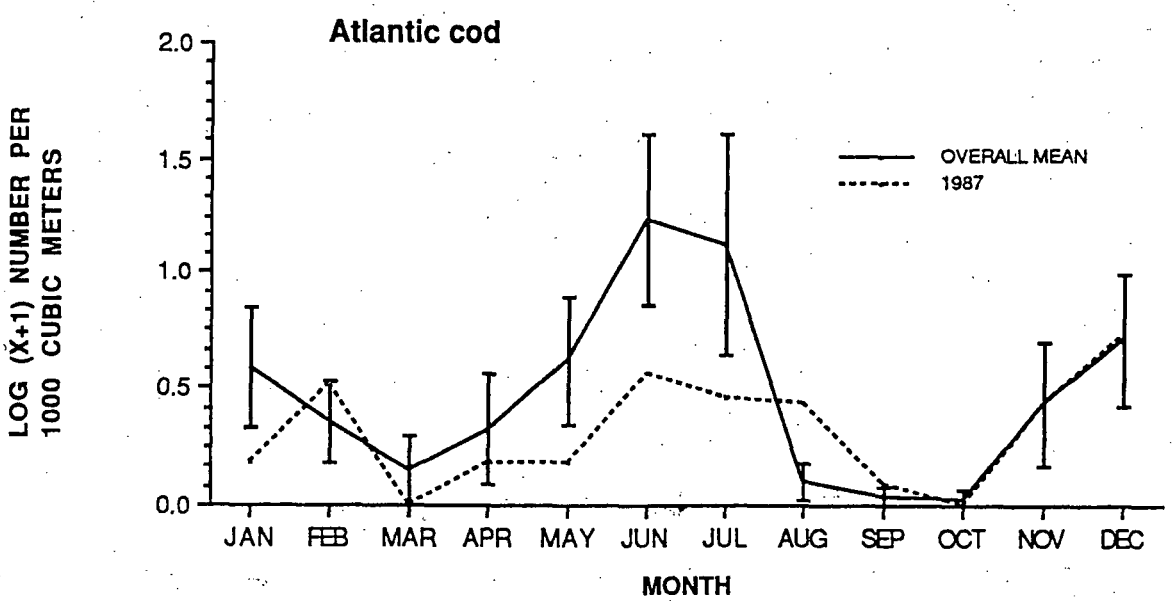


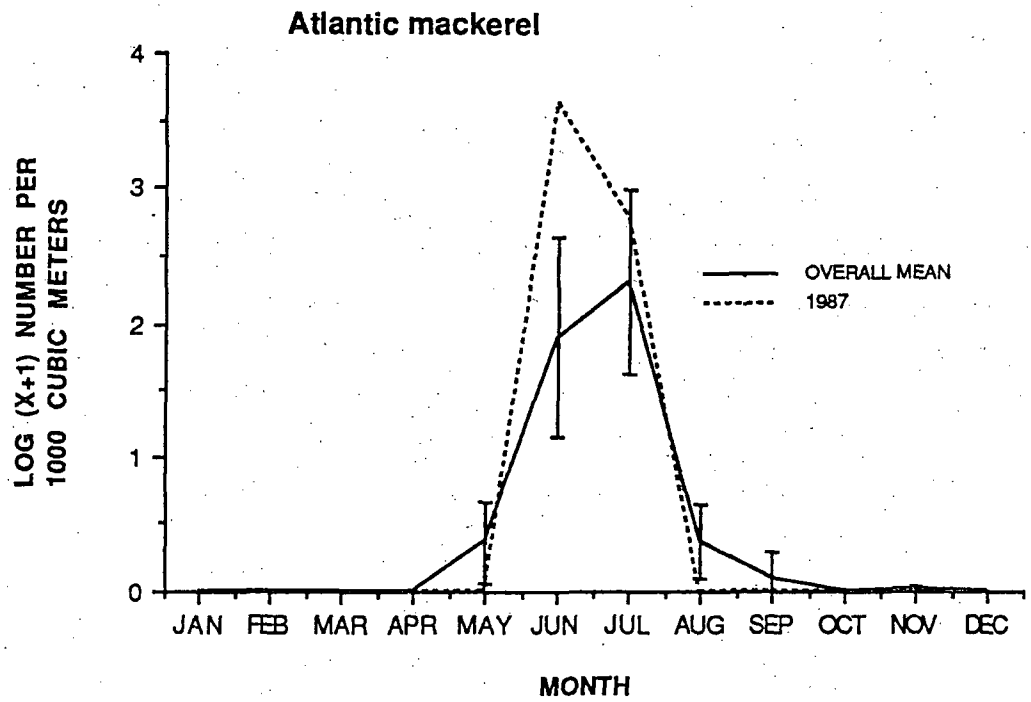
Figure 3.2.1-2. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x+1) transformed abundances (No./1000 m^3) for yellowtail flounder and Atlantic cod larvae stations P2 and P3, July 1975 through December 1987. Seabrook Baseline Report, 1987.

Atlantic Cod

Atlantic cod larvae occurred sporadically from 1976 through 1987 exhibiting a bimodal distribution with one peak lasting from November through January (late fall-winter) and the other (usually stronger) peak in April through July (spring-early summer, Figure 3.2.1-2). Cod larvae also exhibited a bimodal distribution in 1987, however the April through July peak was not as strong as usual. In addition, this peak extended through August instead of decreasing as in previous years. Seasonal geometric mean abundance for Atlantic cod was only computed for the spring-early summer peak, due to the usually higher abundances and the longer period of occurrence in comparison to the late fall-winter peak. In 1987, spring Atlantic cod larvae attained their lowest abundance (0.6 larvae/1000 m^3) in the twelve years of the study, thus continuing to exhibit below-average abundance levels and a general declining trend which began in 1982 (Table 3.2.1-9). A one-way analysis of variance among years found the differences to be significant (Table 3.2.1-10). The Duncan-Waller multiple comparison test shows that 1978 abundances were significantly higher than in 1979 and 1983 through 1987, and 1977 and 1981 abundances were significantly higher than those in 1987.

Atlantic Mackerel

Atlantic mackerel larvae exhibited a May through August pattern of occurrence for all years combined, with peak abundances occurring in July and no larvae found in October through April (Figure 3.2.1-3). In 1987, mackerel larvae were only found in June and July, with June having a much larger value than the overall mean. Seasonal mean abundances for mackerel larvae were variable throughout the study period but have generally been increasing since 1978 (2.3 larvae/1000 m^3). The highest value occurred in 1980 (24.2 larvae/1000 m^3) with the average over all years being 9.0 larvae per 1000 cubic meters. In 1987, the abundance was slightly lower than the overall mean (Table 3.2.1-9). A one-way analysis of variance found no significant difference among log-transformed yearly means.



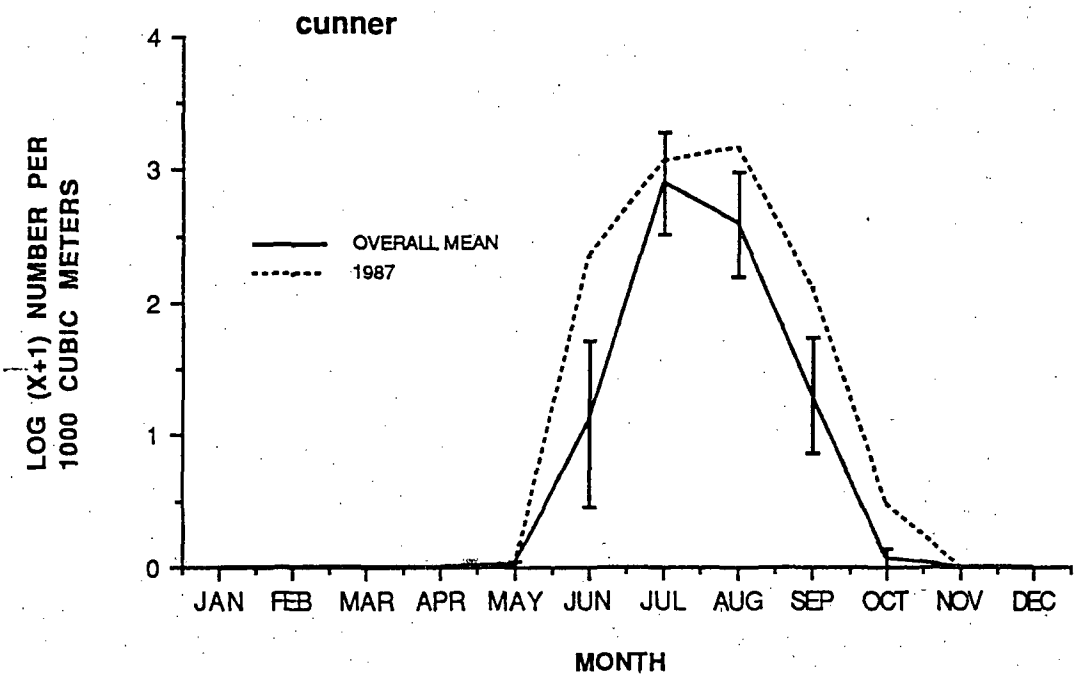


Figure 3.2.1-3. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x+1) transformed abundances (No./1000 m^3) for Atlantic mackerel and cunner larvae at stations P2 and P3, July 1975 through December 1987. Seabrook Baseline Report, 1987.

Cunner

Cunner larvae were present throughout June through September, following a pattern of occurrence similar to mackerel larvae. Cunner larvae peaked historically during July and August and usually disappeared by October (Figure 3.2.1-3). In 1987, values for June through October were all greater than the overall means for those months. Seasonal mean abundances for cunner larvae have been highly variable throughout the past twelve years (Table 3.2.1-9), with 1987 exhibiting the highest abundance (255.2 larvae/1000 m^3) during this period. Cunner larvae were also the most abundant of the nine selected species in 1987. The one-way analysis of variance testing difference between the log-transformed yearly means showed no significant difference among the years.

Hakes

Hake larvae, like mackerel and cunner, are confined to a relatively short period of occurrence. Historically, they have increased through June and July peaking in August and September, decreasing in October, and almost disappearing in November (Figure 3.2.1-4). In 1987, larvae were not caught until August, with the peak abundance not coming until September, and with values for October and November higher than the overall means for those months. Seasonal mean abundance was highly variable among years, with the general trend suggesting relatively high abundances followed by two or three years of relatively low abundances (Table 3.2.3-9). The abundance in 1986 (0.1 larvae/1000 m^3) was the lowest value in the past twelve years. The 1987 abundance was higher (3.2 larvae/1000 m^3), but was still below the overall mean of 4.4 larvae per 1000 cubic meters. A one way analysis of variance showed no significant difference among yearly means.

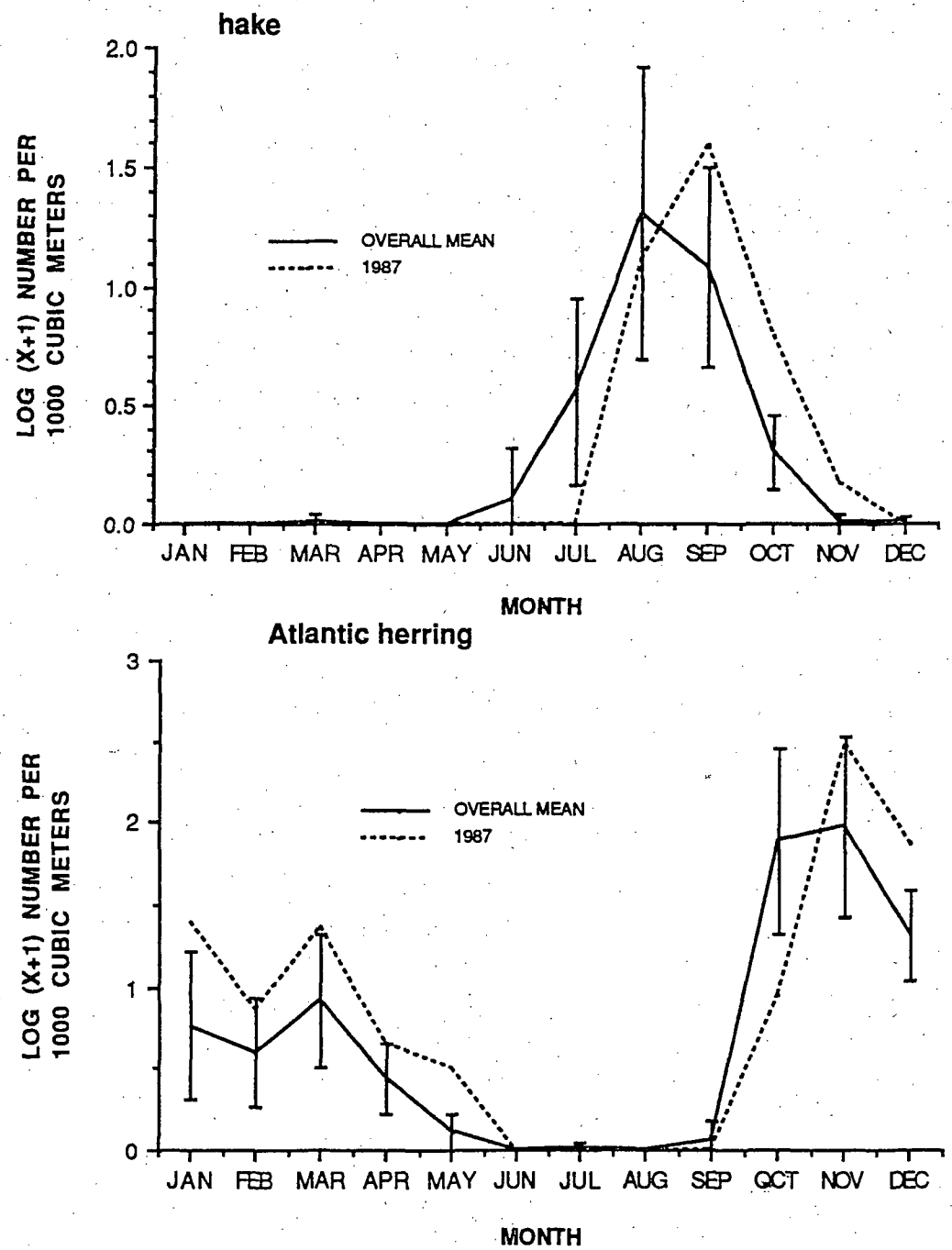


Figure 3.2.1-4. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x+1) transformed abundances (No./1000 m^3) for hake and Atlantic herring larvae at stations P2 and P3, July 1975 through December 1987. Seabrook Baseline Report, 1987.

Atlantic Herring

Atlantic herring larvae typically occurred throughout most of the year, except during June through September when abundances were either at or near zero (Figure 3.2.1-4). January through May saw medium to low abundances, and October through December exhibited the peak values. In 1987, herring followed a pattern similar to that in previous years except that January through May and November abundances were higher and October was lower than their overall monthly means. As is the case with most of the other selected species, herring larvae have a highly variable seasonal mean abundance (Table 3.2.1-9). The highest abundances occurred in 1975 and 1976 (197 and 145 larvae/1000 m^3 respectively), the lowest in 1978 (2.1 larvae/1000 m^3), averaging 30.9 larvae per 1000 cubic meters over all years. The 1987 abundances (28.8 larvae/1000 m^3) were only slightly below the overall mean. A one-way analysis of variance testing the differences among years found them to be significant (Table 3.2.1-10). The Waller-Duncan multiple comparison test showed three large overlapping groups of years, with 1978 abundances being significantly lower than those in 1975, 1976, and 1986, and 1979 abundances being significantly lower than those in 1975.

Pollock

Pollock larvae exhibited an abundance pattern similar to that of herring larvae, with large abundances in November through February and decreasing abundances from March through June (Figure 3.2.1-5). During July through October few if any larvae were present. The abundance of pollock larvae in 1987 was very low during most months, with only November and May slightly above their overall means. Seasonal peak abundances for pollock were highly variable from year to year (Table 3.2.1-9), with increasing abundances followed by two or three years of decreasing abundances. In 1987, the seasonal mean was not computed for pollock because its period of peak abundance which began in November would continue into 1988. However, the 1986 data which were not included in last year's baseline report were the

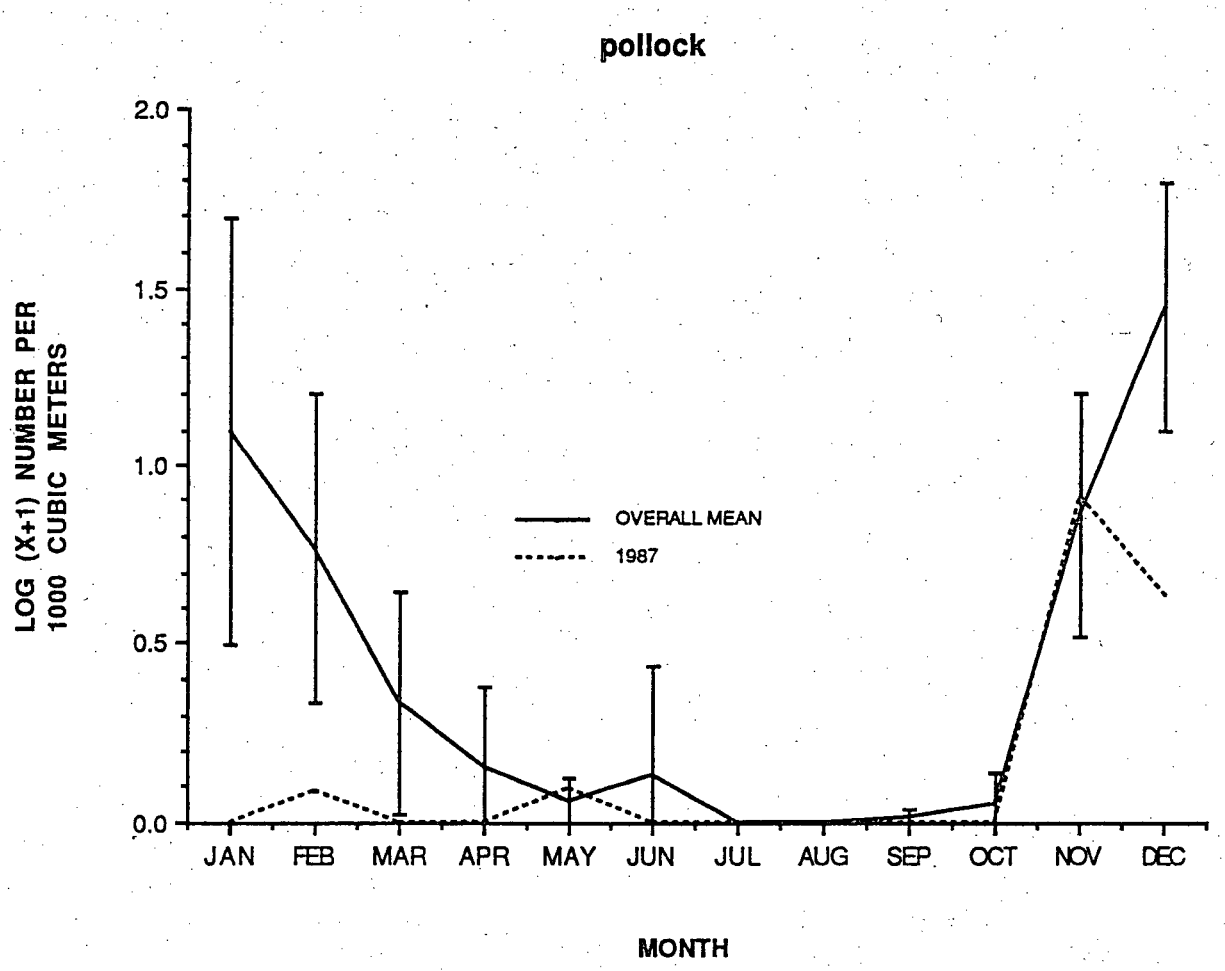


Figure 3.2.1-5. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x+1) transformed abundances (No./1000 m^3) for pollock larvae at stations P2 and P3, July 1975 through December 1987. Seabrook Baseline Report, 1987.

lowest encountered during the 1975 through 1986 baseline period (1.2 larvae/ 1000 m^3). This severe drop in abundance follows the relatively high abundance in 1984 of 22.8 larvae per 1000 cubic meters. The one-way analysis of variance among yearly log-transformed means showed the differences to be very highly significant (Table 3.2.1-10). The Waller-Duncan multiple comparison test of the yearly means showed three overlapping groups of years. Abundances in 1976, 1979, and 1984 were significantly higher than in 1978, 1982, and 1986; and abundances in 1979 were also significantly higher than in 1977, 1981, and 1983.

3.2.2 Adult Finfish

3.2.2.1 Total Community

Temporal Patterns in the Demersal Fish Community

Otter trawl catch per unit of effort (CPUE) for all stations and species combined during the 1976 through 1987 period rose from 50 fish/ten-minute tow (fish/tow) in 1977 to a peak of 95 fish/tow in 1980 and 1981 (Figure 3.2.2-1). CPUE subsequently declined through 1985 when an average of 43 fish/tow were collected. The CPUE increased to 52 fish/tow in 1987, possibly indicating an increase in the low abundances recorded since 1981.

Changes in the annual composition of the demersal fish community were compared using percent composition of the dominant trawl species. Six taxa accounted for nearly 80 percent of the trawl catch abundance for all years combined (Table 3.2.2-1). Yellowtail flounder comprised the largest percentage of the annual catch (20-36%) in all years except 1983 and 1984, when it ranked second below longhorn sculpin. Beginning in 1980, the percentage of yellowtail flounder in trawl collections consistently declined until 1984 when that species represented only 18 percent of the total annual catch. Percent contribution of yellowtail flounder increased to 27 percent in 1985 ending a five-year decline, but dropped again in 1986 (20%) and 1987 (19%) to a level approaching the 1984 low. Hake species (red, white and

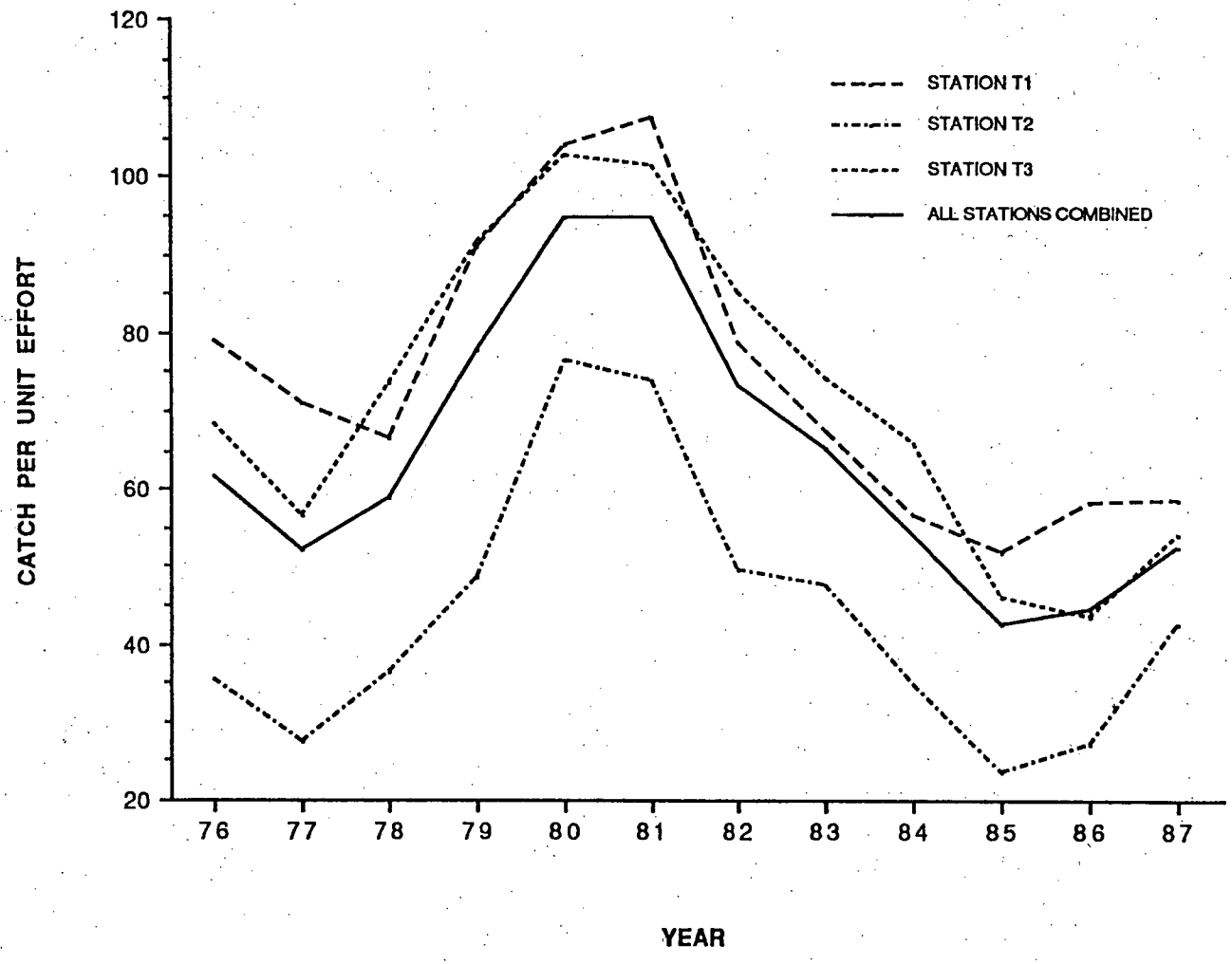


Figure 3.2.2-1. Catch per unit effort (mean number per 10 minute tow) of all species collected in otter trawls by year, station, and all stations combined, 1976-1987. Seabrook Baseline Report, 1987.

TABLE 3.2.2-1. TOTAL PERCENT COMPOSITION BY YEAR AND ALL YEARS COMBINED FOR THE TWELVE MOST ABUNDANT SPECIES IN OTTER TRAWLS DURING 1976 THROUGH 1987 AT STATIONS T1, T2 AND T3 COMBINED. SEABROOK BASELINE REPORT. 1987.

	PERCENT COMPOSITION												
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	ALL YEARS COMBINED
Yellowtail flounder	36	29	23	34	33	28	22	19	18	27	20	19	27
Hake species[a]	18	30	19	9	8	14	19	10	13	15	14	10	15
Longhorn sculpin	5	8	9	13	15	17	16	24	27	22	9	9	14
Winter flounder	5	8	9	7	12	15	9	8	7	9	10	11	9
Atlantic cod	4	3	14	14	9	6	7	8	5	3	3	6	7
Rainbow smelt	13	3	10	7	4	6	5	9	7	1	3	15	7
Skate species[b]	3	5	2	2	2	2	3	7	8	11	14	11	5
Atlantic whiting	6	3	4	3	1	3	4	1	<1	<1	8	1	3
Ocean pout	2	4	3	2	1	2	2	3	5	3	3	3	3
Pollock	<1	<1	<1	4	7	2	1	2	<1	<1	2	<1	2
Windowpane	2	2	1	<1	3	2	2	5	7	5	7	8	3
Haddock	3	2	<1	3	4	<1	2	1	<1	<1	<1	<1	2
Other species	3	3	5	2	1	3	8	3	2	3	7	5	3
Number of other species	(25)	(22)	(26)	(25)	(22)	(27)	(28)	(26)	(26)	(20)	(21)	(25)	(43)

[a] includes red, white, and spotted hakes
[b] includes big, little, and thorny skates

spotted hake) were the second-ranked taxon in trawl collections and comprised 15% of the catch for all years combined. The percent composition of hake species was variable over the years (8-30%) and showed no consistent long-term trends. Longhorn sculpin comprised 14% of the catch for all years combined, and accounted for an increasingly larger percent of the catch from 1976 (5%) through 1984 (27%). In 1986 and 1987, their percent contribution to the total catch fell back to pre-1979 levels (<10%). Winter flounder ranked fourth in percent abundance over all years (9%) and ranged from 5 to 15% of the total annual catch. The percentage of winter flounder in otter trawl collections gradually increased from 7% in 1984 to 11% in 1987. Atlantic cod ranked fifth over all years, and accounted for an average of seven percent of the total catch. Cod percent contribution was highest in 1978 and 1979 (14% each year), and lowest in 1977, 1985 and 1986 (3% each year). The percent contribution increased to 6% in 1987, but was still below the 12-year average (7%). Rainbow smelt, the sixth ranked taxon, fluctuated between 15% (1987) and 1% (1985) of the total annual catch, averaging 6% over all years. Percent composition in 1987 was the highest during the study period, with 1976 (13%) ranking second.

The number of fish species (species richness) collected annually in otter trawls ranged from 32 to 40 and totaled 55 for all years combined (Table 3.2.2-1).

Seasonal changes in the demersal community were examined in past years by numerical classification of the trawl catches (NAI 1982c). Samples were classified into two major groups, reflecting a "winter community" (December through March) and a "summer community" (April through November). Rainbow smelt was the only species that was consistently more abundant in the winter throughout the study area. Catches of hakes and longhorn sculpins were substantially greater in the summer.

Spatial Patterns in the Demersal Fish Community

Mean annual catch per unit of effort was similar at the offshore stations (T1 and T3), while CPUE at the shallower nearshore station (T2) was much lower (Figure 3.2.2-1). Despite the differences, mean annual CPUE for the three stations followed the same long-term abundance pattern from 1976 through 1987. As discussed previously, CPUE for all stations was low in 1977, peaked in 1980 and 1981, declined to lowest levels in 1985, and began to gradually increase in 1986 and 1987.

Otter trawl catches at the offshore stations (T1 and T3) were dominated by yellowtail flounder, hakes, and longhorn sculpin (Table 3.2.2-2). Collectively, these species comprised over 60% of the catch for all years combined at Stations T1 and T3. Of lesser importance at these stations were Atlantic cod, Atlantic whiting and skates. The most notable difference in percent composition between Stations T1 and T3 was that yellowtail flounder predominated at Station T1 while longhorn sculpin was more abundant at Station T3. In addition, cod, skates, and ocean pout comprised a larger percentage of the total catch at Station T3. This and other smaller differences in species composition between Stations T1 and T3 may be attributable to different bottom substrates. Station T1 has a sandy bottom, while the bottom substrate at Station T3 is sand, littered with small cobble and shell debris (NAI 1988). Yellowtail flounder prefer any sandy bottom (Bigelow and Schroeder 1953). Otter trawl catches at the nearshore station (T2) were dominated by winter flounder, yellowtail flounder, rainbow smelt, and pollock, comprising 67% of the catch for all years combined. Hake and sculpin comprised a much smaller percentage at Station T2 than at Stations T1 and T3 while the opposite was true of winter flounder, rainbow smelt and pollock.

Temporal Patterns in the Pelagic Fish Community

Catch per unit of effort for gill nets (one 24-hour set) combined for all species showed a pattern somewhat similar to otter trawl catches

TABLE 3.2.2-2. TOTAL PERCENT COMPOSITION BY STATION OF ABUNDANT SPECIES COLLECTED IN OTTER TRAWLS, ALL YEARS COMBINED (1976-1987). SEABROOK BASELINE REPORT, 1987.

SPECIES	PERCENT COMPOSITION		
	T1	T2	T3
Yellowtail flounder	39	14	21
Hake species[a]	16	10	16
Longhorn sculpin	12	5	22
Atlantic cod	5	5	10
Rainbow smelt	5	17	3
Winter flounder	6	26	5
Atlantic whiting	4	1	3
Windowpane	4	4	2
Skate species[b]	3	2	8
Pollock	2	7	1
Ocean pout	1	3	4
Haddock	1	<1	3
Other species	2	5	2
Number of other species	(42)	(33)	(38)

[a]includes red, white, and spotted hakes
[b]includes big, little, and thorny skates

(Figure 3.2.2-2). CPUE rose to a peak in 1980 of 29 fish/net and subsequently declined to lowest levels in 1985 of 3 fish/net. In 1987 CPUE remained low and was virtually identical to levels encountered in 1984. Sampling frequency for gill nets has been less in recent years, and this change may have impacted the catch statistics. The pattern was not as distinctive as with trawls, in that annual CPUE only ranged from 3 to 16 with the exception of the 1980 peak. In addition, the gill net peak catch occurred only during 1980, while the trawl peak spanned both 1980 and 1981. The high 1980 CPUE for gill nets was due to unusually high catches of Atlantic herring and pollock (NAI 1981e).

Atlantic herring ranked first in gill net collections during every year sampled, comprising from 25 to 82 percent of the total annual catch and averaging 63 percent for all years combined (Table 3.2.2-3). The percent contribution of Atlantic herring to the annual gill net catch was highest in 1978, 1979 and 1980 (74, 80, and 82%, respectively) and lowest in 1984, 1985, and 1986 (26, 25 and 33%, respectively). During all other years, Atlantic herring ranged from 44 to 63% of the total annual catch. In 1987 the percent of total annual catch for Atlantic herring (52%) was below the 12-year average. Atlantic whiting, blueback herring, pollock, and Atlantic mackerel collectively comprised 27% of the gill net catch for all years combined. These taxa were fairly consistently ranked among the top five dominant taxa during the 12-year period. Blueback herring, which ranked second in percent composition for 1987, was 16% of the total annual catch, the highest level during the 12-year period. Lower ranked taxa (e.g., alewife, Atlantic menhaden, hakes, rainbow smelt and Atlantic cod) comprised a more important portion of the total annual catch during 1984, 1985 and 1986 when catch abundances were below normal and Atlantic herring accounted for a smaller percentage of the total annual catch. In 1987 none of these species comprised more than 3% of the total annual catch. Species richness ranged from 19 to 31 species annually and totaled 47 for all years combined, with 1987 exhibiting the lowest value (19) in the past 11 years (1976-1986). No long-term trend of increasing or decreasing species richness was evident.

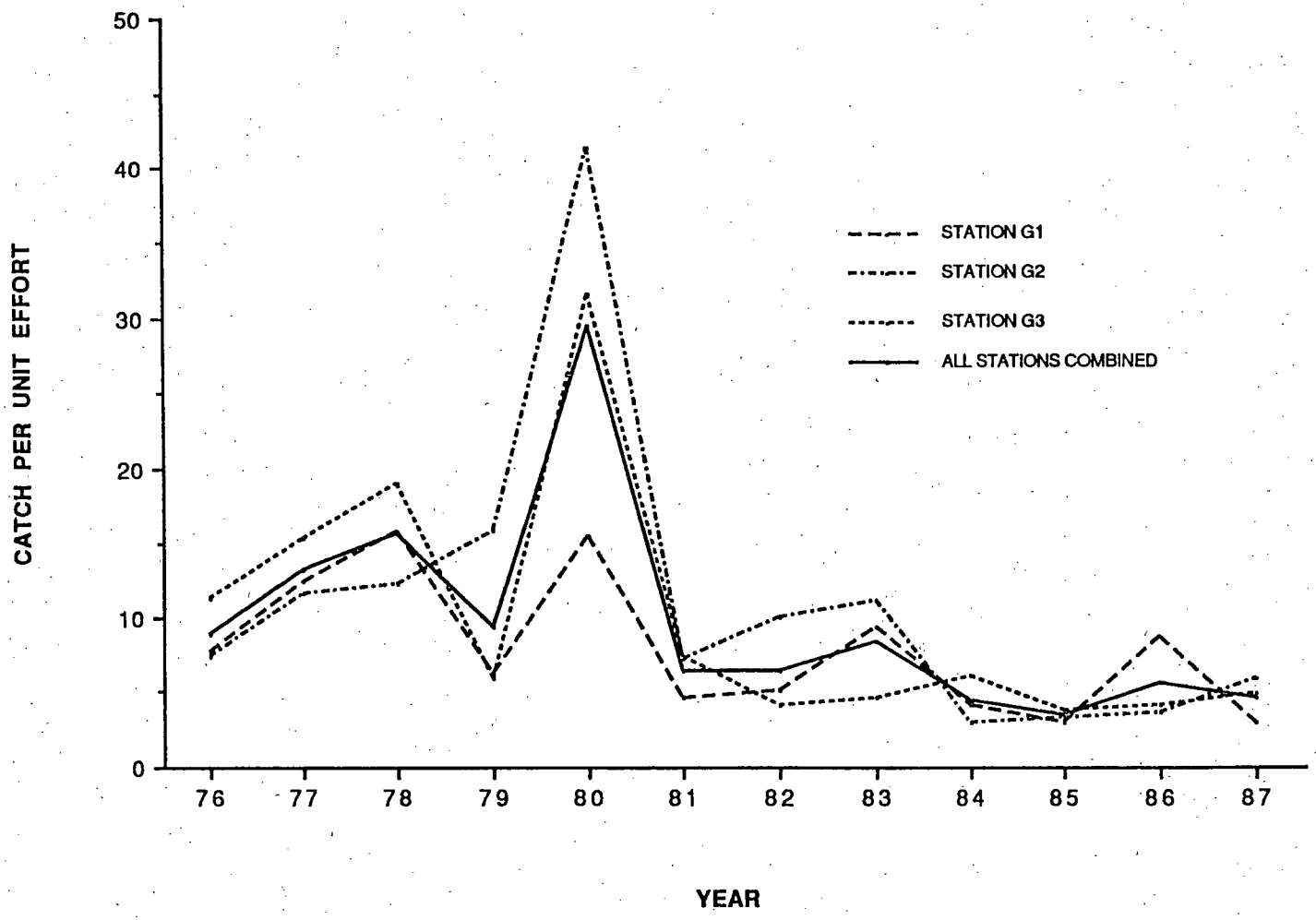


Figure 3.2-2.2. Catch per unit effort (number per 24 hour set of one net, surface or bottom) of all species combined in gill nets by year, station, and all stations combined 1976-1987. Seabrook Baseline Report, 1987.

TABLE 3.2.2-3. TOTAL PERCENT COMPOSTION BY YEAR AND ALL YEARS COMBINED FOR THE TEN MOST ABUNDANT SPECIES IN GILL NET SAMPLES DURING 1976 THROUGH 1987 AT STATIONS G1, G2 AND G3 COMBINED. SEABROOK BASELINE REPORT, 1987.

	PERCENT COMPOSITION												
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	ALL YEARS COMBINED
Atlantic herring	53	48	74	80	82	45	63	44	26	25	33	52	63
Atlantic whiting	17	21	2	4	6	5	7	1	5	2	1	5	8
Blueback herring	5	11	14	2	2	2	10	12	9	9	15	16	8
Pollock	6	4	1	2	5	18	4	12	10	22	18	6	6
Atlantic mackerel	12	7	2	2	2	14	5	5	6	10	5	7	5
Alewife	1	2	2	<1	<1	2	2	4	5	6	3	2	2
Atlantic menhaden	<1	3	<1	2	<1	<1	1	11	5	6	5	2	2
Hake species[a]	2	2	<1	1	<1	4	1	1	7	2	2	<1	1
Rainbow smelt	1	1	<1	1	<1	<1	<1	1	6	2	4	3	1
Atlantic cod	1	<1	<1	<1	<1	<1	2	2	3	<1	2	2	1
Other species	2	<1	3	5	1	8	5	7	18	16	12	4	3
Number of other species	(10)	(16)	(14)	(13)	(13)	(19)	(21)	(18)	(20)	(14)	(14)	(9)	(37)

[a]includes red, white and spotted hake

Seasonality of pelagic species was analyzed in previous reports (NAI 1982c;1983b). Two distinct sample groups were observed based on abundances of the dominant species: "summer" (June-August) and "winter" (September-May). Atlantic mackerel and Atlantic whiting were more abundant in summer samples, while Atlantic herring were more numerous in winter catches. In 1987 the two summer dominants were more abundant in September and October, usually characterized as "winter" months. Blueback herring and pollock showed inconsistent seasonal differences in abundance from 1976 through 1987.

Spatial Patterns in the Pelagic Fish Community

Mean annual catch per unit of effort at the three gill net Stations G1, G2 and G3 showed similar fluctuations across years (Figure 3.2.2-2). Mean annual CPUE peaked in 1980 at all stations. This peak was more evident at Stations G2 and G3 than at Station G1. Percent composition for the dominant species in gill net collections was similar among stations (Table 3.2.2-4). Atlantic herring was the dominant species at each gill net station, accounting for 58 to 69 percent of the total catch for all years combined. Blueback herring comprised a larger percent of the total catch at G3 (10%) than at G1 or G2 (6% at each station). Also numerically important at each station were Atlantic whiting, Atlantic mackerel and pollock; each comprising from 4 to 9 percent of the catch at the three stations for all years combined.

Depth differences in species composition were analyzed by comparing percent composition in surface nets to that in off-bottom nets (3 m above the bottom) for all years combined (Table 3.2.2-5). Atlantic herring was the dominant species in collections at both depths, with a slightly higher percent contribution in surface nets compared to off-bottom nets. The proportions of blueback herring and Atlantic mackerel were also higher in surface nets. Atlantic whiting, pollock, and hakes comprised a larger percent of the catch in the off-bottom nets. Atlantic menhaden and alewives

TABLE 3.2.2-4. TOTAL PERCENT COMPOSITION BY STATION OF ABUNDANT SPECIES COLLECTED IN GILL NETS, ALL YEARS AND DEPTHS COMBINED (1976-1987). SEABROOK BASELINE REPORT, 1987.

SPECIES	PERCENT COMPOSITION G1	G2	G3
Atlantic herring	62	69	58
Atlantic whiting	8	6	9
Blueback herring	6	6	10
Atlantic mackerel	5	4	5
Pollock	6	5	6
Hake species[a]	2	1	1
Atlantic menhaden	2	1	2
Alewife	2	2	2
Rainbow smelt	1	1	1
Longhorn sculpin	1	1	<1
Atlantic cod	1	1	1
Bluefish	1	1	<1
All other species	3	2	3
Number of other species	(25)	(28)	(25)

[a]includes red, white and spotted hakes

TABLE 3.2.2-5. TOTAL PERCENT COMPOSITION OF DOMINANT GILL NET SPECIES ACCORDING TO DEPTH (SURFACE AND OFF-BOTTOM), ALL YEARS COMBINED (1976-1987). SEABROOK BASELINE REPORT, 1987.

SPECIES	PERCENT COMPOSITION	
	SURFACE	OFF-BOTTOM
Atlantic herring	69	56
Blueback herring	10	5
Atlantic mackerel	7	3
Atlantic whiting	5	11
Atlantic menhaden	2	1
Alewife	2	1
Pollock	1	12
Rainbow smelt	1	1
Hake species[a]	<1	3
Other species	2	7

[a]includes red, white, and spotted hakes

accounted for a similar percentage in both surface and off-bottom nets. Trends in 1987 were similar to those encountered during the past eleven years. Since 1980, mid-water nets have been set in addition to the surface and off-bottom nets during February, June and October. Comparison of CPUE among surface, mid-water and off-bottom nets on dates when all three nets were fished revealed that Atlantic menhaden was the only species that was slightly more abundant in mid-water catches than in surface or off-bottom catches (Table 3.2.2-6). As was observed with the regular surface and off-bottom gill net collections, Atlantic herring and Atlantic mackerel were most abundant in surface nets and least abundant in off-bottom nets. Blueback herring were also most abundant in surface nets but were least abundant in off-bottom nets, and intermediate in abundance in mid-water nets. Atlantic whiting, pollock, and rainbow smelt were most abundant in bottom nets. The alewife showed no depth preference, with low CPUE values (<1/net) at each depth. In 1987, Atlantic herring was most abundant in the off-bottom nets, intermediate in abundance in the mid-water nets and least abundant in surface nets, for those dates when all three nets were fished. Since all three nets were fished only three times during the year and since surface nets showed a higher abundance than off-bottom nets throughout the rest of the year, the higher bottom-net abundance is probably due to chance variation.

Temporal Patterns in the Estuarine Community

Catch per unit of effort for seine stations combined for all species ranged from 60 to 362 fish/haul (Figure 3.2.2-3). Seine CPUE values were lower during the period 1982 through 1986 (60 to 114 fish/haul) than during the period 1976 through 1981 (200 to 362 fish/haul). Annual variations in beach seine CPUE were influenced primarily by annual catches of the Atlantic silverside, which was the most abundant species in seine collections each year (Table 3.2.2-7). The percent contribution of silversides to the total annual seine catch ranged from 47 to 88 percent annually. Atlantic silverside contributed 56% of the total annual catch in 1987, somewhat lower

TABLE 3.2.2-6. CATCH PER UNIT EFFORT[a] BY DEPTH FOR THE DOMINANT GILL NET SPECIES OVER ALL STATIONS AND DATES WHEN SURFACE, MID-DEPTH AND BOTTOM NETS WERE SAMPLED, 1980 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

	CATCH PER UNIT EFFORT		
SPECIES	SURFACE	MID-DEPTH	BOTTOM
Atlantic herring	6.3	3.5	2.3
Atlantic whiting	0.2	0.6	0.8
Atlantic mackerel	0.9	0.4	0.4
Pollock	0.2	0.1	1.1
Alewife	<0.1	<0.1	<0.1
Blueback herring	1.1	0.4	0.3
Atlantic menhaden	0.6	0.7	0.2
Rainbow smelt	<0.1	<0.1	0.1

[a]number per one 24-hour set of one net (surface, mid-depth or bottom)

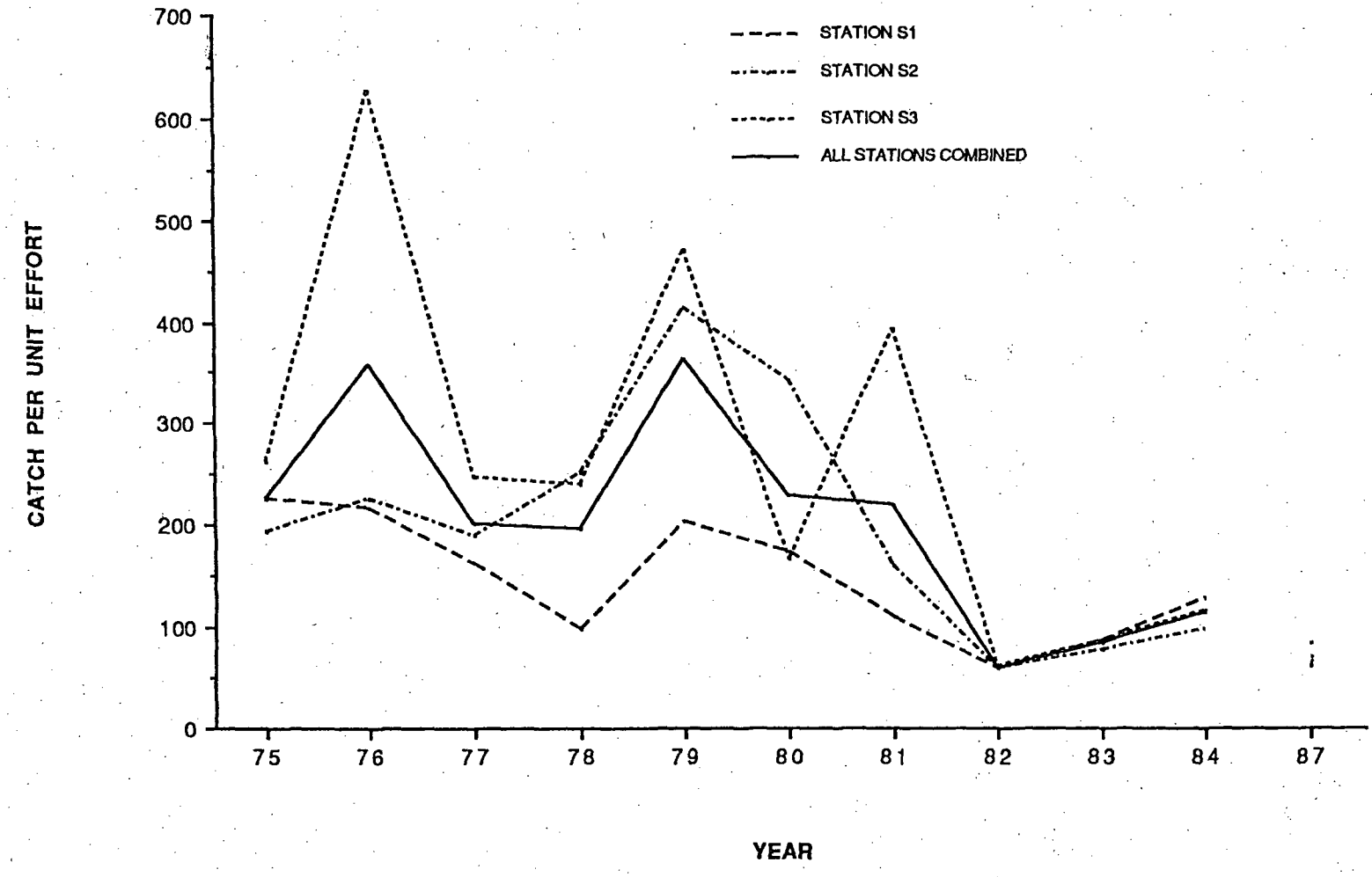


Figure 3.2.2-3. Catch per unit effort (mean number per seine haul) of all species collected in beach seines by year, station and all stations combined 1976-1984 and 1987. Seabrook Baseline Report, 1987.

TABLE 3.2.2-7. TOTAL PERCENT COMPOSITION BY YEAR FOR THE TEN MOST ABUNDANT SPECIES COLLECTED IN BEACH SEINES DURING 1976 THROUGH 1987 (EXCLUDING 1985 AND 1986) AT STATIONS S1, S2 AND S3 COMBINED. SEABROOK BASELINE REPORT, 1987.

	PERCENT COMPOSITION										
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1987	ALL YEARS COMBINED
Atlantic silverside	74	55	75	60	68	88	57	47	48	56	67
Fundulus species[a]	15	23	5	3	4	2	10	8	7	3	8
Pollock	<1	<1	1	8	21	<1	7	5	1	2	5
Alewife	<1	1	<1	18	<1	<1	1	<1	<1	<1	4
Rainbow smelt	4	5	<1	5	<1	2	5	4	9	8	3
American sand lance	2	9	8	<1	<1	<1	8	2	<1	0	3
Atlantic herring	<1	<1	5	<1	4	4	<1	7	8	2	3
Ninespine stickleback	1	4	1	<1	<1	<1	2	7	16	22	3
Winter flounder	<1	2	2	2	3	1	6	3	3	2	2
Blueback herring	<1	<1	<1	1	<1	<1	<1	14	<1	0	2
Other species	3	<1	2	2	<1	2	4	3	7	4	<1
Number of other species	(11)	(17)	(14)	(12)	(9)	(12)	(12)	(13)	(14)	(12)	(34)

[a]includes mummichogs and striped killifish

than the average for all years combined (67%). Also important numerically were *Fundulus* species (primarily mummichog), which consistently accounted for more than one percent of the catch (1-23% annually) and ranked among the top five dominant taxa in all years. All other species collected in seines fluctuated from year to year in their ranking and often comprised less than 1% of the total annual catch. The total number of species collected per year ranged from 19 in 1980 to 27 in 1977. Data for the estuarine fish community for the years of 1985 and 1986 were not included in this year's report. Beach seines were not collected in 1985 and sampling effort was reduced in 1986 (no sampling in April, May and June).

Seasonality of the estuarine fish community was analyzed previously using numerical classification (NAI 1983b, 1984b). The estuarine community was highly seasonal in all years, and all three seine stations exhibited similar seasonal changes in their fish assemblages. Catches in the spring were usually characterized by low abundance, and species composition in early summer was highly variable among years. The most distinct group was the late summer-fall assemblage, which occurred yearly from August-November, and in which Atlantic silverside was the overwhelming dominant (NAI 1984b).

Spatial Patterns in the Estuarine Fish Community

Mean annual catch per unit of effort during the period 1976 through 1983 was usually highest at Station S3 and lowest at Station S1 (Figure 3.2.2-3). During 1984 and 1986, when catches were small relative to earlier years, mean annual CPUE was similar among the three stations, with Atlantic silverside the dominant species at each station (Table 3.2.2-8). Stations S1 and S2 were comparable in their overall species composition, with silversides comprising 55 and 66% of the total catch (respectively) for all years combined and *Fundulus* sp. comprising 13% and 15% respectively. These stations were distinguished from each other and from Station S3 by a relatively high proportion of blueback herring at Station S1 (6%) and American sand lance at Station S2 (4%). Atlantic silverside comprised a larger percentage of the

TABLE 3.2.2-8. TOTAL PERCENT COMPOSITION BY STATION OF ABUNDANT SPECIES COLLECTED IN BEACH SEINES, ALL YEARS COMBINED, APRIL THROUGH NOVEMBER (1976-1984, 1987). SEABROOK BASELINE REPORT, 1987.

SPECIES	PERCENT COMPOSITION S1	S2	S3
Atlantic silverside	66	55	77
Fundulus species[a]	13	15	<1
American sand lance	4	3	2
Blueback herring	6	<1	1
Ninespine stickleback	3	1	3
Atlantic herring	2	5	1
Winter flounder	2	1	3
Pollock	1	6	5
Gasterosteus species[b]	1	1	1
Alewife	1	10	<1
Rainbow smelt	1	1	6
Smooth flounder	<1	<1	<1
All other species	<1	<1	<1
Number of other species	(22)	(19)	(25)

[a]includes mummichog and striped killifish
[b]includes threespine and blackspotted sticklebacks

catch at Station S3 (77%) than at Stations S1 and S2, and mummichogs accounted for a much smaller percentage (<1%). Because of its proximity to the harbor mouth, salinity readings were higher at Station S3 than at S1 and S2 (NAI 1981). *Fundulus* species prefer a more brackish environment, explaining the larger numbers caught at S1 and S2 than at S3. Rainbow smelt, a species which prefers a more saline environment, accounted for a larger percentage of the catch at Station S3 (6%) than at either Station S1 or S2 (1% for each station). Station S3 was also distinguished by a higher species richness (37) than at S2 (31) and S1 (34). Trends in 1987 were similar to those encountered in previous years (NAI 1988).

3.2.2.2 Selected Species

General

Species selections for examination of seasonal, annual, and spatial variations in abundance were determined by the following two criteria: high abundance in at least one life stage and gear type, and importance in local commercial or sport fisheries. The nine species selected and their primary collection methods were:

Species	Gear Type
Atlantic herring	gill nets
Atlantic mackerel	gill nets
Pollock	gill nets
Atlantic cod	otter trawl
Hakes (red, white and spotted)	otter trawl
Yellowtail flounder	otter trawl
Winter flounder	otter trawl and beach seine
Rainbow smelt	otter trawl and beach seine
Atlantic silverside	beach seine

Comparison of yearly mean catches per unit of effort revealed trends in population size, while comparison of monthly mean catches per unit of effort provided additional information on seasonal cycles. Seasonal and

annual variability were then used to examine spatial and temporal differences. Size-structure of fish populations also yields important information on age classes that use the area and supplies information on recruitment patterns. This information was examined thoroughly in the 1984 Baseline Report (NAI 1985b).

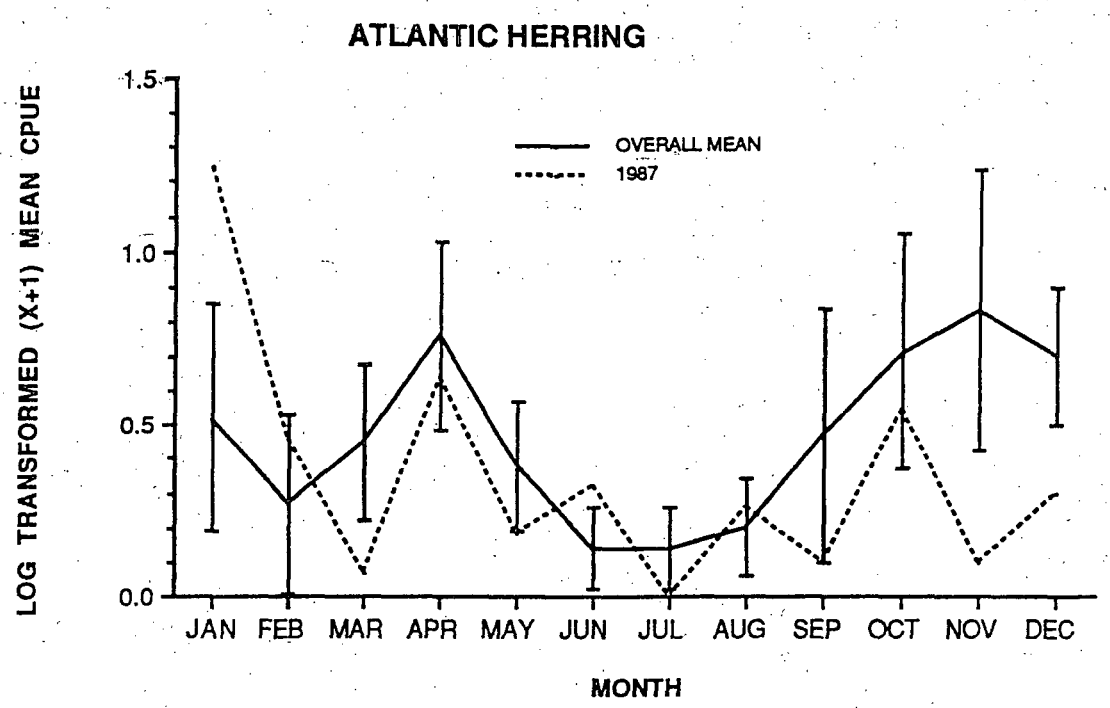
Pelagic Species

Atlantic Herring

Atlantic herring were typically collected in high numbers during the spring and fall (Figure 3.2.2-4), with gill net CPUE values greatest March through May and October through December. The 1987 data generally followed the overall mean with one exception, CPUE for January 1987 was higher than the overall mean. Annual geometric mean CPUE of Atlantic herring rose from 1976 (3.4 fish/net) through 1978 (4.9 fish/net), leveled off through 1980 (4.2/net), and then declined steadily through 1985 (0.6/net), the lowest levels observed during the program (Table 3.2.2-9). Annual mean CPUE increased slightly in 1986 and 1987 (0.8 and 1.2 respectively) but were still below the average mean for all years. A one-way analysis of variance showed significant differences in the yearly log transformed mean CPUE (Table 3.2.2-10). The Waller-Duncan K-ratio t-test for multiple comparison showed that 1978 and 1980, the years with the largest CPUE, were significantly different from 1984-1986, and that 1977 CPUE was significantly higher than that in 1985.

Pollock

Pollock gill net catches were highest during spring and late fall, and lowest during winter (Figure 3.2.2-4). The high catches in the spring and late fall reflected the inshore-offshore movement pollock undergo each year. CPUE for April, May and August in 1987 were lower than the overall mean CPUE. The low values might have been due to the fact that the gill nets



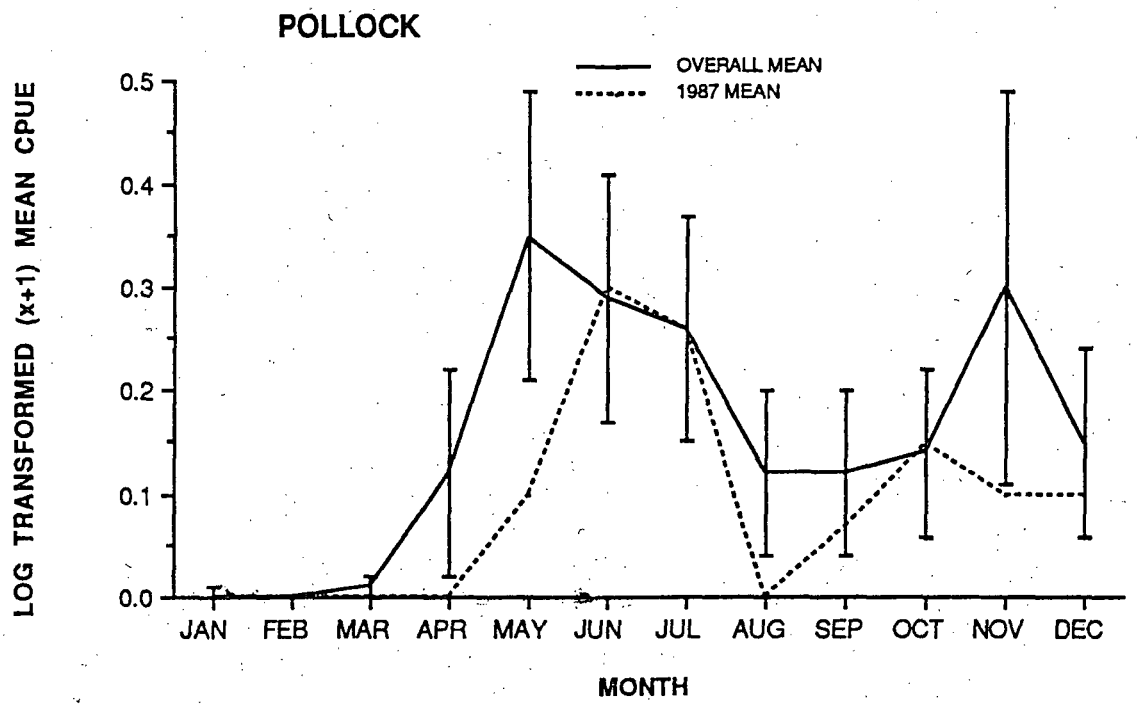


Figure 3.2.2-4. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x + 1) transformed catch per unit effort (one 24-hr. set) for Atlantic herring and Pollock at combined gill net stations G1, G2 and G3 from 1976-1987. Seabrook Baseline Report, 1987.

TABLE 3.2.2-9. ANNUAL GEOMETRIC MEAN[a] CPUE FOR SELECTED FINFISH SPECIES. SEABROOK BASELINE REPORT, 1987.

SPECIES	STATION	YEAR 1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	MEAN[b] OVER ALL YEARS	CONFIDENCE INTERVAL LOWER	UPPER
Winter flounder	T1	1.27	3.11	2.82	2.53	5.32	6.43	4.39	3.39	2.71	3.24	4.60	4.99	3.53	3.12	3.98
	T2	3.79	4.87	7.18	8.90	17.49	17.10	9.55	7.72	5.50	5.65	3.71	4.32	7.16	6.04	8.45
	T3	1.32	1.72	3.20	2.08	5.13	4.11	2.75	2.52	2.26	1.08	2.56	4.47	2.58	2.22	2.99
	T1-T3	2.55	3.52	4.91	4.81	10.33	10.26	6.41	4.85	3.73	3.58	4.04	4.87	4.95	4.39	5.56
	S1-S3	1.87	3.60	3.06	4.98	5.68	2.96	2.94	1.90	2.88	NS[c]	ID[d]	1.00	2.87	2.38	3.43
Yellowtail flounder	T1	33.50	26.34	18.88	33.54	44.88	40.47	22.13	18.03	15.73	14.82	14.51	13.36	22.74	20.30	25.45
	T2	4.21	2.58	1.78	4.73	7.05	4.67	5.28	2.62	1.03	2.91	1.83	2.62	3.17	2.56	3.89
	T3	20.57	12.50	13.12	21.82	27.68	17.98	10.31	8.27	7.66	8.40	4.83	7.53	11.92	10.59	13.41
	T1-T3	20.50	14.19	11.76	21.50	28.39	23.01	14.68	11.31	8.66	9.87	8.01	8.93	13.90	12.62	15.30
Hake species	T1	6.77	7.57	6.63	3.82	4.49	7.27	6.43	3.48	3.61	3.20	4.19	3.22	4.84	3.67	6.30
	T2	1.91	3.08	3.17	1.07	2.11	3.68	2.32	1.39	2.40	1.01	2.36	1.38	2.07	1.58	2.65
	T3	4.32	6.48	5.50	3.49	3.81	8.85	5.93	3.41	3.57	3.43	3.24	3.69	4.44	3.36	5.79
	T1-T3	4.63	6.31	5.73	3.12	3.97	7.94	5.32	3.37	3.87	2.98	4.00	3.26	4.37	3.40	5.57
Atlantic cod	T1	1.83	1.26	3.77	4.04	4.42	4.30	3.96	3.98	2.11	0.94	1.03	2.16	2.56	2.11	3.08
	T2	0.33	0.30	1.30	2.00	1.47	1.50	1.75	0.81	0.60	0.14	0.55	0.71	0.88	0.66	1.13
	T3	3.07	1.47	9.74	6.29	8.63	5.98	4.67	6.29	3.33	0.90	1.55	3.59	3.94	3.20	4.81
	T1-T3	1.96	1.11	5.40	5.21	5.72	4.51	3.90	4.14	2.19	0.81	1.16	2.50	2.84	2.36	3.37
Rainbow smelt	T1	1.88	0.71	1.67	1.23	1.00	1.10	0.92	1.41	0.89	0.30	0.63	2.30	1.10	0.74	1.54
	T2	2.26	0.94	4.63	1.73	1.60	2.48	1.21	2.89	1.69	0.64	1.34	3.28	1.89	1.33	2.58
	T3	1.59	0.74	1.15	1.07	0.80	0.44	0.72	0.37	0.48	0.37	0.38	1.03	0.73	0.48	1.01
	T1-T3	2.12	0.85	2.92	1.58	1.33	1.75	1.06	1.56	1.11	0.54	0.86	2.47	1.42	1.01	1.92
	S1-S3	1.93	1.74	0.11	3.29	0.06	1.35	1.45	1.47	2.20	NS	ID	0.61	1.22	0.67	1.95
Atlantic herring	G1-G3	3.43	3.62	4.89	2.84	4.23	1.75	1.71	1.75	0.65	0.58	0.84	1.25	2.00	1.50	2.59
Atlantic mackerel	G1-G3	0.60	0.49	0.21	0.13	0.36	0.52	0.25	0.33	0.19	0.27	0.15	0.24	0.30	0.22	0.40
Pollock	G1-G3	0.35	0.37	0.15	0.19	0.99	0.87	0.20	0.68	0.38	0.47	0.74	0.23	0.44	0.34	0.56
Atlantic silverside	S1-S3	31.08	18.07	29.54	26.70	18.03	24.77	7.33	12.94	9.40	NS	ID	9.92	16.89	9.54	29.36

a) OTTER TRAWL (T) mean catch per tow per month at each station and mean of all stations.
GILL NET (G) mean catch per 24 hour set of either level (surface or bottom) per month, a mean for all stations.
SEINES (S) mean catch per haul per month, a mean for all stations.
b) Otter Trawl (T) mean of 138 months; Gill Net (G) mean of 143 months; Seines (S) mean of 80 months.
c) NS = not sampled
d) ID = Insufficient data for comparison with previous years (April - June not sampled)

TABLE 3.2.2-10. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE AMONG YEARS OF LOG (x+1) TRANSFORMED CATCH PER UNIT EFFORT FOR SELECTED FINFISH SPECIES FOR ALL GILL NET STATIONS COMBINED DURING 1976-1987. SEABROOK BASELINE REPORT, 1987.

SPECIES	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS											
Atlantic herring	Years	11	5.16	2.24*	78	80	77	76	79	81	83	82	87	86	84	85
	Error	131	27.38													
	Total	142	32.54													
Atlantic mackerel	Years	11	0.32	0.86 NS												
	Error	131	4.43													
	Total	142	4.75													
Pollock	Years	11	0.87	2.22*	80	81	86	83	85	84	77	76	87	82	79	78
	Error	131	4.66													
	Total	142	5.53													

NS = not significant ($p > 0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

were only set once a month for two days, thus decreasing the chances of the fish being encountered. Annual mean CPUE (all stations combined) for pollock varied from 0.2 to 1.0 fish/net and averaged 0.4 fish/net over all years (Table 3.2.2-9). The 1987 mean CPUE of 0.2 fish/net was one of the lowest encountered during the study period. A one-way analysis of variance showed a significant difference in the log-transformed CPUE among years (Table 3.2.2-10). Waller-Duncan's multiple comparison revealed that 1982, 1979, and 1978, the years with the lowest CPUE, were significantly different from 1980 and 1981, and that the 1987 CPUE was significantly lower than that in 1980 (the highest year).

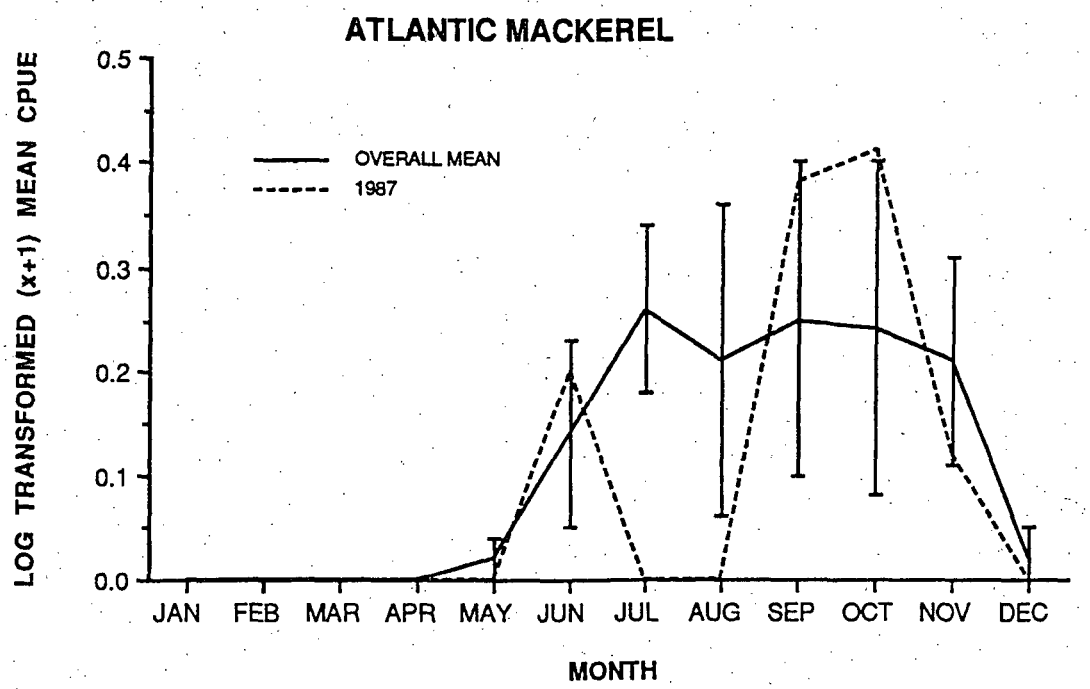
Atlantic Mackerel

Atlantic mackerel were present in gill net collections primarily from May to November with low CPUE January through April (Figure 3.2.2-5). Following a gradual increase in abundance May through July, monthly mean CPUE leveled off and remained at similar levels through November. In July and August of 1987, no Atlantic mackerel were caught, which may have been due to the infrequency of the gill net collections. Catches in September and October were greater than their overall means. Catches for mackerel were variable over the years, with mean CPUE ranging from 0.1 to 0.6 fish/net, and averaging 0.3 fish/net (Table 3.2.2-9). The one-way analysis of variance showed no significant differences among yearly means of log-transformed data (Table 3.2.2-10).

Demersal Species

Atlantic Cod

Atlantic cod were usually present in otter trawl catches throughout the year, with the highest catch per unit of effort (CPUE) in April, May and October through December (Figure 3.2.2-5). The 1987 monthly CPUE at T2



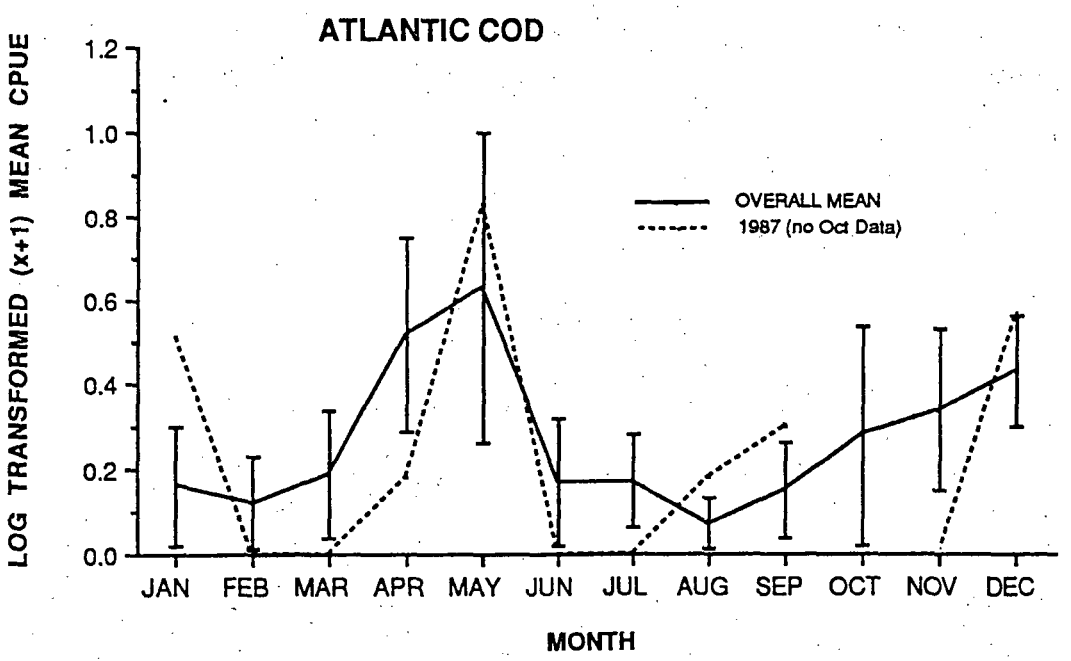
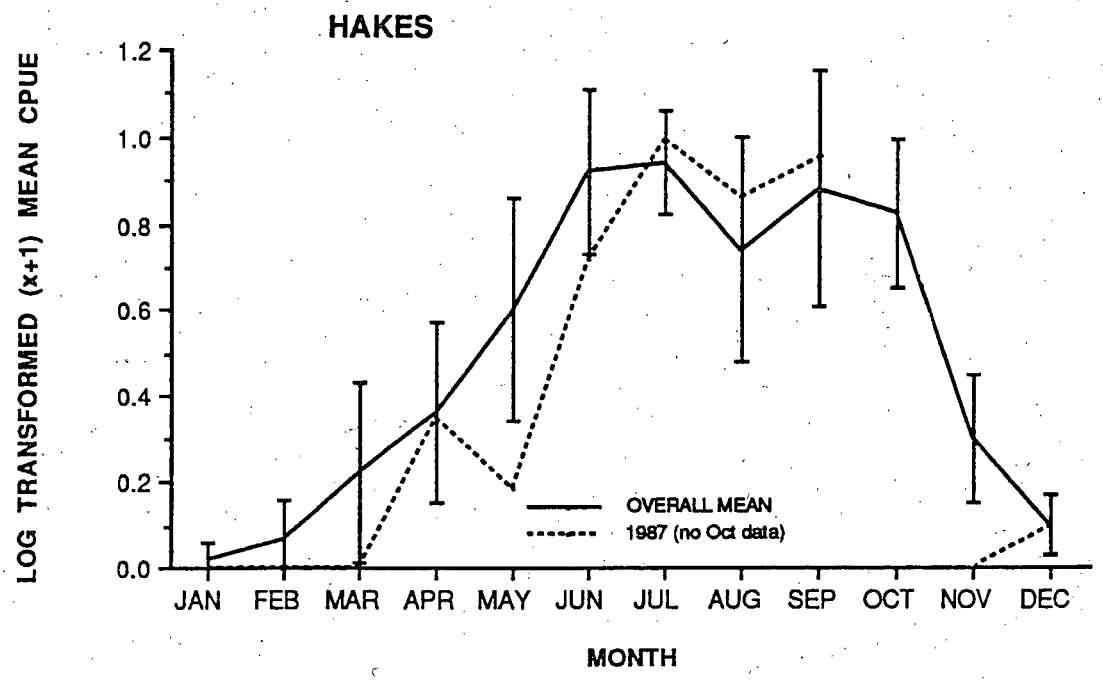


Figure 3.2.2-5. Mean and 95% confidence limits over all years, and 1987 values, by month, for log (x + 1) transformed catch per unit effort (one 24-hr. set for gill nets, one 10-min. tow for otter trawl) for Atlantic mackerel at combined gill net stations G1, G2 and G3 and Atlantic cod at otter trawl station T2, 1976-1987. Seabrook Baseline Report, 1987.

followed this trend, with peaks in May and December and low periods of abundance in February and March and June through August. No October data were collected in 1987 at T2 because lobster pots in that area prevented trawling. In addition, no cod were collected in November, generally a peak period for this species. Length-frequency data analyzed in past years showed that the spring peak was primarily comprised of immature (age one and two) cod, while the fall peak consisted of young-of-the-year (age 0) to age five (NAI 1985). The annual mean CPUE (geometric mean averaged over the three stations) for cod rose from 1.1 fish/tow in 1977 to greater than 5.2 fish/tow from 1978 through 1980 (Table 3.2.2-9). Mean CPUE gradually declined from 1981 through 1985, the lowest level recorded during the study (0.8 fish/tow). However, mean CPUE increased in 1986 and 1987 (1.2 and 2.5 fish/tow, respectively), indicating a possible reversal in the low abundances. A one-way analysis of variance revealed very highly significant differences among years at Station T1 (Table 3.2.2-11). The Waller-Duncan multiple comparison test showed that 1978 through 1983, the years of high abundance were significantly different from 1977, 1985 and 1986, the years of low abundance.

Hakes

Hake species (red, white and spotted) were present in high numbers at Station T2 from March through November, and in low numbers from December through February (Figure 3.2.2-6). Hake CPUE increased slowly in March through May, reaching a peak in June through October and then decreased in November. In 1987, mean CPUE followed this general trend. Although catches in May and June were lower than usual, CPUE from July through September were greater than the mean CPUE for all years. Annual mean CPUE (all three stations combined) ranged from 7.9 fish/tow in 1981 to 3.0 fish/tow in 1985, averaging 4.4 fish/tow overall (Table 3.2.2-9). In 1987, mean CPUE (3.3 fish/tow) was lower than the 12-year mean. The results of a one-way analysis of variance showed no significant differences in catch among years (Table 3.2.2-11).



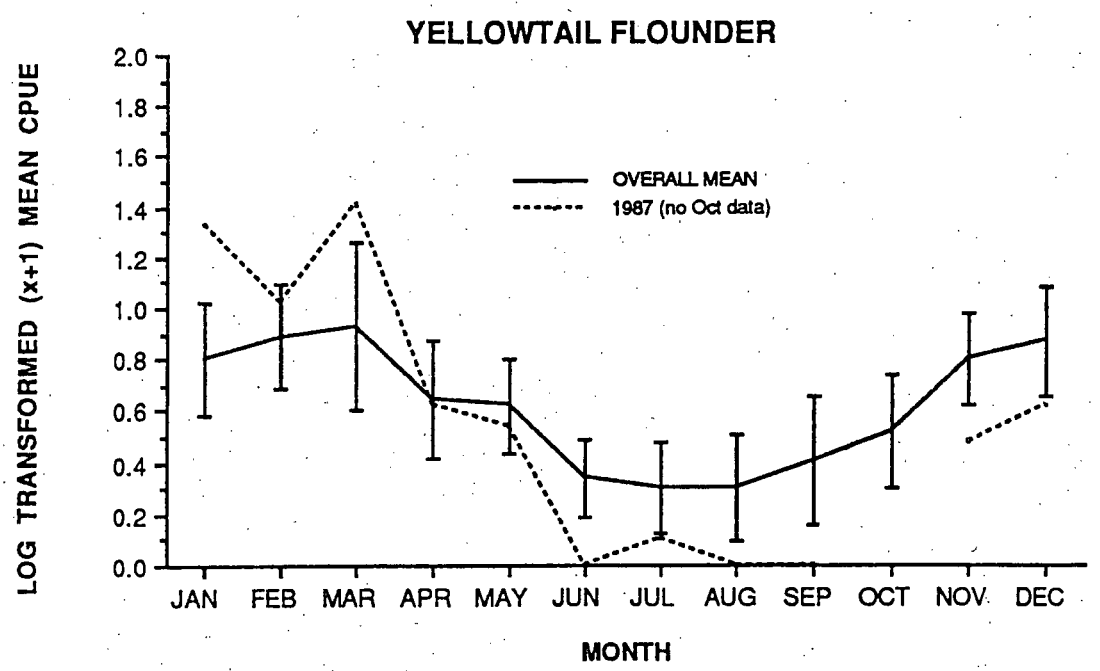


Figure 3.2.2-6. Mean and 95% confidence limits over all years, and 1987 values, by month, for log (x + 1) transformed catch per unit effort (one 10-min. tow) for hakes and yellowtail flounder at otter trawl station T2, 1976-1987. Seabrook Baseline Report, 1987.

TABLE 3.2.2-11. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE AMONG YEARS OF LOG (x+1) TRANSFORMED CATCH PER UNIT EFFORT FOR SELECTED FINFISH SPECIES AT OTTER TRAWL STATION T1 DURING 1976-1987. SEABROOK BASELINE REPORT, 1987.

SPECIES	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS
Winter flounder	Years	11	2.56	4.86***	81 80 87 86 82 83 85 77 78 84 79 76'
	Error	132	6.31		
	Total	143	8.87		
Yellowtail flounder	Years	11	4.18	6.71***	80 81 79 76 77 82 78 83 84 85 86 87
	Error	132	7.48		
	Total	143	11.66		
Hakes	Years	11	1.98	0.5NS	
	Error	132	47.72		
	Total	143	49.70		
Atlantic cod	Years	11	3.94	3.32***	80 81 79 83 82 78 87 84 76 77 86 85
	Error	132	14.23		
	Total	143	18.17		
Rainbow smelt	Years	11	1.69	0.61NS	
	Error	132	33.17		
	Total	143	34.86		

NS = not significant ($p > 0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

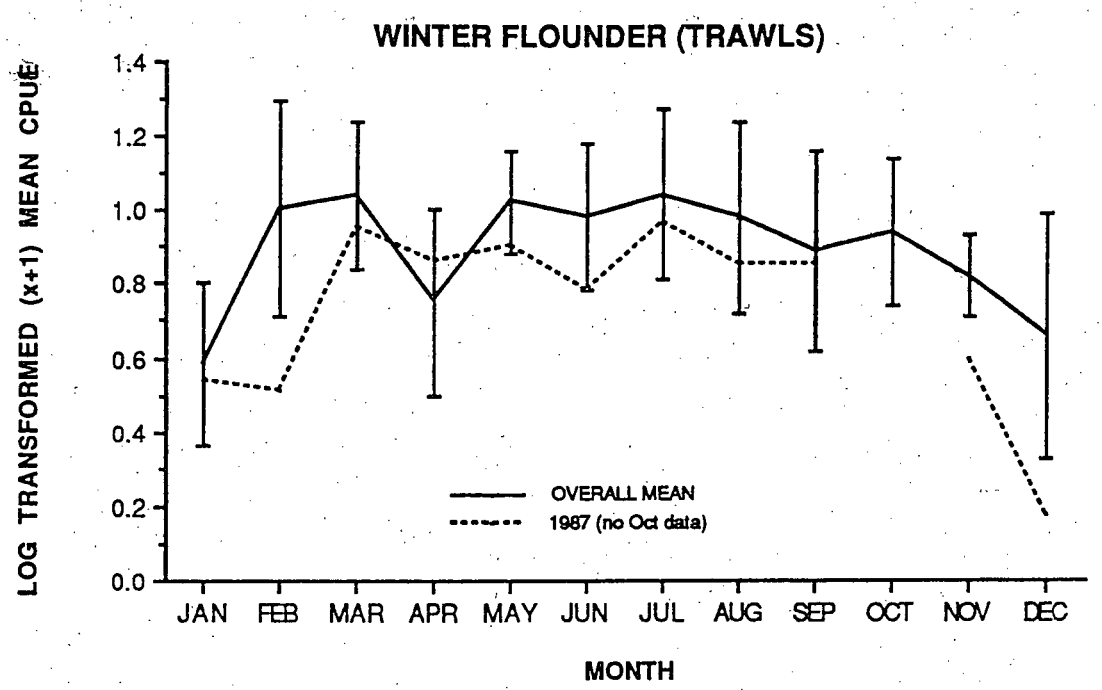
Yellowtail Flounder

Yellowtail flounder were collected year round in otter trawls at Station T2 (Figure 3.2.2-6) with monthly CPUE lower in June through September than in October through May. During June, August, and September of 1987, yellowtail CPUE was zero, well below the mean CPUE for these months over all years. No October data were collected in 1987 due to lobster pots in the trawling area. No distinct seasonal differences were noted for Stations T1 and T3 (NAI 1986). Analysis of length-frequency data in previous years revealed the majority of individuals collected at Station T2 were young-of-the-year fish (< 18 cm) and were most abundant during November through March (NAI 1984). The low summer CPUE at T2 probably reflects the movement of these young-of-the-year fish to other areas. Annual mean CPUE (all three stations combined) ranged from 28.4 fish/tow in 1980 to 8.0 fish/tow in 1986. In 1987 CPUE increased slightly (8.9 fish/tow) but was still below the over-all year mean of 13.9 fish/tow (Table 3.2.2-9). Mean CPUE was greatest at Station T1 (22.7 fish/tow), intermediate at Station T3 (11.9 fish/tow) and lowest at Station T2 (3.2 fish/tow). The one-way analysis of variance among years was very highly significant, and Waller-Duncan's multiple comparison of yearly means showed six overlapping groups with 1987 CPUE significantly lower than in six of the 11 previous years (Table 3.2.2-10).

Demersal and Estuarine Species

Winter Flounder

Winter flounder were present in otter trawl collections year-round, though not always at all three stations (NAI 1986). No distinct seasonal trend was apparent at Station T2, except mean CPUE was lowest in December and January (Figure 3.2.2-7). In 1987, CPUE for November, December and February were all below the overall mean. No October data were collected in 1987 due to lobster pots in the trawling area. Annual mean CPUE (all three stations combined) increased from a low of 2.6 fish/tow in 1976 to 10.3 fish/tow in



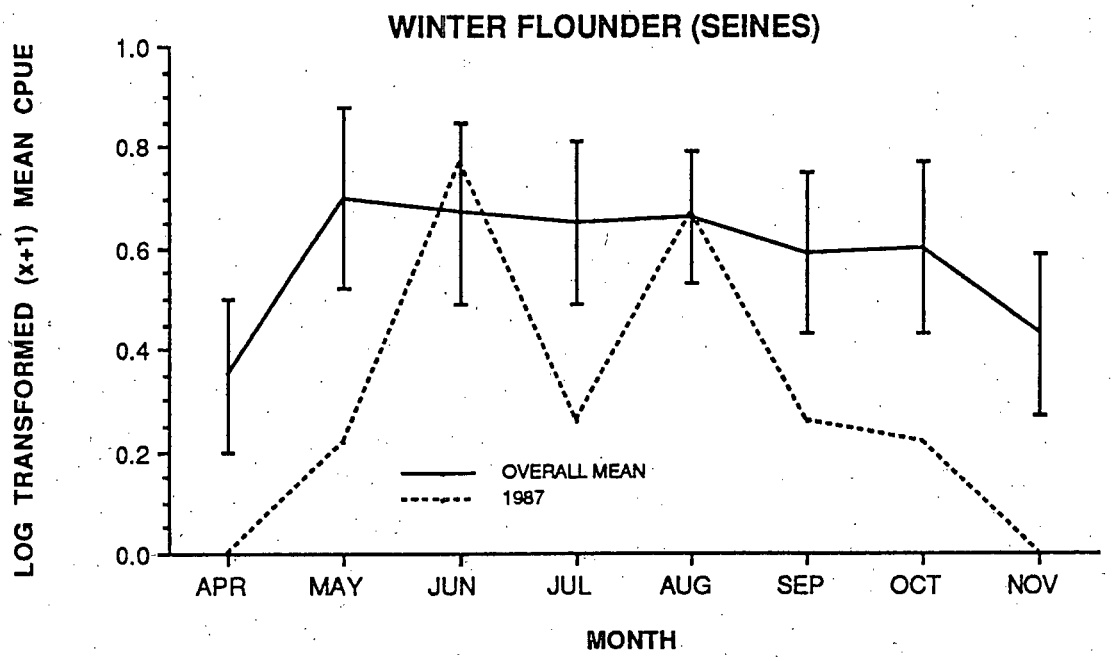


Figure 3.2.2-7. Mean and 95% confidence limits over all years, and 1987 values, by month, for log (x + 1) transformed catch per unit effort (one 10-min. tow for otter trawls and one haul for beach seines) for winter flounder at otter trawl station T2 1976-1987 and combined beach seine stations S1, S2 and S3 1976-1984 and 1987. Seabrook Baseline Report, 1987.

1980 and 1981, averaging 4.9 fish/tow over the 12-year period (Table 3.2.2-9). Annual mean CPUE declined from 1982 through 1985 but increased in 1986 and 1987 to present levels of 4.9 fish/tow. Mean CPUE values were highest at T2 (7.2 fish/tow) followed by Station T1 (3.5 fish/tow) and Station T3 (2.6 fish/tow). Results of the one-way analysis of variance among years was very highly significant (Table 3.2.2-11). The multiple comparisons of yearly catches showed 1976 was significantly lower than all other years.

Winter flounder were also present in beach seine collections from the Hampton-Seabrook estuary throughout the April through November sampling period (Figure 3.2.2-7). In 1987, monthly mean CPUE was much lower than average for all months except June and August. Annual mean CPUE (all three stations combined) ranged from 1.0 fish/tow in 1987 to 5.7 fish/tow in 1980, with an average of 2.9 fish/tow (Table 3.2.2-9). A one-way analysis of variance among years was highly significant, and the multiple comparisons of yearly catches showed 1980 and 1979 to be significantly higher than 1976, 1983, and 1987, and 1987 CPUE to be significantly lower than that in all years except 1976 and 1983 (Table 3.2.2-12). Beach seines were not collected in 1985 and insufficient data were collected in 1986 to use in this comparison.

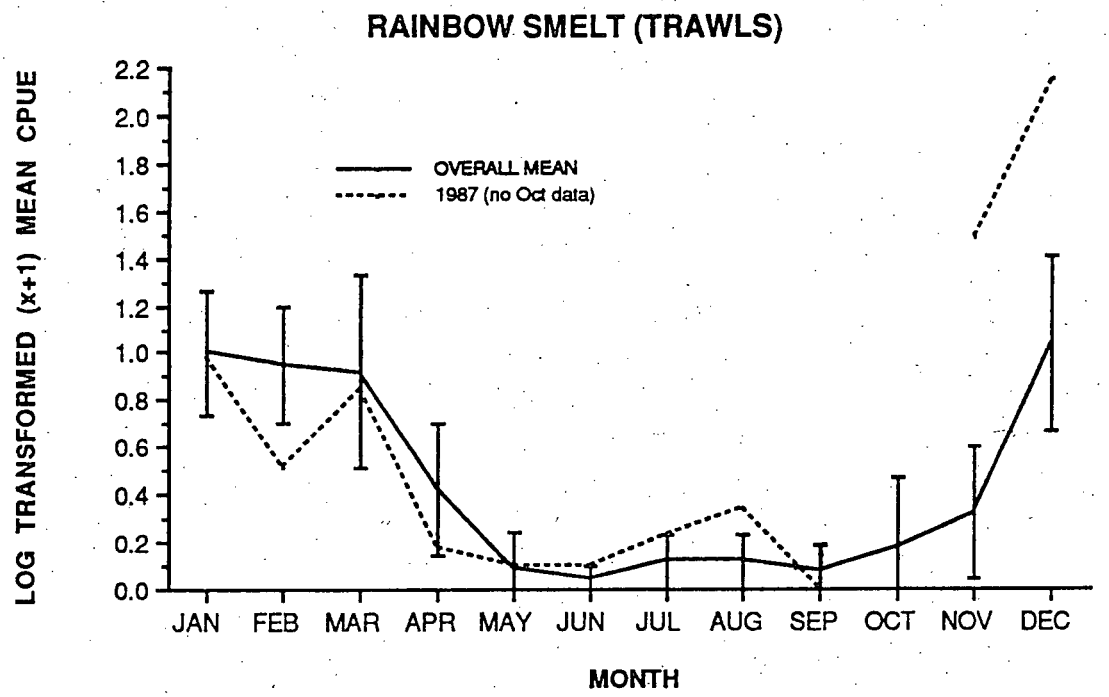
Rainbow Smelt

Rainbow smelt were collected in otter trawls primarily during December through March (Figure 3.2.2-8). In 1987, monthly mean CPUE followed this same pattern except catches in November and December were higher than normal. Annual mean CPUE (all three stations combined) ranged from 2.9 fish/tow in 1978 to 0.5 fish/tow in 1985, averaging 1.4 fish/tow overall (Table 3.2.2-9). In 1987, mean CPUE (2.5 fish/tow) increased over 1986 values (0.9 fish/tow) indicating a possible reversal in the low abundances experienced in 1985. Mean CPUE was greatest at Station T2 (1.9 fish/tow) followed by Station T1 (1.1 fish/tow) and Station T3 (0.7 fish/tow). Results of a one-way analysis of variance showed no significant differences in catch among years (Table 3.2.2-11).

TABLE 3.2.2-12. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE AMONG YEARS OF LOG (x+1) TRANSFORMED CATCH PER UNIT EFFORT FOR SELECTED FINFISH SPECIES FOR ALL BEACH SEINE STATIONS COMBINED DURING 1976-1984 AND 1987. SEABROOK BASELINE REPORT, 1987.

SPECIES	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS
Winter flounder	Years	9	1.71	3.44**	80 79 77 78 81 82 84 83 76 87
	Error	70	3.86		
	Total	79	5.56		
Rainbow smelt	Years	9	2.79	1.02NS	
	Error	70	21.32		
	Total	79	24.11		
Atlantic silversides	Years	9	3.23	0.31NS	
	Error	70	80.98		
	Total	79	84.21		

NS = not significant ($p > 0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)



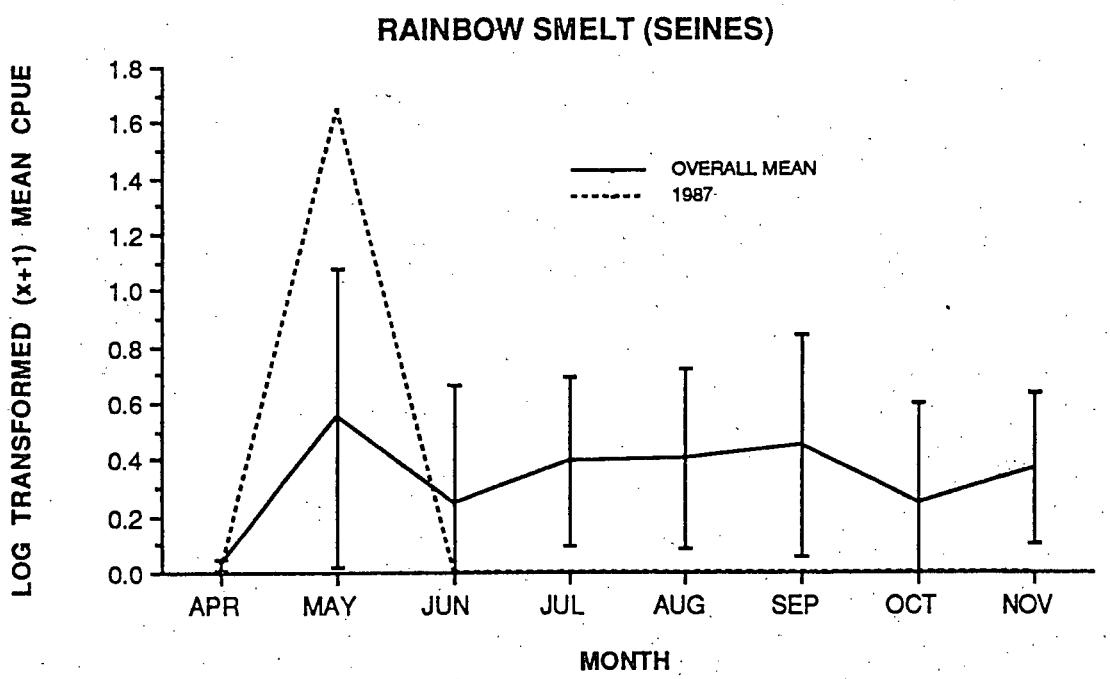


Figure 3.2.2-8. Mean and 95% confidence limits over all years and 1987 values, by month, for log (x + 1) transfored catch per unit effort (one 10-min. tow for otter trawl and one haul for beach seines) for rainbow smelt at otter trawl station T2 1976-1987 and combined beach seine stations S1, S2, S3 from 1976-1984 and 1987. Seabrook Baseline Report, 1987.

Rainbow smelt were also prevalent in beach seine collections in the Hampton-Seabrook estuary. Monthly CPUE was variable with large catches possible any month during the sampling period (Figure 3.2.2-8). In 1987 no fish were caught from June through November. Annual mean CPUE (all three stations combined) ranged from 0.1 fish/seine in 1980 to 3.3 fish/seine in 1979, averaging 1.2 fish/seine (Table 3.2.2-9). In 1987 mean CPUE decreased from 1984 values to the third lowest value during the past 12 years (0.6 fish/seine). Station differences were evident, with mean CPUE much higher at Station S3 (1.7 fish/tow) than at either Station S2 (0.2 fish/tow) or Station S1 (0.1 fish/tow). A one-way analysis of variance on the yearly log-transformed CPUE showed no significant difference among years (Table 3.2.2-12).

Estuarine Species

Atlantic Silverside

Atlantic silverside were present in the Hampton-Seabrook estuary beach seine collections throughout the April through November sampling season in most years, with the largest CPUE values occurring from August through November (Figure 3.2.2-9). The CPUE for 1987 followed this pattern, except September was much lower than the overall mean. The catches were highly variable throughout the years with annual mean CPUE ranging from 7.3 to 31.1 fish/haul and averaging 16.9 fish/haul overall (Table 3.2.2-9). The high variability might be due to the high mobility and schooling characteristics of this species. The one-way analysis of variance showed no significant difference among years for log-transformed CPUE (Table 3.2.2-12).

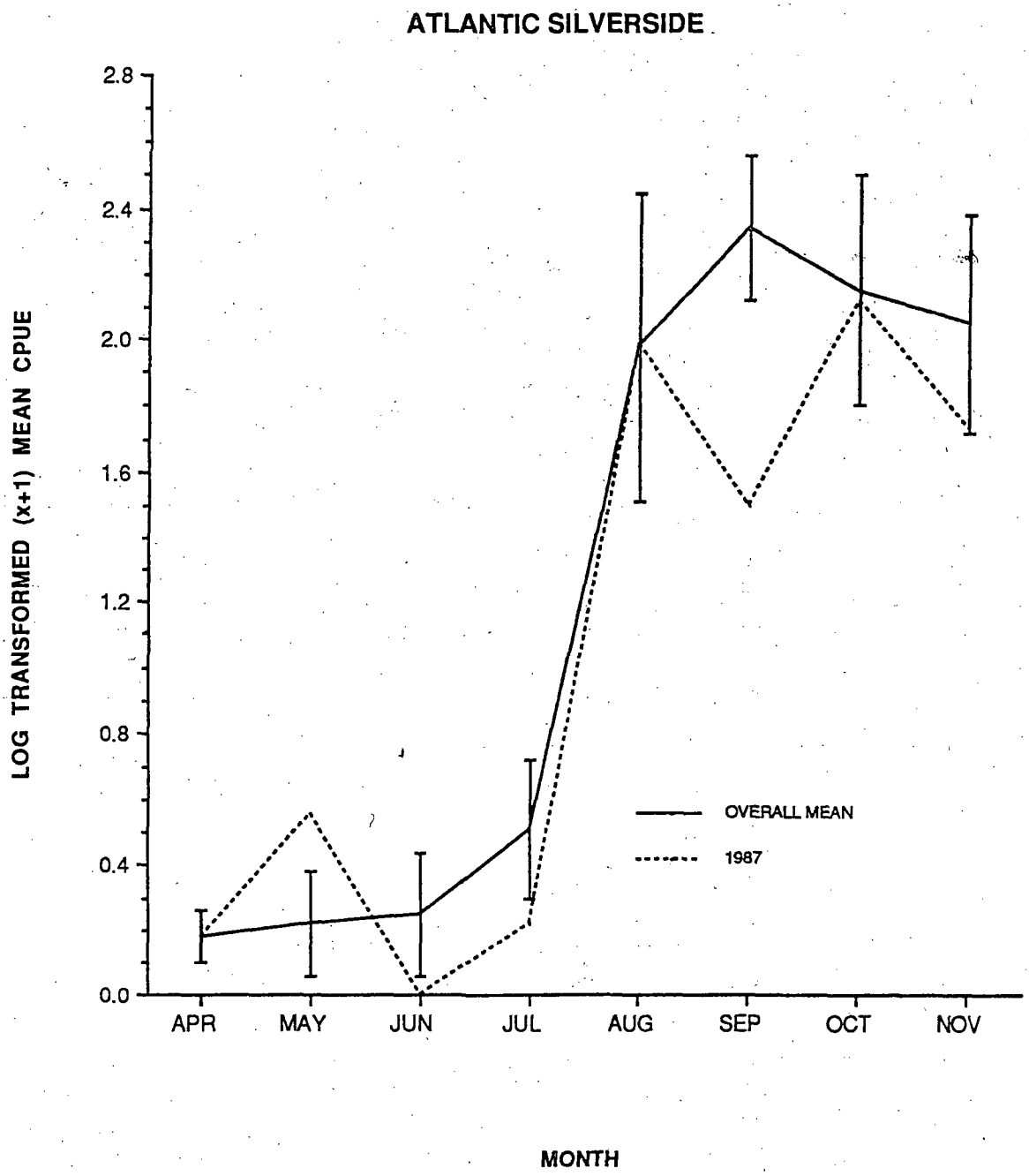


Figure 3.2.2-9. Mean and 95% confidence limits over all years, and 1987 values, by month, for log (x + 1) transformed catch per unit effort (one haul for beach seines) for Atlantic silverside at combined beach seine stations S1, S2 and S3 1976-1984 and 1987. Seabrook Baseline Report, 1987.

3.2.3 Finfish Appendix Tables

APPENDIX TABLE 3.2.1-1. FINFISH SPECIES COMPOSITION BY LIFE STAGE AND GEAR, JULY 1975-DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

SCIENTIFIC NAME[a]	COMMON NAME[a]	ICHTHYO-PLANKTON TOWS		ADULT AND JUVENILE FINFISH		
		EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Acipenser oxyrhynchus	Atlantic sturgeon				R[b]	
Alosa aestivalis	blueback herring			R	C	C
Alosa mediocris	hickory shad				R	
Alosa pseudoharengus	alewife			O	O	O
Alosa sapidissima	American shad			R	O	O
Ammodytes americanus	American sand lance		A	O	R	O
Anarhichas lupus	Atlantic wolffish			R		
Anchoa hepsetus	striped anchovy					R
Anguilla rostrata	American eel		C	R		
Apeltes quadracus	fourspine stickleback					R
Archosargus probatocephalus	sheepshead			R		
Aspidophoroides monopterygius	alligatorfish		C	O		
Brevoortia tyrannus	Atlantic menhaden	O	O		O	R
Brosme brosme	cusk	O	O			
Caranx hippos	crevalle jack					R
Centropristis striata	black sea bass			R	R	
Conger oceanicus	conger eel		R			
Clupea harengus harengus	Atlantic herring		C	O	A	O
Cryptacanthodes maculatus	wrymouth		O			
Cyclopterus lumpus	lumpfish		C	R	R	R
Enchelyopus cimbrius	fourbeard rockling	C	C	O		
Fundulus sp.[c]	mummichog[c]					C
Gadus morhua	Atlantic cod	-	C	C	O	R

(continued)

APPENDIX TABLE 3.2.1-1. (Continued)

SCIENTIFIC NAME[a]	COMMON NAME[a]	ICHTHYO-PLANKTON TOWS		ADULT AND JUVENILE FINFISH		
		EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Gadus/Melanogrammus	Atlantic cod/haddock	C	-	-	-	-
Gasterosteus sp.[d]	stickleback[d]			R		C
Glyptocephalus cynoglossus	witch flounder	C	C	O		
Hemitripterus americanus	sea raven		O	C	O	R
Hippoglossoides platessoides	American plaice	C	C	O		
Hippoglossus hippoglossus	Atlantic halibut			R		
Labridae/*Limanda*	cunner/yellowtail flounder[e]	A	-	-	-	-
Limanda ferruginea	yellowtail flounder	-	C	A	R	O
Liopsetta putnami	smooth flounder		R	R		C
Liparis atlanticus	seasnail		C	-	-	-
Liparis coheni	gulf snailfish		C	-	-	-
Liparis sp.[f]	snailfish[f]		-	O		
Lophius americanus	goosefish		C	O	R	
Lumpenus lampretaeformis[g]	snakeblenny		O	R		
Lumpenus maculatus	daubed shanny		R	R		
Macrozoarces americanus	ocean pout		O	C	R	
Melanogrammus aeglefinus	haddock	-	O	C	R	
Menidia menidia	Atlantic silverside			O	R	A
Menticirrhus saxatilis	northern kingfish				R	
Merluccius bilinearis	Atlantic whiting[h]	C	C	C	C	R

(continued)

APPENDIX TABLE 3.2.1-1. (Continued)

SCIENTIFIC NAME[a]	COMMON NAME[a]	ICHTHYO-PLANKTON TOWS		ADULT AND JUVENILE FINFISH		
		EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Microgadus tomcod	Atlantic tomcod		R			O
Morone americana	white perch					R
Morone saxatilis	striped bass				R	R
Mustelus canis	smooth dogfish				R	
Myoxocephalus aenaeus	grubby		C	O	R	O
Myoxocephalus octodecemspinosus	longhorn sculpin		C	A	O	R
Myoxocephalus scorpius	shorthorn sculpin		O	O	R	R
Odontaspis taurus	sand tiger				R	
Oncorhynchus kisutch	coho salmon				R	R
Osmerus mordax	rainbow smelt		C	C	O	C
Paralichthys dentatus	summer flounder			R		
Paralichthys oblongus	fourspot flounder		O	C		
Peprilus triacanthus	butterfish	O	O	R	O	R
Petromyzon marinus	sea lamprey				R	
Pholis gunnellus	rock gunnel		C	O	R	R
Pollachius virens	pollock	C	C	C	C	O
Pomatomus saltatrix	bluefish				O	R
Prionotus carolinus	northern searobin	-	-	O	R	
Prionotus evolans	striped searobin	-	-	R		
Prionotus sp.	searobin	O	R	-	-	-
Pseudopleuronectes americanus	winter flounder		C	C	O	C
Pungitius pungitius	ninespine stickleback					C
Raja sp.[i]	skate[i]			C	R	
Salmo gairdneri	rainbow trout					R

(continued)

APPENDIX TABLE 3.2.1-1. (Continued)

SCIENTIFIC NAME[a]	COMMON NAME[a]	ICHTHYO-PLANKTON TOWS		ADULT AND JUVENILE FINFISH		
		EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Salmo trutta	brown trout					O
Salvelinus fontinalis	brook trout					R
Scomber japonicus	chub mackerel				R	
Scomber scombrus	Atlantic mackerel	A	A	R	C	R
Scophthalmus aquosus	windowpane	C	C	C	R	O
Sebastes sp.[j]	redfish		O			
Sphoeroides maculatus	northern puffer			R		R
Squalus acanthias	spiny dogfish			R	R	
Stenotomus chrysops	scup		R	O	R	
Stichaeus punctatus	Arctic shanny		O			
Syngnathus fuscus	northern pipefish		C	O	R	O
Tautoga onitis	tautog	-	O		R	
Tautogolabrus adspersus	cunner	-	A	O	O	R
Torpedo nobiliana	Atlantic torpedo			R		
Triglops murrayi	moustache sculpin		O	R		
Ulvaria subbifurcata	radiated shanny		C	O		
Urophycis sp.[k]	hake[k]	A	C	A	O	C

Footnotes: See next page.

APPENDIX TABLE 3.2.1-1. (Continued)

Footnotes:

[a]Names are according to Robins *et al.* (1980) unless otherwise noted. Taxa usually identified to a different level are not included in this list to avoid duplication (e.g., Gadidae, *Enchelyopus/Urophycis, Myoxocephalus* sp., *Urophycis chuss*, etc.)

[b]Occurrence of each species is indicated by its relative abundance or frequency of occurrence for each lifestage or gear type:

A = abundant (≥ 10% of total catch over all years)
C = common (occurring in ≥ 10% of samples but < 10% of total catch)
O = occasional (occurring in < 10 and ≥ 1% of samples)
R = rare (occurring in < 1% of samples)
- = not usually identified to this taxonomic level at this lifestage

[c]Predominantly *Fundulus heteroclitis*, mummichog, but may include a small number of *Fundulus majalis*, striped killifish.

[d]Two species of *Gasterosteus* have been identified from seine samples: *G. aculeatus*, threespine stickleback; and *G. wheatlandi*, blackspotted stickleback (both occurring commonly).

[e]May also include a small number of tautog.

[f]Three species of *Liparis* have been identified from trawl samples: *L. atlanticus*, *L. coheni*, and *L. inquilinus* (inquiline snailfish).

[g]Spelling after Faber (1976).

[h]Previously called silver hake (NAI 1982a); Atlantic whiting was recommended by Kendall and Naplin (1981:707).

[i]Four species of *Raja* have been identified from trawl samples: *R. radiata*, thorny skate (common); *R. erinacea*, little skate (common); *R. binoculata*, big skate (occasional); and *R. eglanteria*, clearnose skate (rare).

[j]Previously called *S. marinus*. Recently *S. mentella* and *S. fasciatus* have also been reported to occur in the northwest Atlantic (Ni 1981a; 1981b). *Sebastes* in coastal New Hampshire waters are probably *S. fasciatus* (Dr. Bruce B. Collette, U.S. National Museum, pers. comm. April 1982), but larval descriptions are insufficient to allow distinction among the three species.

[k]Three species of *Urophycis* have been identified from trawl samples: *U. chuss*, red hake (common); *U. tenuis*, white hake (common); and *U. regia*, spotted hake (rare).

3.3 BENTHOS

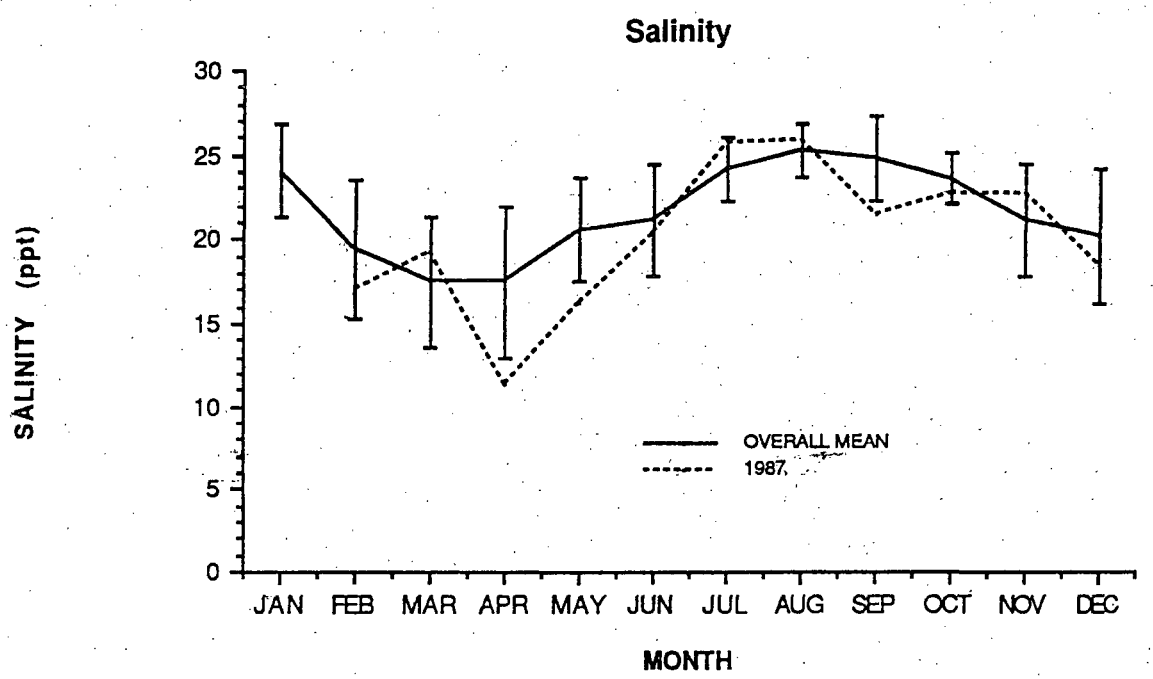
3.3.1 Estuarine Benthos

3.3.1.1 Physical Environment

Salinity and Temperature

Weekly measurements of salinity and temperature at high and low slack tides in Brown's River and Hampton Harbor were taken to investigate annual and monthly patterns. The Brown's River salinity station is just downstream from the benthic transect, and about 0.5 km downstream from the settling basin outfall; the Hampton Harbor station is a control station away from the influence of the outfall (Figure 4.1-4). Low tide collections in Brown's River represent the more extreme environmental conditions in comparison to Hampton Harbor. The water is not as tempered by tidal influx of sea water, as is the Hampton Harbor station.

Mean monthly salinity at low tide in Brown's River ranged from 17.5 ± 4.6 ppt in April to 25.3 ± 1.6 ppt in August during the nine-year study period from May 1979 through December 1987 (Appendix Table 3.3.1-1, Figure 3.3.1-1, Table 3.3.1-1). In 1987, monthly salinities were within the 95% confidence limits of the nine-year averages except for April, May, and September, which had below-average salinities (Figure 3.3.1-1). Rainfall during April 1987 totaled 9.5 inches (Table 3.3.1-2), and nearly half of that occurred on April 5 and 6 (National Climatic Data Center 1987), which caused flood waters to reach a 10-year high in many New Hampshire areas. Rainfall in late April was also well above average, which caused the mean salinity in May 1987 to be well below the nine-year average, despite a total rainfall of only 1.75 inches. Again in September, the total rainfall was very high, and salinities were correspondingly low. In spite of having salinities which fell below the lower 95% confidence limit of the nine-year average during three months of 1987, the annual mean salinity was 20.1 ppt, only very slightly below the average for the study period (Table 3.3.1-1). Likewise, the annual precipitation was 45.5 inches, slightly above the average for the study period (42.18 inches).



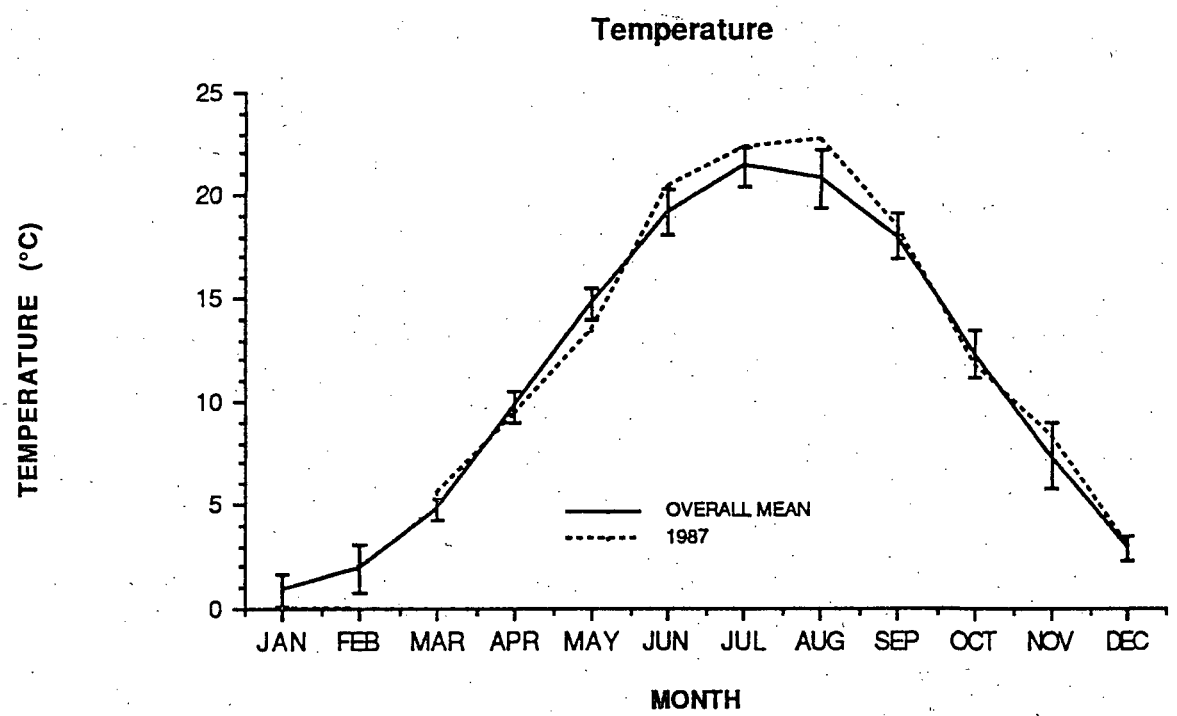


Figure 3.3.1-1. Mean monthly seawater surface temperature and salinity with 95% confidence limits taken at low tide in Brown's River over the entire study period (May 1979 - December 1987) and in 1987. Seabrook Baseline Report, 1987.

TABLE 3.3.1-1. ANNUAL MEAN[a] TEMPERATURE (°C) AND SALINITY (PPT) TAKEN AT BOTH HIGH AND LOW SLACK TIDE FROM BROWN'S RIVER AND HAMPTON HARBOR FROM 1980-1987. SEABROOK BASELINE REPORT, 1987.

	BROWN'S RIVER				HAMPTON HARBOR			
	LOW TIDE		HIGH TIDE		LOW TIDE		HIGH TIDE	
	TEMP (°C)	SALINITY (ppt)	TEMP (°C)	SALINITY (ppt)	TEMP (°C)	SALINITY (ppt)	TEMP (°C)	SALINITY (ppt)
1980	10.9	25.1	9.6	31.0	9.6	29.9	9.1	32.1
1981	10.6	25.5	10.3	30.0	9.3	28.9	9.3	31.5
1982	10.7	22.8	9.9	30.0	10.2	27.3	9.2	31.2
1983	11.9	19.4	11.0	28.0	10.4	25.5	9.9	30.1
1984	11.9	18.1	10.6	28.4	10.4	25.8	9.4	30.2
1985	11.3	21.7	10.1	30.6	10.6	29.1	10.1	32.2
1986	10.3	20.4	9.6	30.2	10.0	27.7	9.4	31.5
1987	-[b]	20.1[c]	-[b]	28.7[c]	10.0	27.5	8.9	30.7
OVERALL	11.1	21.6	10.2	29.6	10.1	27.7	9.4	31.2

[a] Annual mean $= \frac{\Sigma \text{monthly mean temperature}}{12 \text{ months}}$

[b] No data were taken in January or February, therefore no annual mean was computed.

[c] No data were taken in February, therefore n = 11 months.

TABLE 3.3.1-2. TOTAL PRECIPITATION (WATER EQUIVALENT IN INCHES) BY MONTH AND YEAR TAKEN AT LOGAN INTERNATIONAL AIRPORT, BOSTON, MA FROM JANUARY 1978 - DECEMBER 1987.* SEABROOK BASELINE REPORT, 1987.

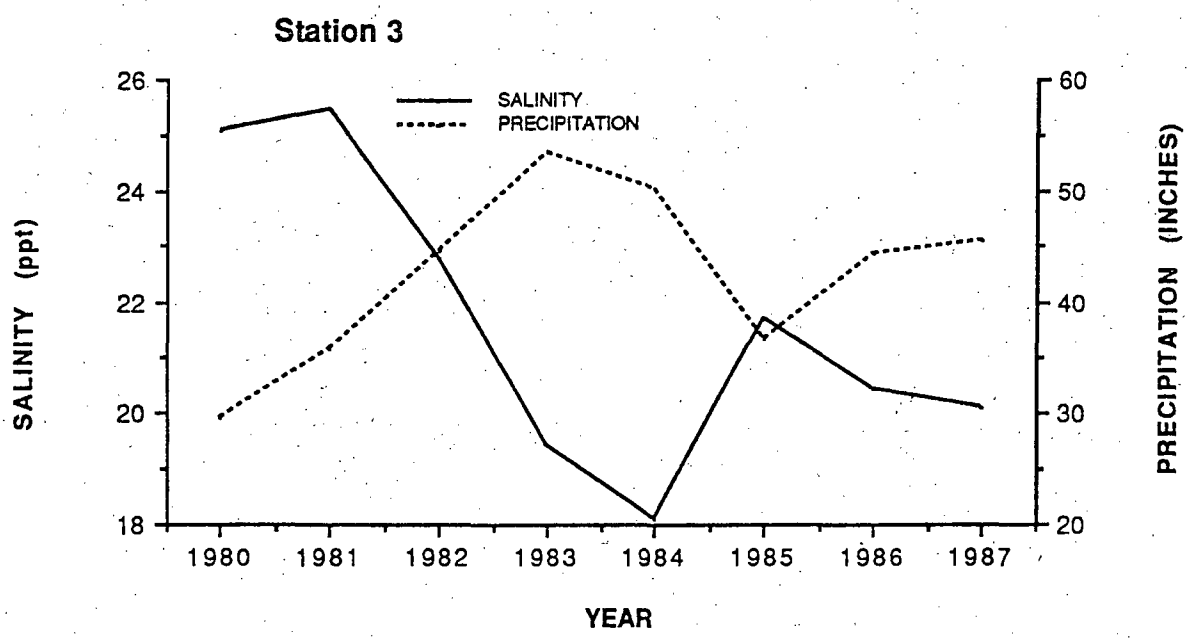
	MONTHLY TOTALS									
MONTH	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
JAN	8.12	10.55	0.74	0.95	4.69	5.03	2.31	1.12	3.42	7.28
FEB	2.87	3.46	0.88	6.65	2.66	5.00	7.81	1.83	2.83	0.72
MAR	2.46	3.03	5.37	0.62	2.17	9.72	6.82	2.29	3.42	4.27
APR	1.79	3.19	4.36	3.14	3.42	6.86	4.43	1.62	1.59	9.46
MAY	4.50	4.24	2.30	1.17	2.58	2.94	8.77	3.36	1.31	1.75
JUN	1.53	0.86	3.05	1.65	13.20	1.07	3.06	3.94	7.74	2.62
JUL	1.48	2.36	2.20	3.47	4.22	1.07	4.43	3.51	3.96	0.82
AUG	4.62	5.02	1.55	1.04	2.22	3.28	1.60	6.67	3.32	2.93
SEP	1.30	3.61	0.82	2.54	1.57	1.06	1.22	3.00	1.08	7.29
OCT	3.13	3.14	4.14	3.43	3.19	3.74	5.18	1.65	3.27	2.73
NOV	2.21	3.29	3.01	4.78	3.42	8.89	1.68	6.39	6.01	3.49
DEC	3.63	1.42	0.97	6.27	1.27	4.94	2.93	1.21	6.38	2.12
ANNUAL	37.64	44.17	29.39	35.71	44.61	53.60	50.24	36.59	44.33	45.48

*Source: National Climatic Data Center. 1987. Local Climatological Data, Monthly Summary January-December. Federal Bldg., Ashville, NC.

The mean monthly salinity at high tide in Brown's River ranged from 26.4 ± 3.2 ppt in April to 31.5 ± 1.1 ppt in January during the nine-year study period (Appendix Table 3.3.1-1, Figure 3.3.1-1). High tide salinity was always higher than low tide salinity due to the influx of more saline water from Hampton Harbor into Brown's River. The influx tempered the extremes which occurred at low tide due to environmental conditions.

At the control station in Hampton Harbor, the mean monthly low tide salinity during the nine-year study period ranged from 24.1 ± 3.8 ppt in April to 29.9 ± 0.7 ppt in September (Appendix Table 3.3.1-1). The salinity in Hampton Harbor was always higher than in Brown's River (Appendix Table 3.3.1-1), due to its proximity to the inlet.

Annual precipitation was inversely related to average yearly salinity during every year of the 1980-1987 study period in Hampton Harbor; when rainfall increased, salinity decreased (Figure 3.3.1-2). Brown's River generally followed the same inverse relationship with rainfall except for 1981 and 1984. In 1981, average yearly low tide salinity decreased by 1.00 ppt in Hampton Harbor, but increased by 0.4 ppt in Brown's River (Table 3.3.1-1). In 1984, when average yearly low tide salinity in Hampton Harbor went up 0.3 ppt, it went down by 1.3 ppt in Brown's River. The Seabrook Station settling pond outfall usually contained fresh water from the station's sewage treatment plant and runoff from rainfall. During the years of highest discharge from November 1979 through November 1983 (Figure 3.3.1-3), the outfall became saline, containing mostly offshore sea water from tunnel dewatering, with salinities of approximately 31 ppt. In 1981, when the amount of discharge peaked, there was a slight (+0.4 ppt) increase in average yearly salinity in Brown's River when the control station showed a decrease (-1.0 ppt) (Table 3.3.1-1). In 1984, when dewatering of the tunnels was terminated and saline discharges ended, the salinity in Brown's River dropped 1.3 ppt from the previous year, while salinity in Hampton Harbor rose 0.3 ppt. Since the salinity changes were small (+0.4 and -1.3 ppt), it is difficult to determine whether they are due to natural variation, or marked the beginning and end of tunnel dewatering.



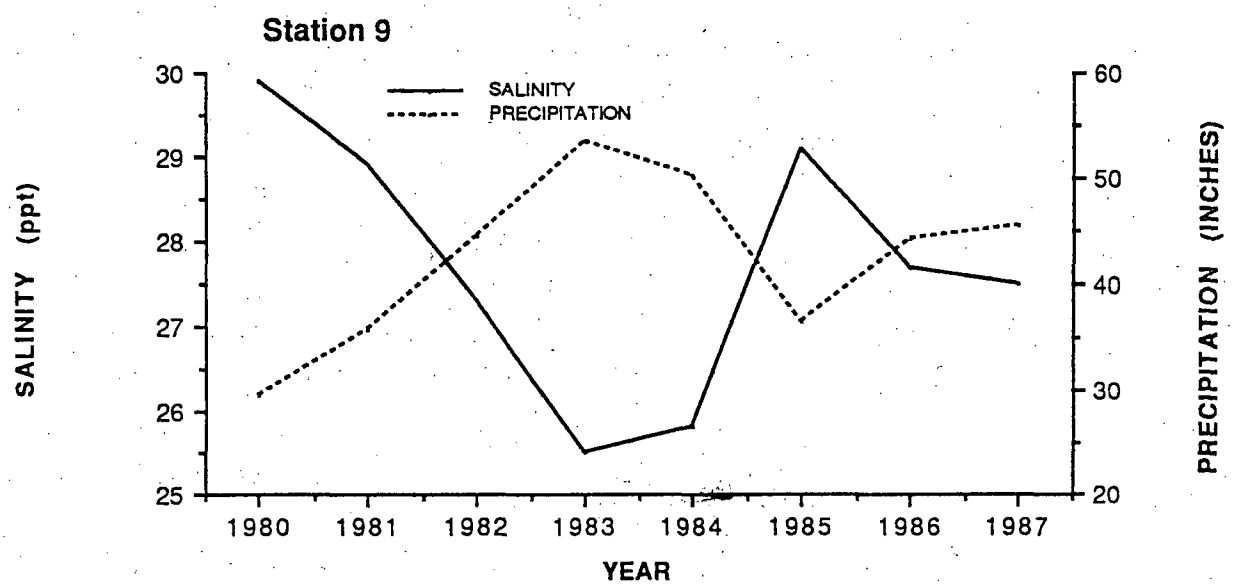
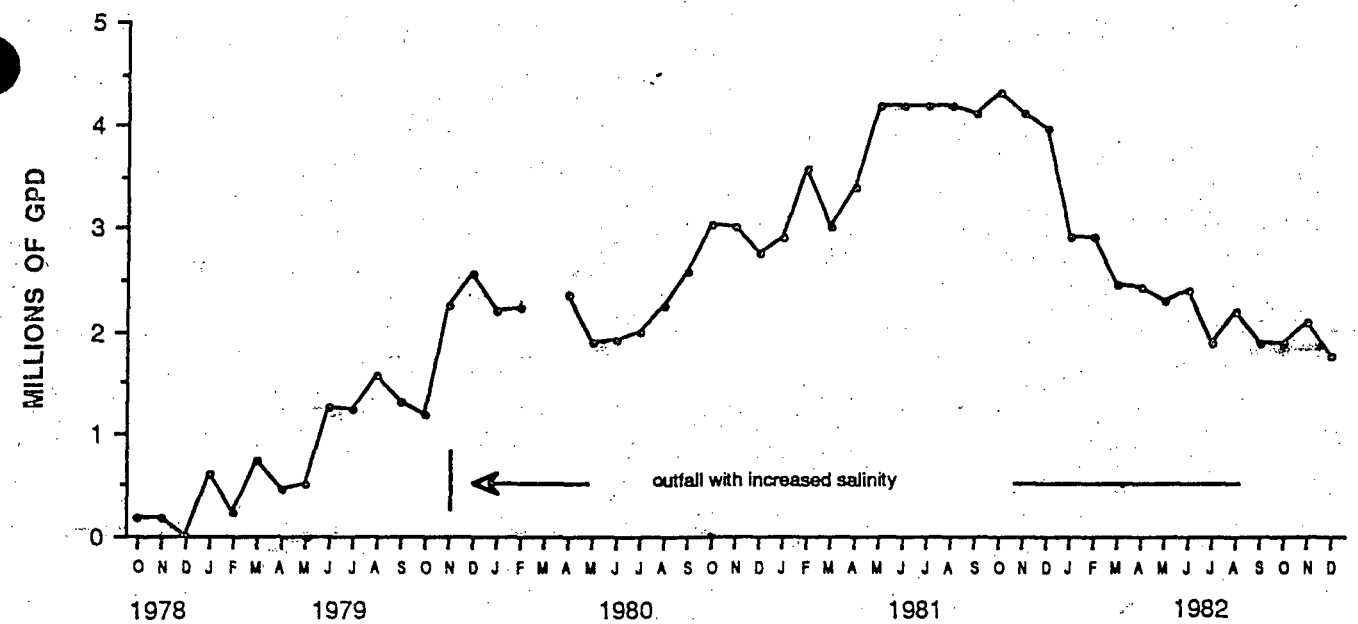


Figure 3.3.1-2. Mean annual salinity at low tide in Brown's River (3) and in Hampton Harbor (9), and total annual precipitation from 1980 through 1987. Seabrook Baseline Report, 1987.



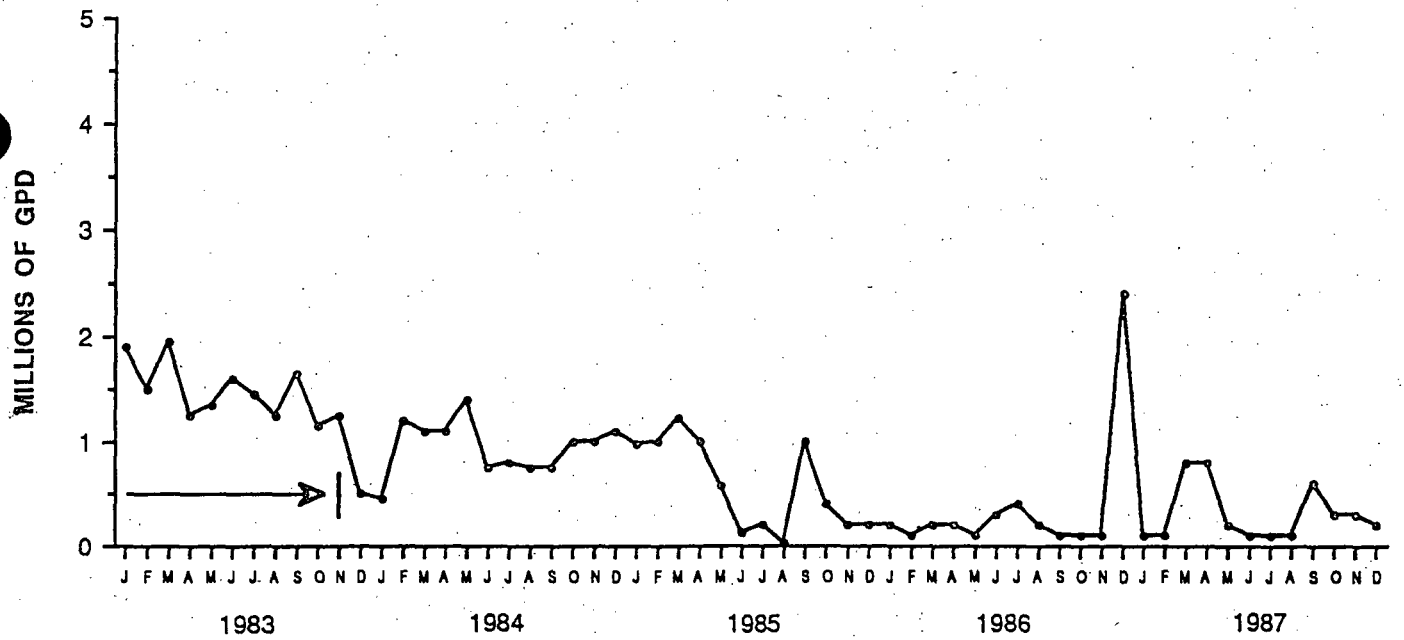


Figure 3.3.1-3. Monthly outfall from the Seabrook Settling Basin from 1978-1987 in millions of gallons per day (GPD). Seabrook Baseline Report, 1987.

Mean monthly temperature at low tide in Brown's River ranged from 0.9 ± 0.8°C in January to 21.4 ± 1.0°C in July during the nine-year study period (Appendix Table 3.3.1-1, Figure 3.3.1-1). In 1987, average monthly temperatures were within the 95% confidence limits of the nine-year monthly averages except for May which was slightly cooler in 1987 (Figure 3.3.1-1) and August, which was warmer. The mean average yearly temperature was not computed for Brown's River in 1987 because no data were collected in January or February, traditionally the coldest months of the year.

In Hampton Harbor, average monthly temperatures at low tide ranged from 1.0 ± 0.7°C in January to 18.6 ± 1.0°C in August during the nine-year study period (Appendix Table 3.3.1-1). Hampton Harbor water at low tide was slightly warmer than Brown's River in November, December, January and colder during the rest of the year. The annual mean low tide temperature in Hampton Harbor in 1987 was 10.0°C, very close to the nine-year average of 10.1°C (Table 3.3.1-1). In both Brown's River and Hampton Harbor, the 1987 monthly temperatures were close to the nine-year average (Figure 3.3.1-1).

Sediment

Yearly and seasonal differences in sediment collected in 1978-1984 indicated estuarine sediments were very patchy with spatial variability often exceeding annual variability (NAI 1985b). Yearly averages at subtidal stations (3 & 9) showed grain size was fine sand, which was usually poorly sorted with organic carbon ranging from 0.97 to 2.08% (NAI 1985b). The yearly averages for intertidal stations (3MLW and 9MLW) showed the grain size varied from fine sand to silt, which was often very poorly sorted. The percentage of organic carbon was higher than at subtidal stations and ranged from 1.56 to 5.86% (NAI 1985b). Although differences in low tide salinity in Brown's River appeared from 1980-1982, sediment parameters during that period were apparently within the range of natural variation.

3.3.1.2 Macrofauna

The estuarine benthic communities in Brown's River (Station 3) and Mill Creek (Station 9) were usual for quiet, tidal creeks with fine-grained sediments, where average monthly salinity ranged from 18 ppt to 25 ppt (Appendix Table 3.3.1-1). Spatial distribution of organisms was very patchy, and large population fluctuations occurred seasonally, as is typical in estuarine habitats. Deposit and surface deposit feeders predominated, usually composing over 70% of the fauna at Stations 3, 9 and 9MLW (NAI 1985b). Three taxa comprised the majority of individuals: *Streblospio benedicti*, Oligochaeta, and *Capitella capitata*. The clam worm, *Nereis diversicolor*, was very abundant intertidally in Brown's River (3MLW). The soft-shelled clam, *Mya arenaria*, was also present in substantial numbers at all sampling locations (Table 3.3.1-3).

Total abundance of organisms (number/m^2) showed year-to-year variations that appear to be related to area-wide environmental trends. The years of highest overall abundance were 1980-1982, when the geometric mean annual abundance reached a 10-year high of 8424/m^2 in 1981 (Table 3.3.1-3). The period of 1980-1982 was the period of lowest precipitation, highest salinity and highest discharge flow from the settling basin into Brown's River. The years 1983 and 1984 were the years of lowest salinities, highest precipitation, and highest temperatures for the study period (Tables 3.3.1-1 and 3.3.1-2). By 1984, total abundance at all four stations had declined greatly. In 1986, the total abundance (2980/m^2) recovered and was close to the abundance in the pre-outfall period, 1978 and 1979 (3514/m^2 and 4099/m^2, respectively; Table 3.3.1-3). In 1987, total abundance reached all time lows at three of the four stations (Figures 3.3.1-4, 5). Extremely low salinities in April, May and September, 1987 (Figure 3.3.1-1) may have affected recruitment rate. When total abundances between corresponding subtidal and intertidal station pairs in Brown's River and Mill Creek were tested with a paired t-test, no significant differences were found (Table 3.3.1-4).

TABLE 3.3.1-3. MEAN NUMBER OF TAXA AND THE GEOMETRIC MEAN DENSITY (No./m^2) FOR EACH YEAR AND OVERALL YEARS WITH 95% CONFIDENCE LIMITS FROM ESTUARINE STATIONS AT BROWN'S RIVER (3) AND MILL CREEK (9) SAMPLED FROM 1978 THROUGH 1987 (EXCLUDING 1985).[a] SEABROOK BASELINE REPORT, 1987.

	STATION	1978	1979	1980	1981	1982	1983	1984	1986	1987	ALL YEARS MEAN	ALL YEARS LOWER	ALL YEARS UPPER
No. of Taxa	3	35	41	38	42	47	32	27	38	33	37	34	40
	9	26	34	47	44	34	36	21	36	21	33	20	37
	3MLW	28	37	31	38	35	28	18	32	23	30	27	33
	9MLW	28	35	35	41	36	33	21	36	16	31	27	35
	MEAN	29	37	38	41	38	32	22	35	23	-	-	-
Total Abundance	3	3170	4616	4978	5360	9331	2635	1244	1182	1198	2950	2091	4162
	9	3619	2209	14,767	11,277	4335	4533	620	2819	726	3180	1973	5126
	3MLW	4260	6136	5695	6833	8022	2723	2187	5632	1727	4271	3203	5694
	9MLW	3120	4512	6947	12,189	11,383	11,151	5131	4302	653	5049	3228	7898
	MEAN	3514	4099	7344	8424	7796	4364	1715	2980	995	3771	3109	4575
Streblospio benedicti	3	367	123	193	525	1064	552	239	99	66	253	153	417
	9	106	26	2396	525	81	538	16	161	49	140	57	343
	3MLW	439	505	1010	928	3584	525	535	1421	316	769	482	1228
	9MLW	566	434	466	2700	2354	3215	1560	1299	11	723	330	1587
	MEAN	314	163	684	912	925	842	242	415	58	375	263	534
Oligochaeta	3	242	270	204	651	2189	556	225	95	133	315	189	525
	9	16	100	2910	969	1058	1603	162	528	131	356	170	743
	3MLW	87	186	318	320	350	292	382	968	215	288	176	469
	9MLW	574	810	1067	861	565	2877	572	742	161	713	410	1239
	MEAN	119	253	671	646	823	931	298	437	157	389	293	517
Capitella capitata	3	11	63	123	473	889	216	66	73	57	110	55	218
	9	238	29	2453	277	291	376	28	808	113	223	118	422
	3MLW	17	29	138	244	540	208	124	197	26	102	57	182
	9MLW	279	45	125	320	276	800	303	234	19	175	102	302
	MEAN	60	40	269	318	443	341	91	228	42	145	107	195

(continued)

TABLE 3.3.1-3. (Continued)

	STATION	1978	1979	1980	1981	1982	1983	1984	1986	1987	ALL YEARS MEAN	ALL YEARS LOWER	ALL YEARS UPPER
Nereis diversicolor	3	83	172	158	352	452	45	50	52	43	107	70	163
	9	21	29	41	205	41	7	7	43	2	22	12	42
	3MLW	800	1343	1169	1613	975	220	296	987	150	645	381	1089
	9MLW	170	164	101	241	135	57	513	184	6	114	62	208
	MEAN	125	183	167	410	223	45	89	143	18	116	82	164
Caulleriella Sp. B	3	330	221	835	1	2	3	12	9	1	18	6	52
	9	10	40	46	292	136	35	7	10	3	27	11	65
	3MLW	106	174	607	3	23	52	44	255	87	72	34	152
	9MLW	8	298	48	43	1634	278	325	307	1	90	30	261
	MEAN	42	147	183	17	64	37	34	53	5	42	27	68
Mya arenaria	3	69	158	92	181	132	75	31	21	30	69	44	108
	9	265	427	299	246	148	168	157	34	53	157	99	251
	3MLW	106	224	26	179	117	103	22	13	27	61	35	106
	9MLW	100	328	62	400	141	70	86	13	73	96	57	162
	MEAN	118	265	82	237	134	98	55	19	42	89	70	114

[a] Yearly mean = $\frac{\Sigma \text{seasonal means}}{\text{3 seasons}}$

Seasonal mean = $\frac{\Sigma \text{total number per replicate}}{\text{3 replicates}}$

Overall years' mean = $\frac{\Sigma \text{yearly means}}{\text{9 years}}$

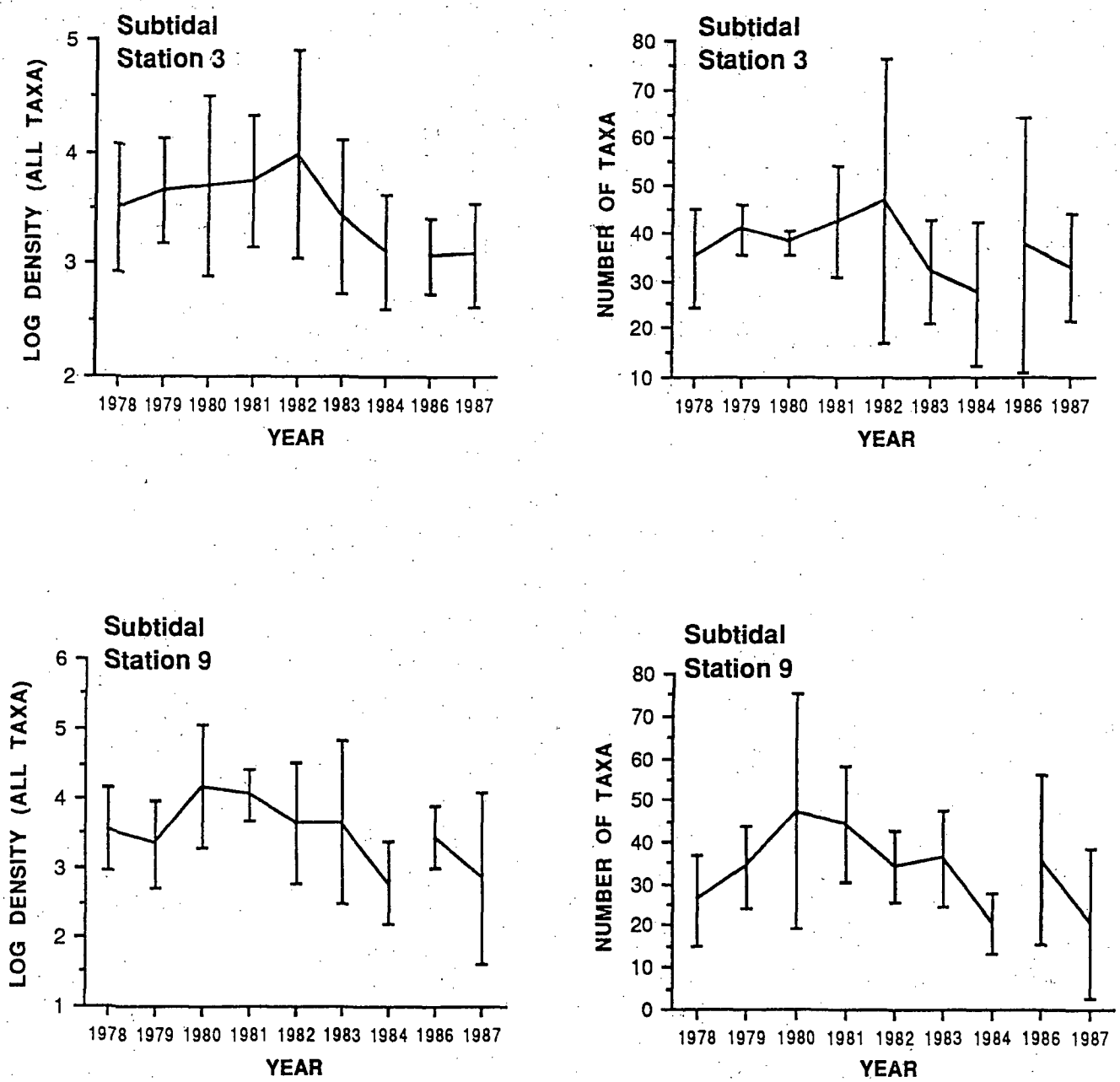


Figure 3.3.1-4. Yearly mean and 95% confidence limits for the log (x+1) density of macrofauna and number of taxa collected at subtidal estuarine stations sampled three times per year from 1978 through 1987 (excluding 1985). Seabrook Baseline Report, 1987.

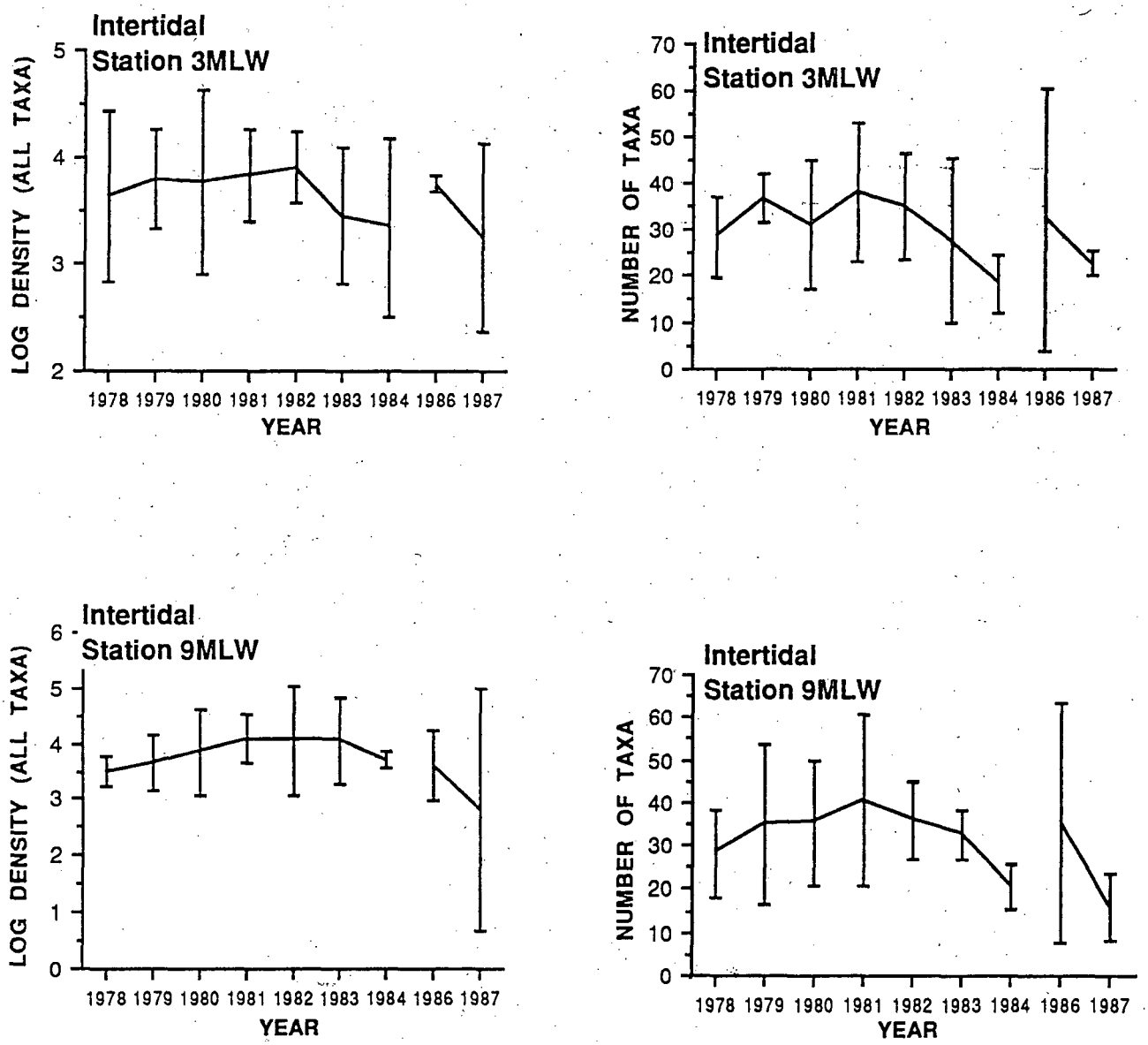


Figure 3.3.1-5. Yearly mean and 95% confidence limits for the log (x+1) density of macrofauna and number of taxa collected at intertidal estuarine stations sampled three times year from 1978 through 1987 (excluding 1985). Seabrook Baseline Report, 1987.

TABLE 3.3.1-4. RESULTS OF A PAIRED t-TEST FOR SELECTED BIOLOGICAL VARIABLES FROM PAIRED SUBTIDAL (STA.3-STA.9) AND INTERTIDAL (STA.3MLW-STA.9MLW) STATIONS SAMPLED THREE TIMES PER YEAR DURING 1978-1987 (EXCLUDING 1985). SEABROOK BASELINE REPORT, 1987.

VARIABLE	STATION PAIR	DEGREES OF FREEDOM	t-VALUE*	PR>|t|
Number of Taxa	Subtidal	26	2.12*	0.0441
	Intertidal	26	-0.96	0.3450
Total Abundance	Subtidal	26	-0.41	0.6816
	Intertidal	26	-0.77	0.4491
Streblospio benedicti	Subtidal	26	1.31	0.2010
	Intertidal	26	0.15	0.8837
Capitella capitata	Subtidal	26	-1.76	0.0906
	Intertidal	26	-1.60	0.1215
Neris diversicolor	Subtidal	26	5.59***	0.0001
	Intertidal	26	5.59***	0.0001
Caulleriella sp. *B*	Subtidal	26	-0.51	0.6129
	Intertidal	26	-0.37	0.7169
Mya arenaria	Subtidal	26	-3.52**	0.0016
	Intertidal	26	-2.12*	0.0442
Oligochaeta	Subtidal	26	0.33	0.7406
	Intertidal	26	-2.62*	0.0144

*The t-value was computed for the difference between the log (X+1) of the abundance (No./m^2) taken seasonally (May, August, November) for nine years for a station pair for the important species and the total abundance of all non-colonial macroinvertebrates in a sample. Number of taxa is the mean for a season, and was not transformed. Negative t-values indicate that the station near the settling basin discharge (3 or 3MLW) had a lower mean value than the control station (Sta. 9 or 9MLW).

* = significant differences at alpha = 0.05
** = highly significant differences at alpha = 0.01
*** = very highly significant differences at alpha = 0.001

The seasonal cycle of total abundance showed density was usually highest in May or August at both intertidal and subtidal stations (NAI 1987b: Figure 3.3.1-4). The usual increase in abundance in spring or summer was probably due to the recruitment of one or more dominant taxa (NAI 1985b). The 1984 densities had no major seasonal peak at any of the four stations. It was also the second consecutive year of very high precipitation (Table 3.3.1-2) and very low salinities (Figure 3.3.1-2). The low densities observed in Brown's River and Mill Creek in 1984 may have been related to spawning and recruitment failures in 1983 and 1984, caused by more extreme natural conditions. Similarly, rainfall in April, 1987 was at a 10-year high, and was also very high in September, and total abundance was at or near an all time low for each of the four stations (Table 3.3.1-3).

The mean number of taxa collected annually at all stations combined ranged from 22 taxa in 1984 to 41 in 1981 (Table 3.3.1-3), and significant differences were found among both years and stations (NAI 1987b: Table 3.3.1-4). The years 1980 through 1982 had the highest number of taxa collected, while 1984 and 1987 had the lowest number of taxa (Table 3.3.1-3, Figures 3.3.1-4, 5). The seasonal cycle at each of the four stations showed that the highest number of taxa usually occurred in August or May, and the lowest number occurred in November (NAI 1987b: Figure 3.3.1-5). The two subtidal stations had a higher number of taxa averaged over all years than the two intertidal stations. When a paired t-test was done between subtidal stations in Brown's River and Mill Creek, Brown's River was found to have a significantly higher number of taxa than Mill Creek. However, the intertidal stations were not significantly different (Table 3.3.1-4).

The annual trend in the number of taxa seems to show a relationship with the mean annual salinity. When annual salinity dipped below 20 ppt, the number of taxa declined. Previous years (1983, 1984) showed decreases in numbers of taxa at most stations coincident with high spring rainfall and low salinity (NAI 1987b; Tables 3.3.1-1, 2), and a similar pattern was noted in 1987.

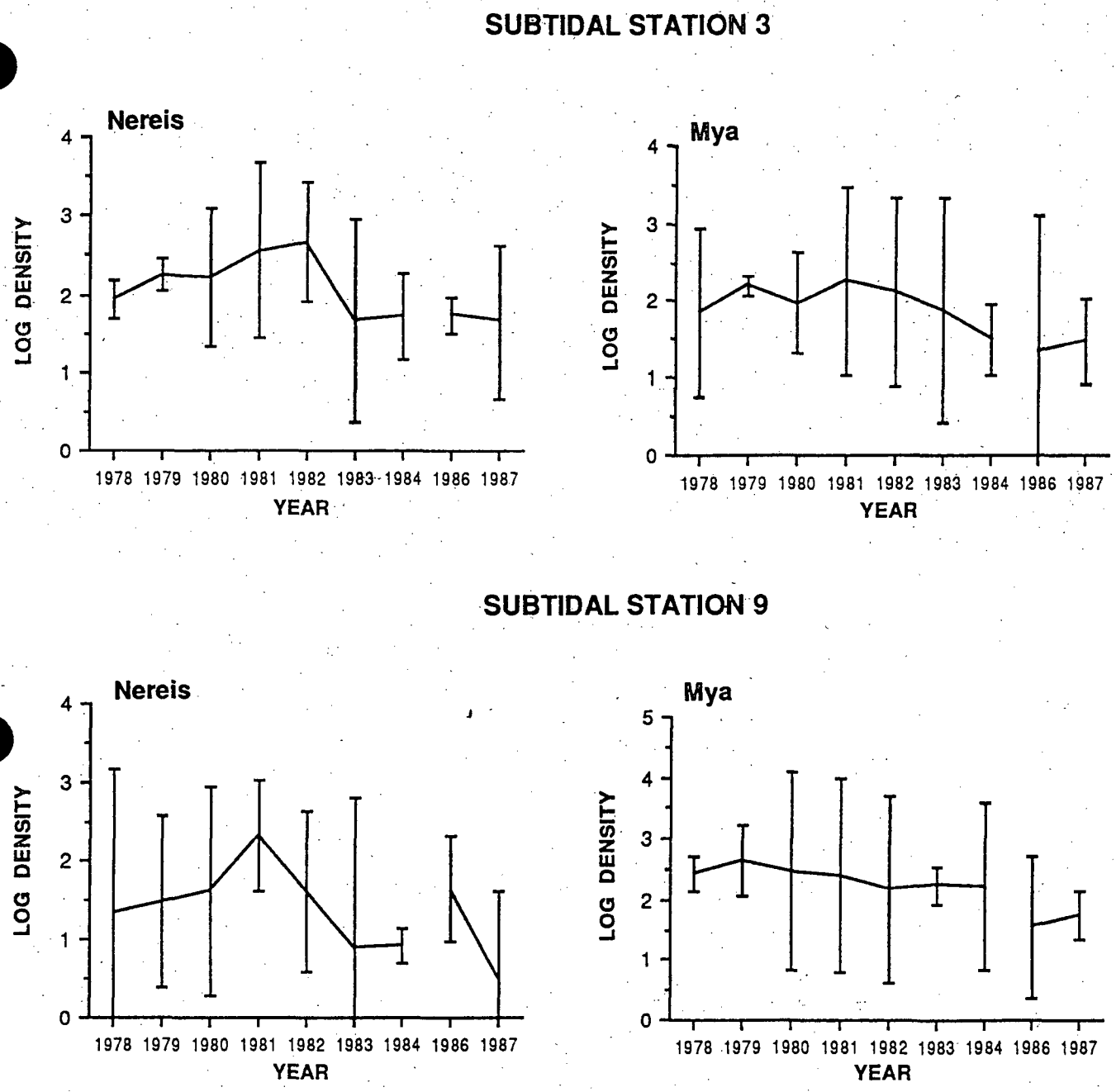


Figure 3.3.1-6. Yearly mean and 95% confidence limits for the log (x+1) density of *Nereis diversicolor* and *Mya arenaria* collected at subtidal estuarine stations three times per year from 1978 through 1987 (excluding 1985). Seabrook Baseline Report, 1987.

Streblospio benedicti is an opportunistic polychaete (Grassle and Grassle 1974), and one of the first to colonize after a perturbation of the environment (Rhoads *et al.* 1978). It is the most abundant species in the estuary, exhibiting significant differences in abundance among both years and stations when tested with a two-way ANOVA (NAI 1987b: Table 3.3.1-4). All-time high geometric mean densities were reached in 1981 and 1982, during the period of high salinity and settling pond discharge (Table 3.3.1-3). In 1987 the population decreased dramatically to an overall density of only $58/m^2$. When stations were compared, the two intertidal stations had the highest densities, and the two subtidal stations had the lowest densities. No significant differences were found between station pairs in Brown's River or Mill Creek (Table 3.3.1-4). The seasonal cycle of *S. benedicti* indicated that extremely high densities occurred during any season at both intertidal and subtidal stations. Such high densities were rarely sustained into the next sampling period, causing tremendous population fluctuations (NAI 1987b: Figures 3.3.1-6,7).

The class Oligochaeta was very abundant in the estuary. Comparisons among years showed the years of highest abundance were 1980-1983 when geometric mean population densities ranged from $646/m^2$ in 1981 to $931/m^2$ in 1983 (Table 3.3.1-3). The years of lowest abundance included 1978 and 1987 when density (averaged over stations) was $119/m^2$ and $157/m^2$, respectively. Thus, the years before and after the period of highest salinity and discharge had similarly low densities. Interstation comparisons showed the stations with the highest overall abundance were Station 9MLW and 9 and stations with the lowest abundance were Stations 3 and 3MLW (Table 3.3.1-3), but these differences are too slight to be significant with a paired t-test (Table 3.3.1-4). The seasonal cycle of oligochaetes indicated that peak densities occurred during any season (NAI 1987b: Figures 3.3.1-6,7), but were not sustained.

The opportunistic polychaete *Capitella capitata* was abundant in the estuary at both intertidal and subtidal stations, but had lower population densities than *S. benedicti* and Oligochaeta. The highest population densities averaged for all stations occurred from 1980-1983, when overall

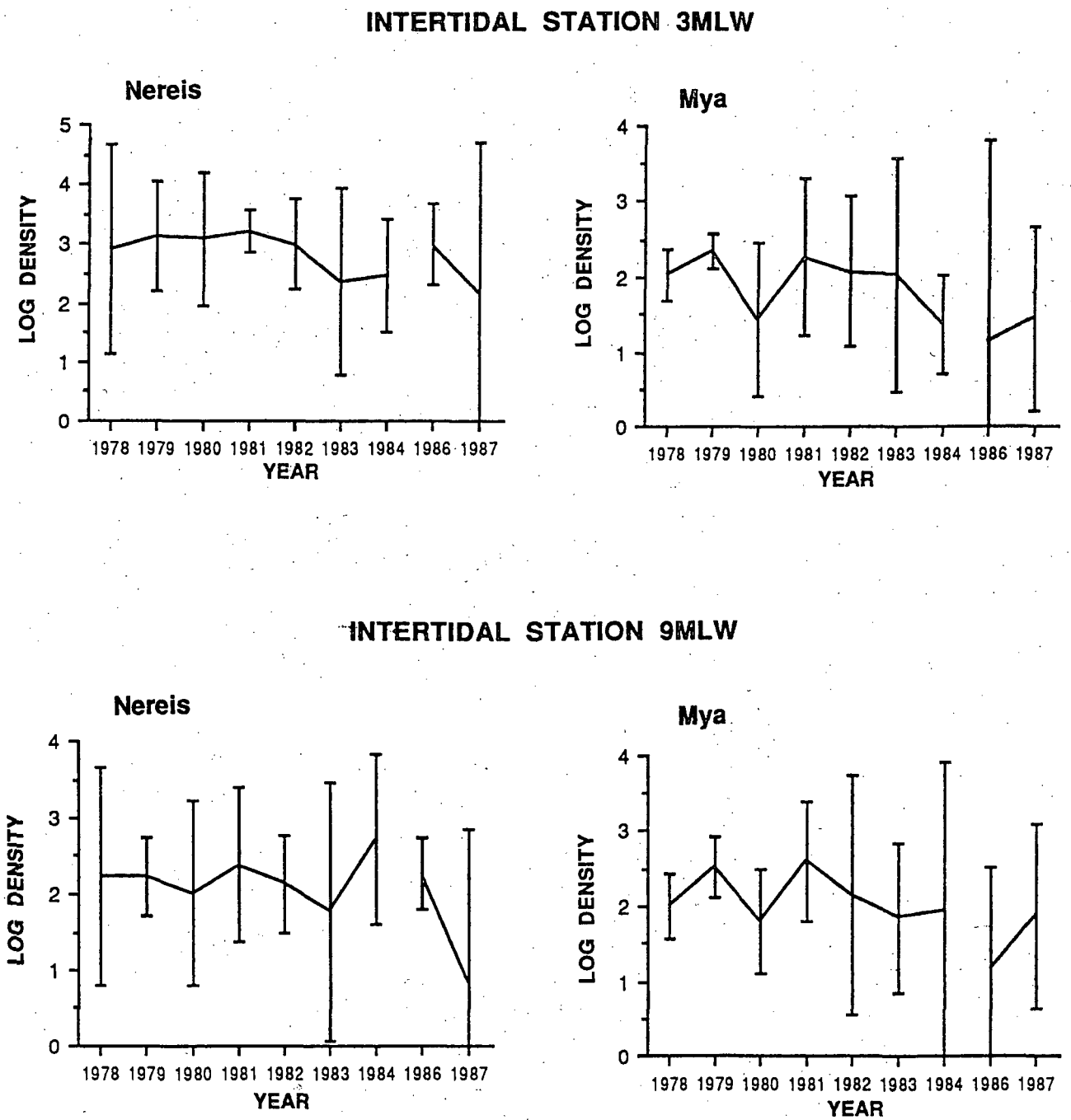


Figure 3.3.1-7. Yearly mean and 95% confidence limits for the log (x+1) density of *Nereis diversicolor* and *Mya arenaria* collected at intertidal stations three times per year from 1978 through 1987 (excluding 1985). Seabrook Baseline Report, 1987.

geometric mean densities were between 269-443/m^2 (Table 3.3.1-3). The years of lowest abundance were 1978, 1979, 1984, and 1987 when abundance was less than 100/m^2 (Table 3.3.1-3). No significant differences were found between station pairs in Brown's River or Mill Creek using a paired t-test (Table 3.3.1-4), but densities were usually higher in Mill Creek (Table 3.3.1-3).

Caulleriella sp. B is a polychete that was occasionally abundant in the estuary. Its annual geometric mean density at all stations ranged from 5/m^2 in 1987 to 183/m^2 in 1980 (Table 3.3.1-3). It rarely sustained densities of over 100 for more than three consecutive years, and in 1987 it had annual densities of less than 10 at three of the four estuarine stations (Table 3.3.1-3). No significant differences were found between Brown's River and Mill Creek (Table 3.3.1-4).

The clam worm, *Nereis diversicolor*, is a highly euryhaline species which can easily adapt to salinities ranging from 1-25 ppt. It is common where there is a mixture of fresh and salt water, and can penetrate up the estuary further than most "marine" worms (Pettibone 1963). It builds a fairly permanent U-shaped burrow, and unlike many nereids, fertilization and development occur in the burrow without a planktonic larval stage. It lives for about 18 months, and has one breeding season. Spawning occurs in late winter or early spring with a marked temperature change, and afterwards the females die. By the end of the first summer, juveniles are 10-20 mm in length. Adults may reach up to 200 mm in length (Pettibone 1963). The geometric mean population densities at each of the four stations were usually highest from 1981-1982, and reached an all time low in 1987 (Table 3.3.1-3, Figures 3.3.1-6, 7). Both intertidal and subtidal stations at Brown's River had significantly higher densities than stations of comparable depth at Mill Creek (Table 3.3.1-4). Intertidal stations had higher densities than subtidal stations (Table 3.3.1-2), as expected, since the species is primarily intertidal (Pettibone 1963).

Mya arenaria, the soft-shelled clam, is a euryhaline species that tolerates rapidly changing salinities, and can survive in sustained salinities as low as 4 ppt (Green 1969). In Hampton Harbor, the green crab, *Carcinus maenas* is an important predator of *Mya*, and its abundance may affect the success of recently-settled young (Section 3.3.7). Recently-settled *Mya* were present at all estuarine stations, and overall densities were highest in 1979 and 1981 ($265/m^2$ and $237/m^2$, respectively), and lowest in 1986 and 1987 ($19/m^2$ and $42/m^2$, respectively) (Table 3.3.1-3). Significant differences were found among years and stations (NAI 1987b: Table 3.3.1-4) with the earlier years generally having higher densities, and Mill Creek having higher densities than Brown's River. Likewise when intertidal and subtidal station pairs in Brown's River and Mill Creek were tested with a paired t-test, densities in Mill Creek were found to be significantly higher (Table 3.3.1-4). Population densities in 1986 reached an all-time low at all four stations (Figure 3.3.1-6 and 7) and green crab densities in Hampton Harbor were very high (Figure 3.3.7-9). However, in 1984, when green crab densities reached a 10-year high, clam densities were about average.

In summary, changes throughout the estuary occurred in total abundance, number of taxa, and abundance of the most dominant species. As these changes were not site-specific, and occurred at Brown's River and Mill Creek at the same time (except in 1983), they were probably related to area-wide environmental variables such as precipitation and corresponding salinity changes, temperature, and abundance of predators and competitors. The period of high salinity and high settling pond discharge (1980-1983) showed population increases for most of the estuarine worms, total abundance, and number of taxa. Increases in the settling basin discharge volume probably acted in conjunction with low precipitation to increase salinity in Brown's River slightly. By 1986, physical and biological parameters had returned to the pre-1980 conditions, but in 1987 abundances for five of the six dominant taxa were at or near all-time lows in both Brown's River and Mill Creek. At the same time salinities reached a 10-year low during three months in 1987, due to heavy rainfall.

3.3.2 Marine Macroalgae

3.3.2.1 Macroalgal Community

Species Collections

From 1978 to 1987, 123 species of macroalgae were recorded from general species collections at 12 benthic stations (Appendix Table 3.3.2-1). As is typical of this region, 52% of these taxa were red algae (Rhodophyta), 25% were brown algae, and 23% were green algae (Mathieson *et al.* 1981a,b). Four of these species were collected only in 1985 and 1986: *Devaleraea ramentaceum* and *Phyllophora traillii*, which are red algae; and *Petalonia zosterifolia* and *Sorapion kjellmanii*, both brown algae. *D. ramentaceum* and *S. kjellmanii* were collected only from tide pools. All four species have been previously collected from the nearshore open coast between Portsmouth and Seabrook, New Hampshire by Mathieson and Hehre (1986). Only one new species, *Polysiphonia denudata*, was recorded in 1987. This species, which was found only once (Station 5MLW), is an estuarine species and was likely a drift specimen from Hampton Harbor. Spatially, the highest number of taxa collected throughout the historical period were in the mean low water (MLW) zone (a median of 57 at Station 5MLW); numbers decreased with increasing depth, with the fewest species collected at the deepest stations (Figure 3.3.2-1). Number of species collected also decreased with increasing elevation from MLW (e.g., at the MSL stations).

For the most part, the numbers of taxa collected at nearfield and farfield stations from 1978 to 1987 were similar. Exceptions were the MLW zone where more taxa were recorded at Rye Ledge (5MLW) than at the Outer Sunk Rocks (1MLW) and the mid-depth zone where fewer taxa were recorded at the station near the intake (Station 16) than at the farfield station (Station 31). Numbers of taxa collected in 1987 were within the range collected over the prior baseline period (1978-1985), with few exceptions. Two additional taxa were recorded at Stations 17 and 31 in 1987; however, these were not species new or unusual in the study area as a whole.

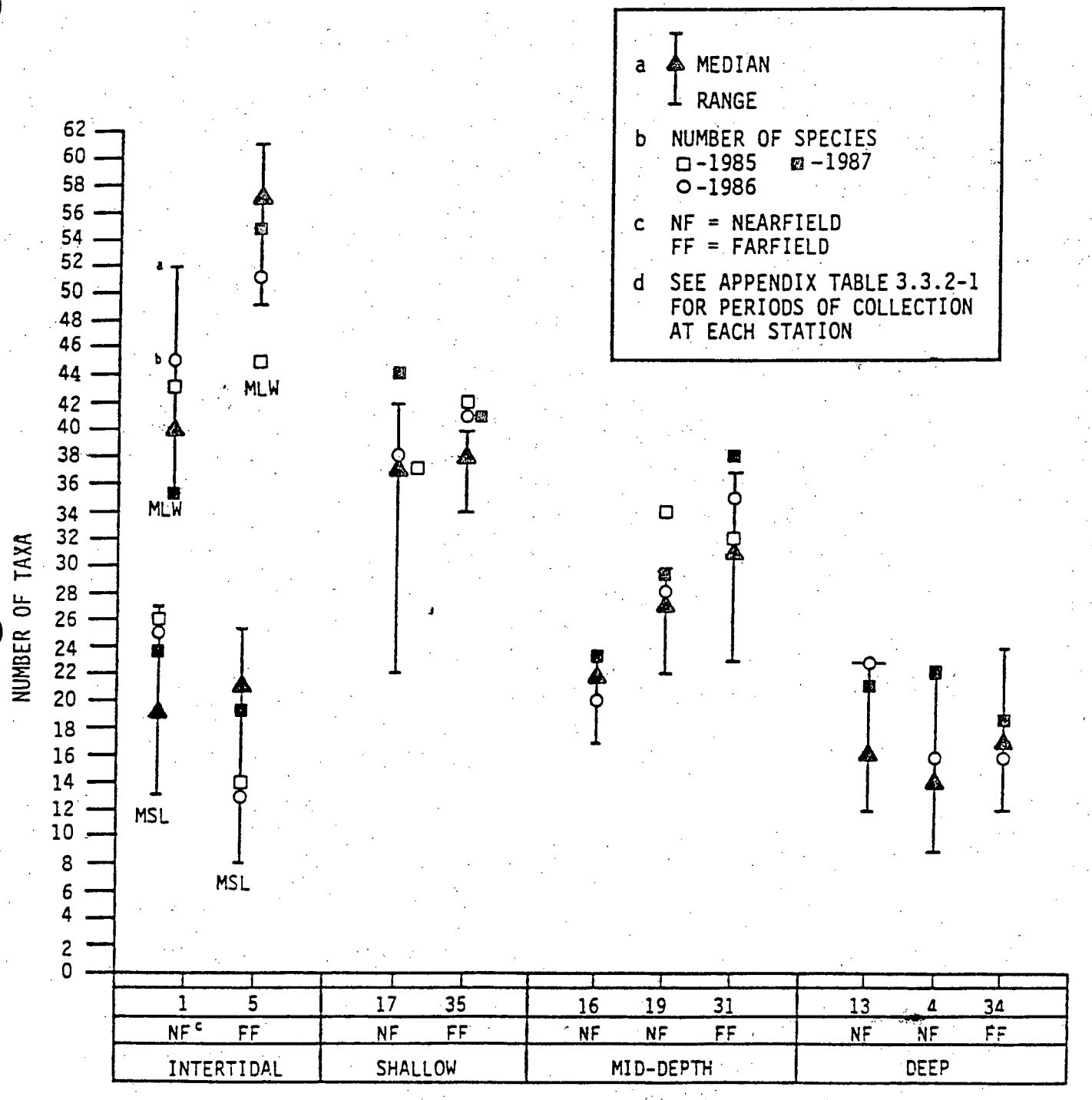


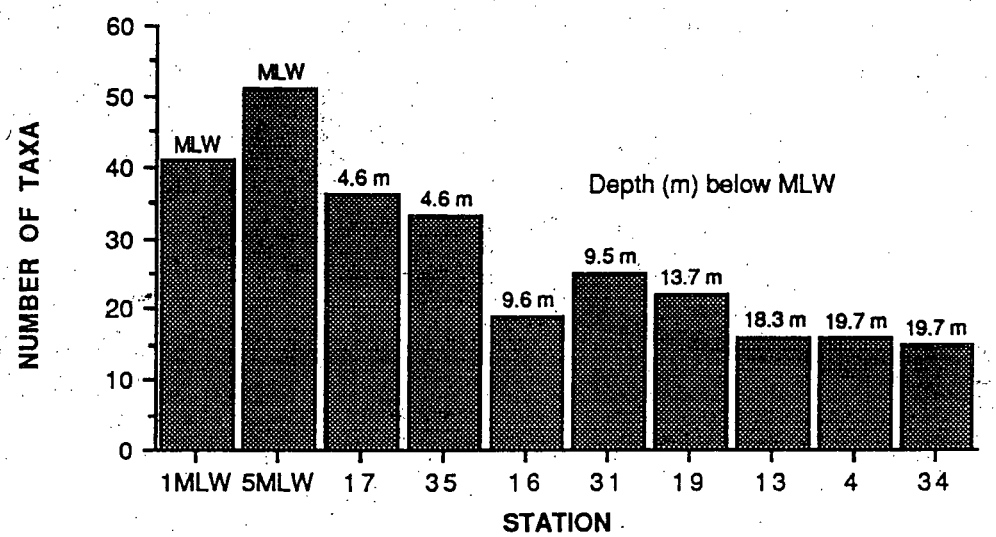
Figure 3.3.2-1. Number of macroalgae species in general collections at each marine benthic station[d] for 1978-1984 (median and range) and 1985-1987 (number collected each year). Seabrook Baseline Report, 1987.

In several cases the number of taxa in 1987 general collections represented the highest (Stations 17,16,31,4) or near-highest (Stations 35 and 19) number collected during the baseline period. However, not all stations were sampled for the entire 1978-1987 period (See Appendix Table 3.3.2-1). Only at Station 1MLW were numbers of taxa collected low in 1987, in fact they were the lowest on record. Low numbers of taxa and abundances were observed at several stations in 1987 for macrofauna in the benthic destructive collections (Section 3.3.3).

Annual Biomass Collections

The effect of depth on light quality and quantity is reflected in the biomass of macroalgae and the number of taxa collected at the hard substrate (algal-covered rock and ledge) stations sampled from 1978 through 1987 (Figure 3.3.2-2). The numbers of taxa recorded were greatest at the intertidal (MLW) sites, declined to 20-25 taxa as depth increased to about 9.5 m, then declined to approximately 15 as depth increased to 20 m. Biomass values were similar at the intertidal and shallow subtidal stations, then declined until depth reached 18-20 m. Numbers of taxa and biomass values were generally similar between nearfield and farfield stations. However, mean biomass at Farfield Station 31 (Rye Ledge) was 46% greater than the Nearfield Station 19 (Discharge) and 42% less than Nearfield Station 16 (Intake). More taxa were recorded in the biomass samples from the farfield intertidal site (5MLW) than from the nearfield station (1MLW).

A temporal presentation of annual August biomass levels (Figure 3.3.2-3) at the nearfield stations indicated no consistency among year trends. At the intertidal Sunk Rocks site (1MLW), mean biomass was lower during the 1978-1981 period than during the 1982-1986 period; the 1987 mean was more similar to the earlier period. At the shallow subtidal (17), mid-depth (19) and deep (4) stations there was some variability among years but it was relatively minor and there were no among year trends evident.



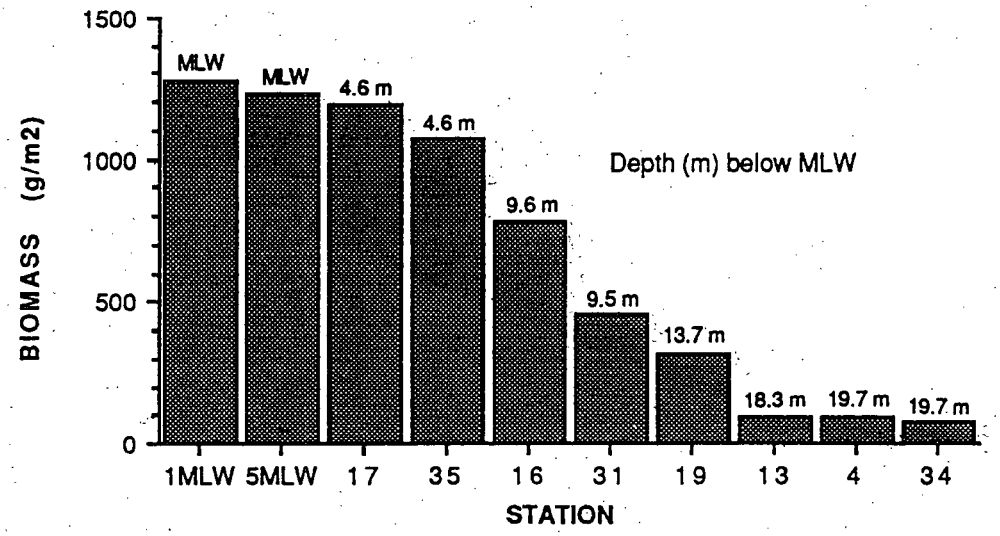
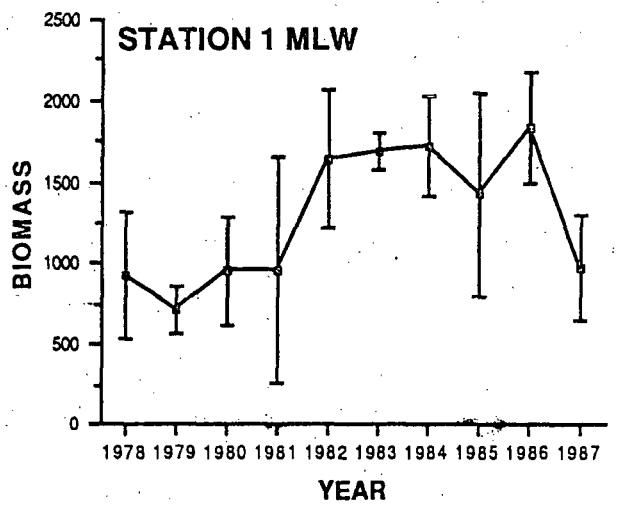
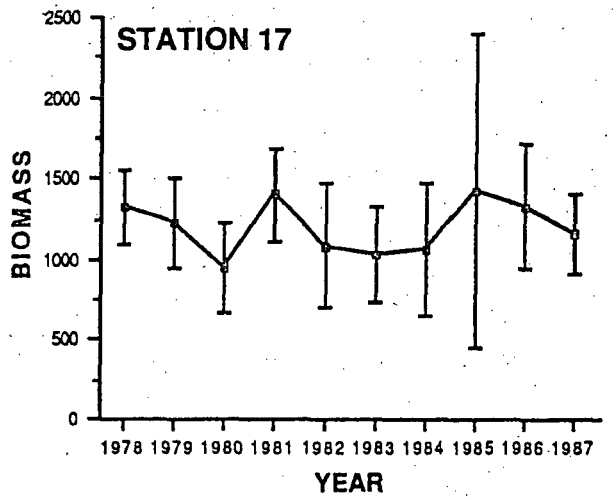
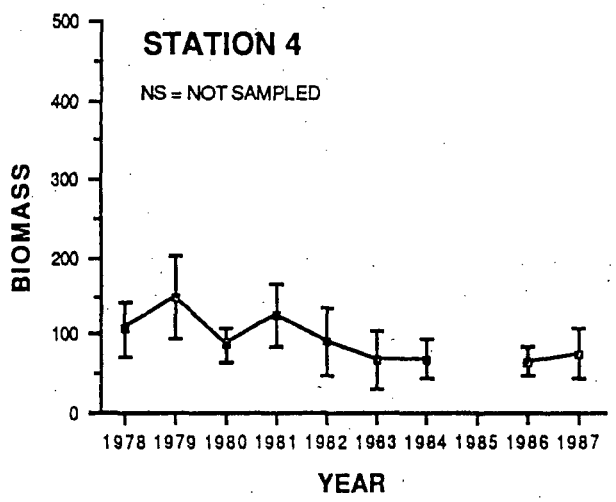


Figure 3.3.2-2. A. Number of taxa and B. mean biomass at intertidal and subtidal benthic stations in August. (See Appendix Table 3.3.2-1 for years each station was sampled) Seabrook Baseline Report, 1987.







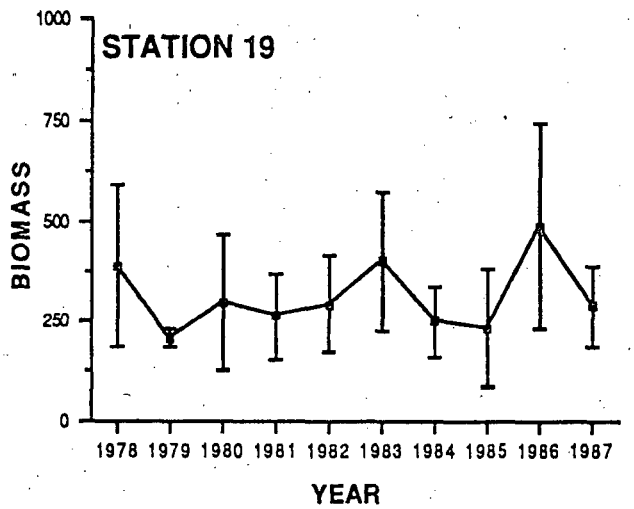


Figure 3.3.2-3. Mean biomass (gms/m^2) and 95% confidence limits for macroalgae collected in August at selected nearfield benthic stations (note differences in scale). Seabrook Baseline Report, 1987.

The number of taxa collected at each station in 1987 (NAI 1988) did not exceed the number collected during the baseline period (NAI 1987b) with one exception. One more species was collected at Station 19 in biomass samples than had previously been collected at that station; however, there were no taxa new to the study area.

The depth differences among benthic stations were also reflected in the relative abundance (biomass) of the six taxa that were dominant during the baseline period (Figure 3.3.2-4). *Ptilota serrata* was dominant at the deepest stations, *Phyllophora* spp. (*P. truncata* and *P. pseudoceranoides*) were most abundant at mid-depth stations, and *Chondrus crispus* was dominant in the shallow subtidal and intertidal. Relative abundances for 1987 showed this same pattern (Table 3.3.2-1). However, *C. crispus* made up a higher than average percentage of biomass in 1987 at Stations 1MLW, 35 and 16 with concomitantly lower percentages of *Mastocarpus stellatus* (Station 1MLW only), *Phyllophora* spp. and *Phycodrys rubens* (Stations 35 and 16 only), respectively. The three other taxa listed in Table 3.3.2-1 were frequent subdominants. These six dominants combined typically represented more than 90% of the biomass at each station. The greatest exception to this occurred in 1987, when "other" taxa comprised between 10 and 25% of the biomass at seven of the 10 stations sampled. This was primarily due to the abundance of red algal epiphytes which were higher in 1987 (NAI 1988a).

Community Analysis

Station differences in the macroalgae community were caused by the depth-related differences in species' relative abundance. Historically, six depth-related station groups had been identified from cluster analysis of August (1978-1984) samples (NAI 1985b; Table 3.3.2-2). Although several taxa had been found across all depths, each species had a depth zone within which it reached peak biomass (Figure 3.3.2-5); it was the unique association of species' biomasses that resulted in a different community structure in each depth zone. Within each depth zone, the paired nearfield and farfield stations were most similar to each other (Table 3.3.2-2).

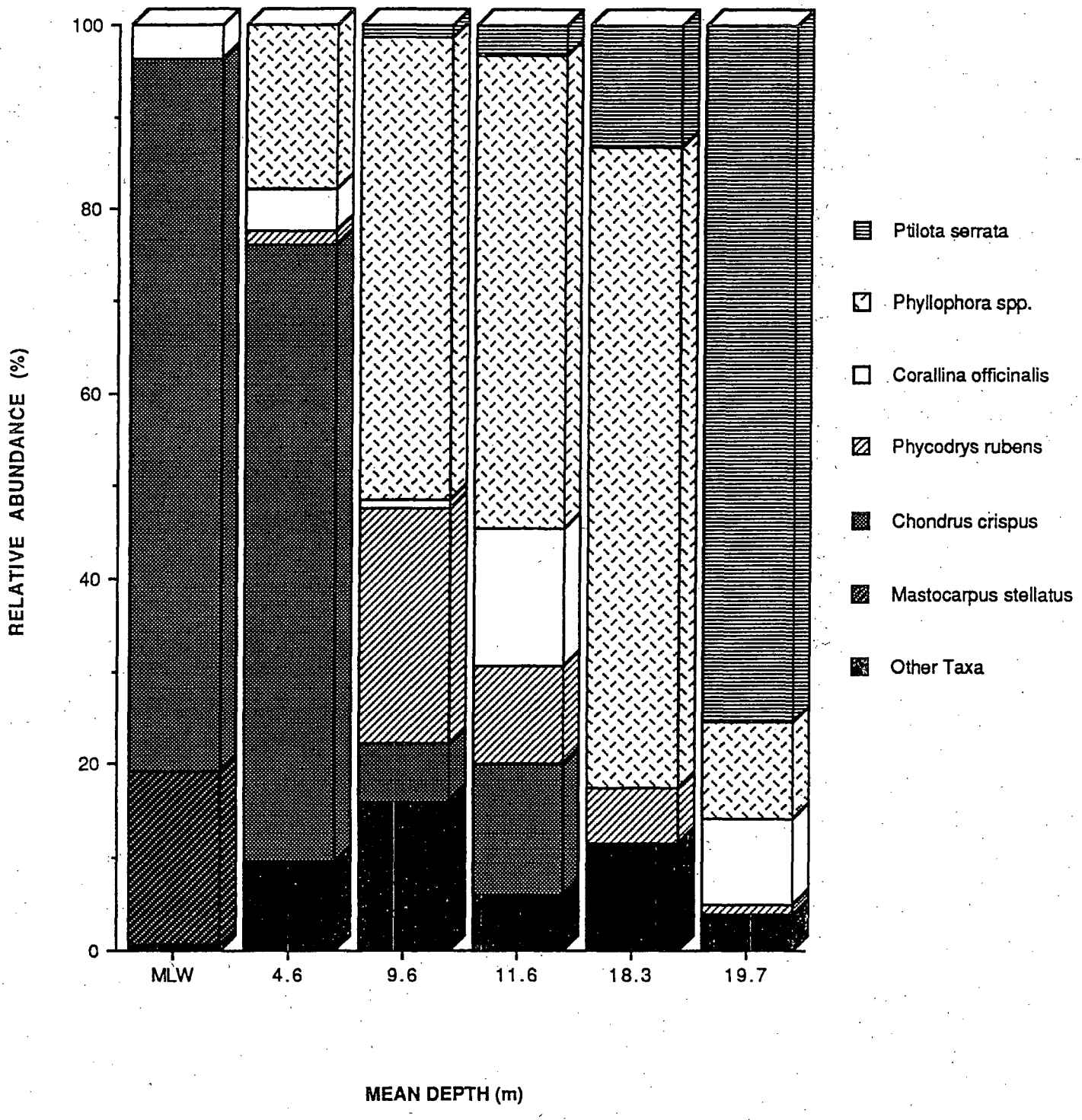


Figure 3.3.2-4. Relative abundance (% biomass) of dominant macroalgae at marine benthic stations (by station-depth group) in August, 1978-1987. Seabrook Baseline Report, 1987.

TABLE 3.3.2-1. RELATIVE ABUNDANCE OF DOMINANT MACROALGAE AT MARINE BENTHIC STATIONS IN AUGUST OF THE THREE MOST RECENT YEARS (1985, 1986 AND 1987). SEABROOK BASELINE REPORT, 1987.

		RELATIVE ABUNDANCE (PERCENT)									
		DEEP STATIONS								INTERTIDAL STATIONS	
SPECIES	YEAR	4[a]	34[a]	13[a]	19	31	16[a]	17	35	1MLW	5MLW
Chondrus crispus	1985	--	--	--	0	43.6	--	89.3	45.6	84.6	53.0
	1986	0.1	0	0	0.4	38.6	3.7	89.8	52.6	62.8	83.5
	1987	<0.1	0	0	0.3	22.9	18.1	81.6	71.8	97.5	73.0
Corallina officinalis	1985	--	--	--	9.6	15.3	--	5.6	2.2	0.3	17.9
	1986	16.7	0	<0.1	2.8	20.0	0.1	1.9	5.6	2.3	2.6
	1987	10.4	0	0	0.8	12.8	<0.1	2.7	8.3	0.1	1.4
Mastocarpus stellatus	1985	--	--	--	0	0	--	0	0	14.9	28.7
	1986	0	0	0	0	0	0	0	0	34.8	13.7
	1987	0	0	0	0	0	0	0	0	2.0	25.1
Phycodrys rubens	1985	--	--	--	17.7	5.0	--	0.5	1.2	<0.1	<0.1
	1986	0.8	0.3	3.4	22.5	2.5	30.3	0.3	2.0	<0.1	<0.1
	1987	1.4	0.2	15.2	12.5	5.7	12.3	0.3	0.2	<0.1	<0.1
Phyllophora spp.	1985	--	--	--	59.4	32.9	--	2.1	26.8	<0.1	<0.1
	1986	31.7	36.0	88.3	62.0	35.2	59.6	2.2	29.4	<0.1	<0.1
	1987	30.5	13.6	58.3	73.3	49.7	44.2	3.1	4.4	0	<0.1
Ptilota serrata	1985	--	--	--	7.2	0.5	--	<0.1	<0.1	0	<0.1
	1986	47.6	59.1	6.4	3.4	0.8	1.0	<0.1	<0.1	0	<0.1
	1987	40.4	63.4	11.3	1.3	1.1	0.6	<0.1	<0.1	<0.1	0
All others	1985	--	--	--	6.2	2.7	--	2.4	24.3	0.2	0.4
	1986	3.1	4.6	1.9	8.9	2.9	5.5	5.8	10.4	0.1	0.2
	1987	17.3	22.8	15.2	11.8	7.8	24.8	12.3	15.3	0.4	0.5

[a] Not sampled in 1985.

TABLE 3.3.2-2. SUMMARY OF SPATIAL ASSOCIATIONS IDENTIFIED FROM NUMERICAL CLASSIFICATION (1978-1984) AND VERIFIED WITH DISCRIMINATE ANALYSIS (1978-1987) OF BENTHIC MACROALGAE SAMPLES COLLECTED IN AUGUST. SEABROOK BASELINE REPORT, 1987.

			SAMPLE SIMILARITY[a]			
GROUP NO.	STA-TIONS	MEAN DEPTH (m)	WITHIN STATION	BETWEEN STA-TIONS	DOMINANT TAXA[b]	MEAN[b] BIOMASS GROUP (g/m^2)
1	13	18.3	.68	-	*Phyllophora* spp.	63.19
					Ptilota serrata	12.09
					Phycodrys rubens	5.50
					Polysiphona urceolata	3.50
					Scagelia corallina	3.32
2	4	19.7	.84	.70	*Ptilota serrata*	65.09
	34		.71		*Phyllophora* spp.	8.96
					Corallina officinalis	7.75
					Scagelia corallina	1.15
					Phycodrys rubens	1.04
3	19	11.6	.78	.70	*Phyllophora* spp.	196.50
	31		.80		*Corallina officinalis*	56.53
	16 (1984)				*Chondus crispus*	53.45
					Phycodrys rubens	40.45
					Callophyllis cristata	12.86
					Ptilota serrata	12.61
4	16	9.4	.87	-	*Phyllophora* spp.	428.07
					Phycodrys rubens	217.92
					Cystoclonium purpureum	60.17
					Chondrus crispus	53.26
					Ceramium rubrum	36.99
					Callophyllis cristata	34.74

continued

A discriminant analysis was used as a comparative method to confirm results of the cluster analysis and to allow a comparison of 1985, 1986 and 1987 results with the previous baseline period. Replicates were averaged in this analysis to avoid the influence of small-scale spatial variability and to be consistent with cluster analysis methods (NAI 1985b) and the macrofauna analysis (Section 3.3.3).

Species assemblages identified by discriminant analysis were identical to those identified for the baseline period by cluster analysis. Samples collected from 1985-1987 were placed in the same group as the majority of samples from previous years, verifying the similarity in species composition (Table 3.3.2-3). Therefore, although there may be differences in the biomass of a species from sample to sample or year to year within a station group, the relationship among species biomass has been very consistent. The degree of differences at the species level is examined for two dominant macroalgae species in the "selected species" section which follows.

In order to monitor the algal community for new or infrequently occurring species which might bloom to "nuisance" levels, the rarer species occurrences were also examined. Twenty taxa occurred sparsely (less than 5% of the biomass collections) from 1978 to 1987 (Appendix Table 3.3.2-2). The only unusual occurrence reported to date was *Bonnemaisonia hamifera* which was new to biomass collections in 1986 (Stations 5MLW, 31 and 35), and occurred in greater than 5% of the samples. This warmer water species has been recorded in Great Bay (Mathieson and Hehre 1986), but not at offshore sites in this study prior to 1986. The recent occurrence may have been related to the increased water temperatures in the nearshore area in 1985 and 1986 (see Section 3.1.1). More of the "sparsely occurring" taxa have also been recorded in recent years (NAI 1985b) and may be related to the same cause. Water temperatures in 1987 were lower than 1985 and 1986; in fact, the bottom temperatures (at the Intakes) averaged the second lowest over the 1978-1987 period. *B. hamifera* was not recorded at any stations in 1987 (NAI 1988a).

TABLE 3.3.2-3. PROBABILITY OF 1978-1987 MACROALGAE SAMPLE MEMBERSHIP IN EACH STATION GROUP IDENTIFIED FROM NUMERICAL CLASSIFICATION (cluster analysis) OF 1978-1987 AUGUST BENTHIC DATA. SEABROOK BASELINE REPORT, 1987.

CLUSTER ANALYSIS GROUP[a]	DISCRIMINANT FUNCTION GROUP					
	1	2	3	4	5	6
1	100[b] (9)	0	0	0	0	0
2	0	100 (17)	0	0	0	0
3	0	0	100 (21)	0	0	0
4	0	0	0	100 (6)	0	0
5	0	0	0	0	100 (16)	0
6	0	0	0	0	0	100 (16)

[a]See Table 3.3.2-2
[b]100 = sample percent probability of group membership
(9) = number of samples per group

Kelp Transect Survey

Spatial differences in kelp species abundance appear primarily attributable to depth differences. *Laminaria saccharina* has historically been most abundant at the shallower stations (Figure 3.3.2-6). *Laminaria digitata* has been shown to reach maximum abundance in the study area at Station 31 (9.4 m below MLW), whereas *Agarum cribrosum*'s greatest abundance was at Station 19 (13.7 m below MLW)(NAI 1985b). Significant spatial differences between nearfield and farfield mid-depth stations (Stations 19 and 31), were found for some species, where *L. digitata* and *Alaria esculenta* were more abundant at Farfield Station 31 (NAI 1985b). Abundances recorded in 1987 followed similar spatial patterns to 1978-1984 occurrences (NAI 1988), but densities of *L. saccharina* were higher than past years in the shallow subtidal (17, 35) while densities of *L. digitata* were higher at the mid-depth stations (19 and 31).

No consistent seasonal variation in abundance was observed for any species of kelp, probably because "juvenile" (<15 cm) plants were not enumerated; these plants are difficult to accurately count *in situ* because of their small size and high density (NAI 1984a, 1985b). Seasonal variation in biomass was reflected in growth studies conducted prior to 1985; growth closely followed the solar irradiance and nutrient cycles (NAI 1985b). Stand density, which is controlled by substrate availability, recruitment and environmental conditions (e.g. storm disruption), showed some variability among years. Kelps, particularly *Laminaria* species, are quick-growing, opportunistic plants. Consequently, they are among the "pioneer" species that colonize freshly exposed substrate, adding to the year-to-year variability in distribution.

Measurements of percent frequency of occurrence of the three understory algae that were dominant at transect sites (Figure 3.3.2-6), showed differences among depths that were similar to those observed from biomass collections (Figure 3.3.2-3). *Chondrus crispus* occurred more frequently in the shallow subtidal zone whereas *Phyllophora* sp. and

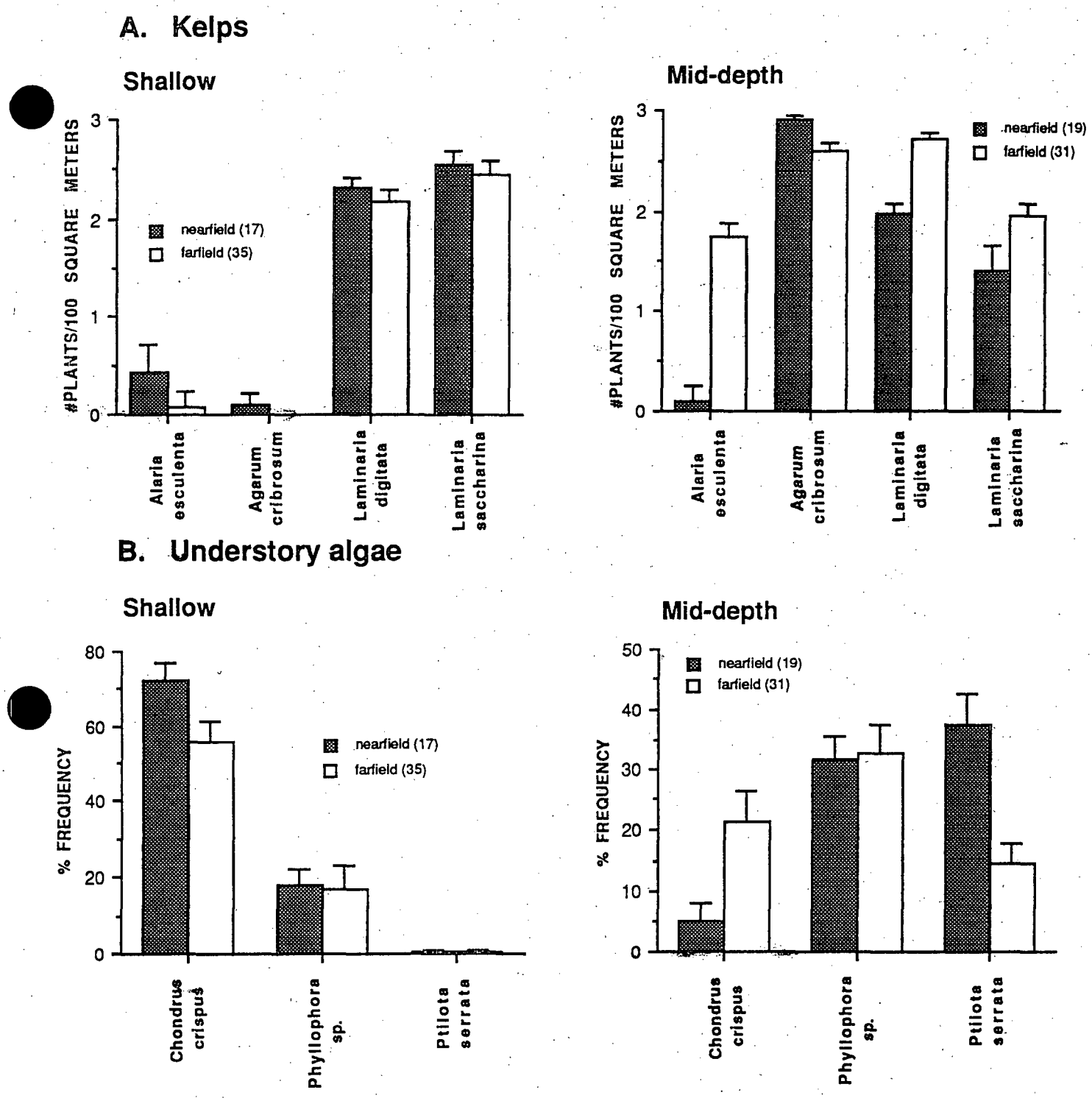


Figure 3.3.2-6. A. Mean and 95% confidence interval of log number/100 m^2) of kelps (1978-1987; station 35: 1982-1987) and B. Percent frequencies and 95% confidence interval of dominant understory algae (1981-1987; station 35: 1982-1987) in the shallow and mid-depth subtidal zone. Seabrook Baseline Report, 1987.

Ptilota serrata were encountered more frequently in the mid-depth zone. *Ptilota serrata* occurred as frequently as *Phyllophora* sp. at Station 19 even though it was not at its peak biomass (Figure 3.3.2-5). *Ptilota serrata* was significantly lower and *Chondrus crispus* significantly higher at Station 31 (which is 9.5 m deep) than at Station 19, which is 13.7 m deep (NAI 1985b). Patterns shown by the 1987 frequencies of occurrence were within the range observed historically, with one exception: *Ptilota serrata* showed fewer occurrences at Station 19 than in past years (NAI 1988). Also, the frequency of this species equalled the lowest recorded value (in 1986) at the counterpart farfield station (31) (NAI 1988).

Intertidal Fixed Quadrat and Transect Surveys

In situ counts of macroalgae in fixed quadrats at the intertidal stations (Stations 1 and 5) were conducted at mean low water (Site "D") and at mean sea level on bare ledge (Site "C") and fucoid-covered ledge (Site "B") habitats. These quadrats were set up in order to monitor the same exact habitat thus eliminating small-scale spatial variability and focusing on temporal variation. Appendix Table 3.3.2-3 shows the occurrence of those species recorded more than once in a quadrat; other less common taxa (i.e., recorded only once in the study to date), were not included. Since the quadrats (sites) have unique characteristics, each will be described in turn.

The Bare Ledge Site (C), at the upper edge of the MSL (mean sea level) zone, was characteristic of "bare" ledge in the area, that is, ledge not continuously covered by macroalgae. Although highly seasonably variable, barnacles have been common in this quadrat (see Section 3.3.3 for faunal coverage). During the spring the annual greens, *Urospora pencilliformis* and *Ulothrix flacca* (at both stations), and the red algae, *Bangia fuscopurpurea* (Station 5MSL), have been abundant. Small, immature perennial *Fucus* sp. plants have also been found in this quadrat; although they occurred frequently, their percent cover was usually less than 10%. Temporal variations in these fucoids have been observed over one to two year periods (Appendix

Table 3.3.2-2). These variations are apparently not related to any seasonal or yearly trend but likely to plant loss and slow regrowth. Algae settlement and growth are controlled by balancing the opportunity for settling on available space versus the effects of predation. Spatially, the bare rock quadrats have been generally similar, although temporal variations in *Fucus* sp. appeared spatially independent. The more persistent red, *Porphyra* sp. was unique to 1MSL, while *B. fuscopurpurea* was unique to 5MSL (in these fixed quadrats).

The Fucoid Ledge Site (B), in the mid-MSL zone, is situated in the area of maximum fucoid algae cover. The perennial, *Fucus vesiculosus*, has been the major species within the quadrats, although some *F. disticus* v. *edentatus* and *Ascophylum nodusum* (Station 5MSL) have been recorded (Appendix Table 3.3.2-3). These fucoids were quite persistent and frequently occurring, although relatively low (<40%) coverages have been recorded at times, e.g., December 1982 (both stations) and winter/spring of 1984-1985 (at 1MSL). The perennial red algae, *Chondrus crispus* and *Mastocarpus stellatus* occurred as understory algae at both stations, but in relatively low amounts (usually <10% frequency); the latter species was more persistent. Few other algae were common in these quadrats, except *Porphyra* sp. and *Spongomorpha* sp. both (both at Station 1MSL only).

Fixed line transects have also been surveyed in the MSL zone from 1983 to 1987 to quantify the areal coverage of the fucoid algae. In the fixed areas studied, the percent frequency of occurrence of *Ascopyllum nodosom* was similar at both stations (Figure 3.3.2-7) while *Fucus vesiculosus* was almost twice as frequent at the nearfield station (1MLW). Some *F. distichus* var. *edentatus* was also recorded at 1MLW, but none at the farfield site (5MLW). The degree of among year variability was low (21-33% CV) for the two dominant fucoids (Figure 3.3.2-7).

The quadrat at Site D, in the MLW (mean low water) zone, is situated in the area of maximum red algae cover. *Chondrus crispus* and *Mastocarpus stellatus* dominated this zone; together they typically cover 80 to 100% of the substrate. Spatially, the frequency of occurrences at the two

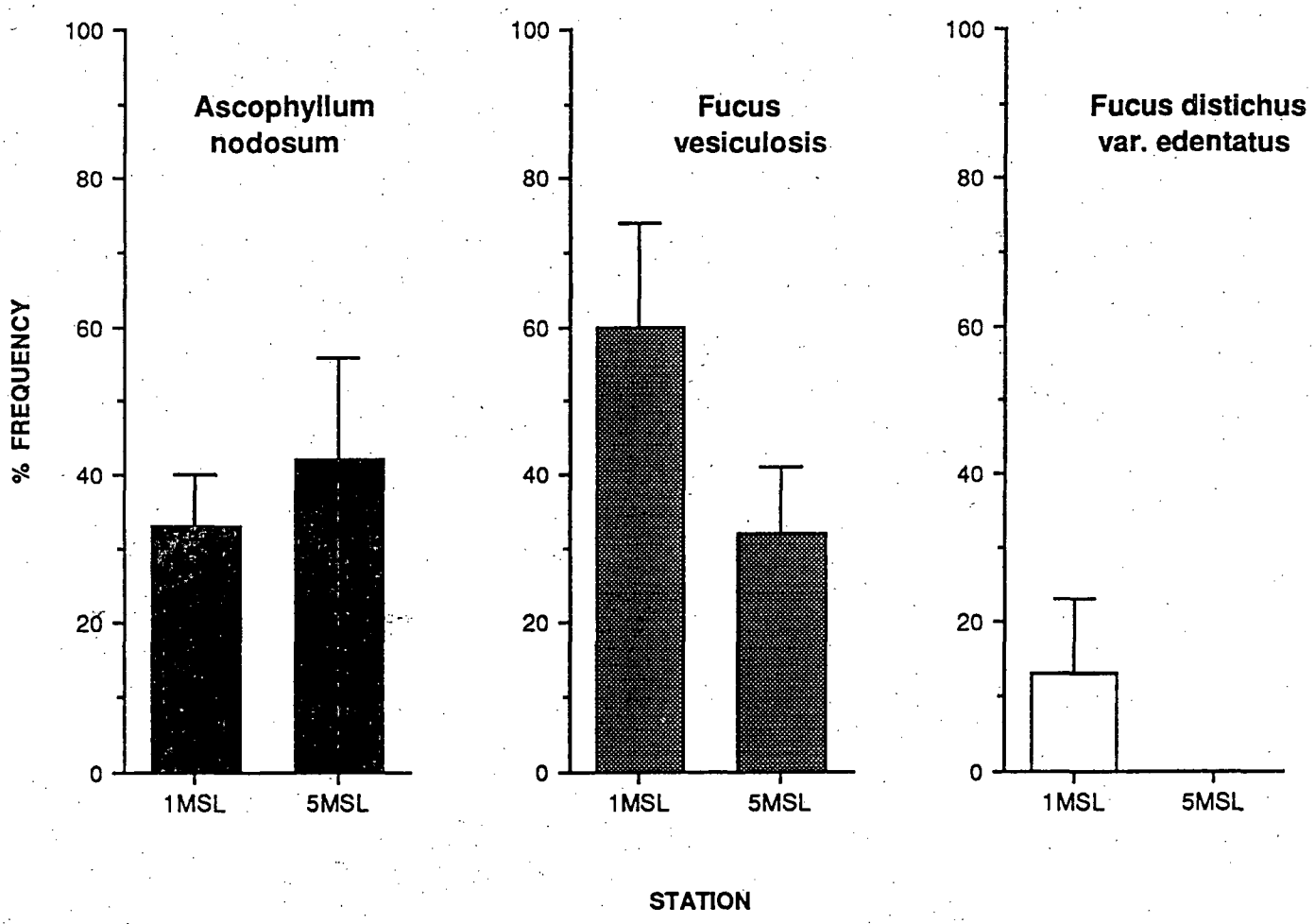


Figure 3.3.2-7. Mean percent frequency and standard deviation of fucoid algae at two fixed transect sites in the mean sea level zone (1983-1987). Seabrook Baseline Report, 1987.

stations' quadrats were generally similar for these two dominants although there has tended to be a greater frequency of *C. crispus* at 5MLW. Spatial differences included the occurrence of *Fucus* sp. which was persistent only at 1MSL as overstory, and *Corallina officianalis* which was persistent at 5MSL as an understory species; small scale vertical differences between stations likely contributed to these species occurrence differences.

3.3.2.2 Selected Species

Laminaria saccharina

Laminaria saccharina has been one of two dominant canopy-forming kelps in the shallow subtidal zone (1 to 9 m deep) surrounding the Inner and Outer Sunk Rocks. Average seasonal densities (1979-1987) of adult plants ranged from 1 to 11 plants/m^2 at the nearfield station (17), while average percent cover ranged from 3% to 43% (Table 3.3.2-4). Density varied greatly due to variability in the amount of substrate available for settlement combined with the contagious (clumped) distribution of these plants. At Station 17, annual mean densities were greatest in 1979 (981 plants/100 m^2), decreased to 285 plants/100 m^2 in 1982, and remained at that approximate level through 1987. The most precipitous change in density occurred between April and July 1982 with an 85% drop in density. There had been a very large and dense stand of kelps in the western portion of this station which has since diminished since 1979; this has contributed to changes observed in 1982. It can be hypothesized that due to scouring from the storm of 1978 larger amounts of substrate became available for *Laminaria* settlement, which resulted in higher densities in 1979; over time these stands may have diminished to a more "typical" level (as in 1982) as substrate became recovered with understory algae. Over the last six years (1982-1987) when both nearfield and farfield stations were monitored, however, annual differences were not significant (Table 3.3.2-5). Average numbers of plants per quadrat were similar between the nearfield (17) and farfield (35)

TABLE 3.3.2-4. SEASONAL AND YEARLY MEAN ABUNDANCE[a] AND PERCENT COVER OF *LAMINARIA SACCHARINA* FROM TRANSECT STUDIES IN THE SHALLOW SUBTIDAL ZONE. SEABROOK BASELINE REPORT, 1987.

		NO./100 m^2		% COVER				NO./100 m^2		% COVER	
		17	35	17	35			17	35	17	35
1979	Apr	1052		35		1984	Apr	311	209	9	9
	Jul	888		43			Jul	252	209	13	18
	Nov	1004		34			Oct	555	152	20	8
	Mean	981		37			Mean	373	190	14	12
1980	Apr	724		18		1985	Apr	340	159	16	5
	Jul	678		32			Jul	212	264	16	19
	Nov	754		37			Oct	286	302	19	6
	Mean	719		29			Mean	279	242	17	10
1981	Apr	719		21		1986	Apr	278	757	17	21
	Jul	519		24			Jul	167	188	8	16
	Nov	500		20			Oct	169	245	7	20
	Mean	579		22			Mean	205	397	11	19
1982	Apr	588		25		1987	Apr	71	195	5	13
	Jul	88	669	6	36		Jul	433	550	22	21
	Oct	179	409	14	14		Oct	367	743	12	17
	Mean	285	539	15	25		Mean	290	496	13	17
1983	Apr	83	104	3	5						
	Jul	217	376	13	18						
	Oct	693	207	13	11						
	Mean	331	229	10	11						

[a]Only plants measuring ≥ 15 cm long were counted.
[b]Station 17 = nearfield; Station 35 = farfield.

TABLE 3.3.2-5. RESULTS OF SIGNIFICANCE TESTS ON MACROALGAE SELECTED SPECIES, *CHONDRUS CRISPUS* AND *LAMINARIA SACCHARINA*. SEABROOK BASELINE REPORT, 1987.

A. *CHONDRUS CRISPUS* BIOMASS (g/m^2)

Temporal (Year) Comparisons (1978-1987): one-way ANOVA of Log (x+1) means

STATION	df	SS	F VALUE	SIGNIFICANCE[a]
1MLW	9	0.495	1.62	N.S.
17	9	0.325	0.67	N.S.

Spatial (Station) Comparisons (1982-1987): Paired t test of sample means

STATIONS	t	SIGNIFICANCE	COMPARISON
1MLW VS. 5 MLW	2.59	*	Nearfield greater
17 VS. 35	2.92	**	Nearfield greater

B. *LAMINARIA SACCHARINA* DENSITIES (NO./m^2)

Temporal (Year) Comparisons (1982-1987): Wilcoxon's Ranks Test

STATIONS	VARIABLE	SIGNIFICANCE
17 and 35 combined	years (1982-1987)	N.S.

Spatial (Station) Comparisons (1982-1987): Wilcoxon's Ranks Test

STATIONS	VARIABLE	SIGNIFICANCE
17 vs. 35	stations	N.S.

[a]N.S. = Not significant
* = Significant at $p < .05$
** = Significant at $p < .01$

stations over the entire 1982-1987 period (Table 3.3.2-5), but the kelp beds were more evenly distributed at Station 17 than at Station 35 (NAI 1985b), evidently because of differences in available substrate.

Chondrus crispus

Chondrus crispus (Irish moss) was the dominant understory algal species in the lower intertidal and shallow subtidal zones near the Sunk Rocks (see Community Analysis section). Destructive samples were collected in May, August, and November from 1978 to 1987 (1982 to 1987 for Stations 35 and 5MLW); maximum biomass typically occurred in August at all stations, except 5MLW (Figure 3.3.2-8). Minimum values generally occurred in May at subtidal stations; at 1MLW the lowest values were generally found in the fall. However, confidence limits (calculated for 1978-87) implied a significant difference between minimum and maximum seasonal biomass only at Stations 17 and 35. Biomass values from 1987 generally differed very little from the historical data (NAI 1988). At intertidal Station 5MLW, biomass in 1987 was noticeably (about 50%) lower in May collections than in previous years (NAI 1988). These data continued to add to the natural variability of the baseline data at this station.

August biomass values at Station 17 ranged from 574.9 g/m^2 in 1980 to 1272.7 g/m^2 in 1985 (Table 3.3.2-6). Overall biomass at Station 17 was significantly higher than that at Station 35 (Table 3.3.2-6). Peak biomass at Station 1MLW was recorded in 1982 (1622.9 g/m^2), its minimum in 1978 (459.7 g/m^2); biomass at 1MLW was statistically different (at $p < .05$) from the farfield station.

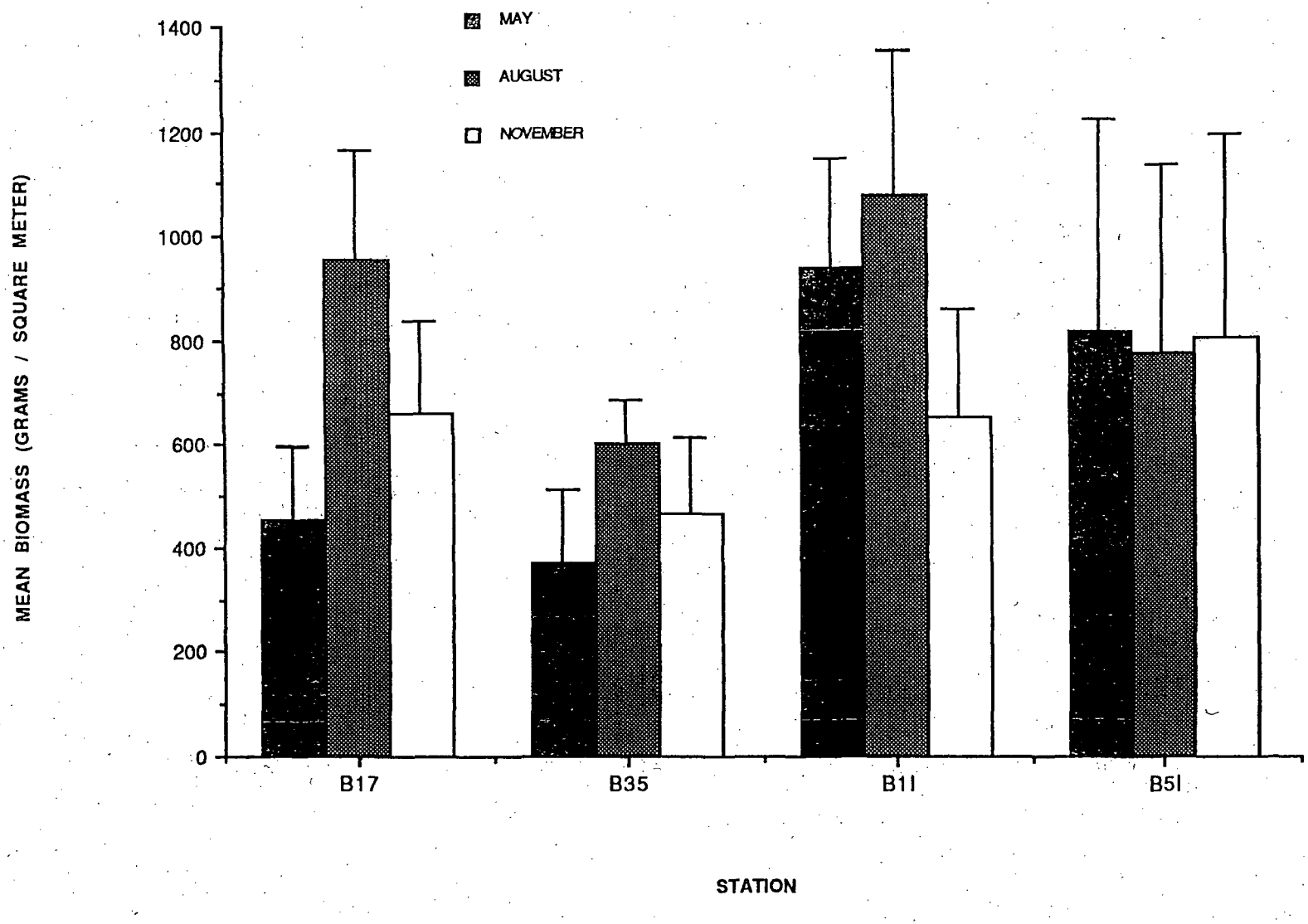


Figure 3.3.2-8 Mean biomass (gm/m^2) and 95% confidence limits of *Chondrus crispus* at selected stations in May, August and November, Stations 17, 35: 1978-1987, Stations 35 and 1MLW: 1982-1987) Seabrook Baseline Report, 1987.

TABLE 3.3.2-6. MEAN BIOMASS (g/m^2) AND STANDARD DEVIATION (SD) OF *CHONDRUS CRISPUS* AT BENTHIC STATIONS 17, 35, 1MLW, AND 5MLW IN AUGUST FROM 1978 TO 1987. SEABROOK BASELINE REPORT, 1987.

	SHALLOW SUBTIDAL				INTERTIDAL			
YEAR	STATION 17 (NEARFIELD)		STATION 35 (FARFIELD)		STATION 1MLW (NEARFIELD)		STATION 5MLW (FARFIELD)	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
1978	860.3	535.7	NS[a]		459.7	532.9	NS	
1979	713.8	301.8	NS		638.6	138.1	NS	
1980	574.9	282.4	NS		797.8	262.1	NS	
1981	1113.8	384.2	NS		917.3	558.1	NS	
1982	593.6	194.5	491.9	234.9	1622.9	345.3	1147.4	174.4
1983	853.8	243.5	663.4	388.9	1539.6	129.1	994.3	461.8
1984	782.1	251.5	484.7	344.2	1612.4	263.8	457.3	321.7
1985	1272.7	366.2	544.3	428.4	1203.5	179.9	530.9	479.7
1986	1193.3	329.7	523.7	343.2	1154.4	723.1	857.7	258.0
1987	943.5	288.1	673.1	414.2	951.9	263.8	628.6	312.7
ALL YEARS MEAN	890.2		563.5		1089.81		769.4	

[a]NS = Not sampled.

3.3.3 Marine Macrofauna

3.3.3.1 Algae Covered Ledge Community

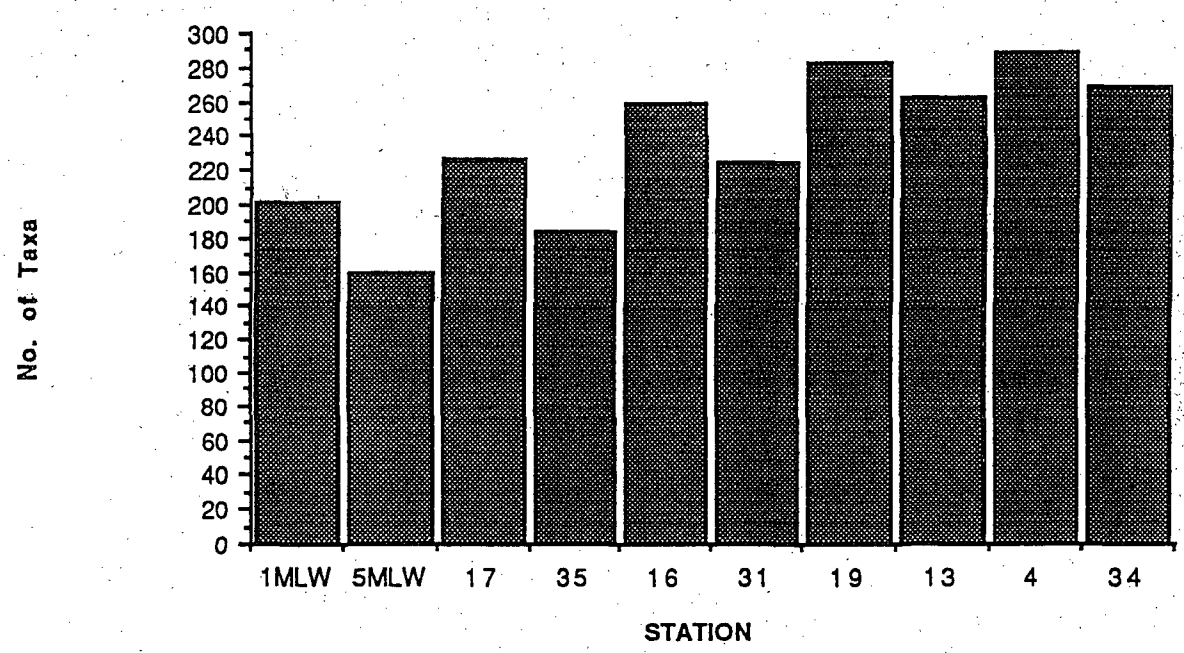
General

Studies of the macrofaunal invertebrates off Hampton Beach, NH since 1978 have focused on the horizontal algae-covered ledge habitat in four depth zones: intertidal (MLW and MSL), shallow subtidal (5 m), mid-depth (9-12 m) and deep (18-21 m)(Table 4.1-1). Nearfield stations near the intake and discharge areas have paired farfield counterparts near Rye Ledge in the same depth zone (Figure 4.1-3) for an optimal impact assessment design (Green 1979). Macrofaunal studies include a community analysis of intertidal and subtidal habitats, a detailed examination of key species (see Section 3.3.5 also) and an investigation of the near-surface and bottom fouling community (see Section 3.3.4 also).

Numbers of Taxa and Total Abundance

Numbers of taxa and total abundance have been used to monitor spatial and temporal trends in the macrofaunal community. These parameters have shown broadscale changes in relation to depth. The number of taxa generally increased with increasing depth, and nearfield stations had higher numbers of taxa in comparison to farfield stations (Figure 3.3.3-1). Total abundance showed a general decrease with increasing depth (Figure 3.3.3-1), mainly due to decreased numbers of mytilids (see Section 3.3.5).

The intertidal area had highest abundance of all of the benthic stations, and nearfield and farfield stations had lower numbers of taxa than subtidal counterparts (Figure 3.3.3-1). Nearfield Station 1MLW had higher numbers of taxa and total abundance than its farfield counterpart, Station 5MLW (Figure 3.3.3-1). The presence of boulders at the farfield site may decrease available habitat space, in turn decreasing the total abundance and



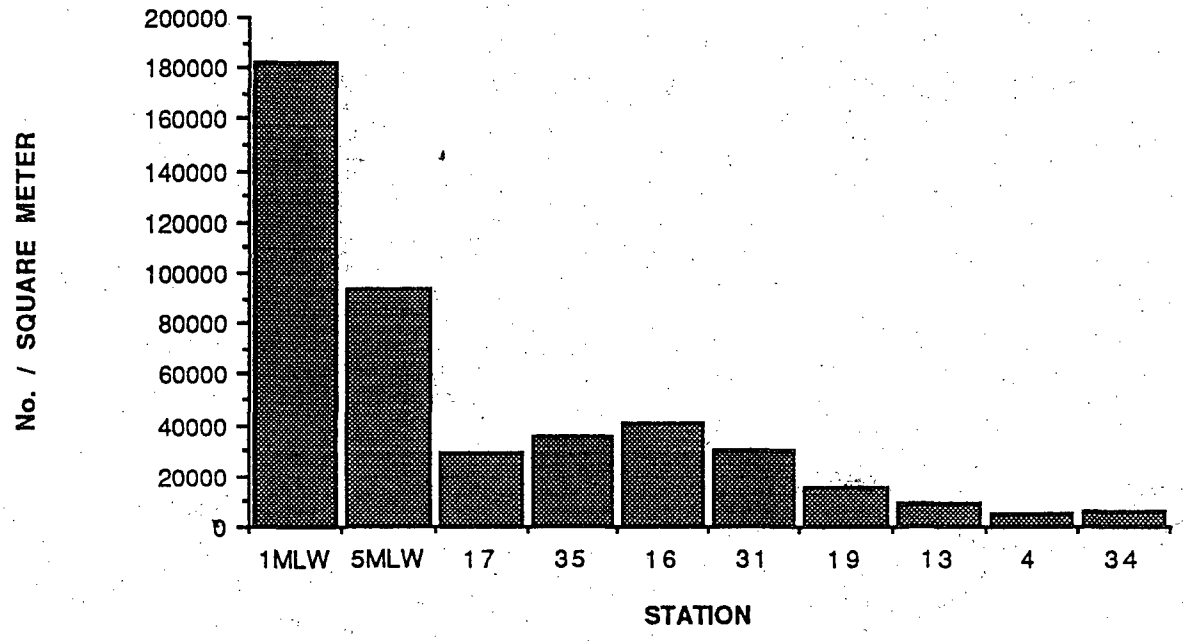
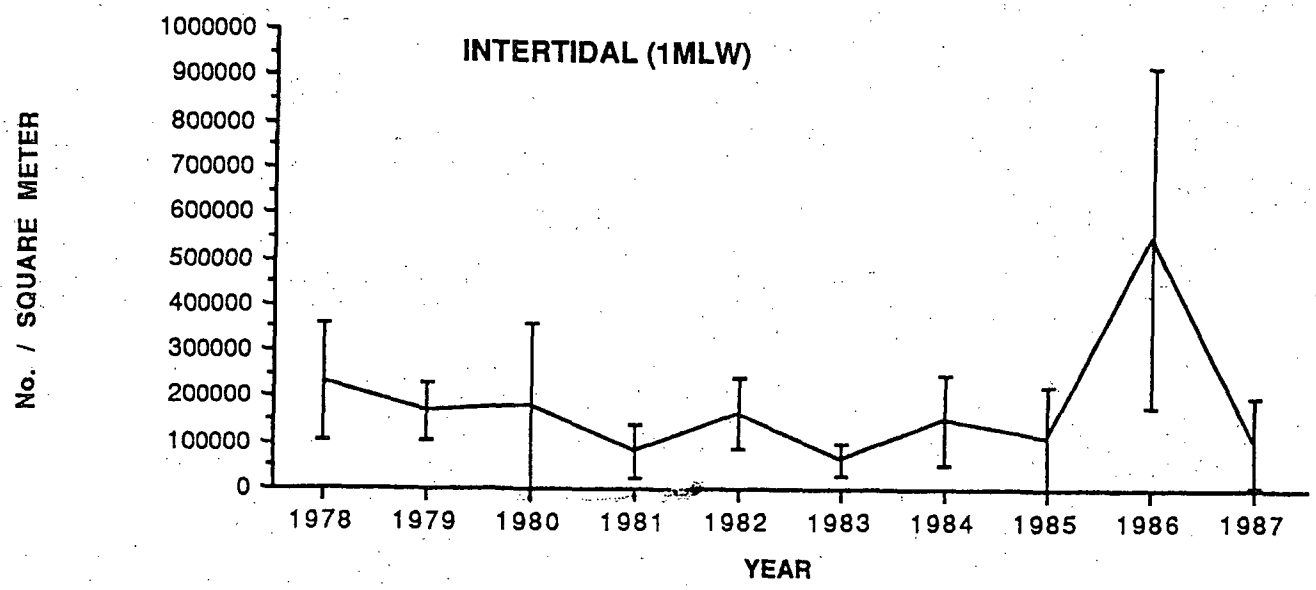


Figure 3.3.3-1. Number of taxa and overall abundance (No./square meter) over all years (1978-1987, stations 1MLW, 17, 19, 31; 1982-1987, 5MLW, 35; 1979-1984, 1986-1987, 34; 1978-84, 86-87, 13, 4, 16) at intertidal and subtidal benthic stations. Seabrook Baseline Report, 1987.

number of taxa. The 1987 abundance levels at 1MLW dropped from the extremely high levels recorded in 1986 to levels similar to previous years (Figure 3.3.3-2), in part due to decreases in mytilid abundances from their peak 1986 levels (see Section 3.3.5). The number of taxa in 1987 was the lowest ever recorded at intertidal stations: 60 at Station 1MLW and 64 at Station 5MLW (Figure 3.3.3-3). This could be a result of the prolonged period of low salinity in April and May (see Section 3.1.1). Bottom salinities were below 31.5 ppt for two to three months at Station P2. In addition, 1987 bottom temperatures at this station were approximately 3°C below average in August and September (Figure 3.1.1-1).

The shallow subtidal stations (5 m), Stations 17 and 35, had higher numbers of taxa than their intertidal counterparts but lower numbers than mid-depth and deep areas (Figure 3.3.3-1). The nearfield station had a higher number taxa (227) in comparison to the farfield area (195) but slightly lower overall abundance (Figure 3.3.3-1). Number of taxa decreased at both stations in 1987, although the decrease was slight at Station 17, remaining within the range of previous years. Total abundance in 1987 decreased at Station 17 following peak levels in 1986 (Figure 3.3.3-2), due to decreases in Mytilidae and *Lacuna vincta*, which were exceptionally high in 1986 (NAI 1987b, 1988).

Mid-depth (9-12 m) stations, Stations 16, 31, and 19, continued the trend of increasing numbers of taxa and decreasing abundance with increasing depth. Numbers of taxa were consistently higher at Stations 19 and 16, where algae-covered ledge predominates and mussel beds comprise 25-40% of the habitat (Figure 3.3.3-1). In comparison, Station 31 was predominantly composed of mussel beds (60%) with cobble and algae-covered rocks also present (Table 4.1-1). Numbers of taxa in 1987 were the lowest encountered since sampling began (Figure 3.3.3-4). Abundance levels at Station 16 were higher than at Station 31 which in turn were higher than at Station 19, because of the varying numbers of mytilids (Figure 3.3.3-1). Abundance levels in 1987 at Station 19 decreased from peak levels in 1986, (Figure 3.3.3-5), diminished by lower mytilid densities (see Section 3.3.5). At Station 16, total abundance was the lowest recorded since sampling began in 1980 (Figure 3.3.3-5).



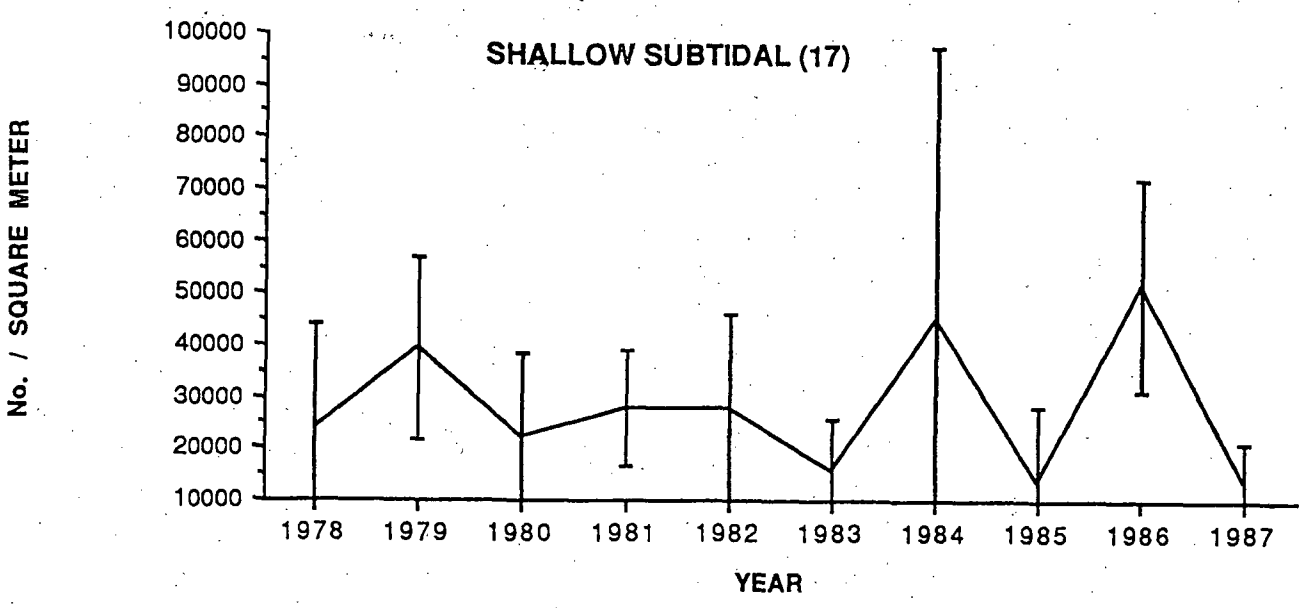
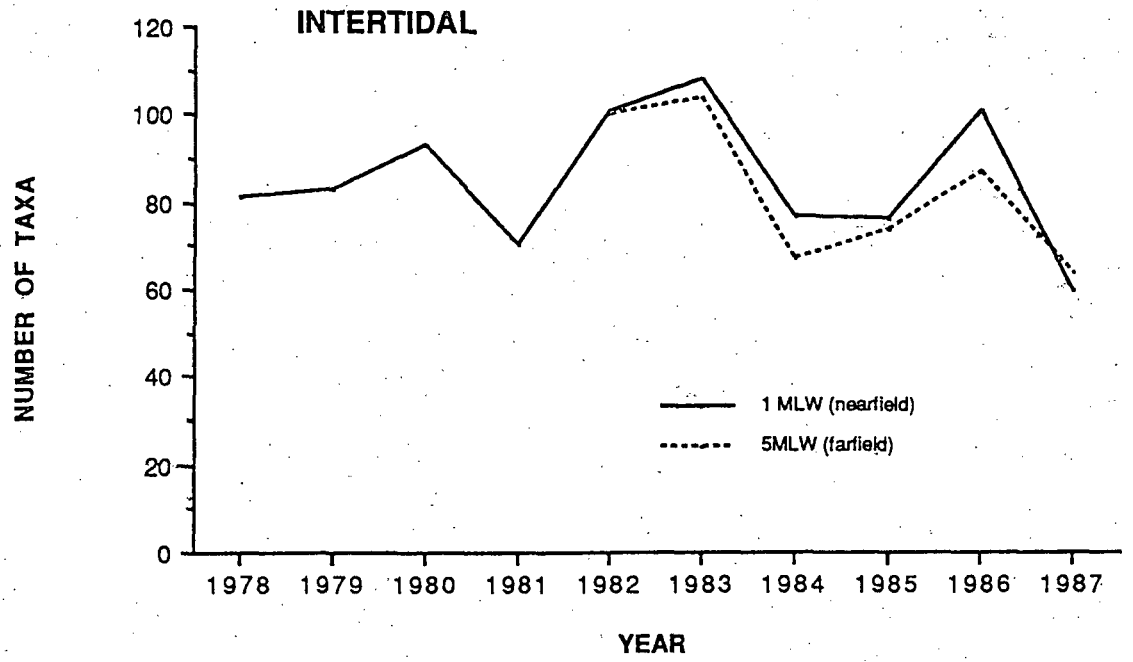


Figure 3.3.3-2. Annual mean abundance (No./square meter) and 95% confidence limits for macrofauna collected in August for nearfield stations 1MLW (intertidal) and 17 (shallow subtidal). Seabrook Baseline Report, 1987.



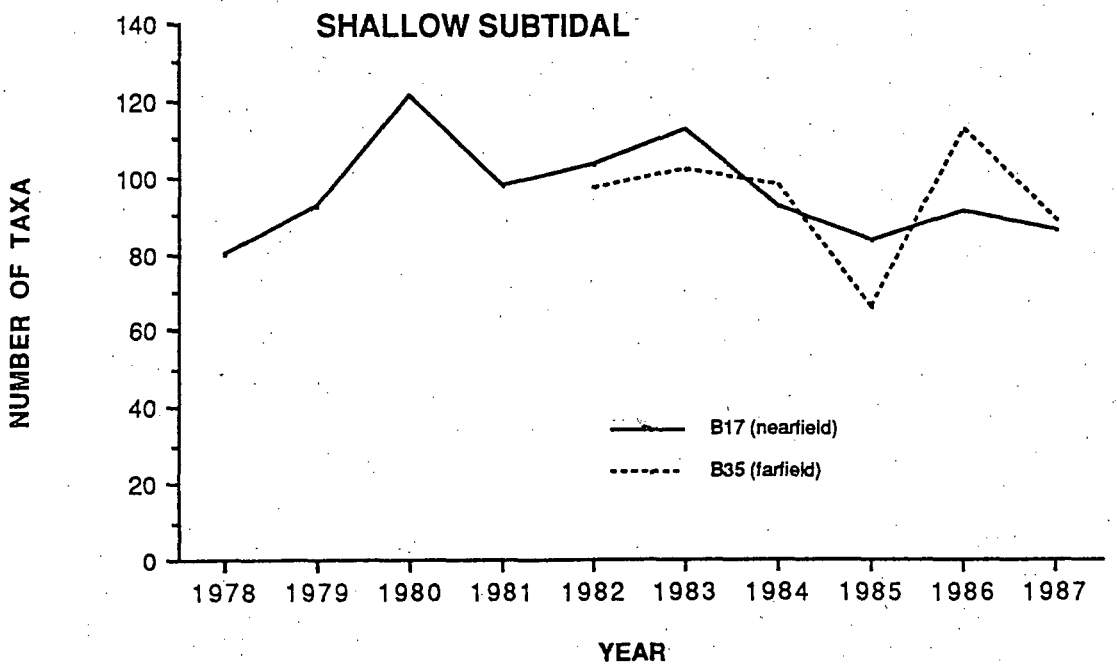
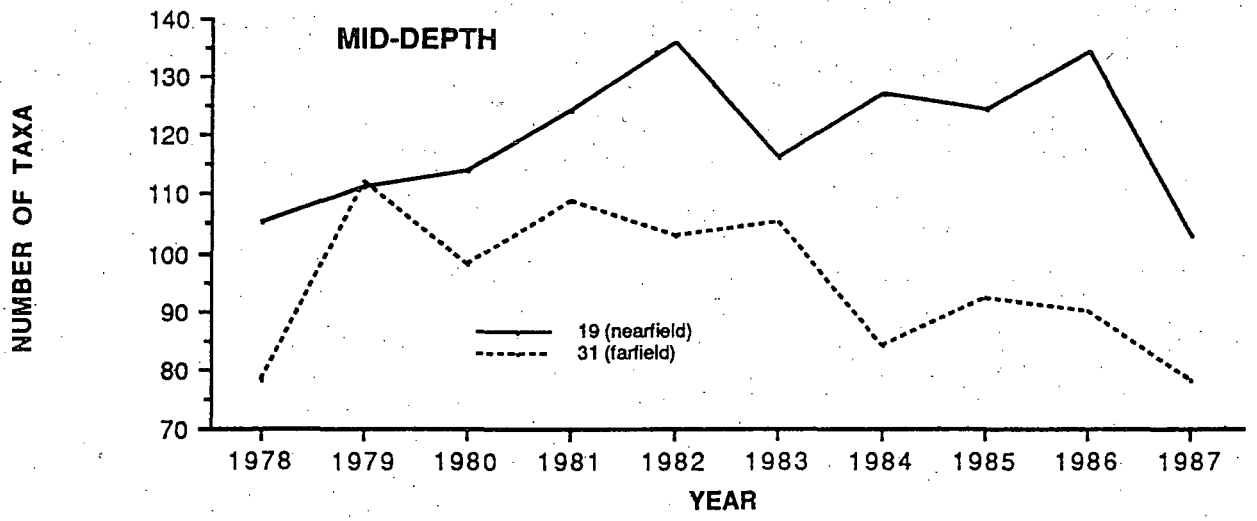
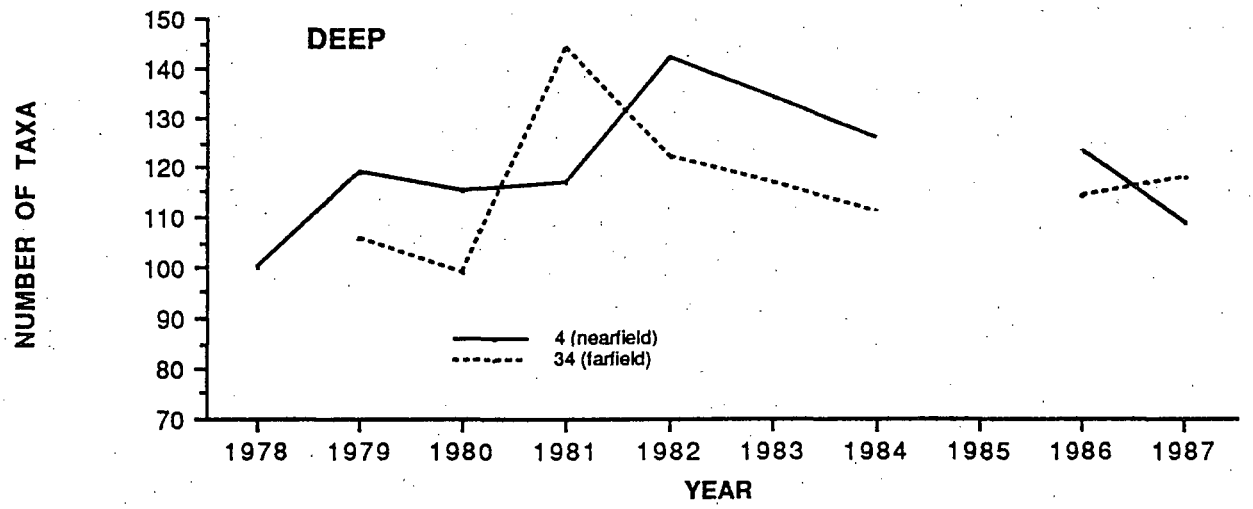


Figure 3.3.3-3. Annual number of taxa collected in August at intertidal stations 1MLW and 5MLW and shallow subtidal stations 17 and 35. Seabrook Baseline Report, 1987.





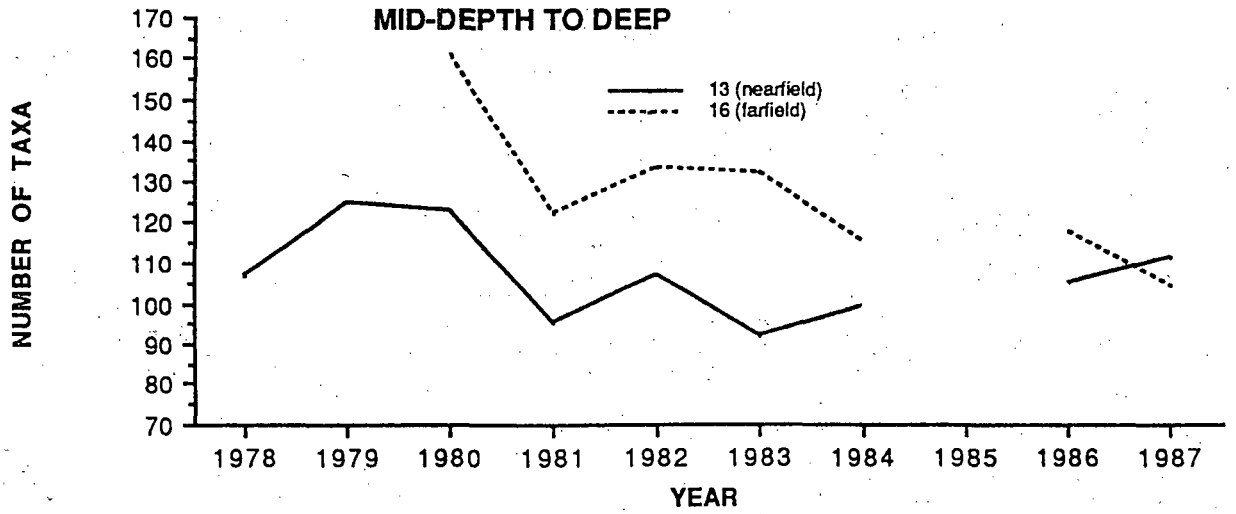


Figure 3.3.3-4. Annual number of taxa collected in August at stations 16, 19, and 31 (mid-depth); and stations 4, 13, and 34 (deep). Seabrook Baseline Report, 1987.

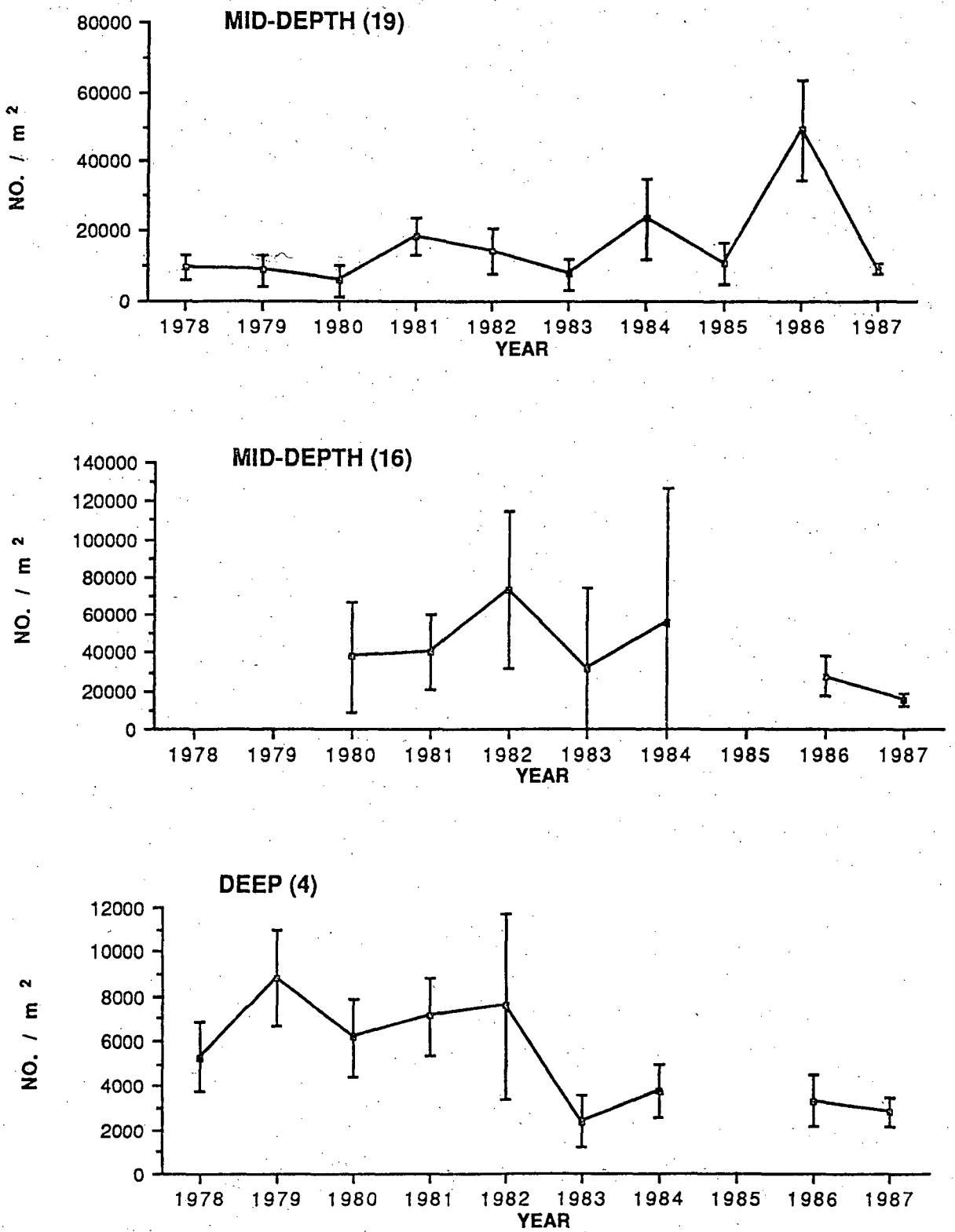


Figure 3.3.3-5. Annual mean abundance (No./square meter) and 95% confidence limits for macrofauna collected in August for nearfield stations 19 and 16 (mid-depth) and 4 (deep). Seabrook Baseline Report, 1987.

The deepest stations (18-21 m), Stations 4, 34 and 13, had the highest number of taxa and the lowest number of individuals in comparison to shallow and mid-depth areas (Figure 3.3.3-1). The overall number of taxa has consistently been lowest at Station 13, which has a mixture of algae-covered ledge, mussel beds, and cobble, and highest at Station 4, where mussel beds predominate, with some algae-covered ledge present. Station 34, slightly deeper at 21 m, has been intermediate in its number of taxa, and is predominantly mussel bed (Figure 3.3.3-1, Table 4.1-1). Numbers of taxa in 1987 fell within the range of previous years at all three stations (Figure 3.3.3-4). Density levels were highest at Station 13 and similar at Stations 4 and 34 (Figure 3.3.3-1). The abundance levels in 1987, while within the range of previous years, were slightly lower than average at Stations 4 (Figure 3.3.3-5) and 34 (NAI 1987b, 1988).

Elevated abundances at Station 13 in 1986 were due mainly to high numbers of *Balanus crenatus* (10,323/m^2) and *Lacuna vincta* (4000/m^2)(NAI 1987a). In 1987, total abundances were similar to those observed in 1986, but instead were a result of high densities of Mytilidae, *Balanus crenatus*, and *Hiatella* sp. all averaging from 4000-5000/m^2 (NAI 1988).

Community Structure

The noncolonial, macrofaunal, hard-bottom community structure has historically shown changes related to depth (NAI 1987b). Intertidal, shallow subtidal, mid-depth, and deep areas were distinct in both species distributions and abundances. The 1987 collections showed highly similar species composition to collections from previous years (Table 3.3.3-1). In all cases, based on the similarity in species composition, the 1987 collections were placed in the group with the majority of historical collections from the same station (Table 3.3.3-1). The addition of 1987 data caused only a few changes in the within-group abundance of dominant taxa, underscoring the similarity of 1987 to previous years.

TABLE 3.3.3-1. STATION GROUPS DEFINED BY DISCRIMINANT ANALYSIS OF NON-COLONIAL MACROFAUNA COLLECTED AT INTERTIDAL AND SUBTIDAL BENTHIC STATIONS, AUGUST 1978-1987. SEABROOK BASELINE REPORT, 1987.

STATION GROUP	STATIONS (YEARS)[a]	SAMPLES/ GROUP	DEPTH/SITE	DOMINANT TAXA	NO./M^2
1	19(1978)	4	Mid-depth - deep/	Pontogeneia inermis	1550
	31(1978)		discharge and	Mytilidae	621
	4(1978)		control	Hiatella sp.	322
	34(1980)			Asteriidae	244
				Caprella septentrionalis	242
				Anomia sp.	234
2	13(1978,1981-84,	9	Deep/discharge and	Balanus crenatus	3427
	86,87)		control	Mytilidae	1725
	34(1983-84,86)			Hiatella sp.	944
				Anomia sp.	887
				Balanus sp.	671
				Lacuna vincta	467
				Pontogeneia inermis	343
				Asteriidae	312
3	19(1979-87)	21	Mid-depth/discharge,	Mytilidae	17797
	31(1979-87)		intake, control	Pontogeneia inermis	1385
	13(1979-80)		deep/discharge	Hiatella sp.	1262
	16(1984)			Anomia sp.	1058
				Caprella septentrionalis	1004
				Balanus crenatus	699
				Molgula sp.	535
				Lacuna vincta	493
4	4(1979-84,86,87)	13	Deep/discharge	Pontogeneia inermis	519
	34(1979,1981-82,1987)		and control	Asteriidae	334
				Caprella sp.	487
				Caprella septentrionalis	256
				Anomia sp.	250
				Balanus crenatus	247
				Musculus niger	237
5	17(1978-87)	22	Shallow - mid-depth/	Mytilidae	8723
	35(1982-87)		discharge, intake	Lacuna vincta	4971
	16(1980-83,86,87)			Pontogeneia inermis	4043
				Caprella septentrionalis	2025
				Idotea phosphorea	1944
				Jassa falcata	1907
6	1MLW(1978-87)	16	Intertidal/Outer	Mytilidae	101630
	5MLW(1982-87)		Sunk Rocks, Rye	Jaera marina	7334
			Ledge	Turtonia minuta	6483
				Hiatella sp.	5798
				Lacuna vincta	4895
				Gammarellus angulosus	4088
				Oliogochaeta	3908
				Nucella lapillus	3031

[a]No samples collected at Station 34 in 1979 or 1985; Stations 5MLW and 35 in 1978-81; or Stations 16 and 13 in 1985.

Differences in community structure among stations were indicated by differences in densities of dominant taxa as well as the species which are restricted to a certain depth zone. The discriminant analysis relied on only 32 of the original 89 species used in the cluster analysis to form the station groups (Appendix Table 3.3.3-1). The most abundant species (i.e., Mytilidae spat, *Pontogeneia inermis, Lacuna vincta, Caprella septentrionalis*) were ubiquitous, and contributed little to the discrimination among stations. Less-abundant species, such as *Nucella lapillus, Calliopius laeviusculus, Jassa falcata, Nereis pelagica, Jaera marina*, and *Musculus niger*, accounted for the majority of the among-station variability.

The intertidal habitat (Group 6) was the most distinct of all areas because of the overwhelming predominance of Mytilidae spat (101,630/m^2) and the presence of species such as *Nucella lapillus, Fabricia sabella, Hyale nilssoni,* and *Jaera marina*, which were restricted to that area. Other dominants included the molluscs *Turtonia minuta, Hiatella* sp., and *Lacuna vincta*, and the amphipod *Gammarellus angulosus*. Intertidal collections made in 1987 were placed in this group based on similar species composition. However, a few of the individual species showed decreases in densities from peak levels noted in 1986, decreasing the overall group density from the 1978-1986 value (NAI 1987b). These included Mytilidae at Station 1MLW only, and *Hiatella* sp. and *Jaera marina* at both 1MLW and 5MLW (NAI 1987b, 1988). Mytilids at Station 5MLW reached their highest density since sampling began in 1982 (see Section 3.3.5).

The shallow subtidal station group (5) has included Station 17 and 35 in all years and Station 16 in 1980-1983 and 1986-1987 (Table 3.3.3-1). Mytilidae was still the predominant taxon, although less abundant than in the intertidal area. Aside from gastropod *Lacuna vincta*, dominants were peracarid crustaceans such as *Pontogeneia inermis, Caprella septentrionalis, Idotea phosphorea,* and *Jassa falcata* (Table 3.3.3-1). Relatively high densities of the latter two species, along with *Calliopius laeviusculus* distinguished this area from other areas. The addition of 1987 collections did not change the order of the dominant species, nor drastically alter the

within-group abundance. However, average group abundance levels of all taxa were lower than 1978-1986 levels due to decreases from the 1986 density levels (NAI 1987b, 1988). Species composition at Station 16, with depth of 10.7 m, was usually more similar to the shallower Stations 17 and 35 because of the predominance of uniform algae-covered ledge, causing increased biomass of algae (see Section 3.3.2). This, in turn, increased numbers of subdominant herbivorous species such as *Lacuna vincta* and *Idotea phosphorea*, which increased the similarity of this station's species composition with that of shallow subtidal stations. Furthermore, flat ledge at Station 16 (with fewer mussel beds and boulders) prevented the accumulation of sediment and detritus, making it less suitable than other mid-depth stations for species which need soft substrate such as *Nichomache* sp., *Cistenides granulata* and *Cerastoderma pinnulatum*.

Mid-depth areas (Group 3) were characterized by a predominance of Mytilidae spat, with other molluscs (e.g., *Hiatella* sp. and *Anomia* sp.) and amphipods (e.g., *Pontogeneia inermis* and *Caprella septentrionalis*) occurring in high numbers (Table 3.3.3-1). Stations 19 and 31 in most years were characterized by this assemblage, as were deep Station 13 and mid-depth Station 16 in one or two years. The 1987 collections at Stations 19 and 31 were similar to previous years, and thus placed in the same group. Densities of dominant molluscs Mytilidae and *Hiatella* sp. in 1987 decreased from the extremely high values recorded in 1985 and 1986 (see Section 3.3.5 and NAI 1987b, 1988).

Stations with depths greater than 15 m formed several loosely-associated deep station groups. All differed from shallower stations in the decreasing influence of molluscs, particularly the overwhelming predominance of Mytilidae spat, and the increased importance of crustaceans and other taxa. The majority of collections at deep stations (4, 34, 13) were placed in two groups. In some years, at Stations 4 and 34, peracarids (*Pontogeneia inermis, Caprella* spp.) Asteriidae, and molluscs (*Anomia* sp., *Musculus niger*) were the dominant taxa, forming Group 4 (Table 3.3.3-1). The 1987 collections at Stations 4 and 34 were placed in Group 4 based on the similarity of

their species composition. In other years, at Stations 13 and 34, *Balanus* spp., along with molluscs (Mytilidae, *Anomia* sp., *Lacuna vincta* and *Hiatella* sp.) were the most abundant taxa, causing these stations to be distinct from other collections, forming Group 2. Collections made at Station 13 in 1987 were placed in this group, in part due to high densities of *Balanus* spp. (4698/m^2) (NAI 1988). The high within-group abundance of *Balanus crenatus* is deceptive, however, as it is heavily influenced by Station 34 in 1984, where *Balanus crenatus* averaged 12,233/m^2 (NAI 1985a), and 1986 at Station 13, where this species averaged 10,323/m^2 (NAI 1987a). A third group of four station collections, including mid-depth 19 and 31 and deep 4 and 34, was formed because they were unlike the other assemblages in having moderate numbers of Mytilidae sp. and *Hiatella* sp. but low numbers of *Balanus* spp. No collections from 1987 showed a similar species composition to this group.

3.3.3.2 Intertidal Bare Rock, Fucoid Ledge, and *Chondrus* Communities

Important species on fucoid-covered and bare rock ledge habitats at mean sea level (MSL) and *Chondrus* zone habitat at mean low water (MLW) were enumerated triannually at fixed stations on Outer Sunk Rocks (Station 1) and Rye Ledge (Station 5). The bare rock areas supported low percentages of algae such as *Porphyra* spp. at Station 1 and *Fucus* spp. mainly at Station 5 (Section 3.3.2). The predominant macrofaunal resident was *Balanus* spp., which had slightly higher frequencies in April following the spring recruitment period, than in July and December (Table 3.3.3-2). Gastropods *Littorina littorea* (at Station 5) and *Littorina saxatilis* (at both stations), chief consumers of *Fucus* sp., were also important constituents of the bare rock community, showing lower frequencies in April than in July or December. Mytilidae spat occurred in low frequencies in July and December. Patterns of faunal distribution in 1987 were similar to those observed in previous years with one exception. *Nucella lapillus*, normally not encountered in the bare rock zone, occurred in all three months in 1987 at Station 5 (NAI 1988).

TABLE 3.3.3-2. MEDIAN AND RANGE OF PERCENT FREQUENCIES[a] OF THE DOMINANT FAUNA AT BARE ROCK, FUCOID LEDGE, AND CHONDRUS ZONE INTERTIDAL SITES AT STATIONS 1 (OUTER SUNK ROCKS) AND 5 (RYE LEDGE) MONITORED NONDESTRUCTIVELY. *SEABROOK BASELINE REPORT, 1987.*

			FUCOID LEDGE[b]			BARE ROCK[b]			CHONDRUS ZONE[c]		
			APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Acmaea testudinalis	1	median	0	3	10	0	0	0	13	13	13
		(range)	(0-6)	(0-19)	(6-19)	(0)	(0)	(0)	(6-38)	(6-25)	(6-25)
	5	median	3	6	13	0	0	0	0	0	0
		(range)	(0-19)	(0-38)	(0-38)	(0)	(0)	(0)	(0)	(0-13)	(0-25)
Balanus spp.	1	median	17	2	1	71	63	21	0	0	0
		(range)	(4-100)	(1-38)	(0-63)	(19-100)	(9-88)	(1-88)	(0-47)	(0-4)	(0)
	5	median	35	23	4	93	78	64	0	0	0
		(range)	(15-100)	(12-100)	(1-88)	(58-100)	(24-100)	(5-100)	(0)	(0)	(0-3)
Littorina littorea	1	median	0	0	0	0	0	0	0	0	0
		(range)	(0)	(0)	(0-6)	(0)	(0-13)	(0-13)	(0)	(0)	(0)
	5	median	19	60	13	0	13	91	81	100	81
		(range)	(0-38)	(44-75)	(6-31)	(0-6)	(0-56)	(50-100)	(75-100)	(100)	(44-94)
Littorina obtusata	1	median	0	6	6	0	0	0	0	0	0
		(range)	(0-6)	(0-13)	(6-19)	(0)	(0-19)	(0)	(0-6)	(0-19)	(0)
	5	median	7	10	7	0	3	0	0	0	0
		(range)	(0-25)	(0-44)	(0-44)	(0-6)	(0-19)	(0-13)	(0-13)	(0)	(0)
Littorina saxatilis	1	median	0	0	0	7	72	22	0	0	0
		(range)	(0)	(0)	(0-6)	(0-44)	(0-88)	(6-88)	(0)	(0)	(0)
	5	median	0	0	0	28	66	75	0	0	0
		(range)	(0-6)	(0)	(0-6)	(0-81)	(38-94)	(6-100)	(0)	(0)	(0)

(continued)

TABLE 3.3.3-2. (Continued)

			FUCOID LEDGE[b]			BARE ROCK[b]			CHONDRUS ZONE[c]		
			APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Mytilidae	1	median	82	93	83	0	16	12	94	93	68
		(range)	(21-100)	(35-100)	(43-100)	(0-20)	(0-40)	(0-75)	(54-95)	(71-95)	(15-85)
	5	median	6	1	3	0	6	15	41	27	3
		(range)	(2-100)	(0-100)	(0-100)	(0-5)	(0-38)	(1-75)	(10-72)	(23-80)	(0-48)
Nucella lapillus	1	median	10	78	35	0	0	0	75	100	56
		(range)	(0-25)	(25-100)	(13-50)	(0)	(0)	(0)	(50-75)	(100)	(50-69)
	5	median	0	47	0	0	0	0	94	31	69
		(range)	(0)	(13-81)	(0-6)	(0-94)	(0-44)	(0-56)	(75-100)	(13-44)	(56-81)

[a] Method of computing percent frequency varies among species (point-contact method for Mytilidae and Balanus since July 1983, percent frequency of occurrence for all other instances).
[b] 1982-1987, mean sea level.
[c] 1985-1987, mean low water.

Fucoid-covered ledge areas at mean sea level were characterized by a heavy cover (over 80%) of the perennial algae *Fucus* spp. (mainly *F. vesiculosus*), with an understory of perennial red algae (*Mastocarpus stellata* and *Chondrus crispus*). Highly-seasonal annual algae occurred in spring or spring and summer, particularly at Station 1 (Section 3.3.2). Mytilidae spat was the most common taxon at Station 1, with high percentages during all three sample periods (Table 3.3.3-2). Mytilidae usually did not show high frequencies at Station 5. *Balanus* spp. was also an important member of the fucoid ledge community and was more frequently encountered at Station 5. As on bare rock, frequencies were highest in April following spring recruitment and lowest in December. *Balanus* frequencies were exceptionally low in 1987 at Station 1 (NAI 1988). *Nucella lapillus* occurred mainly on the fucoid-covered ledge, most commonly encountered in July. Other important gastropods were *Acmaea testudinalis* and *Littorina obtusata* (most frequent in July and December) and *Littorina littorea* (almost exclusively occurring at Station 5).

The intertidal community in the mean low water zone, the "*Chondrus* zone", was characterized by rock ledge with a thick cover of red algae, mainly *Chondrus crispus* and *Mastocarpus stellata*. *Fucus* spp. were also frequently encountered at Station 1 only (Section 3.3.2). Of the macrofaunal species that were monitored, *Nucella lapillus* and Mytilidae spat were the most frequently encountered. At Station 1, *Nucella* were more abundant in July than in April or December (Table 3.3.3-2). This is consistent with other studies which show adult *Nucella* to be active from May through October, while juveniles tend to be active throughout the year (Menge 1978). On Rye Ledge (Station 5), *Nucella* was less-frequently encountered in July, a seasonal pattern that was reversed from its nearfield counterpart. Seasonal movements of *Nucella* appeared unrelated to those of its main prey, Mytilidae. Mytilidae had medium-to-high frequencies in April and July at Station 1, with generally lower percentages in December. Mytilidae, historically not common at Station 5, settled in large numbers between December 1986 and April 1987, only to decrease by August (NAI 1987a, 1988). No relationship with abundance levels of either species at mean low water or with the fucoid community at

mean sea level were noted (NAI 1987a, 1988). Another important species in this community was the gastropod *Littorina littorea*, which occurred at Station 5 only throughout the year. *Acmaea testudinalis* was enumerated in low-to-moderate frequencies at Station 1 in all years and Station 5 in 1985 only (Table 3.3.3-2). Seasonal distributional patterns observed in 1987 were similar to previous years.

3.3.3.3 Subtidal Fouling Community

Data collected from subtidal bottom panels gives information on recruitment of benthic macrofaunal species. *Balanus* spp. (mainly *Balanus crenatus*, with some *Balanus balanus*) typically settled by April. Recruitment continued in some years after the April sampling period so that densities were higher in the August samples, while in other years April sampling occurred near the settlement peak, so that densities were lower in August (Table 3.3.3-3). Densities in December were consistently low, as *Balanus* populations disappeared as a result of mortality or disturbance. The 1987 panels showed this same pattern. *Balanus* spp. densities were higher at Station 31 in all years except 1984.

Anomia sp. had a pattern of late-summer-fall recruitment. Although low densities of *Anomia* sometimes occurred on panels by August, numbers were typically highest by December's collections (Table 3.3.3-3). Similar densities in August and December collections in 1984 suggested an earlier set than other years. In 1987, December densities were lower than average at Station 31, suggesting recruitment was late or unsuccessful. Nearfield and farfield stations showed similar levels of *Anomia*.

Hiatella sp., another sessile mollusc, showed highest densities by August collections, with most disappearing from panels by December. Densities in 1987 showed a similar seasonal pattern (Table 3.3.3-3). Numbers were generally higher at Station 31 than at Station 19 (1987 was an exception), a pattern not borne out in the natural environment. Especially high

TABLE 3.3.3-3. ESTIMATED DENSITY (PER 1/4 m^2) OF SELECTED SESSILE TAXA ON TRIANNUAL (FOUR MONTHS' EXPOSURE) HARD-SUBSTRATE BOTTOM PANELS. SEABROOK BASELINE REPORT, 1987.

TAXA		1981 APR	1981 AUG	1981 DEC	1982 APR	1982 AUG	1982 DEC	1983 APR	1983 AUG	1983 DEC	1984 APR	1984 AUG	1984 DEC	1986[a] DEC	1987 APR	1987 AUG	1987 DEC
Balanus spp.	Sta. 19	7600	7950	1	1600	9250	0	2630	1409	0	25060	12,360	25	9	20683	750	2
	Sta. 31	NS	NS	NS	82803	13023	26	35100	4304	0	19768	9290	46	9	48100	117	0
Anomia sp.	Sta. 19	0	0	278	0	0	997	1	27	0	0	184	195	1017	2	4	1669
	Sta. 31	NS	NS	NS	0	0	1387	0	58	340	0	104	166	450	0	7	61
Hiatella sp.	Sta. 19	NS	NS	NS	NS	NS	NS	0	160	2	0	4345	20	4	1	3868	5
	Sta. 31	NS	NS	NS	NS	NS	NS	0	1369	2	1	19226	18	25	0	1235	53
Mytilidae	Sta. 19	NS	NS	NS	NS	NS	NS	0	19	19	1	709	80	161	7	391	11
	Sta. 31	NS	NS	NS	NS	NS	NS	0	300	5	21	23018	80	77	17	572	39

MEAN AND STANDARD DEVIATION (SD) FOR ALL YEARS (1981-1984, 1986[b], 1987)

		APR MEAN	APR SD	AUG MEAN	AUG SD	DEC MEAN	DEC SD
Balanus spp.	Sta. 19	11515	10725	6344	5071	6	10
	Sta. 31	46443	26864	6684	5650	16	20
Anomia sp.	Sta. 19	1	1	43	80	693	640
	Sta. 31	0	0	42	49	481	529
Hiatella sp.	Sta. 19	<1	1	2791	2291	8	8
	Sta. 31	<1	1	7277	10349	24	21
Mytilidae	Sta. 19	3	4	373	345	68	69
	Sta. 31	13	11	7963	13038	50	35

NS = Not sampled.

[a] Only December collections were made in 1986.
[b] Only December computations include 1986.

densities on bottom panels in 1984 were reflected in higher densities in the natural environment in 1984 (NAI 1985a).

Mytilidae spat generally had settled on bottom panels by August, with numbers diminishing by December (Table 3.3.3-3). In the natural environment, small mytilids appeared from August through October, but information from surface fouling panels suggests that settlement can take place throughout the year. Few of these newly-settled mytilids survived through the winter in the natural habitat or on artificial substrate (NAI 1985b). Densities on bottom panels at Station 31 were usually much higher than at Station 19, a pattern which also occurred in the natural habitat (Section 3.3.5). However, in 1987, densities on bottom panels were similar between the two stations, unlike densities from the natural habitat.

3.3.3.4 *Modiolus modiolus* Community

As part of the subtidal nondestructive program, *Modiolus modiolus* populations were enumerated by divers along randomly pre-selected, radiating transects at selected stations. Previous reports have demonstrated that there has been little seasonal variability in density levels (NAI 1985b). Over the eight-year period 1980-1987, no significant difference was detected between nearfield and farfield stations by a Wilcoxon's signed rank test (Table 3.3.3-4). Significant differences were detected among years using a Kruskal-Wallis test ($p < 0.001$, DF = 7). Densities were highest in 1982 and 1983, averaging over $110/m^2$ (Table 3.3.3-4). In subsequent years, annual mean density was less than $100/m^2$ at both stations. The 1987 densities were lower than the 1980-1987 average at both stations (Table 3.3.3-4). Despite year-to-year fluctuations in *Modiolus* density, the community as a whole can be relatively persistent and is an important refuge from large predators for macroinvertebrates. At the 8 m depth off Portsmouth, N.H., *Modiolus* beds persisted for over five years. However, survival depended on the ability of *Modiolus* to avoid predation by *Asterias vulgaris* or dislodgement by attached kelps, which in turn are regulated by grazing sea urchins (Witman 1985).

TABLE 3.3.3-4. ANNUAL MEAN DENSITY (PER 1/4 m^2) AND STANDARD DEVIATION OF MODIOLUS MODIOLUS OBSERVED AT SUBTIDAL TRANSECT STATIONS, 1980-1987. SEABROOK BASELINE REPORT, 1987.

STATION		1980	1981	1982	1983	1984	1985	1986	1987	ALL YEARS
Nearfield	MEAN	98	108	132	112	97	77	90	97	101
(19)	SD	48	45	60	66	55	46	39	50	54
Farfield	MEAN	119	93	121	116	88	93	62	67	95
(31)	SD	44	54	64	50	38	44	42	44	52

Station 19 = Station 31 ($p = 0.08$)

3.3.4 Surface Fouling Panels

The fouling panels program was designed to study both settlement patterns and community development. The short-term (ST) panels provided information on the temporal sequence of settlement activity, while monthly sequential (MS) panels provided information on growth and successional patterns of community structure. Surface fouling panels have been collected at nearfield (19, 4) and farfield (31, 34) stations since 1978 (except 34; since 1982). Panels were not collected, however, for the period January 1985 through June 1986. Panel collection resumed in July 1986 and continued through December 1987.

3.3.4.1 Seasonal Settlement Patterns

Historically, species richness (number of taxa) on Seabrook short-term surface panels has increased steadily throughout the summer and early fall and decreased in late fall (NAI 1987b). In 1987, faunal richness increased rapidly to a peak in July (except Farfield Station 34, which peaked in June and September), then declined steeply throughout late fall. In 1987, the mean number of taxa reached the lowest point since sampling began in 1978, with only one taxon reported from Station 31 (farfield) in February (Figure 3.3.4-1). The mean number of taxa was the highest ever reported (19) in July at Station 19 (nearfield). For all baseline years combined, the mean number of taxa ranged between two (Station 4 in March) and 16 (Station 19 in July and Station 34 in September). Fauna appearing on the panels included bivalves, amphipods, polychaetes and colonials; all groups that have occurred previously on panels. Overall, in 1987 species richness in the offshore nearfield (Station 4) was slightly higher than at the farfield station (34). However, faunal richness at nearfield Station 19 (near the discharge) was lower than farfield station 31.

Over the baseline period, the greatest mean species abundance occurred in the summer and declined through the fall at all stations (NAI 1987b). Stations 4 (nearfield) and 34 (farfield) have followed similar

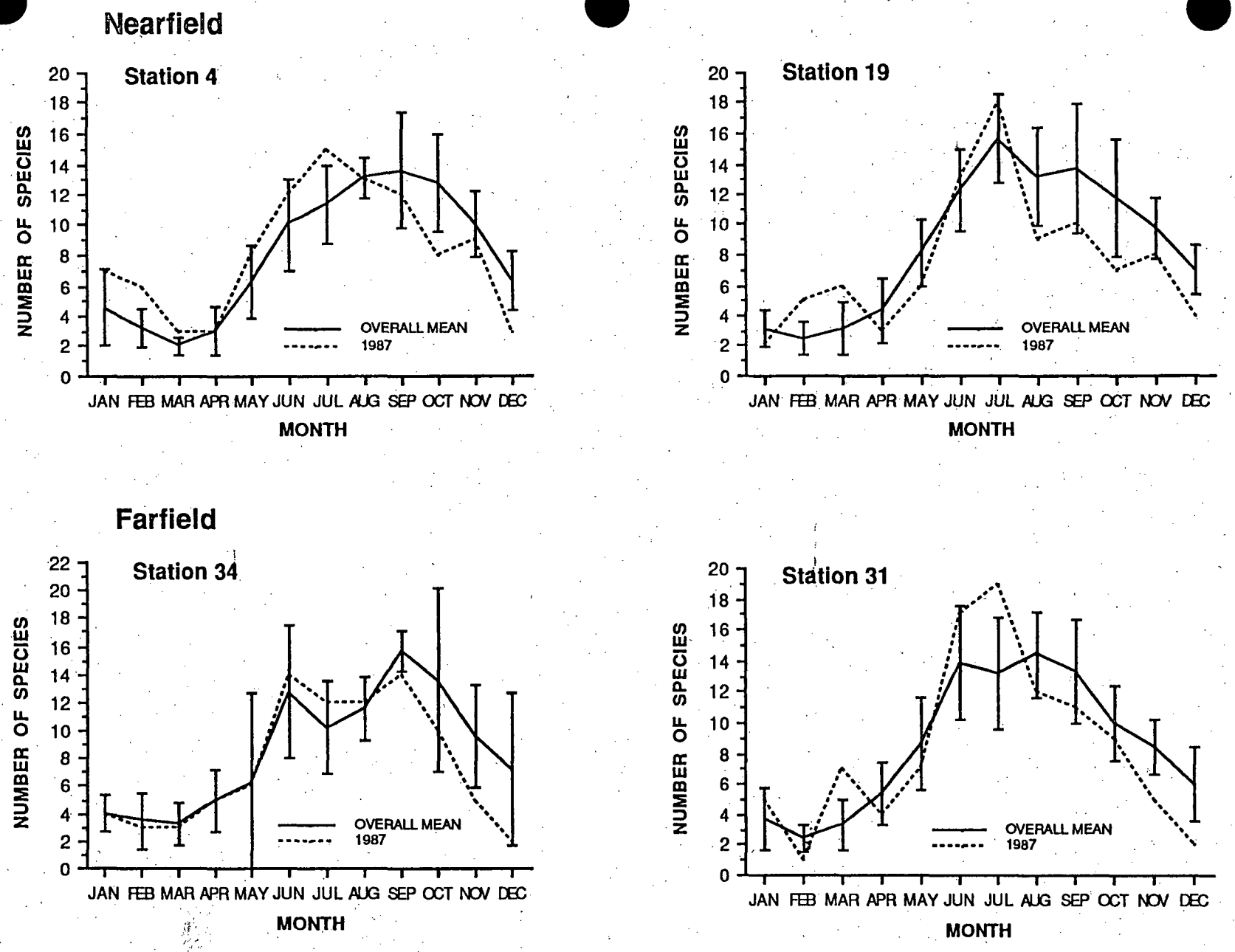


Figure 3.3.4-1. Faunal richness (number of different taxa over two replicates) in 1987 compared to mean species richness and ±95% confidence limits from 1978-1987 on short term panels. Seabrook Baseline Report, 1987.

temporal patterns; however, abundances at Station 34 were generally higher that at Station 4, especially in October and November. Species abundance patterns at Station 19 (nearfield) and Station 31 (farfield) have remained quite similar. The species abundance values for 1987 were comparable to past years, with a few notable exceptions (Figure 3.3.4-2). In July 1987, abundance values at all stations were higher than the mean of all years combined, as were abundance values in February (except Station 34). Compared to other years, mean species abundances were also higher in the winter and early spring at Station 19 and during the late summer and early fall at Station 34. These deviations from the historical mean are specifically a reflection of differences in Mytilidae, *Hiatella* sp., *Balanus* sp. and *Jassa falcata* abundances (NAI 1988, 1986, 1987a, 1985a, 1984a, 1983a).

The dry-weight biomass (g/panel) for short-term panels followed the pattern observed for the seasonal distribution of density and species richness. Historically, biomass values have been normally highest during August and September (1987b). Seasonal trends in 1987 were similar to baseline years, but in 1987 weights at all stations were exceptionally high in September in comparison to previous years (except for 1981)(Table 3.3.4-1). Stations 4 (nearfield) and 34 (farfield) also exhibited substantial biomass increases in August, unlike past years. Total biomass at Station 31 peaked in October, a value which represents a notable increase over the baseline period at this station. High biomass values in 1987 at these three stations were due to dense *Tubularia* sp. coverage and several large *Mytilus edulis* individuals (NAI 1988 and photographs in project file). Biomass values at Station 19 were similar to past years.

Several dominant taxa on panels were monitored to determine their long-term recruitment patterns at nearfield (19, 4) and farfield (31, 34) stations. A summary of notable differences for each species on the 1987 short-term panels compared to the baseline period is shown in Table 3.3.4-2.

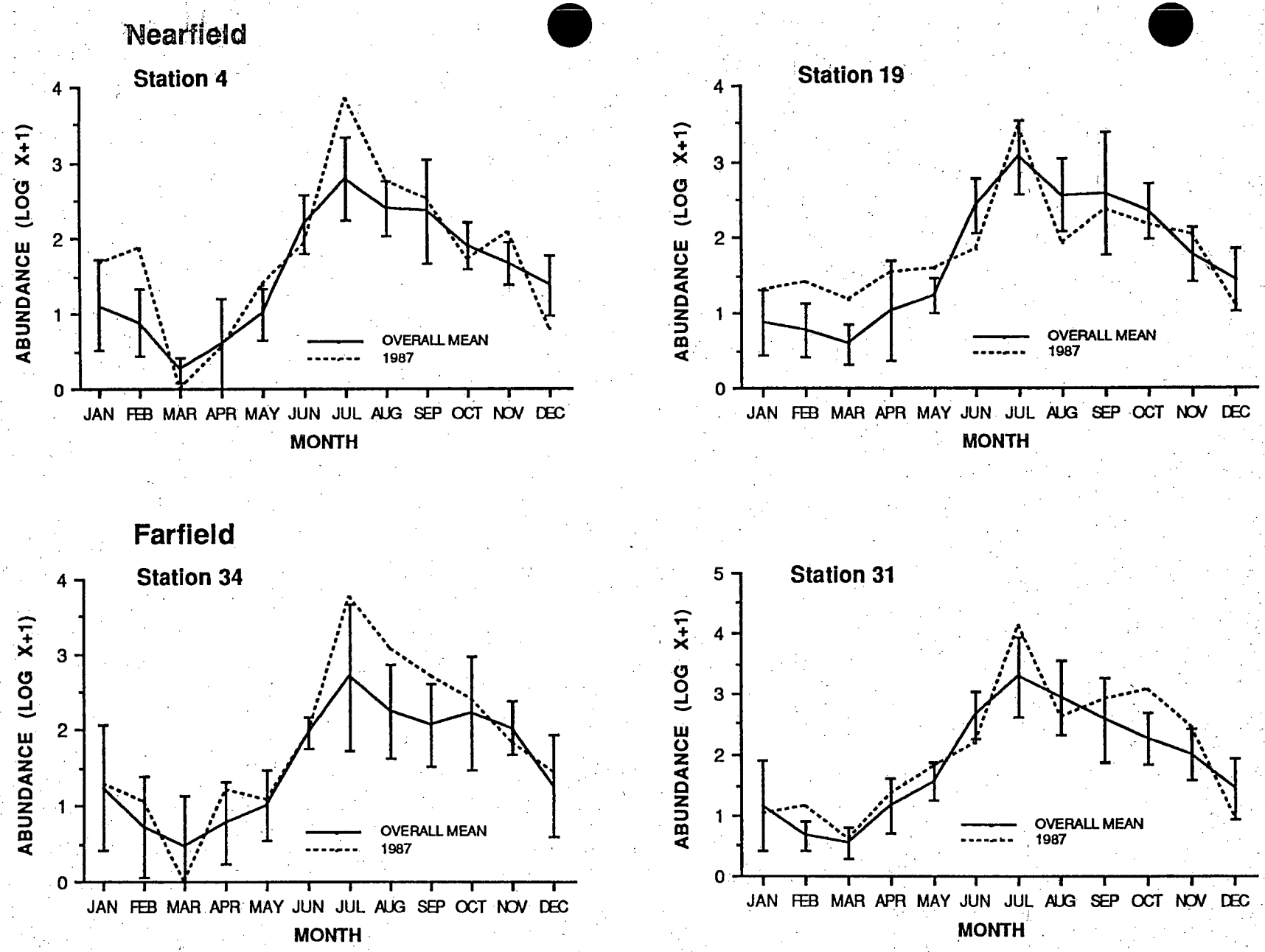


Figure 3.3.4-2. Species abundance (log x + 1) in 1987 compared to mean species abundance (log x + 1; ±95% confidence limits) from 1978-1987 for non-colonial fauna on short-term panels. Seabrook Baseline Report, 1987.

TABLE 3.3.4-1. DRY WEIGHT (g/PANEL) BIOMASS ON SHORT-TERM SURFACE FOULING PANELS BY YEAR, STATION AND MONTH. SEABROOK BASELINE REPORTS, 1987.

YEAR	STATION	J	F	M	A	M	J	J	A	S	O	N	D
1980	19	.4	<.1	<.1	.5	.4	.5	.8	.5	.9	.9	.5	.8
	31	.4	<.1	<.1	.7	.4	.4	.6	2.2	.6	.6	.6	.5
	4	.4	<.1	<.1	.6	.4	.6	.8	.7	1.1	.4	1.2	.4
1981[b]	19		.1	.2	.2	.2	.2	.4	3.2	9.0	.3	.2	.2
	31		.1	.2	.2	.2	.1	.6	10.9	5.0	.8	.3	.2
	4		.1	.1	.2	.2	.2	.4	.7	9.5	.6	.3	.5
1982[a]	19	<.1	.1	<.1	.2	.4	.1	1.8	1.9	1.9	2.1	.1	.1
	31	.1	.1	.1	.3	.1	.3	2.6	2.7	2.0	1.9	<.1	.1
	4	.1	.1	.1	.3	.1	.1	1.5	2.0	2.3	2.0	.1	.1
	34	.1	.2	.1	.2	.2	.2	1.7	1.6	1.9	2.3	.1	.1
1983	19	.1	.1	.1	.2	.2	.3	.3	.3	2.4	6.8	.1	.1
	31	.1	.1	.1	.1	.2	.1	.1	.1	.9	<.1	<.1	.1
	4	.1	.1	<.1	.1	<.1	.3	<.1	2.0	1.1	1.1	.3	.1
	34	.1	.1	.1	.1	.1	.3	.3	.4	2.8	6.3	.5	.3
1984	19	<.1	<.1	<.1	.1	.2	.1	<.1	.3	1.7	4.3	.8	.1
	31	.1	.1	<.1	<.1	.5	.1	.8	.1	1.4	.5	.8	.1
	4	<.1	<.1	<.1	<.1	.3	.3	.1	.5	.2	.2	1.1	.1
	34	<.1	<.1	<.1	<.1	.1	.1	<.1	.1	.5	.3	1.2	<.1
1986[b]	19							.5	.7	1.5	.2	.7	1.1
	31							.2	1.7	.8	.7	.2	.1
	4							.1	.3	1.0	.8	.2	.1
	34							.1	.9	1.1	1.7	4.9	<.1
1987	19	<.1	.1	<.1	<.1	.2	<.1	.2	.1	3.3	.6	.1	.1
	31	<.1	<.1	<.1	<.1	.3	<.1	.5	.1	2.1	4.2	.2	<.1
	4	<.1	.1	<.1	<.1	.1	.1	.9	3.3	6.8	.5	.1	<.1
	34	<.1	.1	<.1	<.1	.1	.5	.5	5.4	9.1	2.2	.3	.3

[a] Station 34 was first sampled in 1982.
[b] No fouling panels placed or collected in January 1981, or from January 1985 through June 1986.

TABLE 3.3.4-2. DIFFERENCES OBSERVED ON 1987 NEARFIELD SHORT-TERM PANELS COMPARED TO BASELINE PERIOD (1978-1986[a]) AND TO FARFIELD STATIONS. SEABROOK BASELINE REPORT, 1987.

SPECIES	TEMPORAL (NEARFIELD 4,19)	SPATIAL (NEARFIELD VS. FARFIELD 19 VS. 31 4 VS. 34)
Anomia sp.	Station 19 September abundance higher compared to baseline	Station 19 abundance higher in September vs. Station 31 Station 34 higher in September and October vs. Station 4
Asteridae	No Differences Observed	
Balanus sp.	Abundances at 4 and 19 higher in April, May and June (except in April 1980).	
Hiatella sp.	Station 4 higher abundance during June and July (except in 1981).	Station 4 abundance higher in July and and lower in August and September vs. Station 34
Jassa falcata		July through November abundance substantially higher at 31 vs. 19 July, September and October abundance higher at 34 vs. 4
Lacuna vincta	No differences observed	Station 19 lower than 31
Mytilidae	Station 19 higher abundance in February and March; lower in June and August Station 4 higher in January, February, July and November; lower in December	Station 19 abundance substantially lower than 31 July through December.

(continued)

TABLE 3.3.4-2. (Continued)

SPECIES	TEMPORAL (NEARFIELD 4,19)	SPATIAL (NEARFIELD VS. FARFIELD 19 VS. 31 4 VS. 34)
Nudibranchia		Abundance at 31 higher in July than at 19
Pontogeneia inermis	Density extremely low	
Strongylocentrotus drobachiensis	Density extremely low	
Diatoms	No differences observed	
Obelia spp.	No differences observed	July percent frequency higher at 31 vs. 19 and at 34 vs. 4
Tubularia sp.	Station 19 percent frequency higher in November Station 4 higher in July, October and November	High percent frequency extends into November at Station 4 vs. 34 and at Station 19 vs. 31

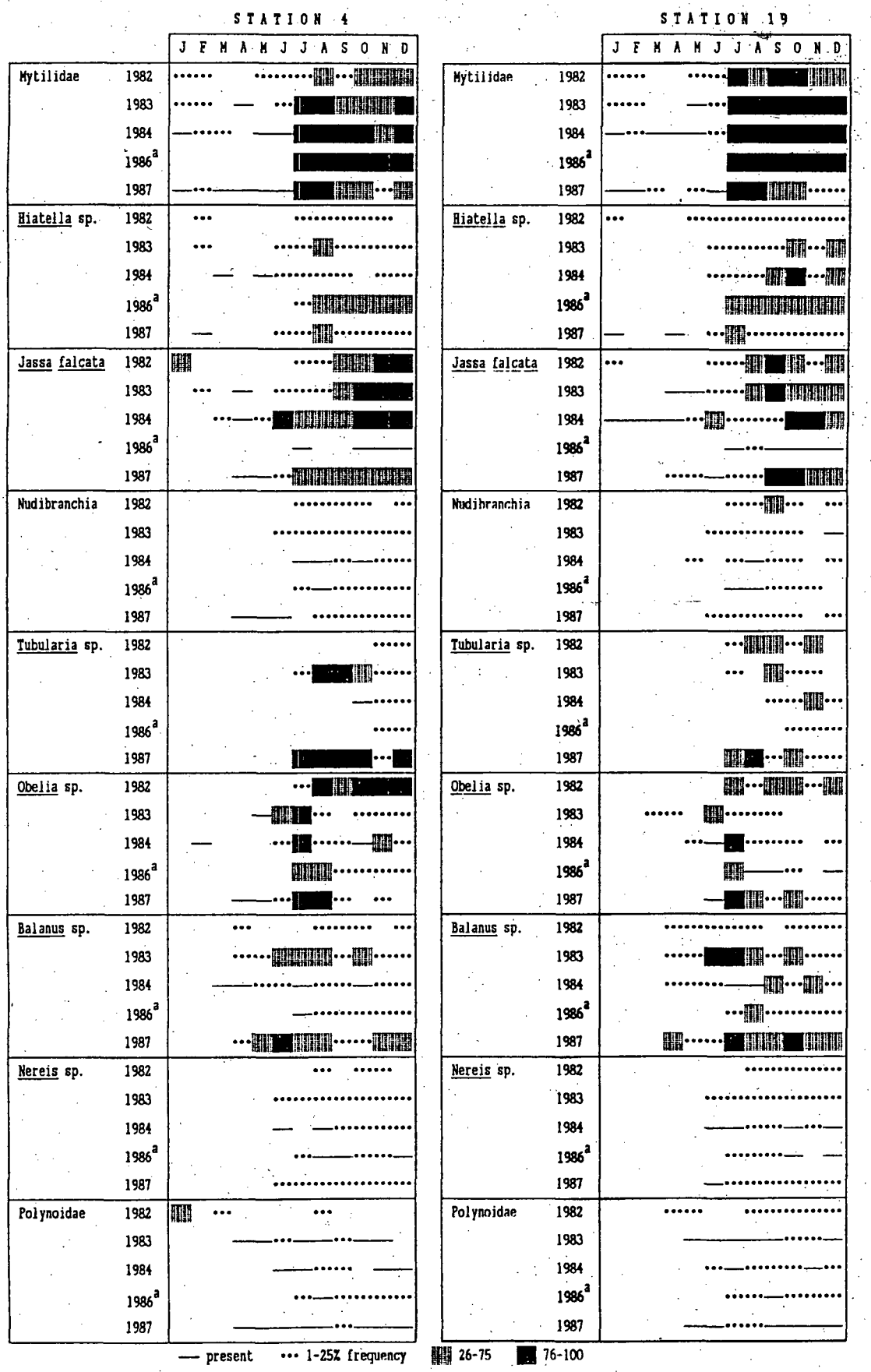
[a]except at Station 34 which was 1982-1986 and from January 1985 through July 1986, when no panels were placed or collected.

Monthly mean abundances for these short-term panels species are shown for all years sampled in Appendix Tables 3.3.4-1 and 3.3.4-2. The panels' selected species, Mytilidae, and *Jassa falcata* are discussed in Section 3.3-5.

3.3.4.2 Patterns of Community Development

Monthly sequential panels measure growth and successional patterns of community development. Historically, settlement activity has been most intense in the summer months and has continued into fall (NAI 1987b). In 1987, the pattern of community development on monthly sequential panels was similar to that of previous years. A comparison of the settlement sequence and survival of species on nearfield (Stations 4 and 19) monthly panels is shown in Figure 3.3.4-3. Similar to previous years, settlement density in 1987 was high in summer months, especially for Mytilidae, *Obelia* spp. and *Balanus* sp., and persisted throughout the fall. Densities and settlement patterns of *Jassa falcata* and *Hiatella* in 1987 reflect closely recent years in which panels were exposed for up to a full year (1982-1984). The hydroid *Tubularia* sp. settled earlier and more densely at Station 4 in 1987 than compared to previous years; similarly, settlement at Station 19 was slightly more dense. *Balanus* sp. was a regular colonizer April through December in 1987 and exhibited higher frequencies at both Stations 4 and 19 in comparison to previous years. Nudibranchia were present earlier at Station 4 in 1987 than in the past, but summer and fall patterns of settlement and density were similar to previous years, as were those of Polynoidae and *Nereis* sp.

The patterns of community growth and development are generally reflected in the biomass data from the monthly sequential panels (Table 3.3.4-3). Over the baseline period, a pattern of increased biomass dry-weights has normally occurred from summer into the fall months (NAI 1987b). However, a sharp decline in biomass dry-weights in 1987 occurred at Station 19 (nearfield) and Station 31 (farfield) in September followed by increases in subsequent months. Stations 4 (nearfield) and 31 (farfield) also showed decreases in December. Consequently, overall biomass weights in



[a]No fouling panels placed or collected from January 1985 through June 1986.

Figure 3.3.4-3. Annual settlement periods, abundance and survival of major taxa based on examination of sequentially-exposed panels at nearfield Stations 4 and 19. Seabrook Baseline Report, 1987.

TABLE 3.3.4-3. DRY WEIGHT (g/panel) BIOMASS ON MONTHLY SEQUENTIAL SURFACE FOULING PANELS BY YEAR, STATION AND MONTH. SEABROOK BASELINE REPORT, 1987.

YEAR	STATION	J	F	M	A	M	J	J	A	S	O	N	D
1978[a]	19												758.8
	31												735.7
	4												804.8
1979[b]	19		.1	.4	.5	2.0	7.0	52.4	77.5	82.5	94.2	129.9	213.3
	31		.2	.6	.6	1.5	8.8	46.4	92.0	205.9	974.9	589.1	443.1
	4		.1	.4	1.2	2.2	14.5	34.0	70.1	310.5	689.7	392.3	226.4
1980	19	<.1	.7	.7	1.8	19.1	130.0	257.2	184.5	221.5	105.9	155.5	241.9
	31	<.1	.8	1.9	2.6	6.5	19.5	47.6	55.4	514.9	414.1	382.2	347.9
	4	<.1	.7	.8	1.3	4.2	86.1	266.0	151.7	173.3	213.9	52.2	115.5
1981[c]	19		.1	.2	.3	1.1	.6	17.8	24.1	32.3	32.1	38.0	33.7
	31		.2	.1	.4	2.1	3.8	20.4	32.3	36.7	113.3	28.6	207.8
	4		.1	.2	.4	2.7	3.0	13.7	5.2	5.8	56.2	40.1	70.6
1982[d]	19	.1	.4	2.6	9.5	1.8	3.5	9.8	20.8	93.4	90.1	141.6	133.3
	31	.1	.8	1.9	2.6	2.9	7.1	20.3	33.8	431.3	193.0	274.6	349.6
	4	.2	.2	1.6	1.8	5.8	9.1	8.5	40.5	51.5	86.1	73.7	108.6
	34	.1	.4	1.1	2.0	.9	6.6	13.4	31.2	39.4	75.9	61.3	115.1
1983[e]	19	<.1	.1	.6	.5	.7	18.7	40.5	44.4	87.2	327.1	454.2	714.9
	31	.1	<.1	.6	.7	2.0	11.0	17.8	52.0	131.6	221.0	160.4	397.6
	4	<.1	.1	.5	.6	1.1	6.9	7.7	27.6	34.7	28.0	9.6	665.7
	34	<.1	.1	.7	.8	.8	5.7	10.9	34.5	141.4	106.9	513.8	821.5

TABLE 3.3.4-3. (Continued)

YEAR	STATION	J	F	M	A	M	J	J	A	S	O	N	D
1984[e]	19	<.1	.1	.5	.6	3.1	8.6	17.9	53.0	213.6	666.9	774.9	1117.6
	31	.1	.2	1.2	1.9	2.2	20.3	56.6	116.4	199.6	364.0	929.6	773.6
	4	<.1	.1	.7	1.2	1.4	2.7	4.8	52.5	232.4	363.6	583.4	1035.5
	34	<.1	.2	.8	1.2	1.1	9.7	15.4	57.5	262.0	349.0	706.2	1266.1
1986[c,e]	19							33.3	164.3	422.9	931.1	494.7	698.1
	31							22.1	179.3	449.3	857.7	716.8	883.3
	4							20.8	157.1	357.0	899.0	481.3	1071.3
	34							29.7	123.9	502.3	873.2	576.9	952.6
1987[e]	19	<.1	.7	1.8	.4	1.8	28.4	131.6	220.0	54.1	90.7	129.7	170.8
	31	.1	.2	1.1	1.3	3.3	17.6	88.8	100.1	40.3	73.1	165.3	93.1
	4	<.1	1.5	2.1	1.5	1.7	21.9	62.9	49.3	60.3	75.5	114.0	85.2
	34	<.1	.6	1.5	1.5	2.1	13.8	62.8	95.2	129.5	172.9	170.1	167.5

[a] In 1978, biomass measured only from December monthly sequential panels.
[b] Data not available for January 1979.
[c] Panels were not sampled in January 1981; or from January 1985 through June 1986.
[d] Station 34 was first sampled in 1982.
[e] December weights in 1983 through 1987 represent means calculated from two repolicate panels (10 x 10 cm).

1987 were substantially lower than recent baseline years (1983-1986). Temporal patterns at paired stations, (19 vs. 31 and 4 vs. 34) were similar in 1987, but over all biomass values were depressed September through December, in comparison to 1983-1986 (NAI 1988 and photographs in project file).

Laminaria spp. sporelings (mostly *L. saccharina*, but occasionally *L. digitata*) settlement on MS panels has been highly variable from year to year, but generally, more *Laminaria* spp. fronds have been present in July, August and September than later in the year (NAI 1987b). Settlement was dense in 1987, especially at Station 19 and Stations 31 and 34 (Table 3.3.4-4). Settlement at Station 4 was slightly higher compared to recent years. The highest mean density compared to past years occurred at Station 19 in 1987; a value similar to that of Station 31 at which densities have historically far exceeded any other station. Station 34 exhibited notably higher abundances throughout 1987 than those recorded at Station 4.

TABLE 3.3.4-4. LAMINARIA SP.[a] COUNTS ON MONTHLY SEQUENTIAL SURFACE FOULING PANELS BY AREA, STATION, YEAR AND MONTH. SEABROOK BASELINE REPORT, 1987.

AREA	STATION	YEAR[b]	APR[c]	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	S.D.
NEARFIELD	19	1980	0	0	10	19	10	18	14	23	31	13.9	10.22
		1981	4	13	0	2	0	0	0	0	0	2.1	4.31
		1982	53	54	32	116	67	64	48	65	51	61.1	23.21
		1983	0	10	8	3	34	25	38	21	16	17.2	13.35
		1984	9	1	34	10	22	6	4	1	6	10.3	10.90
		1986				8	3	1	3	4	0	3.2	2.79
		1987	0	22	69	102	27	176	85	63	97	71.2	52.80
FARFIELD	31	1980	0	0	--[d]	22	39	12	79	75	39	33.3	30.92
		1981	4	0	6	19	0	1	0	5	5	4.4	5.98
		1982	108	98	72	92	104	95	122	103	64	95.3	17.85
		1983	0	97	126	143	136	175	113	126	78	110.4	49.75
		1984	2	16	23	22	49	19	26	21	13	21.2	12.59
		1986				16	2	9	3	4	11	7.5	5.47
		1987	0	31	73	125	161	41	154	109	48	82.4	57.28
NEARFIELD	4	1980	0	0	18	15	4	4	5	18	29	10.3	10.06
		1981	3	1	0	0	0	0	0	0	0	.4	1.01
		1982	48	128	112	76	125	97	69	83	92	92.2	26.48
		1983	0	0	0	11	1	1	2	0	0	1.7	3.57
		1984	2	1	2	0	0	0	0	0	0	.6	.88
		1986				7	0	1	0	0	0	1.3	2.80
		1987	0	2	6	0	24	1	2	6	1	4.7	7.60
FARFIELD	34	1982	27	51	46	69	65	50	53	47	65	52.6	12.83
		1983	0	8	11	27	11	1	0	6	0	7.1	8.78
		1984	3	3	0	5	2	4	0	0	0	1.9	1.96
		1986				1	5	0	0	0	1	1.2	1.94
		1987	0	9	13	15	54	35	31	23	43	24.6	17.66

[a] Fronds counted were L. saccharina and occasionally L. digitata.
[b] No panels collected from January 1985 through June 1986.
[c] No Laminaria sp. >3 cm (minimum length for counting) present before April.
[d] Data missing for Station 31 June 1980.

3.3.5 Selected Benthic Species

Seven macrofaunal taxa from the area of the discharge (nearfield) and from a control area off Rye Ledge (farfield) (Figure 4.1-3) were selected for intensive monitoring. Three nearfield/farfield stations pairs were sampled: intertidal Stations 1MLW and 5MLW, 5-m Stations 17 and 35, and 9 to 12-m Stations 19 and 31. Selection of taxa was based on abundance, and/or trophic level (Table 2.3-1).

3.3.5.1 Mytilidae

Mytilidae, composed primarily of juvenile *Mytilus edulis*, was the most abundant taxon at all three nearfield/farfield station pairs. *Mytilus edulis* reaches 100 mm in length (Gosner 1978), and is an important prey species for fish, sea stars, lobster, and gastropods. It clings to hard substrate with strong byssal threads, and is an important fouling organism. The geometric mean density for the entire 1978-1987 study period was highest intertidally, and generally decreased with increasing depth (Table 3.3.5-1), a trend also reported in NAI (1985b). The highest density (geometric mean over all years) was 112,927/m^2 at intertidal Station 1MLW and the lowest was 1,553/m^2 at Station 19, which has a depth of about 12 m.

Each station in the three nearfield/farfield station pairs was tested separately for annual differences. Significant differences in annual abundance occurred among years for five of the six stations when tested with a one-way ANOVA (Table 3.3.5-2). The year 1985 had the highest abundance at both 9 to 12-m stations (Stations 19 and 31), but 1985 had nearly the lowest abundance at the 5-m stations (Stations 17 and 35) and for intertidal station 1MLW using the Waller-Duncan comparison test (Table 3.3.5-2). At the 5-m subtidal stations the abundance was at the all time high in 1979 at Station 17, and was also very high in 1984 and 1987 at both 5-m stations. At intertidal Station 1 MLW, the highest abundance occurred in 1982.

TABLE 3.3.5-1. ANNUAL GEOMETRIC MEAN[a] OF THE ABUNDANCE (No./m²) OF SELECTED BENTHIC SPECIES SAMPLED TRIANNUALLY IN MAY, AUGUST, AND NOVEMBER FROM 1978 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

TAXA	STA	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	OVERALL YEARS MEAN	UPPER	LOWER
Ampithoe rubricata	1MLW	518	545	448	343	133	23	9	3	<1	0	38	71	20
	5MLW	-[b]	-	-	-	88	15	<1	0	0	0	3	6	1
Asteriidae	17	-	-	-	1738	669	208	392	592	373	448	514	651	405
	35	-	-	-	-	630	39	167	198	79	245	158	244	103
Jassa falcata	17	1007	884	679	3389	3198	398	660	1622	2166	1513	1248	1699	917
	35	-	-	-	-	5307	4980	2031	1465	1387	809	2110	3310	1345
Mytilidae	1MLW	161,759	116,973	70,760	130,890	253,375	60,978	78,849	63,307	196,498	126,996	112,927	139,905	91,151
	5MLW	-	-	-	-	42,213	60,552	73,895	57,505	120,455	127,304	74,176	96,240	57,170
	17	1875	8789	1269	2257	3490	963	7980	566	4744	5171	2658	3860	1830
	35	-	-	-	-	1566	7328	13,416	1055	5294	7981	4359	6764	2809
	19	85	307	905	2069	1776	1247	6493	6651	4943	3521	1553	2371	1018
	31	1437	3338	13,422	13,650	1688	1095	17,842	81,457	3,995	8000	6135	8815	4270
Nucella lapillus	1MLW	1355	2987	3973	1981	944	1586	5176	3250	2559	1037	2152	2610	1775
	5MLW	-	-	-	-	649	783	909	1378	691	1326	914	1188	703
Pontogeneia inermis	19	902	538	599	584	762	562	386	604	908	308	585	745	460
	31	196	400	390	650	554	470	512	280	773	105	379	505	284
Strongylocentrotus droebachiensis	19	20	70	152	281	80	15	29	188	135	99	75	117	48
	31	28	60	73	142	72	55	33	35	23	17	45	62	32

[a] n = 9 (3 replicates taken 3 times per year)

[b] - = not sampled

TABLE 3.3.5-2. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE AMONG YEARS[a] FOR THE LOG (x+1) TRANSFORMED DENSITY (No./m^2) OF SELECTED BENTHIC SPECIES SAMPLED FROM 1978 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

SPECIES	STA-TION	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS[b]
Ampithoe rubricata	1MLW	Years	9	97.85	18.35***c	79 78 80 81 82 83 84 85 86 87
		Error	80	47.39		
		Total	89	145.23		
	5MLW	Years	5	31.25	15.54***	82 83 84 85 86 87
		Error	48	19.30		
		Total	53	50.56		
Nucella lapillus	1MLW	Years	9	5.05	4.90***	84 80 85 79 86 81 83 78 87 82
		Error	80	9.17		
		Total	89	14.23		
	5MLW	Years	5	0.89	1.03 NS	
		Error	48	8.30		
		Total	53	9.19		
Jassa falcata	17	Years	9	7.69	2.38*	81 82 86 85 87 78 79 80 84 83
		Error	80	28.69		
		Total	89	36.38		
	35	Years	5	4.78	2.05 NS	
		Error	48	22.41		
		Total	53	27.19		
Asteriidae	17	Years	6	4.37	6.87***	81 82 85 87 84 86 83
		Error	56	5.94		
		Total	62	10.31		
	35	Years	5	7.72	4.38**	82 87 85 84 86 83
		Error	48	16.93		
		Total	53	24.65		
Pontogeneia inermis	19	Year	9	6.78	1.67 NS	
		Error	80	36.03		
		Total	89	42.82		
	31	Year	9	5.48	1.87 NS	
		Error	80	26.06		
		Total	89	31.54		

(continued)

TABLE 3.3.5-2. (Continued)

SPECIES	STA-TION	SOURCE OF VARIATION	df	SS	F	MULTIPLE COMPARISONS									
Strongylocentrotus droebachiensis	19	Year	9	14.92	1.97 NS										
		Error	80	67.26											
		Total	89	82.18											
	31	Year	9	6.04	1.51 NS										
		Error	80	35.54											
		Total	89	41.58											
Mytilidae	1MLW	Year	9	3.71	2.38*	82	86	78	81	87	79	84	80	85	83
		Error	80	13.85											
		Total	89	17.56											
	5MLW	Year	5	1.61	2.07 NS										
		Error	48	7.49											
		Total	53	9.10											
	17	Year	9	12.91	2.85**	79	84	87	86	82	81	78	80	83	85
		Error	80	40.31											
		Total	89	53.21											
	35	Year	5	8.48	4.67**	84	87	83	86	82	85				
		Error	48	17.42											
		Total	53	25.90											
	19	Year	9	27.62	3.36**	85	84	87	81	82	83	86	80	79	78
		Error	80	72.67											
		Total	89	100.29											
	31	Year	9	27.91	11.10***	85	84	81	80	87	86	79	82	78	83
		Error	80	22.34											
		Total	89	50.25											

[a]For each year n=9 (3 sampling periods X 3 replicates)
[b]Waller-Duncan multiple comparison test
[c] NS = not significant ($p > 0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

The Mytilidae collected usually ranged from less than 1 mm to 30 mm in length, and many of the smallest mytilids had settled on macroalgae rather than on the bottom or hard substrate, a pattern also observed by other investigators (Bayne 1965; Suchanek 1978). Information from surface fouling panels suggests that primary or secondary settlement takes place throughout the year, but is heaviest from June through October (NAI 1985b). The overall mean length of intertidal mytilids (3.2 mm) was slightly larger than subtidal mytilids, (2.4 mm) (Table 3.3.5-3), even though intertidal population densities were much higher than subtidal densities. Mytilid lengths showed no significant differences between nearfield and farfield station pairs when tested with a two-way ANOVA (NAI 1987b: Table 3.3.5-4). Yearly differences in mean length for each of the nearfield/farfield station pairs were not significant (NAI 1987b: Table 3.3.5-4). In 1987, the lengths at the intertidal station pair were about average even though the density had increased; at subtidal station pairs the mean lengths in 1987 were below average, and densities decreased at three of the four stations (Tables 3.3.5-1, 3), indicating below average growth and recruitment.

The level of mytilid recruitment is indicated by the abundance on short term fouling panels set 3 m below the surface at Stations 19 and 31 and exposed for one month intervals from 1978 through 1987. Recruitment was the highest ever at Station 31 in 1979, with a yearly average of 4687 spat per panel, and again in 1981 with 4082 spat per panel (Appendix Table 3.3.4-1). During the next two years, 1982 and 1983, recruitment was the lowest with just under 60 individuals per panel. Abundance in 1987 was below average at Station 19, but at Station 31, the 1987 abundance was the highest in six years, with 1187 spat per panel. Over 90% of the mytilids collected from panels at Stations 19 and 31 in 1987 were 3 mm or less in length (NAI 1988: Appendix Table 9-8). Mytilid lengths at Stations 19 and 31 ranged from <1 mm to 20 mm in 1987 (NAI 1988: Appendix Table 9-7), about the same as previous years.

TABLE 3.3.5-3. ANNUAL MEAN LENGTH (mm) AND THE 95% CONFIDENCE INTERVAL (CI) FOR SELECTED BENTHIC SPECIES SAMPLED TRIANNUALLY IN MAY, AUGUST, AND NOVEMBER AT SELECTED STATIONS FROM 1982 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

TAXA	STATION	OVERALL MEAN[a]	OVERALL CI	1982 MEAN	1982 CI	1983 MEAN	1983 CI	1984 MEAN	1984 CI	1985 MEAN	1985 CI	1986 MEAN	1986 CI	1987 MEAN	1987 CI
Ampithoe rubricata	1MLW	7.0	0.3	6.7	0.3	7.7	0.6	6.9	1.5	10.9	4.1	-[b]	-	-	-
	5MLW	7.8	0.4	7.6	0.5	8.5	0.8	8.9	-	-	-	-	-	-	-
Asteriidae	17	5.5	0.2	4.0	0.3	5.4	0.7	7.8	0.8	7.5	0.4	7.3	0.6	3.1	0.3
	35	6.5	0.4	5.3	0.5	11.4	3.4	5.7	0.9	10.1	1.0	13.1	2.6	4.6	0.6
Jassa falcata	17	4.1	0.1	3.3	0.2	4.3	0.2	4.4	0.2	4.5	0.2	4.4	0.2	3.8	0.2
	35	3.8	0.1	3.5	0.2	3.7	0.2	3.7	0.1	4.5	0.2	4.1	0.2	3.5	0.1
Mytilidae	1MLW	3.1	0.1	2.7	0.1	4.5	0.2	2.7	0.1	2.6	0.2	2.8	0.1	3.1	0.2
	5MLW	3.2	0.1	2.8	0.1	3.2	0.2	2.9	0.1	3.0	0.1	4.0	0.2	3.1	0.1
Mytilidae	17	2.3	0.0	1.9	0.1	2.1	0.1	2.8	0.1	2.4	0.2	2.5	0.1	1.9	0.1
	35	2.4	0.1	1.8	0.1	2.1	0.1	3.1	0.2	2.4	0.1	2.7	0.2	2.3	0.1
Mytilidae	19	2.1	0.0	2.0	0.1	2.3	0.1	2.1	0.1	2.4	0.2	2.3	0.1	1.8	0.1
	31	2.7	0.1	2.2	0.2	1.9	0.1	2.1	0.1	3.5	0.1	4.1	0.3	2.0	0.1
Nucella lapillus	1MLW	6.1	0.2	8.0	0.3	3.3	0.2	4.0	0.2	5.0	0.3	7.7	0.5	11.9	0.6
	5MLW	5.9	0.2	5.7	0.5	6.2	0.6	6.9	0.6	6.3	0.5	6.2	0.5	4.3	0.4
Pontogeneia inermis	19	4.9	0.1	4.4	0.3	5.2	0.3	4.9	0.2	5.3	0.3	4.7	0.3	4.7	0.3
	31	5.1	0.1	4.6	0.2	5.2	0.3	4.6	0.2	5.8	0.3	5.2	0.2	5.6	0.4
Strongylocentrotus droebachiensis	19	1.9	0.1	1.8	0.3	1.8	0.5	1.7	0.3	2.7	0.4	1.5	0.3	1.7	0.2
	31	1.9	0.1	1.7	0.2	2.3	0.3	1.7	0.2	2.5	0.6	1.5	0.2	1.7	0.3

[a] $\text{MEAN} = \frac{\text{sum of the lengths of all individuals measured in May, August, and November}}{\text{total number of individuals measured in that year}}$

[b] - = none collected

3.3.5.2 *Nucella lapillus*

Nucella lapillus reaches 51 mm in length (Abbott 1974), and is an abundant intertidal gastropod and an important predator, particularly on mytilid spat. Significant differences in abundance between stations were found between intertidal Stations 1MLW and 5MLW from 1982 through 1986 (NAI 1987b: Table 3.3.5-2). The overall abundance at Station 1MLW was more than double the overall abundance at Station 5MLW (Table 3.3.5-1). Very highly significant differences among the years 1978 through 1987 were found for Station 1MLW with 1984 having the highest abundance and 1987 and 1982 having the lowest abundances (Table 3.3.5-2). Farfield Station 5MLW was sampled from 1982-1987, and no significant differences were found among years (Table 3.3.5-2).

Large numbers of small *Nucella* occurred in August or September, indicating recruitment occurred at that time (NAI 1985b). Larger individuals (10-25 mm) were collected in most months, but disappeared from November 1983 through June 1984. Previous studies have shown adult snails to be active only from May through October, retreating into crevices in the winter; while juveniles (2-5 mm) are more evenly dispersed throughout the year (Menge 1978). The overall mean length for the 1982 through 1987 study period was 6.1 mm ± 0.2 at Station 1MLW, and 5.9 mm ± 0.2 at the farfield control (Table 3.3.5-3). The average yearly length ranged from 3.3 mm at Station 1MLW in 1983 to an unusually large 11.9 mm at Station 1MLW in 1987. No significant differences in the yearly mean length were found between stations or among years (NAI 1987b: Table 3.3.5-4).

3.3.5.3 Asteriidae

The Asteriidae collected are juveniles, too young to be assigned to genera. Two species of both *Asterias* and *Leptasterias* can occur within the study area (Gosner 1978). Asteriidae are important predators on bivalves, particularly on the recently-settled stages, as well as other molluscs and barnacles (Gosner 1978).

Significant differences in annual abundances were found among years and between stations at subtidal Stations 17 and 35, sampled from 1982 through 1986 (NAI 1987b: Table 3.3.5-2). Station 17 had higher geometric mean densities during all years and the overall average density was over three times higher than at Station 35 (Table 3.3.5-1). Highly significant differences were found among years at both Station 17 and 35 when tested with one-way ANOVA (Table 3.3.5-2). The yearly trend was very similar at both stations: highest abundances occurred in 1982, 1985 and 1987 and lowest abundances occurred in 1983, 1984 and 1986 at both stations (Tables 3.3.5-1 and 2).

A successful set of juvenile Asteriidae occurred in August of 1982 (NAI 1983a), and very little recruitment occurred in 1983 or 1984. In 1985 and 1987 annual densities were relatively high, indicating successful recruitment. Spatial and temporal changes in abundance and length seem to be related to the recruitment success of each year's cohort (NAI 1985b). The overall average length at Station 17 was 5.5 mm ± 0.2, and at Station 35 it was 6.5 mm ± 0.4 (Table 3.3.5-3). Yearly mean length of sea stars collected at Station 35 was usually greater than Station 17, and the two stations were significantly different according to the results of a two-way ANOVA (NAI 1987b: Table 3.3.5-4). Likewise, the mean seasonal length from 1982 through 1987 as compared with a paired t test, showed interstation differences were highly significant (N = 18 pairs, t = -4.08, probability of a greater t = 0.008), with larger sea stars occurring at Station 35. The average yearly length ranged from 3.1 mm in 1987 to 7.8 mm in 1984 at Station 17, and from 4.6 mm in 1987 to 13.1 mm in 1986 at Station 35 (Table 3.3.5-3).

A few recently-settled Asteriidae were collected on short term surface fouling panels from 1978 through 1987, and only occurred from July through September. All years except 1980 and 1981 had very low densities averaging less than one per panel per year (Appendix Table 3.3.4-1).

3.3.5.4 *Pontogeneia inermis*

Pontogeneia inermis (maximum length, 11 mm) is a pelagic, cold water amphipod (Bousfield 1973), and a dominant species in benthic and macrozooplankton collections (NAI 1985b). It clings to submerged plants and algae from the lower intertidal to depths greater than 10 m (Bousfield 1973). Population densities were remarkably consistent from 1978-1986, and no significant differences were found among years with two-way ANOVAs (NAI 1987b: Table 3.3.5-2). Likewise, when a one-way ANOVA was used to test for differences among years, including 1987 data, no significant difference was found for either station (Table 3.3.5-2). However, interstation differences were significant, and the overall geometric mean abundance from 1978-1987 was 1.5 times higher at Station 19 than at Station 31 (Table 3.3.5-1).

Ovigerous and brooding females were collected in low numbers from January through September (NAI 1985b). Recruitment, as indicated by a sharp increase in density and increased numbers in the 1 to 3-mm size class, took place between May and July. In fall and winter, abundance decreased, but average size increased as the population grew (NAI 1985b). The overall mean length for the 1982-1987 study period was 4.9 mm (95% confidence interval = ± 0.1) at Station 19 and 5.1 mm ± 0.1 at Station 31 (Table 3.3.5-3). No significant difference in mean lengths was found between stations (NAI 1987b: Table 3.3.5-4). The average yearly length ranged from 4.4 mm at Station 19 in 1982 to 5.8 mm at Station 31 in 1985, with no significant difference among years (NAI 1987b: Tables 3.3.5-3 and 4). The 1987 data did not change the range of the annual mean lengths (Table 3.3.5-3).

Pontogeneia inermis was common on short term fouling panels, at Stations 19 and 31 from 1979 through 1983, but numbers decreased sharply in 1984, 1986 and 1987 (no samples in 1985). Peak abundance usually occurred from April through June, and annual mean abundances were highest in 1981 (Appendix Table 3.3.4-1). By 1987 the average yearly abundance had declined to zero.

3.3.5.5 *Jassa falcata*

Jassa falcata (maximum length 9 mm) is a tube-building amphipod, and a dominant fouling organism on hard substrates in areas with strong tidal and wave currents (Bousfield 1973). It is a suspension feeder and also preys on small crustaceans. Very highly significant differences in yearly abundance (1978-1987) were found for subtidal Station 17, but not for Station 35. At Station 17 yearly abundance was low from 1978-1980, peaked in 1981 and 1982, and declined to all time lows in 1983 and 1984. From 1985-1987 populations were rebuilding, and yearly abundance was above average. Station 35 had a higher population density of *Jassa* than Station 17 during all years except 1985-1987. The mean geometric density at Station 35 for the 1982 through 1986 study period was $2110/m^2$ and fluctuated between $809/m^2$ in 1987 and $5307/m^2$ in 1982 (Table 3.3.5-1).

Most lifestages of *Jassa* were collected at Station 17 and 35, ranging from gravid females to newly-hatched young (NAI 1985b). Gravid females were most abundant from April to November, and newly-recruited juveniles measuring 1-2 mm were most abundant in July, and were collected during the remainder of the year (NAI 1985b). The overall average length for the 1982-1987 study period was 4.1 mm at Station 17 and 3.8 mm at Station 35; interstation differences were not significant (NAI 1987b: Tables 3.3.5-3,4. Average yearly lengths ranged from 3.3 mm in 1982 at Station 17 to 4.5 mm in 1985 at Stations 17 and 35 (Table 3.3.5-3).

Densities on short term fouling panels, exposed for one-month intervals, from 1978 through 1987 give an indication of recruitment or settlement activity. From 1978-1987, substantial numbers of young began appearing in July and continued to settle through October (NAI 1985b). Record high monthly densities occurred at Station 31 in 1987 from July through October, peaking in September with 541 individuals per panel (Appendix Table 3.3.4-1). Mytilid spat densities were also high on short term panels at Station 31 in 1987 (Appendix Table 3.3.4-1).

3.3.5.6 *Ampithoe rubricata*

Ampithoe rubricata (maximum length, 14-20 mm) is an amphi-Atlantic boreal amphipod which constructs a nest among macroalgae (fucoids) and in mussel beds (Bousfield 1973). Average yearly densities have dropped steadily and significantly during the study period (NAI 1987b: Tables 3.3.5-1, 2), and populations at both Stations 1MLW and 5MLW had virtually disappeared by 1986. Significant differences were found between stations, with Station 1MLW having much higher densities than the farfield Station 5MLW (NAI 1987b: Table 3.3.5-2). During the extended study period between 1978 and 1987, the geometric mean yearly density declined significantly, ranging from $545/m^2$ in 1978 to $0/m^2$ in 1987 (Table 3.3.5-1). *Ampithoe rubricata* is a boreal species near its southern zoogeographic limit, Long Island Sound (Bousfield 1973), and it may have been affected by increasing annual temperatures from 1980 through 1986 (Table 3.1.1-1).

Ovigerous and brooding females were rare, but were occasionally collected from April through September (NAI 1985b). The largest numbers of small (1-3 mm) individuals were collected from April through September, suggesting recruitment occurred during this time period. In 1983 and 1984, recruitment appeared depressed, accounting for both lower overall densities and larger mean size (NAI 1985b), and the trend continued through 1987. The overall mean length for the 1982 through 1987 study period was 7.0 mm at Station 1MLW, and 7.8 mm at Station 5MLW (Table 3.3.5-3), and no significant difference in the average yearly length was found between stations (NAI 1987b: Table 3.3.5-4). The average yearly length ranged from 6.7 mm at Station 1MLW in 1982, when young were present, to 10.9 mm at Station 1MLW in 1986, when only a few large specimens were collected (Table 3.3.5-3). When mean seasonal lengths were compared with a paired t test, interstation differences were not significant ($n=6$ pairs, $t=0.21$, probability of a greater $t=0.843$).

3.3.5.7 *Strongylocentrotus droebachiensis*

Strongylocentrotus droebachiensis, the green sea urchin, reaches 75 mm in diameter, and is an important prey species for lobster, cod and other fish, and sea stars (Gosner 1978). It is an omnivore, but prefers *Laminaria saccharina* over other common algal species (Larson *et al.* 1980; Mann *et al.* 1984). When the macroalgal supply is depleted, it will prey on *Mytilus edulis* (Briscoe and Sebens 1988). It is subject to population explosions which can denude large areas of macroalgae, leaving barren rock (Breen and Mann 1976). No significant differences were found between Stations 19 and 31 (NAI 1987b: Table 3.3.5-2) for the 1978-1987 study period. No significant differences were found among years at either station, when tested with a one-way ANOVA (Table 3.3.5-2). The geometric mean yearly population density over all years at nearfield Station 19 was $75/m^2$, and at farfield Station 31, it was $45/m^2$. Yearly geometric mean density ranged from $15/m^2$ in 1983 at $281/m^2$ in 1981 at Station 19 (Table 3.3.5-1).

Most of the individuals collected subtidally were juvenile, measuring less than 3 mm in diameter, and recruitment of newly-settled young usually occurred in August and September (NAI 1985b). The average length for the 1982 through 1987 study period was 1.9 mm at both stations (Table 3.3.5-3). Neither yearly nor interstation differences in average length were significant (NAI 1987b: Table 3.3.5-4). The average yearly length ranged from 1.5 mm at both Stations in 1986 to 2.7 mm at Station 19 in 1985.

In order to account for adult individuals which were too large to be collected in the destructive program, urchins were enumerated in the subtidal transect program done by SCUBA divers. No more than 13 large (> 10 mm) sea urchins per year were counted in three years of sampling (NAI 1986a, 1987a, 1988).

Recently-settled sea urchins occurred occasionally in monthly samples from short term fouling panels set at Stations 19 and 31 during the 10 year study period (Appendix Table 3.3.4-1). Most were collected at

Station 19 from June through September 1981, when the yearly density averaged 1 per panel. The yearly density for all other years was less than one specimen per panel per year. The geometric mean yearly density from bottom samples reached an all-time high in 1981, at Station 19 (Table 3.3.5-1), and is a reflection of successful recruitment of young-of-the-year.

3.3.6 Epibenthic Crustacea

3.3.6.1 American Lobsters (*Homarus americanus*)

Lobster Larvae

Lobster larvae have been relatively rare during the ten-year study period at Station P2. Mean density of lobster larvae at the intake site was highest in 1978 (1.45/1000 m^2) and lowest in 1980 (0.46/1000 m^2) (Table 3.3.6-1). The mean number of lobster larvae caught in 1987 at Station P2 was slightly below the average of the other years sampled but similar to 1986. The maximum abundance of lobster larvae usually occurred in July-September (Figure 3.3.6-1). During 1987 lobster larvae first appeared in early-June at Station P2 which was earlier than most other sampling years and peaked in mid-July.

The farfield sampling site, Station P7, was sampled beginning in 1982. The density of lobster larvae collected at this station fell from 1.32/1000 m^2 in 1982 to the lowest level in 1984 and increased again in 1985 and 1986 to the highest levels recorded in this study (Table 3.3.6-1). Abundances in 1987 were was similar to the 1986 levels. Abundances were always higher at Station P7 than P2; this difference was most pronounced in 1985 and 1986, when abundances at Station P7 were more than twice those at Station P2. Larvae first appeared at Station P7 in late June during 1987.

In 1986, a third station, P5, was added to the sampling regime, located in the vicinity of the intake structure. This station was sampled only from July 1 through October 14, 1986. Larval abundances were intermediate between abundances at Station P2 and P7 (Table 3.3.6-1). Larvae were observed from early July through mid-September matching the pattern at the other two stations in 1986 (NAI 1987).

TABLE 3.3.6-1. PERCENT COMPOSITION OF LOBSTER LARVAE STAGES AT STATIONS P2, P5 AND P7, 1978-1987. SEABROOK BASELINE REPORT, 1987.

YEAR	STATION[a]	PERCENT PER STAGE I	II	III	IV	TOTAL % OF STAGES I AND IV	NO. OF LARVAE COLLECTED	MEAN[b] NO. OF LARVAE COLLECTED
1978	P2	10.1	0.0	0.6	89.3	99.4	169	1.45
	P7	--	--	--	--	--	NS	NS
1979	P2	70.8	2.5	1.7	25.0	95.8	120	1.18
	P7	--	--	--	--	--	NS	NS
1980	P2	86.5	0.0	0.0	13.5	100.0	57	0.46
	P7	--	--	--	--	--	NS	NS
1981	P2	31.8	1.9	6.5	59.8	91.6	107	0.86
	P7	--	--	--	--	--	NS	NS
1982	P2	3.2	0.0	0.0	96.8	100.0	161	1.17
	P7	3.8	0.0	0.5	95.6	99.4	185	1.32
1983	P2	41.4	0.8	4.9	52.9	94.3	115	0.79
	P7	47.5	0.6	3.5	48.4	95.9	162	1.10
1984	P2	14.6	11.5	21.8	52.1	66.7	79	0.57
	P7	37.2	1.0	2.8	59.0	96.2	101	0.73
1985	P2	1.5	2.9	2.9	92.6	94.1	68	0.85
	P7	7.0	2.1	2.1	88.8	95.0	143	1.91
1986	P2	--	--	1.4	98.6	98.6	69	0.84
	P5	3.5	--	--	96.5	100.0	102	1.79
	P7	21.6	--	--	78.4	100.0	156	2.01
1987	P2	13.0	--	1.4	85.5	98.5	69	0.92
	P7	7.5	--	--	92.5	100.0	146	1.94

[a] = Station P5 sampled from July 1 through October 14, 1986 only.

[b] = $\bar{X}/1000\ m^2$

NS = Not sampled

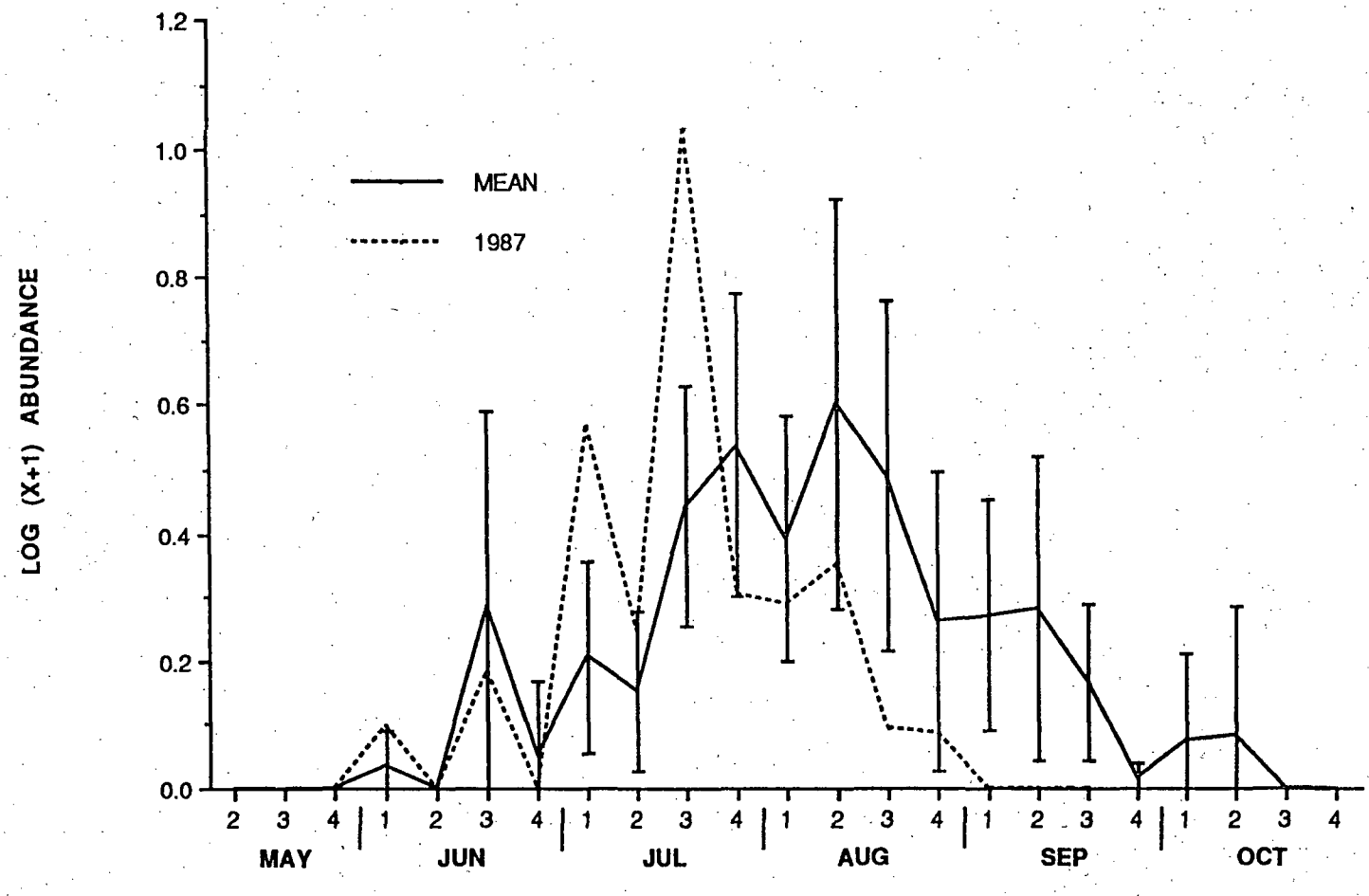


Figure 3.3.6-1. Weekly mean log (x + 1) abundance (No./1000 m^2) of lobster larvae at Station P2 1978-1987, all year's mean and 95% confidence interval and 1987. (No data collected January 1985-June 1986). Seabrook Baseline Report, 1987.

Historically, Stage I and IV larvae have dominated the collections at both Stations P2 and P7, with few Stage II or III larvae collected (Table 3.3.6-1). Stage I larvae dominated the collections in 1979 and 1980, while Stage IV larvae dominated the collections in all other years. Stage II and III larvae collectively constituted 7% or less of the larvae collected except in 1984, when they made up 33% of the total abundance at Station P2. In 1983 and 1985, the majority of lobster larvae were Stages I and IV at Stations P2 and P7 (Table 3.3.6-1). During 1986, the pattern at Stations P5 and P7 was similar to previous years. At Station P2, only Stages III and IV were collected and the overwhelming majority of larvae were Stage IV. In 1987, Stage IV larvae dominated the collection at both stations with few Stage I larvae also at each station; a few Stage III larvae were collected only at Station P2. No Stage II larvae were collected in 1987.

Stage I larvae usually appeared at Station P2 during July with large peaks also occurring in June in 1980 and 1983. Peak abundance of Stage IV larvae varied in occurrence between July and August (NAI 1985b). Stage I larvae first appeared in 1985 in late May at Station P7 (NAI 1986). Stage IV larvae were observed in late July at Stations P2 and P7. Stage IV larvae appeared at all stations and dominated the collections in 1986. Stage I larvae were observed at Station P2 in early June and early July at P5; however, collections did not begin until July at Station P5. At all three stations, Stage IV larvae were first observed in mid-July. During 1987, Stage I larvae appeared in early June and late June at Stations P2 (Figure 3.3.6-1) and P7 respectively. Stage IV larvae occurred in early July at both stations while Stage III larvae were collected in early July at Station P2 only (NAI 1988).

Trends in the occurrence of lobster larvae in this study have generally agreed with other lobster larvae studies in New England (Sherman and Lewis 1967; Lund and Stewart 1970). An extensive review of New England lobster larvae studies (Fogarty and Lawton 1983) indicated that the period of peak abundance in the region coincided with that observed off New Hampshire

waters, as described by this study. Also, the high predominance of Stage I and Stage IV larvae among years in this study has been shown to vary from year to year in other New England studies (Fogarty and Lawton 1983).

Abundances and occurence of lobster larvae in inshore areas have been associated with wind direction. Grabe *et al.* (1983) reported that 67% of Stage IV larvae were collected off the New Hampshire coast when winds were on- or along- shore. Thermal differences between air and land masses, combined with predominantly light westerly summer winds, produced onshore winds during the day and offshore winds at night. In addition, hydrographic studies in the Hampton/Seabrook area indicated a net drift northward or southward along the New Hampshire coastline. Combined, these two actions suggested that lobster larvae were moved by nontidal water mass movements into New Hampshire waters, and were then transported onshore by winds.

A synthesis of lobster larvae distribution studies by Harding *et al.* (1983) supports this hypothesis. They noted that lobster landings for all regions neighboring on the Gulf of Maine have been very similar since the mid-1940s. They interpret this to indicate a single lobster stock with common recruitment. They further concluded that warm southwestern waters of the Gulf of Maine and Georges Bank supply the Maine coast and adjoining areas with advanced larval stages, evidenced by a preponderance of Stage IV larvae in the cooler surface waters from southwestern Nova Scotia to Hampton, New Hampshire. This may explain the abundance of Stage IV lobster larvae in the present study. A recent examination of hydrographic drift studies (Harding and Trites 1988) also supports the theory of lobster larvae dispersion into the region through current transport.

Adults

Adult lobsters (legal and sublegal sizes combined) have been collected in the vicinity of the discharge site (L1) from 1974 to 1987 (Table 3.3.6-2). During that period, the highest monthly catch usually occurred

TABLE 3.3.6-2. SUMMARY OF TOTAL LOBSTER CATCH PER TRIP EFFORT[a], BY MONTH AND YEAR, AT THE DISCHARGE SITE (4) FROM 1974 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

YEAR	JUN	JUL	MONTH AUG	SEP	OCT	NOV	YEARLY AVERAGE
1974	41.7	51.2	73.6	103.0	78.6	59.7	68.0
1975	41.1	42.5	73.9	74.0	71.6	55.2	59.7
1976	35.0	40.7	68.6	69.1	63.7	48.0	54.2
1977	45.8	32.3	63.5	67.3	54.5	61.1	53.7
1978	49.7	34.8	63.4	86.4	79.1	65.5	63.2
1979	54.1	57.6	61.5	62.8	69.9	58.8	61.4
1980	32.2	30.2	70.3	59.7	41.3	43.4	46.2
1981	38.1	42.5	80.2	94.3	65.6	59.3	63.3
1982	35.7	52.3	83.9	71.7	88.8	79.1	68.6
1983	49.2	39.9	89.3	128.2	96.3	29.6	72.1
1984	49.9	28.2	72.1	117.9	146.6	140.5	92.5
1985	25.3	45.2	81.3	121.3	131.2	130.4	89.1
1986	32.4	37.5	75.0	86.9	80.5	99.7	68.7
1987	39.5	26.3	33.3	57.2	83.2	48.2	46.0
MONTHLY AVERAGE	40.7	40.1	70.7	85.7	82.2	69.9	

[a]Catch per trip effort = total catch from 15 traps per trip.

from August through October. Monthly catch was highest in September during 1987. However, in 1980 the greatest catch was in August; in 1979, 1982, 1984, and 1985, in October; and in 1986, November. June or July have had the lowest monthly catches (Table 3.3.6-3). Data from 1945 to 1973 reported by the New England Fishery Management Council (1983) for the Maine lobster fishery also indicate August, September and October as peak months in lobster abundance. Average yearly catches per fifteen-trap trips at the discharge station ranged from 46.2 in 1980 to 92.5 in 1984 (Table 3.3.6-2). Lobster catch abundance was also high in 1985 (89.1), but dropped to average levels in 1986 (68.7). The average yearly catch for 1987 was 48.0 per fifteen-trap trip, the lowest average since 1980.

Results of one-way ANOVAs of lobster catch for years (1982-1987) and months at the discharge site indicated significant differences among months but not for years (Table 3.3.6-3). Multiple comparisons among months also indicated August, September, October and November differed from catch during June and July. Among stations, lobster catch was significantly greater at the farfield station (L7) than at the discharge site (L1) (Table 3.3.6-4). The pattern of peak monthly abundances and the greater abundance of lobster catch at the farfield station is consistent throughout the study since sampling at the that station was begun in 1982.

Adult lobster abundances have been related to seawater temperature. McLeese and Wilder (1958), Dow (1969) and Flowers and Saila (1972) have examined this relationship. In the Hampton/Seabrook study area, continuous bottom temperature monitoring (1978-1984) at Station ID, near the discharge area, was compared to monthly mean lobster catch. A relationship between bottom water temperature and lobster catch was established at the discharge station (NAI 1985b). During June, catch declined as bottom water temperature increased; however, this was probably caused by the onset of molting which would reduce the catchability of lobsters. Peak catch of adult lobsters usually occurred after bottom water temperatures reached approximately 10°C and lobsters had molted to legal size (NAI 1985b). As bottom temperatures cooled, catch declined in November, perhaps reflecting seasonal inshore movement patterns (Ennis 1984) or decreased activity level. Lobsters

TABLE 3.3.6-3. RESULTS OF ONE-WAY ANOVA AT THE DISCHARGE SITE FOR LOBSTER (*H. AMERICANUS*), JONAH CRAB (*C. BOREALIS*) AND ROCK CRAB *C. IRRORATUS*). SEABROOK BASELINE REPORT, 1987.

SPECIES	SOURCE OF VARIATION	df	ss	F-VALUE	MULTIPLE COMPARISONS
Lobster	Year	12	14011.66	1.62^{NS}	
	Error	65	46975.38		
	Total	77	60987.04		
	Month	5	26287.64	10.91***	9 10 11 8 6 7
	Error	72	34699.40		
	Total	77	60987.04		
Jonah Crab	Year	5	405.95	1.70^{NS}	
	Error	30	1428.89		
	Total	35	1834.84		
	Month	5	892.45	5.68***	8 9 7 11 10 6
	Error	30	942.38		
	Total	35	1834.83		
Rock Crab	Year	5	60.99	6.67***	85 86 84 87 83 82
	Error	30	54.89		
	Total	35	115.88		
	Month	5	28.60	1.97^{NS}	
	Error	30	87.29		
	Total	35	115.89		

NS = Not Significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

TABLE 3.3.6-4. PAIRED t-TEST COMPARISONS OF THE DISCHARGE SITE (L1) AND THE FARFIELD STATION (L7) FOR LOBSTER (*H. AMERICANUS*), JONAH CRAB (*C. BOREALIS*) AND ROCK CRAB (*C. IRRORATUS*). SEABROOK BASELINE REPORT, 1987.

	CATCH/15 TRAPS					
SPECIES	L1	L7	MEAN DIFFERENCE	n	t	SIGNIFICANT DIFFERENCES
Lobster	46.0	70.1	18.59	36	4.43***	L7 > L1
Rock Crab	10.7	10.4	0.85	36	3.76***	L1 > L7
Jonah Crab	11.2	11.5	0.18	36	0.24NS	

NS = Not Significant; *** $p \leq 0.001$

typically show a seasonal migration pattern which is thought to maintain the population at the highest local water temperature (Campbell 1986). It is uncertain whether New Hampshire lobsters undergo seasonal migrations (NHFG 1974).

Although the relationship between lobster catch and bottom water temperature has been shown to be significant for some months, the combined effects of molting and other factors such as food availability probably interact, affecting lobster catchability and its relationship to bottom temperature (NAI 1975b). Further, the New Hampshire Fish and Game Department conducted similar studies off the New Hampshire coast from 1971 through 1974 and concluded that bottom water temperature did affect lobster catch, but was influenced by other factors as well (NHFG 1974).

Low catches of lobsters in 1987 may be temperature related. Bottom water temperatures at Station P2 were 1 to 3°C lower from July through October than the overall mean temperature (See Figure 3.1.1-1). Also, benthic invertebrate abundances and numbers of taxa at Stations 17 and 19 in the vicinity of the discharge site were lower than previous years (See Figure 3.3.3-2) perhaps further indicating the effect of cooler bottom water temperatures.

Catch per effort of legal-sized lobsters at the discharge station averaged from 7 to 10 individuals per fifteen-trap trip from 1975 through 1986 (Appendix Table 3.3.6-1). However, in 1987, this declined to three individuals per fifteen-trap trip. The catch of legal-sized lobsters constituted approximately 12% of the total catch during 1975-1981, but decreased slightly to approximately 10-11% of the total catch during 1982 and 1983. In 1984 despite having the highest yearly mean catches, the legal-sized lobster catch at the discharge, declined to approximately 7% of the total catch (Appendix Table 3.3.6-1; Figure 3.3.6-2). Legal-sized lobster catch increased slightly to 7.2 (10%) in 1986. In 1987, 6.7% of the lobster catch was of legal size, comparable to 1984 and 1985 catches. However, the total catch of lobsters in 1987 was the lowest yearly average since 1980 (Table 3.3.6-2). In 1984, an increase in the legal size limit for lobsters from 3-1/8" (79.2 mm) to 3-3/16" (80.9 mm) was enacted. Because of the change in the law, a number of adults which would have been legal-sized under the old size limit, were retained in the sublegal size class during 1984 and 1985, adding to those lobsters molting to legal-sized lobsters in 1986.

Annual size-class distributions (Figure 3.3.6-3) indicate that the abundances of lobsters in the 42-54 and 54-67 mm size classes have steadily declined since 1975, while catches in size class 67-79 mm (2-5/8" to 3-1/8") have increased through 1985. Size classes above 79 mm have had low catch abundances, indicating that commercial fishing in the study area quickly removed the majority of lobsters as they attained minimum legal size.

The increase in catch abundance within size class 88.9 mm since 1984 may be attributed to the increase in the legal-size limit implemented by the State of New Hampshire. Lobsters in this size class, measuring 3-1/8" to 3-3/16" which had been available for harvest through 1983 were now protected until their next molt. New Hampshire inshore lobster landings reported for 1984, the first year the change was enacted, had decreased by nearly twenty-four percent based on information obtained from state-required annual reports. However, adjusting catch for a generally poor catch in the southern Gulf of Maine in 1984, the actual reduction that was due to the change in

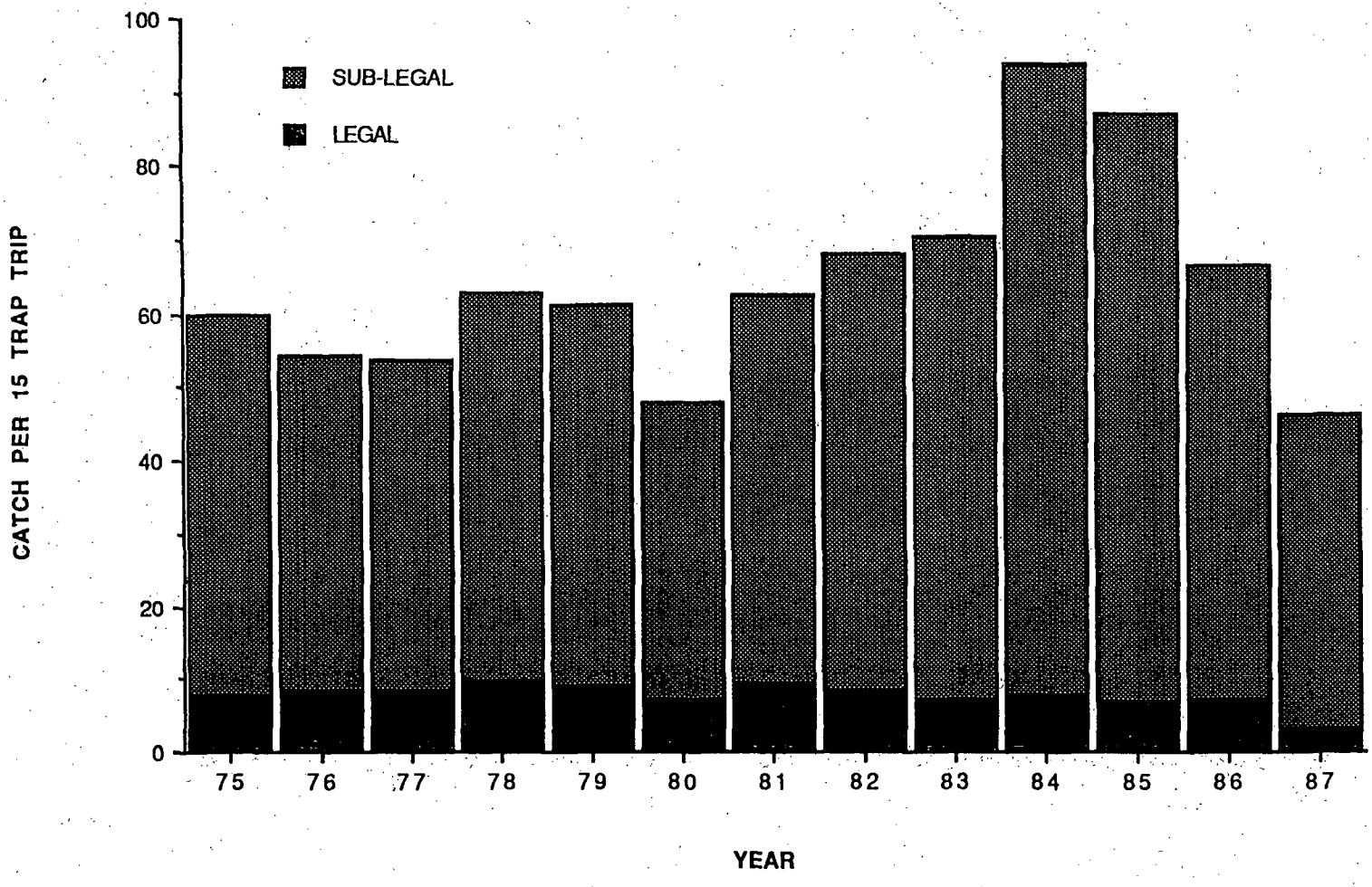


Figure 3.3.6-2. Comparisons of legal and sub-legal sized catch of *Homarus americanus* at the Discharge Site, 1975-1987. Seabrook Baseline Report, 1987.

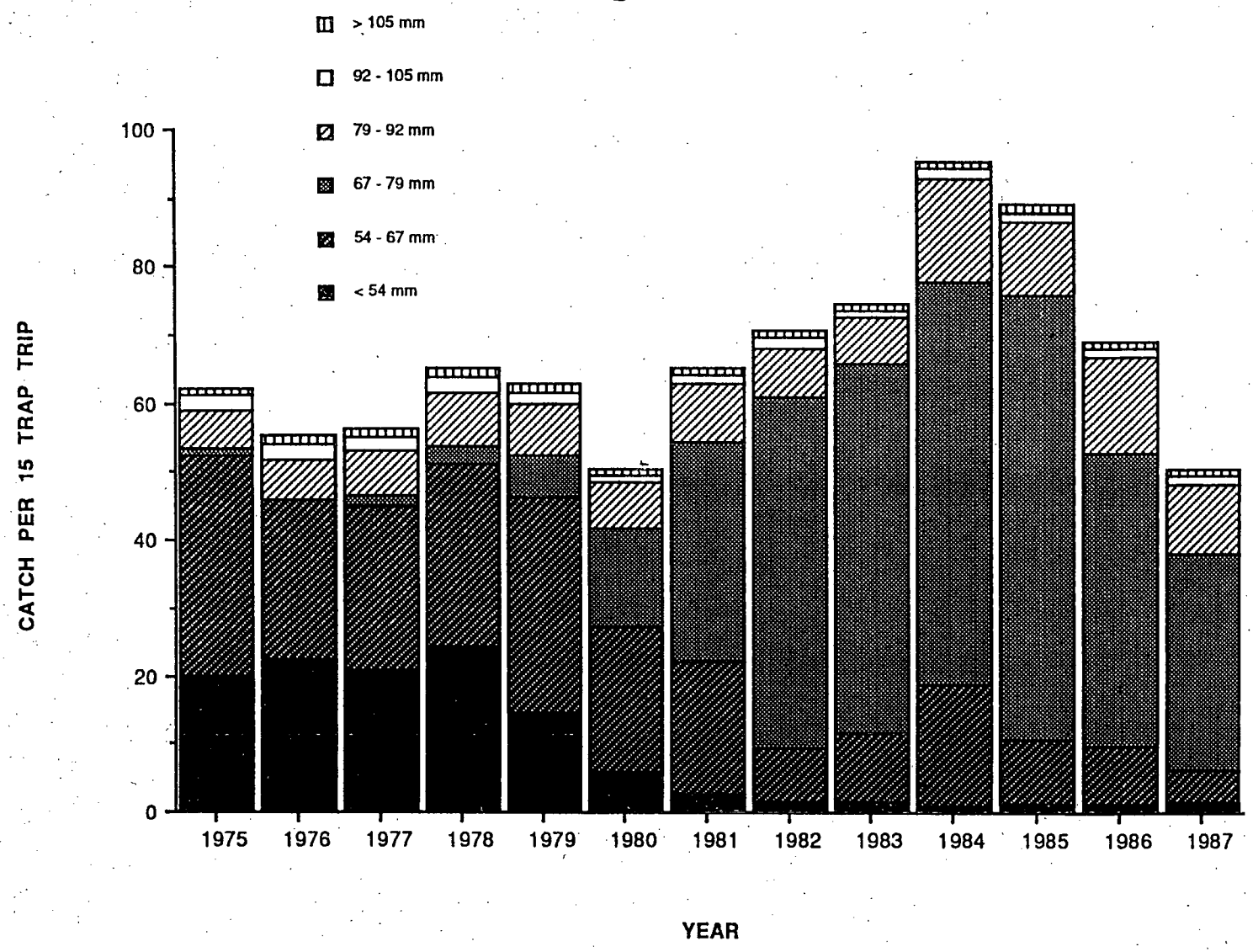


Figure 3.3.6-3. Size-class distribution (carapace length) of *Homarus americanus* at the discharge site, 1975-1987. Seabrook Baseline Report, 1987.

size limit was approximately 13% (Edward Spurr, NHFG, pers. comm.). This resulted in an estimated 28% loss in total catch weight in 1984 (Perry 1985). Preliminary data reported to the state in 1986 indicated that the catch weight had recovered (Edward Spurr, NHFG, pers. comm.). Data for 1987 were not available in time to be considered in this report. This agreed with results from this study, which showed an increase in legal-sized lobster catches in 1986 to 1983 levels (Appendix Table 3.3.6-1).

Female lobsters have represented nearly 60% of the total catch for all years at the discharge (NAI 1984b) although percentages have been lower (54-56%) in recent years. Egg-bearing female lobsters comprised 1.1% of the catch in 1987 slightly greater than in 1985 and 1986 but still consistent with previous years' data (Figure 3.3.6-4).

3.3.6.2 Rock Crab (*Cancer irroratus*) and Jonah Crab (*Cancer borealis*)

Larvae

Cancer spp. (*Cancer borealis* and *Cancer irroratus*) larvae generally exhibited a pattern for all sampling years of very low or near-zero density from January through April with rapidly increasing numbers in May, reaching peak abundance in August and declining density from October through December. At plankton Station P2, *Cancer* spp. larvae were usually most abundant during August, except in 1981, 1983, and 1987 when density was greatest in July (Figure 3.3.6-5). In 1987, from July through December, the observed pattern was very similar to previous years.

Adults

Adult rock crab (*C. irroratus*) and Jonah crab (*C. borealis*) catches have been monitored since 1975 at the discharge site (NAI 1985b). Since 1982, these populations have been monitored at two stations, the discharge site (L1) and at Rye Ledge (L7). Historically, catches of Jonah crabs have

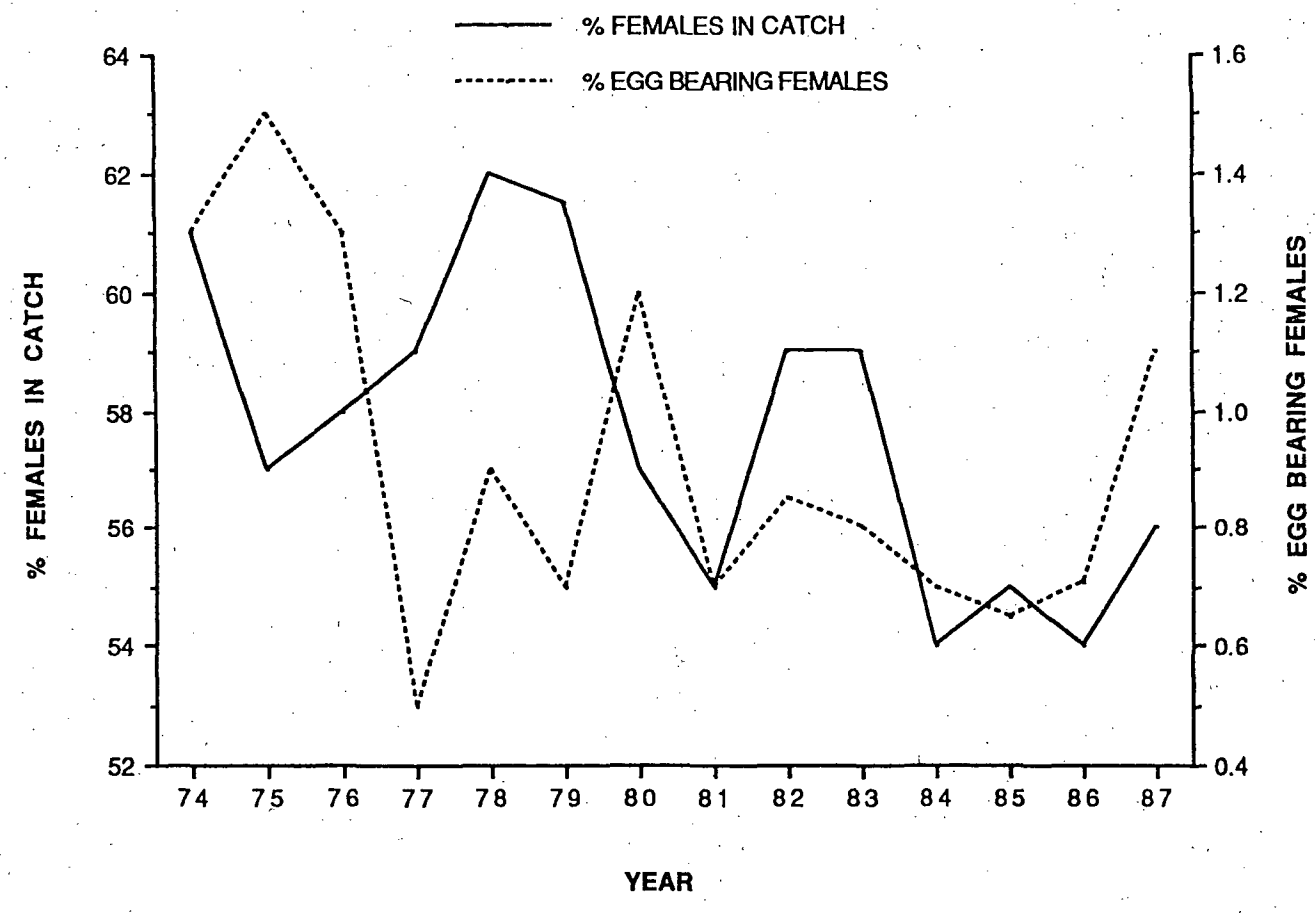


Figure 3.3.6-4. Summary of female lobster catch data at the Discharge Site, 1974-1987. Seabrook Baseline Report, 1987.

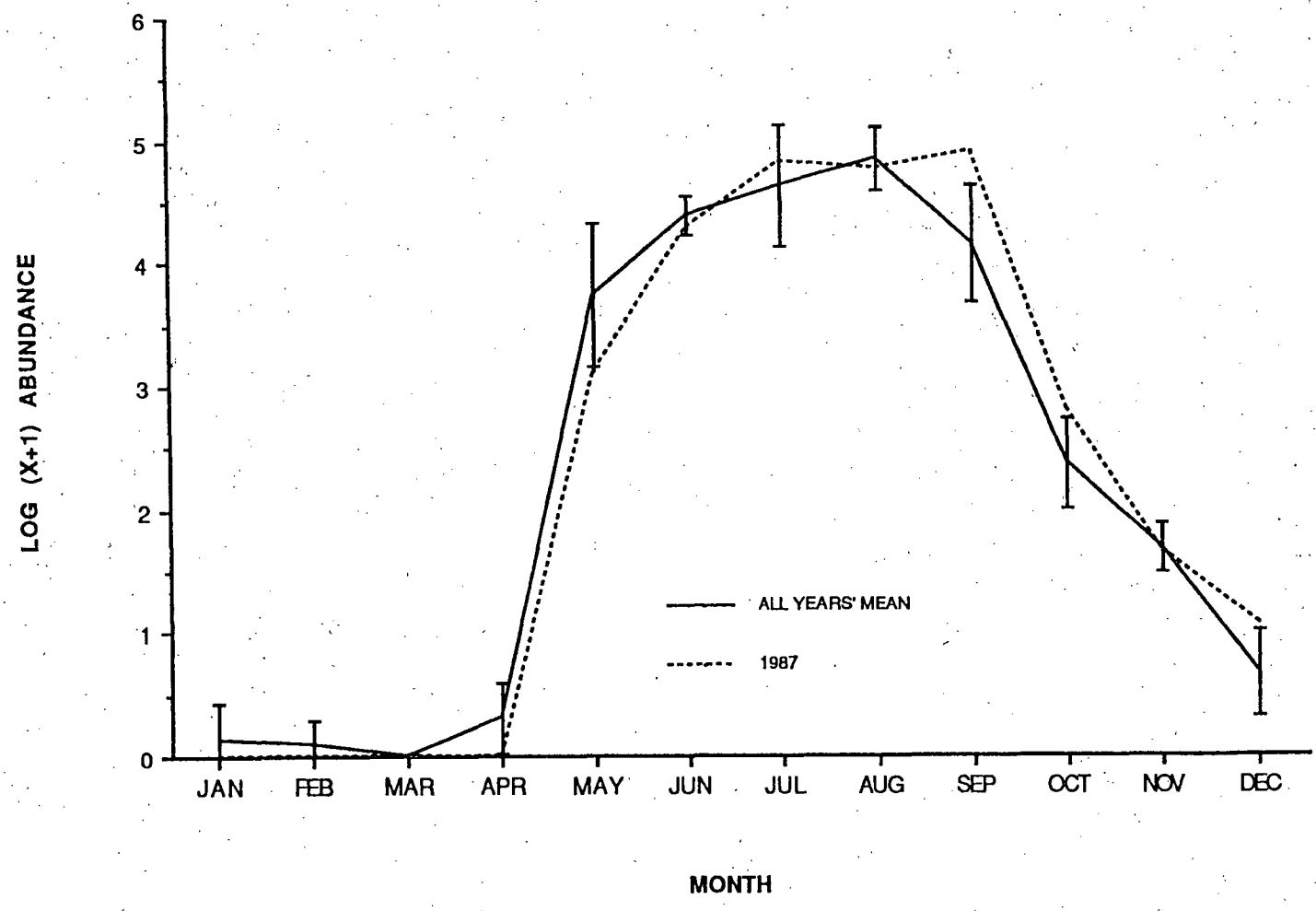


Figure 3.3.6-5. Monthly mean log (x + 1) abundance (No./1000 m^3) of *Cancer* spp. larvae at Station P2, 1978-1987. Seabrook Baseline Report, 1987. (No data collected January 1985-June 1986).

been significantly greatest in August, although catches were occasionally higher in September at both stations (Table 3.3.6-5). Average monthly catches per fifteen-trap trip have ranged from 0.6 to 26.7 at the discharge station and from 3.0 to 31.5 at Rye Ledge from 1982 through 1987 (Table 3.3.6-5). The total annual catch of Jonah crabs increased from 1982 through 1985, when catches were significantly higher than other years, and declined in 1986 at both stations (Table 3.3.6-5). In 1987, the decline continued at the discharge station but catch increased at Rye Ledge.

Catches of Jonah crab at the discharge site from 1982 through 1987 were not significantly different from year to year. However, monthly catch data during August and September was significantly different than other months (Table 3.3.6-3). A paired t-test comparison of the discharge site and the farfield station, Rye Ledge, did not indicate a significant difference between the two sites (Table 3.3.6-4) for Jonah crab, however.

Catch of rock crabs has ranged from 0.0 to 6.7 per fifteen-trap trip at the discharge station and from 0.0 to 2.9 at Rye ledge from 1982 through 1987. The catch of rock crabs has also been generally increasing from 1982 through 1985, when catches were higher than all other years; catches then decreased in 1986 at both stations (Table 3.3.6-3). Rock crab catches have generally been greatest in July or August, and since 1984 have been greatest at the discharge station.

Rock crab catches at the discharge site from 1982 through 1987 were significantly different from year to year (Table 3.3.6-3). Monthly catch data, however, was not significantly different. Comparison of station differences between the discharge site and the farfield station, Rye Ledge, indicated that the discharge site had significantly greater catch than at Rye Ledge (Table 3.3.6-4).

Total catch of rock crabs has been low at both stations relative to the catch of Jonah crabs; this may be due to intra-specific competition between the two species of crabs (Richards *et al*. 1983). Also, rock crabs

TABLE 3.3.6-5. COMPARISON OF CRAB CATCH STATISTICS OF JONAH CRAB (CANCER BOREALIS) AND ROCK CRAB (CANCER IRRORATUS) AT THE DISCHARGE SITE AND RYE LEDGE, 1982-1987. SEABROOK BASELINE REPORT, 1987.

	CATCH PER UNIT EFFORT*						PERCENT FEMALES						PERCENT EGG BEARING FEMALES					
A. DISCHARGE STATION	1982	1983	1984	1985	1986	1987	1982	1983	1984	1985	1986	1987	1982	1983	1984	1985	1986	1987
JONAH CRAB																		
JUN	2.7	2.8	3.6	9.3	7.5	0.6	57.1	61.3	53.1	64.7	63.9	28.6	3.8	0.0	6.3	2.0	1.2	0.0
JUL	3.9	6.9	4.5	14.2	9.6	9.2	51.9	70.8	57.1	59.6	71.7	63.3	0.0	2.3	4.1	0.0	3.8	5.0
AUG	4.9	12.1	11.5	26.7	26.6	25.5	86.7	74.5	72.0	81.6	89.6	78.0	1.4	1.4	1.9	0.0	0.0	4.5
SEP	8.4	8.4	9.3	11.4	18.5	26.2	84.0	92.9	83.3	87.7	95.6	87.3	0.0	0.0	2.0	0.0	0.0	0.9
OCT	2.7	4.3	7.2	9.7	5.6	2.5	80.0	88.2	81.6	85.6	88.7	84.0	0.0	0.0	0.0	0.0	0.0	0.0
NOV	3.0	1.8	8.9	11.7	6.2	1.4	74.0	81.3	69.7	72.6	81.1	91.4	0.0	0.0	0.0	0.0	0.0	0.0
YEARLY AVERAGE	4.3	6.1	7.5	14.0	13.3	11.3	72.3	78.2	69.5	75.5	85.8	78.5	0.9	0.6	2.4	0.2	0.6	3.1
ROCK CRAB																		
JUN	0.0	0.2	0.7	2.7	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JUL	0.7	0.9	2.0	5.3	3.7	4.2	21.7	9.1	6.9	1.6	0.0	18.8	0.0	0.0	0.0	0.0	0.0	0.0
AUG	0.0	1.0	3.4	6.7	3.2	2.5	0.0	0.0	8.3	0.0	2.4	39.4	0.0	0.0	0.0	0.0	0.0	0.0
SEP	0.0	0.2	1.5	0.6	1.2	1.2	0.0	0.0	12.5	0.0	7.7	27.3	0.0	0.0	0.0	0.0	0.0	0.0
OCT	0.1	0.0	0.2	3.3	1.7	0.1	0.0	0.0	50.0	57.6	36.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOV	0.2	0.1	0.2	5.7	2.2	0.0	0.0	0.0	50.0	45.6	46.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YEARLY AVERAGE	0.2	0.4	1.3	4.1	2.4	1.6	3.6	1.5	21.3	17.4	9.8	25.5	0.0	0.0	0.0	0.0	0.0	0.0
B. RYE LEDGE	1982	1983	1984	1985	1986	1987	1982	1983	1984	1985	1986	1987	1982	1983	1984	1985	1986	1987
JONAH CRAB																		
JUN	3.6	4.4	5.9	7.7	5.9	1.3	37.4	50.0	41.5	36.5	50.8	14.3	7.4	2.1	1.9	0.2	3.1	0.0
JUL	3.2	12.6	6.4	16.0	8.6	7.7	50.2	56.7	50.0	50.0	66.3	69.0	4.6	1.3	0.0	5.9	1.1	2.0
AUG	4.0	13.6	19.3	31.5	7.5	27.4	89.3	77.9	62.9	84.4	83.7	73.3	0.0	1.2	1.6	1.0	0.0	3.7
SEP	5.6	9.8	11.4	9.8	11.4	20.1	91.8	82.7	86.4	92.9	88.8	77.0	0.0	0.0	2.4	1.2	0.0	1.2
OCT	3.4	4.6	8.3	7.7	7.4	1.6	70.9	86.5	78.0	84.4	95.1	81.3	0.0	0.0	2.0	0.0	0.0	0.0
NOV	3.5	3.0	8.5	13.1	7.3	1.3	75.1	70.0	80.0	70.2	79.5	61.9	0.0	0.0	0.0	0.0	0.0	0.0
YEARLY AVERAGE	3.9	8.0	10.0	14.5	8.1	10.3	69.1	70.6	66.5	71.8	78.9	72.3	2.0	0.8	1.3	1.2	0.6	2.6
ROCK CRAB																		
JUN	0.2	0.4	0.2	1.5	0.5	0.1	0.0	0.0	0.0	94.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JUL	1.5	0.9	1.7	1.2	2.0	0.8	29.9	0.0	10.5	100.0	0.0	36.4	0.0	0.0	0.0	0.0	0.0	0.0
AUG	0.1	1.3	1.5	2.9	0.2	2.3	100.0	6.3	5.0	96.9	33.3	43.3	0.0	0.0	0.0	0.0	0.0	0.0
SEP	0.1	0.2	1.6	0.8	0.2	1.4	0.0	0.0	16.7	100.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0
OCT	0.0	0.0	0.6	1.6	0.5	0.1	0.0	0.0	0.0	37.5	83.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOV	0.1	0.2	0.2	1.9	0.0	0.0	0.0	0.0	50.0	57.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YEARLY AVERAGE	0.3	0.5	1.0	1.7	0.6	0.8	21.7	1.1	13.7	81.3	15.8	33.3	0.0	0.0	0.0	0.0	0.0	0.0

*Catch per unit effort = total catch from 15 traps per trip

prefer sandy habitat which is available near the discharge site compared to rocky habitat preferred by Jonah crabs (Jefferies 1966; Bigford 1979).

The percent of female crabs in the catch has been monitored since 1982 (Table 3.3.6-5). The highest proportion of females at the discharge station occurred during September in most years, ranging from 83.3% to 95.6%. In 1987 the highest percentage of females was in November (91.4%). At Rye Ledge, they reached their greatest proportion in September or October (81.3 to 95.1%). Female catch of Jonah crabs generally increased from 1982 through 1987, particularly at the discharge, due to larger catches and higher proportions of females. Trends of female rock crab occurrence were less defined than Jonah crabs due to the low overall catch of rock crabs. In 1984-1986, catches of female rock crabs were generally greatest in the fall, but some earlier months had greater percentages in some years due to a low catch comprised of only female crabs (Table 3.3.6-5). Percentages of females in 1987 were higher than most of the previous years' catch figures. Egg-bearing Jonah crabs were most abundant in 1987 at both stations (about 3% of the total catch), occurring mainly in June or July, compared to generally less than 1% of the total catch at both stations from 1982 to 1986. No ovigerous rock crabs were collected in 1987 at either site, similar to findings from 1982 to 1986 (Table 3.3.6-5). This is as expected, considering the low catches of rock crabs and the low proportion of the population that would be ovigerous females.

Width frequency distributions taken in 1985 and 1986 indicated that male Jonah crabs were slightly larger than females, although ovigerous females were slightly larger than males in 1986 (NAI 1986, 1987a). This trend generally continued in 1987; however, both females and ovigerous females were slightly larger than males at the discharge site but at Rye Ledge, males were slightly larger than females (NAI 1988). Due to low overall catch, trends in the size class distribution of rock crabs were less apparent. Male rock crabs were generally larger than females (NAI 1988). Gear selectivity had an influence on size distributions reported, since catches from lobster traps do not include the smaller size classes in the crab populations.

3.3.7 *Mya arenaria* (Soft-shell Clam)

3.3.7.1 Larvae

Mya arenaria larvae occurred in plankton samples May through October from 1978 to 1987 (Figure 3.3.7-1). Each year, maximum abundances were recorded in late summer or early fall, while in many years a secondary peak also occurred in early summer. Peak densities observed in 1985 ($63/m^3$) were the lowest encountered from 1978-1987. The late-summer peak ($99/m^3$) in 1987 was higher than 1985, but much lower than the remaining years, 1978-1986. A late-summer peak in 1987 occurred from mid to late August, similar to 1981-1983.

Factors influencing the timing and magnitude of the observed pattern of larval abundance are not fully understood. *M. arenaria* is known to spawn in the spring at temperatures greater than 4-6°C with summer spawning at 15-18°C (Brosseau 1978). Maximum larval abundances in August and September coincided with water temperatures in Hampton Harbor that regularly exceeded 15-18°C. However, these temperatures also occurred frequently in June and July, which were characterized by much lower larval abundances, suggesting that temperature is a minimum requirement for spawning. In addition, recruitment of larvae of non-local origin is likely due to currents in the Gulf of Maine, which may move water masses and their entrained larvae significant distances before larval settlement. The late-summer peaks have been observed to be coincident with northward-flowing currents. This implies that these offshore larval peaks may in part have a more southern estuarine component. Overall, factors controlling the occurrence of *M. arenaria* larvae off Hampton Harbor Beach are complex, the result of environmental and biological factors including: adult condition at the time of spawning, temperature at spawning sites, location of spawning sites relative to prevailing coastal currents, water column stratification and larval behavior.

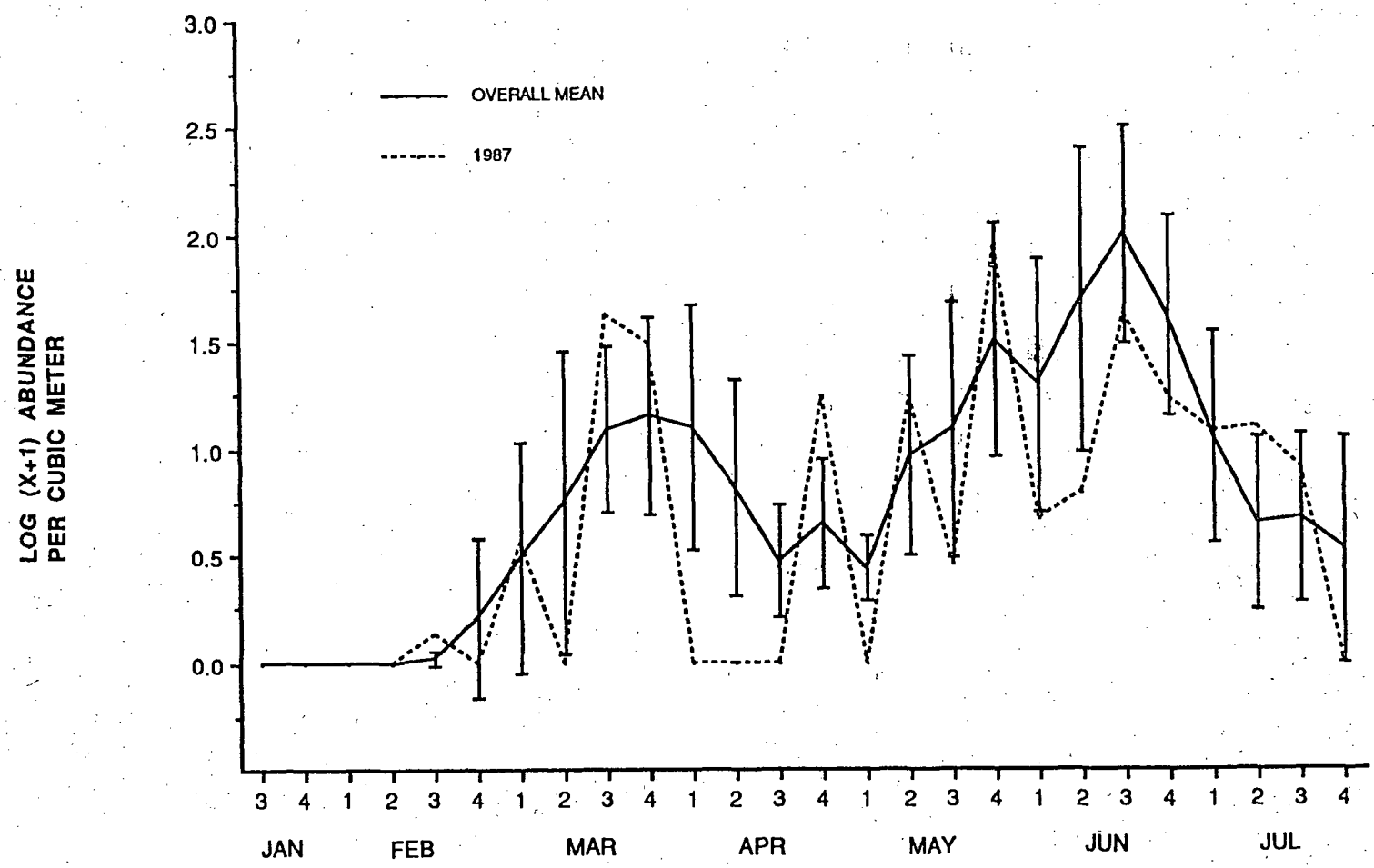


Figure 3.3.7-1. Weekly log (x+1) abundance per cubic meter of *Mya arenaria* larvae at station P2, 1978-1987, all years' mean and 95% confidence interval and weekly mean for 1987. Seabrook Baseline Report, 1987.

A comparison of larval densities at nearfield (P2) and farfield (P7) stations indicated similar patterns at the two stations, 1982-1984 and 1986-1987 (Figure 3.3.7-2). Only Station P2 was examined in 1985. In 1986 and 1987, Hampton Harbor Station P1 added in July 1986, was also similar to patterns at P2 and P7 (Figure 3.3.7-2).

3.3.7.2 Reproductive Patterns

Developing stages in the *Mya* reproductive cycle in the Hampton estuary appeared in March or early April during most years. Ripe individuals were observed between the second week in April and the third week in June. In most years, ripe individuals occurred at similar times at both Hampton Harbor and Plum Island Sound, with the exception being 1984 (NAI 1985b).

The onset of spawning in Hampton Harbor and Plum Island Sound, as indicated by the reproductive studies, usually occurred following the appearance of larvae in offshore tows. Only in 1980 and 1981 was spawning detected before larval occurrence. The peak larval abundance always occurred well after spawning had commenced, indicating both Hampton Harbor and Plum Island Sound clams may contribute to the large nearshore larval densities of late summer (NAI 1985b).

3.3.7.3 Hampton Harbor and Regional Population Studies

Hampton Harbor Spatfall

The soft-shell clam population has been studied through intensive surveys of spat and adults in Hampton Harbor (Appendix Table 3.3.7-1). These surveys have been supplemented by quantitative studies of regional spatfall in nearby estuaries, where settlement is known to occur. Over a 14-year period, the Hampton Harbor population has gone through substantial changes in abundance. The *Mya* population structure during the 1984-1987 period

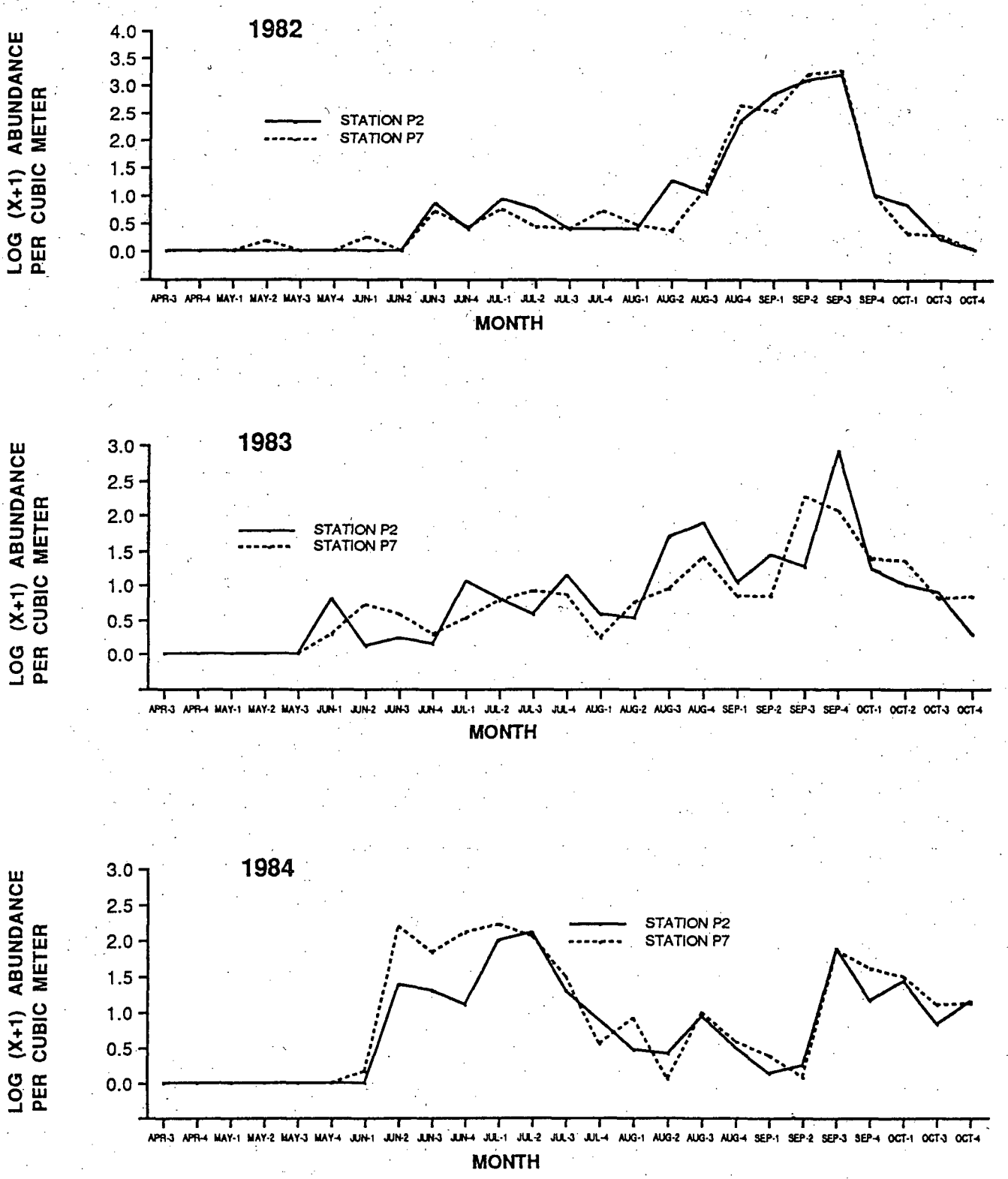
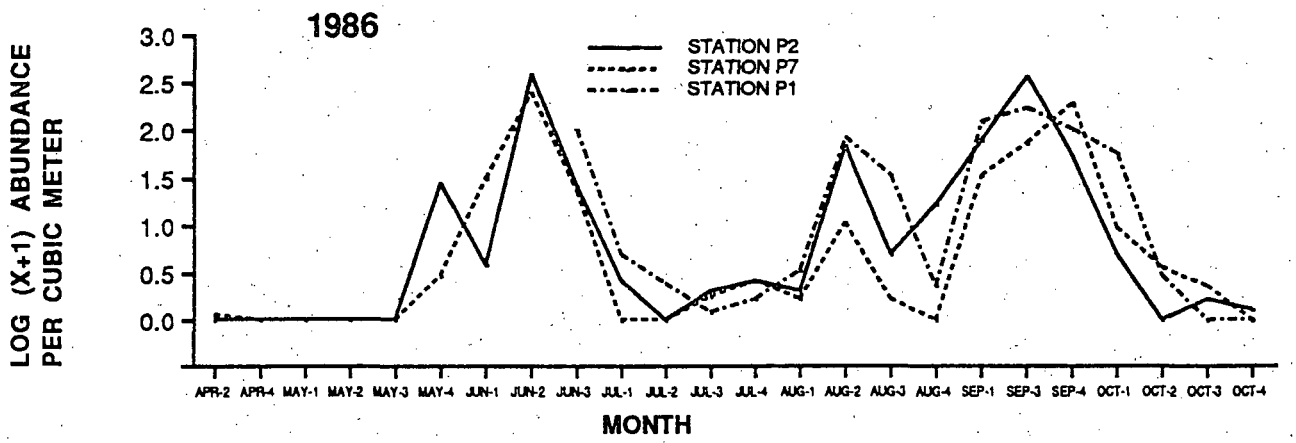


Figure 3.3.7-2. Log (x+1) abundance per cubic meter of *Mya arenaria* veligers at nearfield station P2, farfield station P7 and Hampton Harbor station P1, 1982-1987.[a,b] Seabrook Baseline Report, 1987.

a. Only station P2 was examined for *Mya* veligers in 1985.



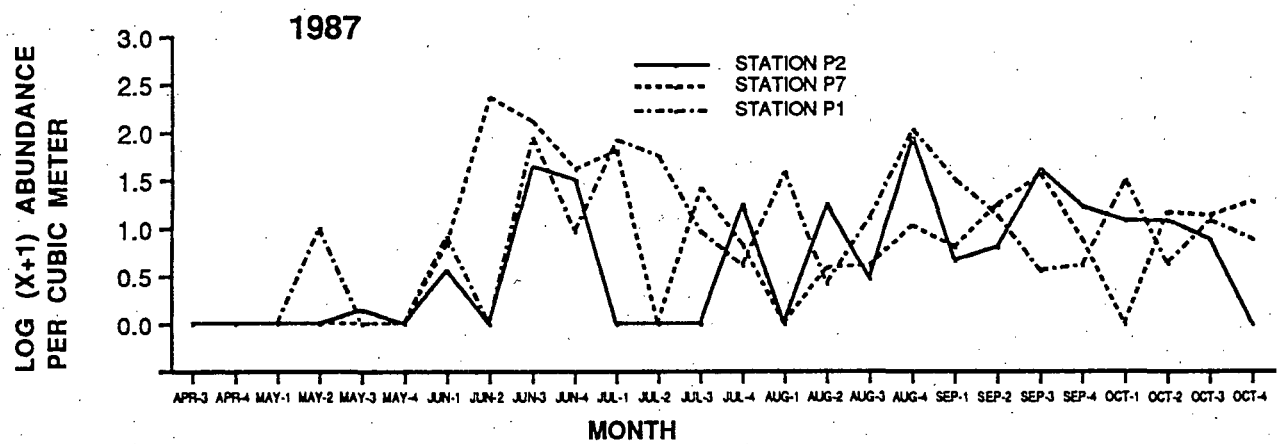


Figure 3.3.7-2. (Continued)

b. Station P1 was added in June 1986.

resembled that observed in 1974-1975, suggesting long-term trends based on the interaction of spatfall, and disturbance possibly due to natural and human predation (Figure 3.3.7-3). The continuing decline in juvenile and adult (>25 mm) clam densities is partially the result of light spatfalls (1982-1987). The size distribution in 1974-1975 also indicated a decreasing juvenile and adult (>25 mm) population with an absence of any clams between 5-25 mm in 1974 and 1975 except for the young-of-the-year settlement (1-5 mm). In 1976, a large settlement occurred at all flats (Figure 3.3.7-4) which initiated changes in the population during the 1976-1982 period. The current state of low juvenile and adult densities is not likely to be reversed without a significant spatfall.

The 1976 spat settlement was the largest observed in the study; however, other important settlements occurred in 1977, 1980, 1981 and in 1984 (Figure 3.3.7-4). The 1976 recruitment was successful on all flats, while the spatfall in 1980 and 1981 was most successful on Flat 2 and in 1984 on Flat 4. In Hampton Harbor, the least-successful recruitment years occurred in 1974, 1982, and 1985-1987.

Regional Spatfall

The regional spatfall study verified that the large 1976 recruitment occurred throughout the region (Figure 3.3.7-5). Generally, spat recruitment was similar between estuaries, though variation between flats within estuaries was often considerable. Overall, 1987 had the lowest abundance of spat observed in the regional study. In 1987, Flat 4 and Plum Island Sound spatfalls were the lowest observed during the 1976-1987 period while Flat 2 spatfall was higher than 1982 but lower than all other years.

Yearling and Adult Clams

Yearling clams (10-12 mm) became numerous in 1977 following the 1976 spatfall and began showing a decline in 1981 at Flat 1 and 1982 at Flat

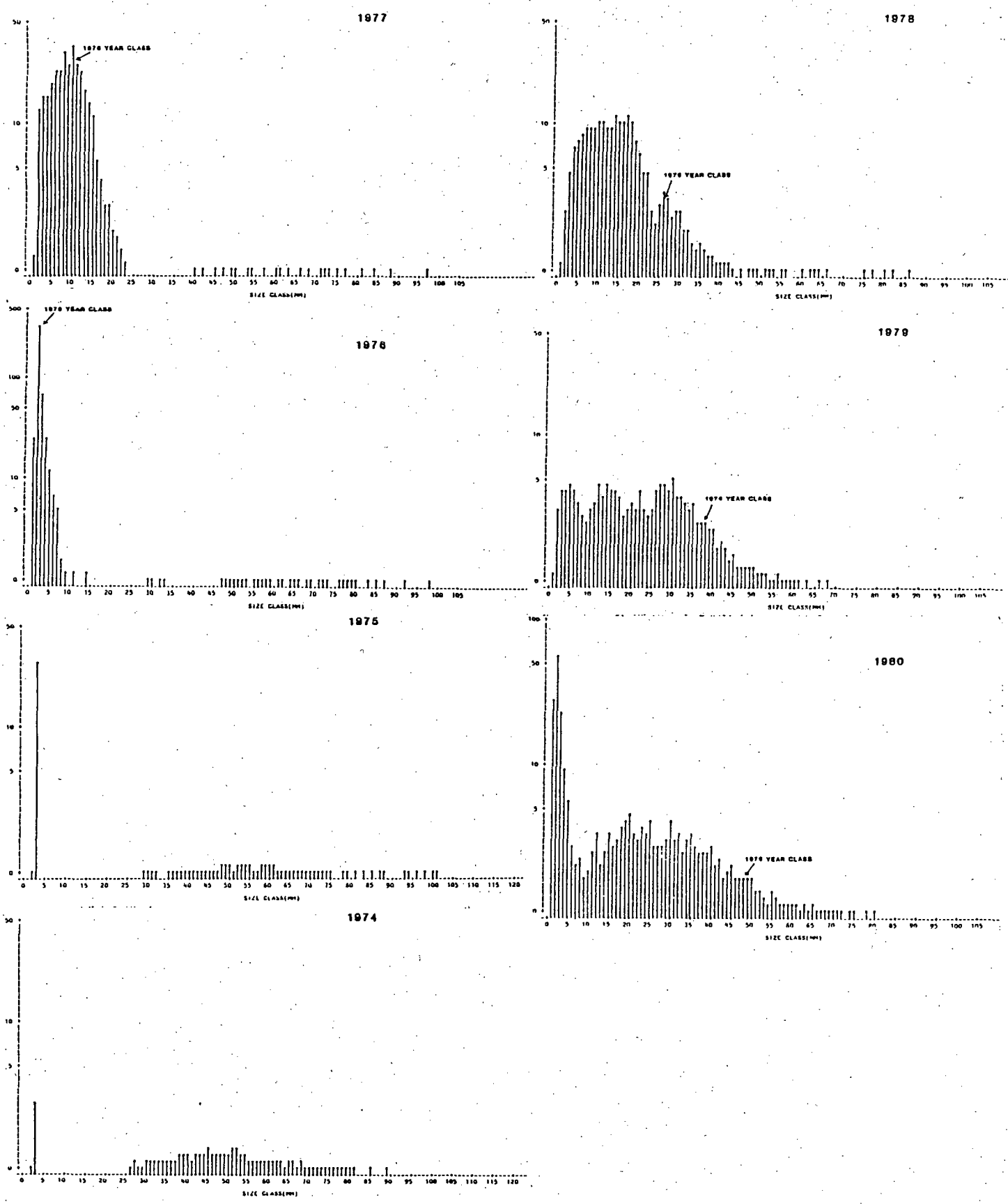


Figure 3.3.7-3. Abundance (No./ft^2) of 1-mm size classes of *Mya arenaria* in Hampton-Seabrook Harbor during early fall, 1974-1987 (Note differences in abundance scale). Seabrook Baseline Report, 1987.

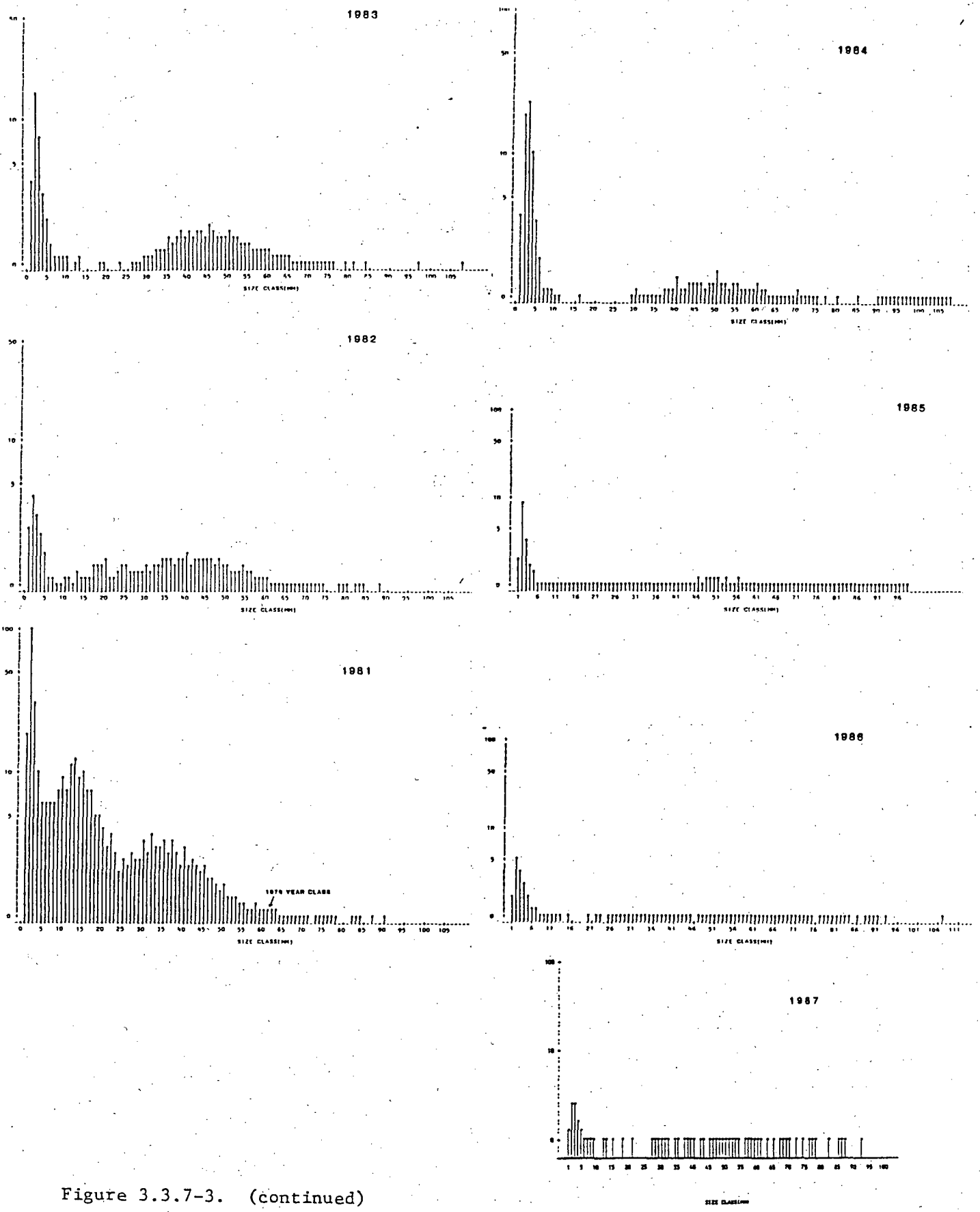


Figure 3.3.7-3. (continued)

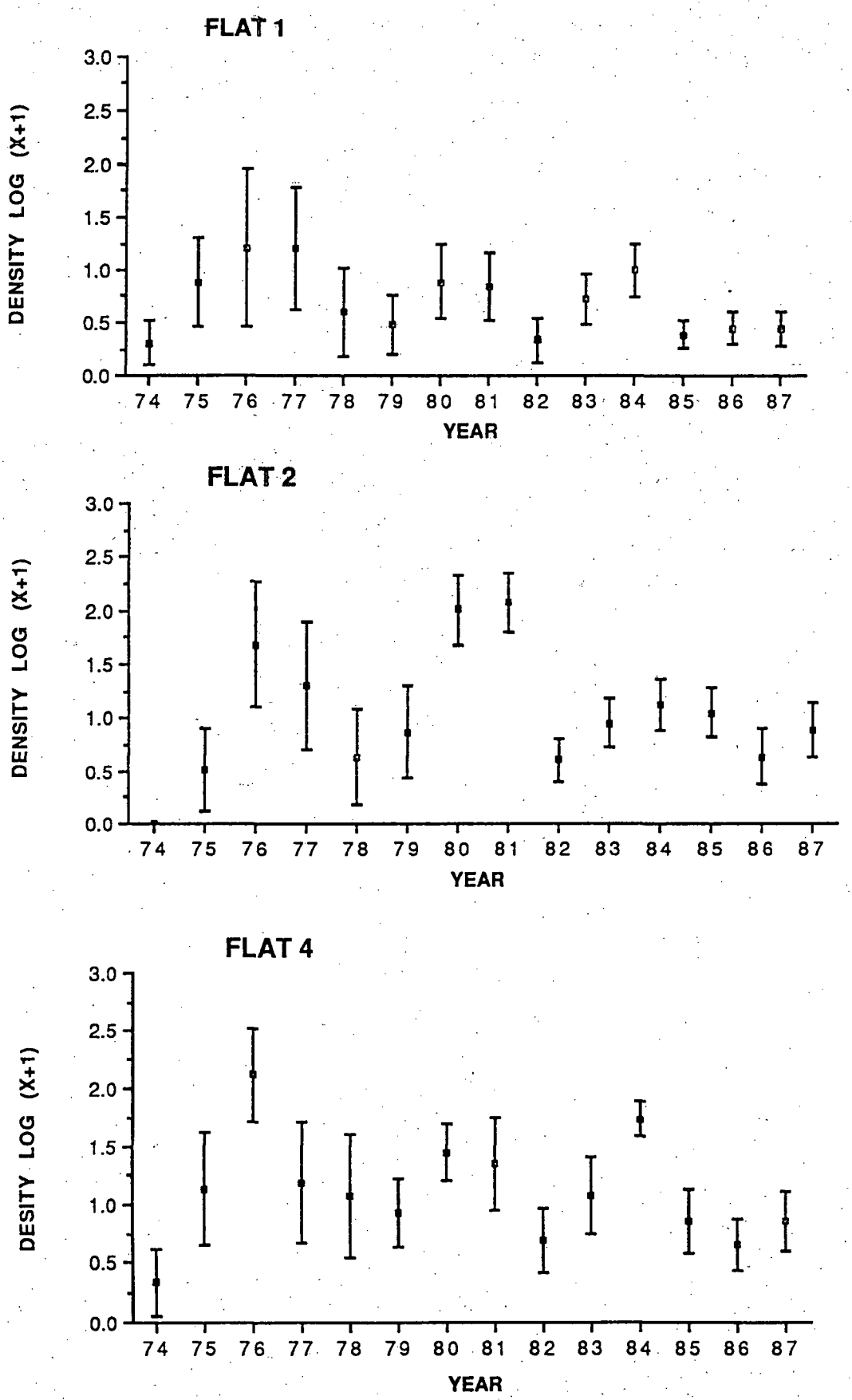


Figure 3.3.7-4. Annual mean density (number per square foot) and 95% confidence limits of young-of-the-year *Mya arenaria* (1-5 mm) at Hampton-Seabrook Harbor, 1974-1987. Seabrook Baseline Report, 1987.

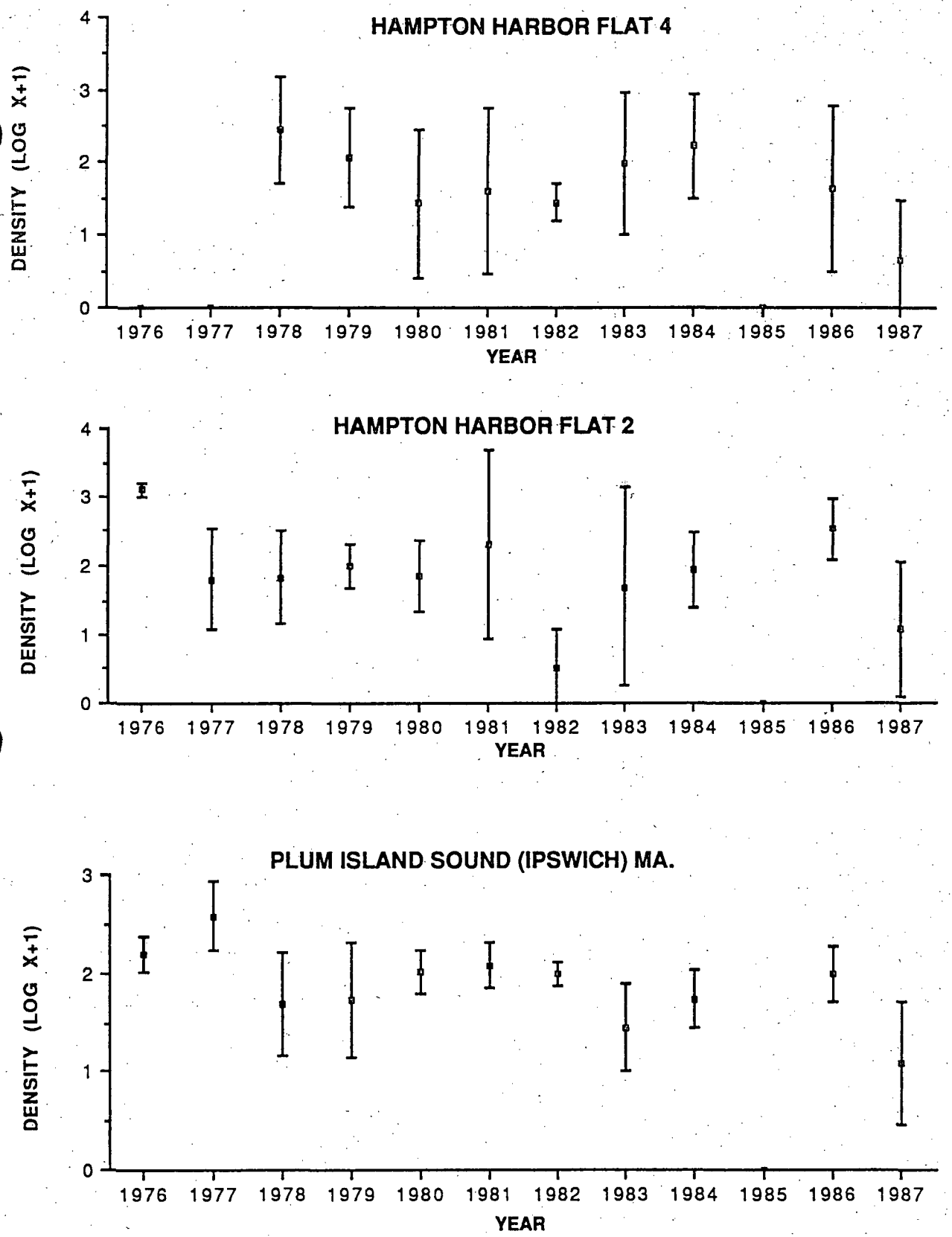


Figure 3.3.7-5. Mean and 95% confidence limits of *Mya arenaria* spat (shell length ≤ 12 mm) densities (No./ft^2) at two northern New England estuaries, 1976 through 1984 and 1986 through 1987. Seabrook Baseline Report, 1987.

2 and Flat 4 (NAI 1982b, NAI 1983a). Juveniles (26-50 mm) age two to four years old, were relatively scarce from 1976 to 1978, but became abundant from 1979 to 1981 at all three flats. This pattern reflects the growth of the large sets of 1976 and 1977. The large spat sets of 1980 and 1981 did not result in increased densities of juveniles. High adult densities (>50 mm) were recorded in 1980 and have declined from 1983 through 1987 (Figures 3.3.7-6, 3.3.7-7 and 3.3.7-8). The 1980-1982 adult densities reflected the success of the 1976 and 1977 year classes; subsequent decline resulted from the harvesting of these clams (see below) and the failure to recruit the spatfalls of 1980, 1981 and 1984 into the juvenile and adult size clams. The New Hampshire Fish and Game Department seeded Flat 5 with 45,000 juvenile clams in late June of 1987, but during a qualitative survey of Flat 5 in October, no clams from the seeding experiment were found.

In order to better understand the patterns of population structure, growth and survivorship of the one-year and older clams, the size-class density distributions were separated into year classes utilizing NORMSEP (Hasselblad 1966). This method attempts to fit normal distribution curves to complex frequency distributions so that the mean and standard deviation of each cohort can be estimated. A chi square test was also performed to test the difference between actual and predicted distributions. The resulting mean sizes and density for each year class for each year (1976-1984) were utilized to provide estimates of survivorship (density remaining) and growth. The relative paucity of juvenile and adult clams, 1985 through 1987, did not warrant a NORMSEP analysis for those years.

The 1976 year class (Figure 3.3.7-3) was most easily traceable as few juvenile and adult clams existed when it entered the population. By November 1976, the clams reached a mean size of 2.5 mm. It took four years until these clams began appearing as harvestable adults in 1980, with a mean size of 48 mm. Subsequent year classes experienced similar growth patterns, but older years were more difficult to separate successfully.

An examination of survivorship from the NORMSEP analysis of size density data, indicated that the 1980 to 1982 year classes experienced far

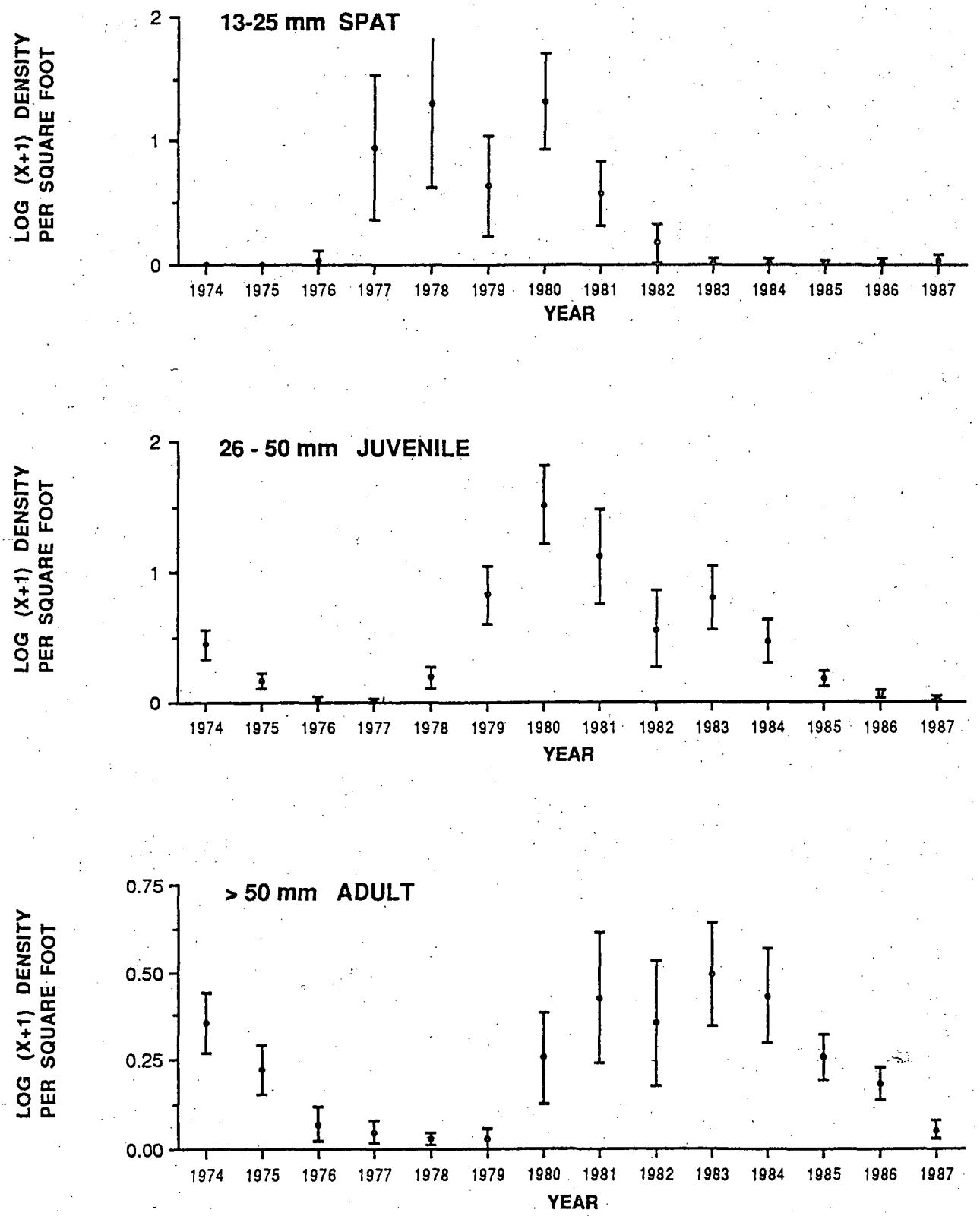


Figure 3.3.7-6. Means and 95% confidence limits of spat, juvenile and adult log (x+1) densities at Flat 1, Hampton-Seabrook Harbor, 1974 through 1987. Seabrook Baseline Report, 1987.

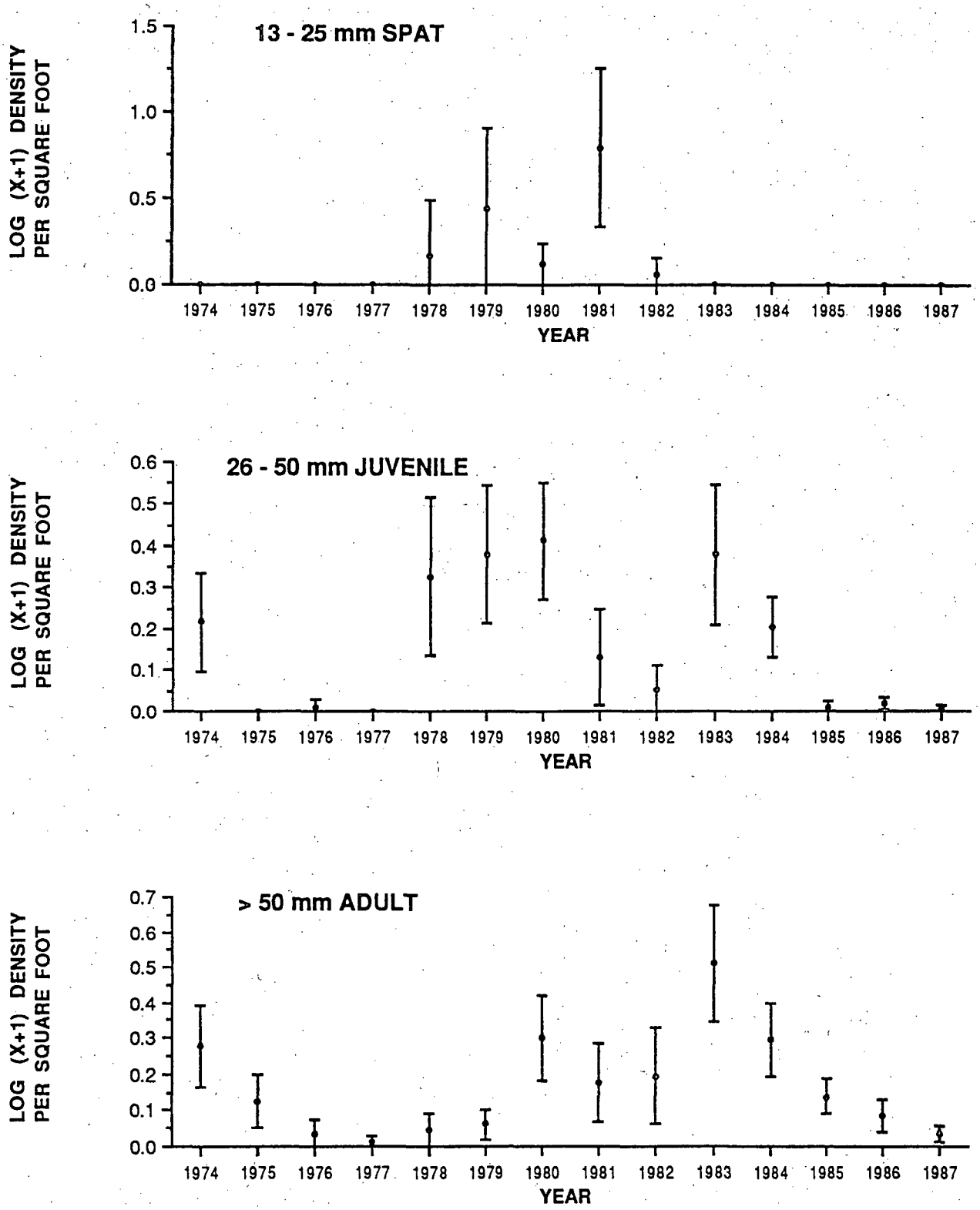


Figure 3.3.7-7. Means and 95% confidence limits of spat, juvenile and adult log (x+1) densities at Flat 2, Hampton-Seabrook Harbor, 1974 through 1987. Seabrook Baseline Report, 1987.

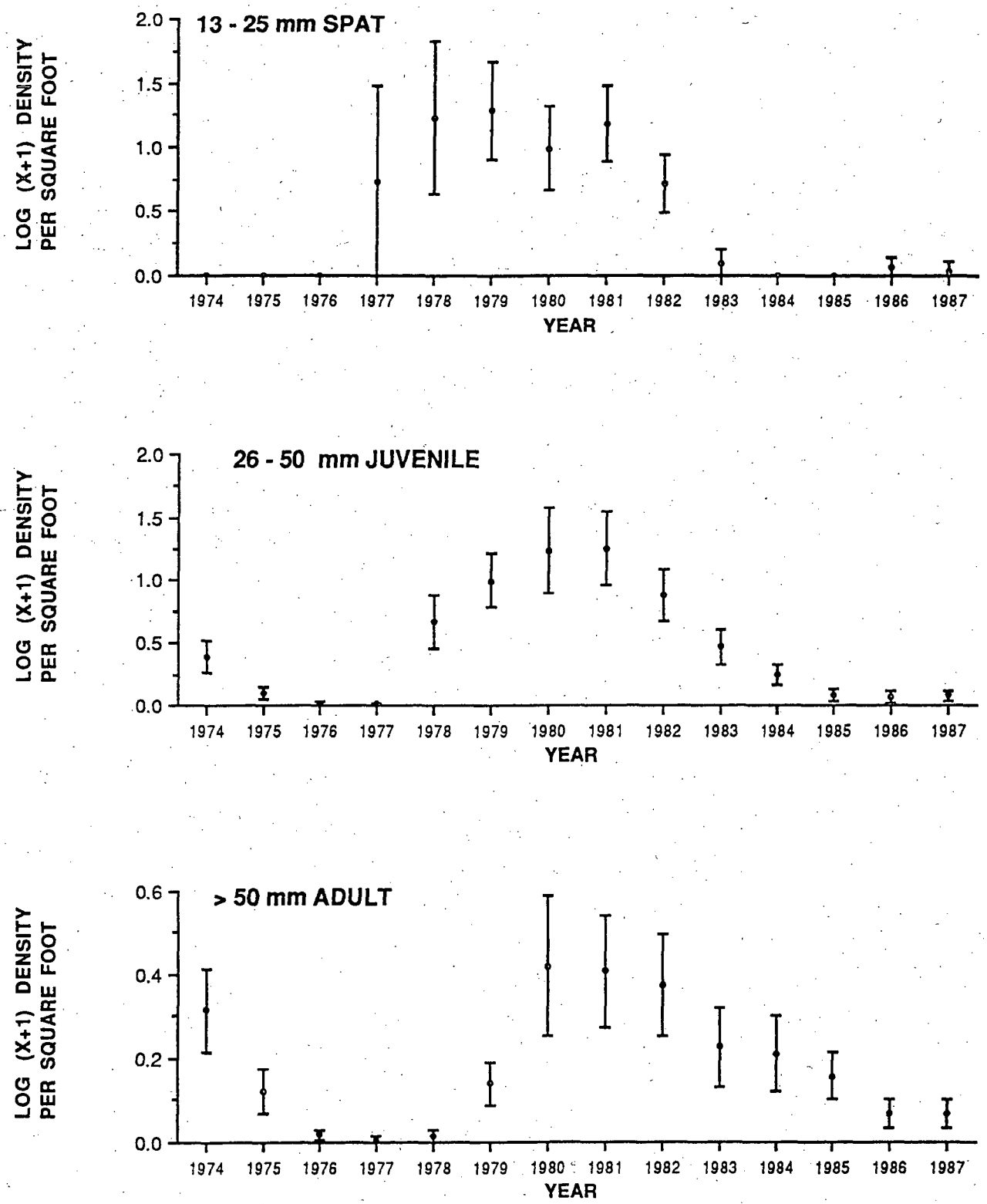


Figure 3.3.7-8. Means and 95% confidence limits of spat, juvenile and adult log (x+1) densities at Flat 4, Hampton-Seabrook Harbor, 1974 through 1987. Seabrook Baseline Report, 1987.

greater mortality during the first two years than was observed for the 1976 year class. The higher mortality for year classes 1980 through 1986 (Figure 3.3.7-3) corresponded to an increase in density of its main predator, the green crab, during this period. Each year class during 1982-1986 appears to have been virtually eliminated by its second year.

Predation and Harvestable Clam Resources

Clams in Hampton Harbor are subject to predation pressure from two major sources: green crab consumption of spat (1-25 mm) and juvenile (26-50 mm) *Mya*, and humans who dig adult *Mya* (>50 mm) but also cause mortality to smaller clams by disturbing the flat. Sea gulls may also be major predators, as they are commonly observed picking over clamdigger excavations for edible invertebrates, including spat and juvenile clams. The green crab (*Carcinus maenas*) is a major predator of *Mya*, with clams being a major source of food particularly in the fall months (Ropes 1969). Green crab catches in Hampton Harbor have shown a substantial increase in abundance since 1980 (Table 3.3.7-1). Maximum abundances usually occurred in the fall, with the highest number recorded in 1984. Green crab numbers, from 1983 to 1987 appear to have stabilized somewhat at higher densities, with fall abundances fluctuating between 69.3 (1985) and 123.9 (1984) CPUE (catch per unit effort).

Green crabs generally feed more actively at temperatures above 9°C, and females are more active predators on *Mya* than males (Ropes 1969). The presence of more females in the catch in Hampton Harbor from July through September (1981-1987) indicated greater predation pressure for the newly-settled spat in the estuary. Continued high catches of males and females occurred until late November or December when temperatures declined below 7°C and activity decreased.

Welch (1969) and Dow (1972) have shown that green crab abundances increased markedly when winter temperatures were warmer. Green crab CPUE by season 1978-1987, showed an increase from fall of 1980 through 1984 and again in 1986. The increase in green crab abundance corresponded to elevated winter minimum temperatures observed from 1981-1984 (Figure 3.3.7-9); a

TABLE 3.3.7-1. AVERAGE CATCH PER UNIT EFFORT[a], PERCENT FEMALE, AND PERCENT GRAVID FEMALES FOR *CARCINUS MAENAS* COLLECTED AT ESTUARINE STATIONS FROM 1977-1987. SEABROOK BASELINE REPORT, 1987.

YEAR	SAMPLE PERIOD	AVERAGE CATCH PER UNIT EFFORT	PERCENT FEMALE	FECUNDITY (% GRAVID FEMALES)
1977	Oct-Dec	17.5	47.4	0.3
1978	Apr-Jun	7.5	76.7	7.0
	Jul-Sep	8.6	56.5	3.2
	Oct-Dec	7.2	56.5	0.5
1979	Apr-Jun	6.4	50.0	6.0
	Jul-Sep	6.0	60.0	0.6
	Oct-Dec	22.1	60.0	0.0
1980	Apr-Jun	6.7	52.4	8.4
	Jul-Sep	15.8	50.0	2.3
	Oct-Dec	53.1	66.7	0.0
1981	Apr-Jun	39.5	60.0	4.6
	Jul-Sep	34.0	67.7	1.6
	Oct-Dec	39.4	54.5	0.0
1982	Apr-Jun	37.4	61.5	4.1
	Jul-Sep	44.6	80.0	0.8
	Oct-Dec	56.1	66.7	0.0
1983	Apr-Jun	47.5	61.5	3.7
	Jul-Sep	61.8	66.7	1.0
	Oct-Dec	117.4	61.5	<0.1
1984	Apr-Jun	84.7	54.5	2.4
	Jul-Sep	80.6	73.0	1.2
	Oct-Dec	123.9	58.3	0.0
1985	Apr-Jun	58.3	56.5	3.9
	Jul-Sep	54.8	68.8	1.0
	Oct-Dec	69.3	58.3	0.0
1986	Apr-Jun	52.6	71.4	6.6
	Jul-Sep	53.5	73.7	0.7
	Oct-Dec	113.5	56.5	<0.1
1987	Apr-Jun	62.0	68.2	6.5
	Jul-Sep	76.0	73.9	1.1
	Oct-Dec	70.8	66.4	0.0

[a]Number of *C. maenas* per trap per day, eight "box" traps fishing for 24 hours, twice per month.

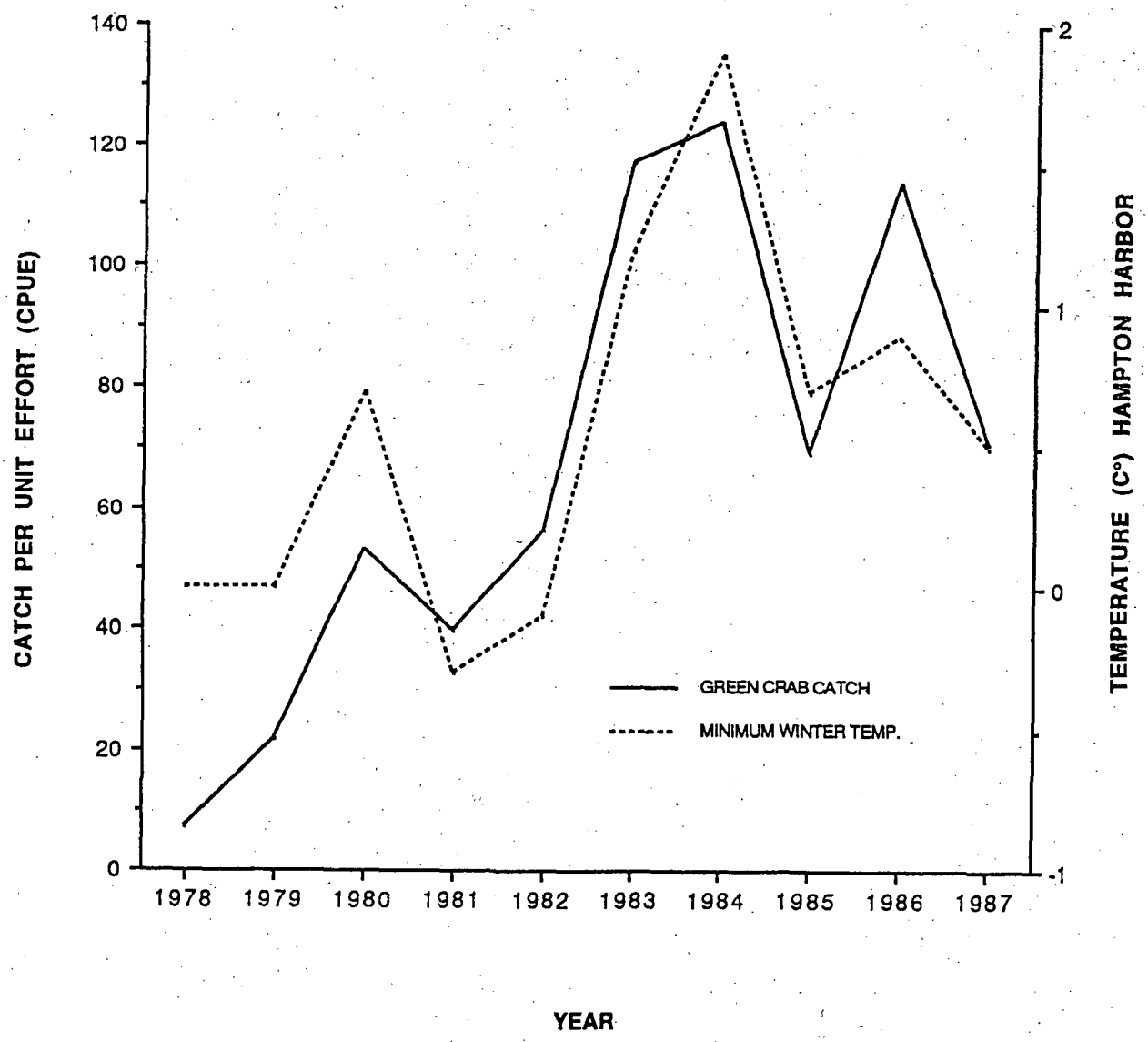


Figure 3.3.7-9. Fall mean catch per unit effort for green crabs (*Carcinus maenas*) in Hampton-Seabrook Harbor and its relationship to minimum winter temperature, 1978-1987. Seabrook Baseline Report, 1987.

significant correlation ($\alpha = 0.05$) was obtained between fall abundances (time of peak activity), 1980-1987, and the previous winter minimum temperature. Close examination of the yearly data indicated the type of response proposed by Welch (1969). Following the winter of 1979-1980 when the temperature minimum was high, the fall crab population showed a marked increase (Figure 3.3.7-9). A much lower minimum temperature in winter 1980-1981, and a somewhat higher one in 1981-1982, resulted in a noticeable decrease in crab density in the fall of 1981 followed by a moderate increase in fall 1982. Higher minimum winter temperatures in 1983, 1984 and 1986 were associated with a marked rise in fall green crab catches. In 1987 green crab CPUE decreased following a decrease in minimum winter temperature, the lowest since winter of 1981.

The increase in green crab CPUE, and associated predation in the years 1980-1987 can be observed in examination of the 1981-1987 *Mya* year classes, as estimated by densities of young-of-the-year clams (Figure 3.3.7-4). The 1981 year class, which was relatively large, showed decreased survivorship and substantially-reduced first and second year clams (Figure 3.3.7-3). In 1982, settlement was the poorest since 1974 (Figure 3.3.7-4) and the subsequent mortality, probably related to green crab predation, has virtually eliminated this year class (Figure 3.3.7-3). Recruitment into Hampton Harbor clam populations, 1983-1987, has been very low, corresponding to high green crab abundances and low spat recruitment.

Welch and Churchill (1983) reported the increase in near-surface temperature at Boothbay Harbor, Maine, in the early 1970s along with an increase in green crab abundance. Although no green crab or temperature data are available for Hampton Harbor for this time period, catches from Kittery, Maine, showed a maximum crab occurrence (1973- 1975) corresponding to the reduction in younger year classes observed in Hampton Harbor prior to the 1976 settlement. Subsequent reductions in the reported sea surface temperature and related decreases in green crab abundance and predation along the southern Maine coast (Welch and Churchill 1983) may have also occurred in Hampton Harbor, which may have contributed to the survivorship of the strong 1976 and 1977 year classes.

Recreational clam digging on the Hampton Harbor flats is the most significant source of mortality for clams of >45 mm, but also is a source of mortality to spat and juvenile clams due to disturbance. Census figures indicate digging activity tripled from 1980 to 1981 (Table 3.3.7-2). This level of effort was maintained through 1982 before undergoing successive reductions 1983-1985. Digging activity increased slightly in 1986 over 1985 levels, but remained lower than in previous years, 1982-1984. Digging activity in 1987 was the lowest observed in the study 1980-1987.

The changing pattern of clam abundance on the Hampton Harbor flats is reflected in the number of licenses issued by the State of New Hampshire (Figure 3.3.7-10). Changes in the number of licenses lag the changes in standing crop one to two years illustrating a typical predator-prey cycle. Diggers shifted some of their activity in late 1983 and 1984 from Flat 4 to Flat 2 (Table 3.3.7-2), probably in response to declining resources overall, and particularly at the most accessible area, Flat 4. As clam densities continued to sharply decline in 1985 and 1986 digger activity again shifted, from Flat 2 and Flat 4 to Flat 1, possibly due to slightly greater densities at Flat 1. In 1987, nearly 90% of digging activity was confined to Flat 1 and Flat 4 which had the highest remaining standing crop. Flat 2, Flat 3 and Flat 5 accounted for the remaining digging activity.

Mortality to younger clams (<50 mm) from digging is dependent on the depth of burial, the size of the clams, and the time of the year (Glude 1954). The highest survival is inversely proportional to the depth of burial; the deepest burial tested (13 cm) resulted in the lowest survival. Clams 9-20 mm suffered the greatest mortality (51%) with 36-50 mm clams having only 31.5% mortality. No data has been collected on the amount of disturbance caused by digging on the Hampton Harbor flats; however, Flat 1 and Flat 4, with the highest usage by clammers, would likely have suffered substantial mortality to young clams due to digging.

Sarcomatous neoplasia, a lethal form of cancer in *Mya arenaria*, has been observed in Hampton Harbor *Mya* populations (Hillman 1986, 1987). A

TABLE 3.3.7-2. ESTIMATED DISTRIBUTION (PERCENT OF TOTAL) OF CLAM DIGGERS BY FLAT AT HAMPTON HARBOR, SPRING 1980 THROUGH FALL 1987. SEABROOK BASELINE REPORT, 1987.

SEASON	FLATS 1	2	3	4	5	ESTIMATED[a] TOTAL DIGGER TRIPS	ESTIMATED[b] NUMBER OF BUSHELS HARVESTED
Spring[c] 1980	12.5	17.9	1.7	52.5	15.4	3,860	1,200
Fall[d] 1980	11.3	18.4	3.3	55.1	11.8	2,700[e]	840
Spring 1981	9.7	15.6	0.8	65.9	7.9	12,500	3,900
Fall 1981	13.9	12.9	0.2	63.8	9.1	7,060	2,200
Spring 1982	12.6	13.0	0.8	67.1	6.4	10,800	3,400
Fall 1982	26.6	8.5	0.7	60.7	3.5	9,300	2,900
Spring 1983	30.7	7.1	1.3	58.6	2.2	7,700	2,400
Fall 1983	29.4	14.7	0.5	54.7	0.7	6,690	2,100
Spring 1984	22.1	26.4	0.6	49.9	1.0	6,200	1,950
Fall 1984	26.9	28.9	0.3	43.2	0.8	5,850	1,830
Spring 1985	51.6	11.3	0.4	36.1	0.8	6,940	2,169
Fall 1985	63.1	5.0	0.4	31.5	0.0	2,873	898
Spring 1986	59.3	6.4	0.3	33.4	0.6	6,210	1,941
Fall 1986	58.1	6.4	0.4	34.7	0.4	4,713	1,473
Spring 1987	39.4	8.1	1.5	49.0	2.0	1,763	551
Fall 1987	38.8	6.9	0.8	49.8	3.8	1,541	482

[a]Based primarily on Friday head counts at time of low slack water; most Saturday counts are assumed from observed Fri:Sat ratio (n=14 pairs) of 2.24 ± .96; seasonal totals have approximate error of ± 18%
[b]Assumes each clammer takes 10 quarts per trip; 1 bushel = 32 quarts or 3.2 clammer trips
[c]Includes the period 1 January through weekend before Memorial Day
[d]Includes the weekend after Labor Day through 31 December
[e]Based on average Spring:Fall ratio for 1981 and 1982 (0.68 ± .02)

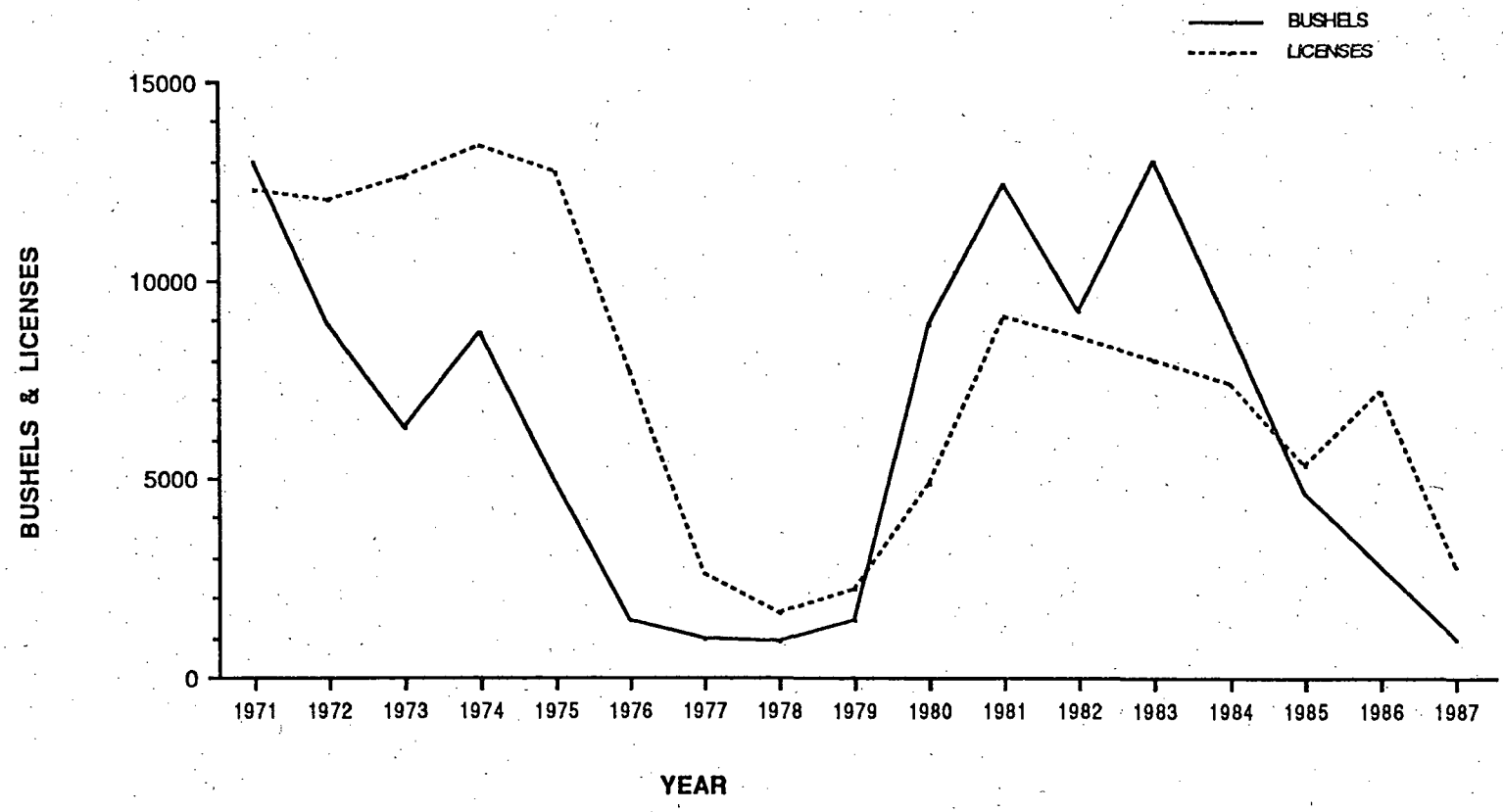


Figure 3.3.7-10. Number of adult clam licenses issued and the adult clam standing crop (bushels), Hampton-Seabrook Harbor, 1971-1987. Seabrook Baseline Report, 1987.

virus, similar to the B-type retroviruses, is known to initiate the disease in *Mya* (Oprandy *et al.* 1981). Although the infection has been observed in regions of relatively-pristine waters, the rate of infection may also be enhanced by pollution-mediated deterioration of the environment (Reinisch *et al.* 1984). The infection rate in some *Mya* populations may reach 100 percent with 100 percent mortality of infected clams (Farley *et al.* 1986). The incidence of sarcomatous neoplasms in Hampton Harbor *Mya* populations was observed in October 1986 and February 1987 (Hillman 1986, 1987). Neoplastic infections were more prevalant in February, reaching 6% at Flat 1 and 27% at Flat 2. Infections were absent from Flat 4. Assuming 100 percent mortality of infected clams (Farley *et al.* 1986), Flats 1 and 2 may suffer significant disease-related reductions in clam production. However, since no historical data is available on the incidence of neoplasms in Hampton Harbor clam population, it is not known if current infection rates are typical or indictative of an increasing trend. In 1987 clam flat surveys did indicate, however, that juvenile and adult densities fell by over 50% at Flat 1 and Flat 2 while Flat 4 remained unchanged.

Harvestable Clams

The patterns discussed above have resulted in substantial changes in the number of harvestable clams on the Hampton flats (Table 3.3.7-3). The greatest adult standing stock in Hampton Harbor was reported by Ayer (1968) for 1967. Subsequent years indicated a gradual decline in available adult clams to a low of six bushels/acre in 1977 and 1978. In 1976, the State of New Hampshire applied more stringent clamming regulations, closing the flats for the summer (Memorial Day to Labor Day) and eliminating digging on Sundays and holidays. Survival of the 1976 year class made a substantial increase in the standing crop in 1980, four years after settlement. The number of harvestable clams continued to increase in 1981 as more of the 1976 and part of the 1977 year class became harvestable.

TABLE 3.3.7-3. SUMMARY OF STANDING CROP ESTIMATES OF ADULT[a] *MYA ARENARIA* IN HAMPTON HARBOR, 1967 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

DATE	ESTIMATED NUMBER OF BUSHELS PER ACRE	TOTAL ESTIMATED NUMBER OF OF BUSHELS
November 1967	152[b]	23,400[b]
July 1969	103	15,840
November 1971	94	13,020
November 1972	58	8,920
November 1973	41	6,310
November 1974	56	8,690
November 1975	29	4,945
November 1976	11	1,350
November 1977	6	1,060
November 1978	6	940
November 1979	9	1,400
October 1980	54	8,890
October 1981	75	12,400
October 1982	55	9,200
October 1983	78	13,020
October 1984	54	8,821
November 1985	39	4,615
October 1986	23	2,793
October 1987	8	976

[a]Shell length >50 mm
[b]From Ayer (1968)

Through 1984, the number of harvestable bushels had not decreased substantially. However, in 1985 through 1987, the harvestable standing crop dropped precipitously (Table 3.3.7-3), reflecting poor recruitment observed in 1980-1984, increased predation by green crabs, and continued human disturbance. Since recruitment has remained low through 1987, the trend of decreasing adult standing crop will likely continue for at least another three to four years, assuming a successful spatfall in 1988.

The distribution of clams by flat has changed since 1980 when the 1976 year class became harvestable (Tables 3.3.7-2, 3.3.7-4). Flat 1 showed a continuous increase in its percentage of adult clams through 1984, while Flat 4 showed a steady decrease. In 1985 the percentage of harvestable clams decreased on Flat 1 and increased on Flat 4, followed by increases on Flats 1 and 2 and a decrease on Flat 4 during 1986 (Table 3.3.7-2). In 1987, the percentage of harvestable clams increased at Flat 4, while decreasing at Flat 1 and Flat 2, reflecting the stabilization of clam populations at Flat 4 at low levels, while populations on Flat 1 and Flat 2 continued to decline.

TABLE 3.3.7-4. DISTRIBUTION (PERCENT OF TOTAL STANDING CROP) OF HARVESTABLE CLAMS BY FLAT AT HAMPTON HARBOR, 1979 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

YEAR	FLATS				
	1	2	3	4	5
1979	33.3	6.2	2.2	55.7	2.5
1980	45.1	10.5	1.0	39.5	3.9
1981	53.0	7.3	1.5	34.4	3.7
1982	52.2	7.0	1.0	38.4	1.3
1983	62.9	25.6	0.5	10.5	0.5
1984	72.0	13.6	1.9	11.5	0.9
1985	60.2	14.6	NS	25.1	NS
1986	63.0	21.9	NS	15.1	NS
1987	40.0	15.9	NS	44.2	NS

3.3.8 Benthos Appendix Tables

APPENDIX TABLE 3.3.1-1. MEAN MONTHLY SEAWATER SURFACE TEMPERATURE (°C) AND SALINITY (ppt) TAKEN IN BROWN'S RIVER AND HAMPTON HARBOR, MAY 1979 - DECEMBER 1987. SEABROOK BASELINE REPORT, 1987.

	BROWN'S RIVER				HAMPTON HARBOR			
	HIGH-TIDE		LOW-TIDE		HIGH-TIDE		LOW-TIDE	
TEMPERATURE	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
JAN	1.0	1.26	0.9	0.80	2.5	0.91	1.0	0.69
FEB	1.2	0.86	1.9	1.16	2.3	0.89	1.7	0.68
MAR	3.7	0.88	4.7	0.52	3.7	0.61	4.1	0.77
APR	7.1	0.77	9.8	0.77	6.3	0.87	8.1	0.68
MAY	13.2	1.81	14.7	0.71	10.1	0.58	12.8	0.61
JUN	15.8	0.97	19.2	1.14	13.4	0.74	16.4	0.82
JUL	18.0	0.99	21.4	0.95	15.8	0.84	18.4	0.84
AUG	18.8	1.05	20.8	1.42	16.8	0.85	18.6	0.97
SEP	16.0	0.89	18.0	1.11	14.6	0.97	16.2	0.91
OCT	12.2	1.01	12.3	1.17	12.3	0.71	12.2	0.80
NOV	8.2	0.87	7.3	1.58	9.1	0.76	8.3	1.11
DEC	4.8	1.23	2.9	0.61	5.5	0.78	3.8	0.82

	BROWN'S RIVER				HAMPTON HARBOR			
	HIGH-TIDE		LOW-TIDE		HIGH-TIDE		LOW-TIDE	
SALINITY	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
JAN	31.5	1.09	24.0	2.76	32.1	0.67	28.4	2.02
FEB	29.4	2.70	19.5	4.11	31.6	0.76	27.5	2.93
MAR	28.7	2.02	17.5	3.86	31.1	0.98	24.9	2.41
APR	26.4	3.24	17.5	4.56	30.0	1.84	24.1	3.82
MAY	29.0	1.68	20.6	3.05	30.0	1.07	26.8	1.89
JUN	28.8	1.86	21.2	3.36	30.3	1.06	27.4	2.39
JUL	30.3	1.03	24.1	1.91	31.0	0.56	28.9	0.81
AUG	30.5	0.43	25.3	1.58	31.3	0.43	29.8	0.62
SEP	30.7	1.02	24.8	2.56	31.5	0.31	29.9	0.72
OCT	30.4	0.87	23.6	1.48	31.6	0.31	29.3	0.75
NOV	30.1	1.61	21.1	3.29	31.9	0.40	28.3	1.51
DEC	30.3	2.06	20.1	3.96	31.7	0.71	27.5	2.44

APPENDIX TABLE 3.3.2-1. MACROALGAE SPECIES RECORDED IN GENERAL COLLECTIONS FROM BENTHIC STATIONS SAMPLED FROM 1978 TO 1987 (a,b,e). SEABROOK BASELINE REPORT, 1987.

SPECIES	INTERTIDAL				SUBTIDAL							
	1		5									
	MSL	MLW	MSL	MLW	17	35	16	19	31	13	4	34
Chlorophyta												
Acrochaete viridis	X[c]											
Blidingia minima	X	X	X		X							
Bryopsis plumosa	X[d]											
Chaetomorpha sp.		X		X	X	X		X	X			
Chaetomorpha aerea		X										
Chaetomorpha brachygona	X[d]	X	X	X	X	X		X	X		X	
Chaetomorpha linum	X	X	X	X	X	X	X	X	X		X	X
Chaetomorpha melagonium	X	X	X[d]	X	X	X	X	X	X			X
Chaetomorpha picquotiana		X	X	X	X	X	X	X	X	X	X	
Cladophora sericea	X	X	X	X				X				
Codiolum petrocelidis		X										
Enteromorpha sp.	X	X[d]		X	X							
Enteromorpha intestinalis	X	X		X								
Enteromorpha linza	X			X	X							
Enteromorpha prolifera	X	X			X			X			X	
Monostroma grevillei	X	X	X	X	X					X		
Monostroma pulchrum	X	X	X	X								
Pseudendoclonium submarinum		X										
Rhizoclonium tortuosum	X	X	X	X	X	X	X	X	X	X		
Spongomorpha sp.										X		
Spongomorpha arcta	X	X		X								
Spongomorpha spinescens	X	X	X	X		X						
Ulothrix flacca	X											
Ulva lactuca	X	X		X	X	X	X	X	X			X
Ulvaria obscura[f]	X[d]	X		X	X	X			X			
Ulvaria oxysperma[f]		X		X								X
Urospora penicilliformis	X	X[c]	X	X								
Urospora wormskjoldii		X[c]										
Phaeophyta												
Agarum cribrosum				X	X	X	X	X	X	X	X	X
Alaria esculenta	X	X			X	X			X			
Ascophyllum nodosum	X	X	X	X								
Chordaria flagelliformis		X	X[d]	X								
Desmarestia aculeata		X		X	X	X	X	X	X			
Desmarestia viridis		X	X[d]	X	X	X		X	X			

(continued)

APPENDIX TABLE 3.3.2-1. (Continued)

SPECIES	INTERTIDAL				SUBTIDAL							
	1		5									
	MSL	MLW	MSL	MLW	17	35	16	19	31	13	4	34
Phaeophyta (cont)												
Ectocarpus fasciculatus	X	X		X	X	X		X				
Ectocarpus siliculosus	X	X	X	X	X	X				X		
Elachista fucicola	X	X	X	X	X							
Fucus sp.	X	X	X[d]	X[d]								
Fucus distichus	X											
Fucus distichus ssp. *distichus*	X											
Fucus distichus ssp. *edentatus*	X	X	X	X								
Fucus distichus ssp. *evanescens*	X	X		X								
Fucus vesiculosus	X	X	X	X								
Fucus vesiculosus v. spiralis			X									
Giffordia granulosa				X								
Laminaria sp.	X				X			X			X	
Laminaria digitata	X	X	X[d]	X	X	X	X	X	X	X		
Laminaria saccharina	X	X	X[d]	X	X	X	X	X	X	X	X	X
Leathesia difformis	X	X		X								
Petalonia fascia	X	X	X	X	X				X			
Petalonia zosterifolia				X								
Petroderma maculiforme	X[d]	X[d]										
Pilayella littoralis	X	X	X	X								
Ralfsia verrucosa			X	X								
Saccorhiza dermatodea					X				X			
Scytosiphon lomentaria	X	X	X	X								
Sorapion kjellmanii			X									
Sphacelaria cirrosa				X	X	X		X	X			
Sphacelaria plumosa		X		X	X	X						
Sphacelaria radicans	X	X		X					X			
Spongonema tomentosum	X	X	X	X								
Rhodophyta												
Ahnfeltia plicata	X	X	X	X	X	X		X	X			
Antithamnionella floccosa		X		X	X	X	X	X	X	X	X	X
Audouinella sp.	X			X				X				
Audouinella purpurea	X		X									
Bangia atropurpurea	X	X[c]		X								
Bonnemaisonia hamifera		X		X	X	X			X			

(continued)

APPENDIX TABLE 3.3.2-1. (Continued)

SPECIES	INTERTIDAL 1 MSL	INTERTIDAL 1 MLW	INTERTIDAL 5 MSL	INTERTIDAL 5 MLW	SUBTIDAL 17	SUBTIDAL 35	SUBTIDAL 16	SUBTIDAL 19	SUBTIDAL 31	SUBTIDAL 13	SUBTIDAL 4	SUBTIDAL 34
Rhodophyta (cont)												
Callithamnion tetragonum	X[d]	X		X	X	X		X		X		
Callophyllis cristata		X	X[d]	X	X	X	X	X	X	X	X	X
Ceramium deslongchampii v. hooperi		X									X	
Ceramium rubrum	X	X	X	X	X	X	X	X	X	X	X	X
Ceratocolax hartzii		X			X	X	X	X	X	X	X	X
Chondrus crispus	X	X	X	X	X	X	X	X	X	X	X	X
Choreocolax polysiphoniae	X	X	X	X								
Clathromorphum circumscriptum		X	X[d]	X	X	X	X	X	X	X		X
Clathromorphum compactum											X	
Colaconema secundata	X	X										
Corallina officinalis	X	X	X	X	X	X	X	X	X	X	X	X
Cystoclonium purpureum v. cirrhosum	X	X	X	X	X	X	X	X	X	X	X	X
Dermatolithon pustulatum		X		X	X	X	X	X	X	X	X	X
Devaleraea ramentacea			X									
Dumontia contorta		X	X	X	X			X			X	
Erythrotrichia carnea		X		X								
Gloiosphonia capillaris		X[d]	X[d]	X[d]								
Mastocarpus stellatus[f]	X	X	X	X	X							
Gymnogongrus crenulatus			X[d]	X	X	X	X	X	X			
Halosaccion ramentaceum			X[d]	X[d]								
Hildenbrandia rubra			X	X[d]	X			X				
Leptophytum foecundum					X	X	X	X	X	X	X	X
Leptophytum laeve					X	X	X	X	X	X	X	X
Lithophyllum corallinae				X					X			
Lithothamnion glaciale		X		X	X	X	X	X	X	X	X	X
Melobesia lejolisii					X	X	X	X	X	X	X	X
Membranoptera alata		X		X	X	X	X	X	X	X	X	X
Palmaria palmata	X	X	X[d]	X	X	X			X		X	
Petrocelis cruenta	X	X	X	X								
Petroderma maculiforme				X								
Peyssonnelia rosenvingii					X	X	X	X	X		X	
Phycodrys rubens		X	X[d]	X	X	X	X	X	X	X	X	X
Phyllophora sp.		X		X	X	X	X	X	X	X	X	X
Phyllophora pseudoceranoides				X	X	X	X	X	X	X	X	X
Phyllophora traillii		X	X									
Phyllophora truncata				X	X	X	X	X	X	X	X	X
Phymatolithon sp.						X			X			X

(continued)

APPENDIX TABLE 3.3.2-1. (Continued)

SPECIES	INTERTIDAL 1 MSL	INTERTIDAL 1 MLW	INTERTIDAL 5 MSL	INTERTIDAL 5 MLW	SUBTIDAL 17	SUBTIDAL 35	SUBTIDAL 16	SUBTIDAL 19	SUBTIDAL 31	SUBTIDAL 13	SUBTIDAL 4	SUBTIDAL 34
Rhodophyta (cont)												
Phymatolithon laevegatium					X	X	X	X	X	X	X	X
Phymatolithon lenormandii		X	X	X			X	X	X	X	X	X
Phymatolithon rugulosum								X	X		X	X
Plumaria elegans	X	X	X	X				X				
Polyides rotundus		X		X	X	X		X	X	X		
Polysiphonia denudata				X								
Polysiphonia flexicaulis	X[d]	X		X	X	X			X		X	
Polysiphonia harveyi	X[c]	X[c]	X	X	X	X						
Polysiphonia lanosa	X	X	X	X	X	X		X	X			X
Polysiphonia nigra	X			X	X				X			
Polysiphonia nigrescens		X		X	X	X		X	X	X		
Polysiphonia urceolata	X	X	X[d]	X	X	X	X	X	X	X	X	X
Porphyra leucosticta	X	X	X	X	X	X						
Porphyra miniata	X	X		X	X				X			
Porphyra umbilicalis	X	X		X	X				X	X		
Pseudolithoderma extensum						X						
Ptilota serrata		X		X	X	X	X	X	X	X	X	X
Rhododermis elegans										X		
Rhodomela confervoides	X[d]	X		X	X	X	X	X	X			
Rhodophyllis dichotoma				X	X	X	X	X		X	X	X
Rhodophysema elegans			X[d]		X		X	X	X			X
Scagelia corallina		X		X	X	X	X	X	X	X	X	X
Turnerella pennyi											X	X

[a]Collections from May, Aug, Nov except in 1982-84 when:
STA 4, 13, 16, 34 collected Aug. only
STA 1MLW, 5MLW, 17, 19, 31, 35 collected all months
[b]STA 1, 4, 13, 17, 19, 31 - 1978-1987; STA 4, 13 not sampled in 1985
STA 34 - 1979-1987, except 1985
STA 16 - 1980-1987, except 1985
STA 5MLW, 35 - 1982-1987
[c]Not collected in 1978-82 period, but recorded in earlier collections
[d]Collected in tide pools only.
[e]G. Robin South, 1986 and William Randolph Taylor, 1962 were used for taxonomic nomenclature and identification.
[f]Species name changes: *Mastocarpus stellatus* was *Gigartina stellata*
Ulvaria obscura was *Monostroma fuscum* var. blytii
Ulvaria oxysperma was *Monostroma oxyspermum*

APPENDIX TABLE 3.3.2-2. SPARSELY OCCURRING (< 5% frequency of occurrence) MACROALGAE TAXA IN AUGUST BENTHIC DESTRUCTIVE SAMPLES, 1978-1987. SEABROOK BASELINE REPORT, 1987.

Monostroma oxyspermum
Enteromorpha sp.
Enteromorpha intestinalis
Enteromorpha linza
Enteromorpha prolifera
Ectocarpus siliculosus
Giffordia granulosa
Sphacelaria cirrosa
Desmarestia viridis
Petalonia fascia
Scytosiphon lomentaria
Dumontia contorta
Ceramium deslongchampii
Plumaria elegans
Polysiphonia sp.
Polysiphonia denudata
Polysiphonia harveyi
Gigartinales
Entocladia viridis
Spongonema tomentosum

APPENDIX TABLE 3.3.2-3. A. PERCENT FREQUENCY OF PERENNIAL AND ANNUAL MACROALGAE SPECIES AND B. PERCENT COVER OF PERENNIAL MACROALGAE SPECIES PER 0.25 m^2 AT FIXED INTERTIDAL NON-DESTRUCTIVE SITES. SEABROOK BASELINE REPORT, 1987.

A. PERCENT FREQUENCY

		QUADRAT B (MSL) FUCOID LEDGE			QUADRAT C (MSL) BARE LEDGE			QUADRAT D (MLW)[d] CHONDRUS ZONE		
	YEAR	APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
PERENNIAL ALGAE										
Station 1										
Species										
Fucus spp.[a]	1982	100	100	88	31	31	44			
	1983	100	100	94	6	44	56			
	1984	100	88	69	81	88	94			
	1985	75	81	87	63	94	6	10	2	16
	1986	94	100	94	6	6	0	25	75	60
	1987	75	81	75	0	0	0	44	13	0
Chondrus crispus	1982[c]	0	0	0	0	0	0			
	1983	P[b]	0	2	0	0	0			
	1984	2	0	7	0	0	0			
	1985	0	8	1	0	0	0	21	27	47
	1986	8	2	1	0	0	0	45	20	36
	1987	0	0	3	0	0	0	20	37	53
Mastocarpus stellatus	1982[c]	0	0	0	0	0	0			
	1983	P[b]	6	9	0	0	0			
	1984	7	2	5	0	0	0			
	1985	3	8	21	0	0	0	21	65	47
	1986	12	19	9	0	0	0	47	65	48
	1987	9	0	17	0	0	0	47	71	32
Station 5										
Species										
Ascophyllum nodosum[a]	1982	0	0	0	0	0	0			
	1983	0	0	0	0	0	0			
	1984	0	0	0	0	0	0			
	1985	0	0	0	0	0	0	0	0	0
	1986	0	0	0	0	0	0	0	0	0
	1987	0	0	0	0	0	0	0	0	0

(continued)

APPENDIX TABLE 3.3.2-3. (Continued)

		A. PERCENT FREQUENCY								
		QUADRAT B (MSL) FUCOID LEDGE			QUADRAT C (MSL) BARE LEDGE			QUADRAT D (MLW)[d] CHONDRUS ZONE		
	YEAR	APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
PERENNIAL ALGAE										
Station 5										
Species										
Fucus spp.[a]	1982	62	69	31	12	12	6			
	1983	81	100	100	0	13	0			
	1984	100	100	94	0	13	63			
	1985	94	88	94	69	94	100	0	0	0
	1986	94	94	94	94	100	100	0	0	0
	1987	88	81	88	100	100	100	0	0	0
Chondrus crispus	1982[c]	0	0	0	0	0	0			
	1983	1	2	0	0	0	0			
	1984	1	0	0	0	0	0			
	1985	0	8	1	0	0	0	0	45	39
	1986	3	3	1	0	0	0	30	54	48
	1987	0	0	0	0	0	0	54	48	41
Mastocarpus stellatus	1982[c]	0	0	0	0	0	0			
	1983	5	2	4	0	0	0			
	1984	5	5	7	0	0	0			
	1985	8	4	8	0	0	0	0	51	43
	1986	4	2	11	0	0	0	49	41	44
	1987	15	13	19	0	0	0	53	56	56
Corallina officinalis	1982	0	0	0	0	0	0			
	1983	0	0	0	0	0	0			
	1984	0	0	0	0	0	0			
	1985	0	0	0	0	0	0	15	33	31
	1986	0	0	0	0	0	0	21	37	65
	1987	0	0	0	0	0	0	30	52	45

(continued)

APPENDIX TABLE 3.3.2-3. (Continued)

		A. PERCENT FREQUENCY								
		QUADRAT B (MSL) FUCOID LEDGE			QUADRAT C (MSL) BARE LEDGE			QUADRAT D (MLW)[d] CHONDRUS ZONE		
	YEAR	APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
ANNUAL ALGAE										
Station 1										
Species										
Porphyra sp.	1982	0	0	0	0	0	0			
	1983	P[b]	0	0	15	78	21			
	1984	3	9	1	8	43	1			
	1985	9	17	0	2	0	0	0	0	0
	1986	0	8	3	0	3	1	0	0	0
	1987	2	0.6	0	0.6	9	0	0	9	0
Spongomorpha sp.	1982	0	0	0	0	0	0			
	1983	0	0	0	0	0	0			
	1984	1	1	0	0	0	0			
	1985	5	0	0	0	0	0	27	0	0
	1986	21	0	0	0	0	0	0	0	0
	1987	1	0	0	0	0	0	2	0	0
Urospora pencilliformis/ Ulothrix flacca	1982	0	0	0	0	0	0			
	1983	P[b]	0	0	85	0	0			
	1984	0	0	0	99	0	0			
	1985	0	0	0	2	0	0	0	0	0
	1986	0	0	0	57	0	0	0	0	0
	1987	0	0	0	80	0	0	0	0	0
Station 5										
Species										
Bangia fuscopurpurea	1982	0	0	0	100	0	0			
	1983	0	0	0	25	0	0			
	1984	0	0	0	74	0	0			
	1985	0	0	0	24	0	0	0	0	0
	1986	0	0	0	75	0	0	0	0	0
	1987	0	0	0	0	0	0	0	0	0

(continued)

APPENDIX TABLE 3.3.2-3. (Continued)

		A. PERCENT FREQUENCY								
		QUADRAT B (MSL) FUCOID LEDGE			QUADRAT C (MSL) BARE LEDGE			QUADRAT D (MLW)[d] CHONDRUS ZONE		
	YEAR	APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Station 5										
Species										
Urospora pencilliformis/ Ulothrix flacca	1982	0	0	0	100	0	0			
	1983	0	0	0	75	0	0			
	1984	0	0	0	100	0	0			
	1985	0	0	0	91	0	0	0	0	0
	1986	5	0	0	71	0	0	0	0	0
	1987	0	0	0	33	0	0	0	0	0
Rhizoclonium sp.	1982	0	0	0	0	0	0			
	1983	0	0	0	0	0	0			
	1984	0	0	0	0	0	0			
	1985	0	0	0	0	0	0	0	0	0
	1986	0	0	0	0	0	0	0	14	0
	1987	0	0	0	0	0	0	2	2	1

(continued)

APPENDIX TABLE 3.3.2-3. (Continued)

		B. PERCENT COVER								
		QUADRAT B (MSL) FUCOID LEDGE			QUADRAT C (MSL) BARE LEDGE			QUADRAT D (MLW)[d] CHONDRUS ZONE		
	YEAR	APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Station 1										
Species										
Fucus spp.[e]	1982	92	99	25	5	5	1			
	1983	95	85	75	2	1	5			
	1984	75	95	36	4	4	40			
	1985	25	60	70	8	10	<1	38	13	13
	1986	85	100	85	<1	<1	0	13	69	38
	1987	98	90	95	0	0	0	30	15	18
Station 5										
Species										
Ascophyllum nodosum[e]	1982	20	15	5	0	0	0			
	1983	0	3	5	0	0	0			
	1984	3	0	0	0	0	0			
	1985	0	10	0	0	0	0	0	0	0
	1986	0	0	0	0	0	0	0	0	0
	1987	0	0	0	0	0	0	0	0	0
Fucus spp.[e]	1982	60	75	2	0	1	<1			
	1983	95	97	90	0	<1	0			
	1984	92	97	80	0	<1	<1			
	1985	95	89	94	<1	<1	15	0	0	0
	1986	60	65	95	15	20	40	0	0	0
	1987	75	100	95	12	20	30	0	0	0

[a]Percent frequency of fucoid algae is based on presence of holdfasts only

[b]Present; % frequency not recorded

[c]% frequency not recorded with similar method in 1982

[d]MLW quadrat initiated in 1985

[e]Percent cover of fucoid algae is based on whole plant.

APPENDIX TABLE 3.3.3-1. SPECIES USED IN DISCRIMINANT ANALYSIS OF BENTHIC MACROFAUNA.

Ampithoe rubricata
Balanus crenatus
Calliopius laeviusculus
Caprella sp.
Cancer sp.
Caulleriella sp.
Cerastoderma pinnulatum
Cingula aculeus
Dendrodoa sp.
Dodecaceria sp.
Eulalia viridis
Fabricia sabella
Gammarus oceanicus
Gammarellus angulosus
Golfingia sp.
Harmothoe imbricata
Hiatella sp.
Idotea phosphorea
Jaera marina
Jassa falcata
Lacuna vincta
Littorina littorea
Musculus niger
Nereis pelagica
Nucella lapillus
Ophiura robusta
Ophiura sp.
Sabellidae
Thelepus cincinnatus
Terebellidae
Tonicella marmorea
Velutina velutina

APPENDIX TABLE 3.3.4-1. NUMBER (MEAN PER TWO REPLICATES) OF SELECTED NON-COLONIAL SPECIES OCCURRING ON SHORT-TERM FOULING PANELS BY MONTH, STATION, AND YEAR. SEABROOK BASELINE REPORT, 1987.

SPECIES=ANOMIA SP.

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	1	0	0	0	1	0
19	1979	0	0	0	0	0	0	11	3	1	1	0	0	1
	1980	0	0	0	0	0	0	1	11	6	20	0	0	3
	1981		0	1	0	0	0	3	0	24	0	2	1	3
	1982	0	0	0	0	1	1	1	0	12	4	1	1	2
	1983	1	0	0	0	1	1	1	1	2	0	1	0	1
	1984	0	0	1	0	0	0	1	5	1	1	1	0	1
	1986							3	0	22	2	7	0	6
	1987	0	0	1	0	0	0	4	0	49	4	2	1	5
STA	1978	0		0	0	0	1	0	0	1	0	0	0	0
31	1979	0	0	0	0	0	0	6	26	1	2	0	0	3
	1980	0	0	0	0	0	0	3	1	9	10	2	0	2
	1981		0	1	0	1	1	3	48	3	0	1	1	5
	1982	0	0	0	0	0	1	0	2	3	3	1	0	1
	1983	0	1	0	0	0	0	0	1	1	1	17	0	2
	1984	0	0	0	0	0	0	0	5	0	0	1	0	0
	1986							6	0	43	7	1	0	9
	1987	0	0	1	0	0	0	2	0	23	7	1	0	3
STA	1978	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1979	0	0	0	0	0	0	0	21	0	1	0	0	2
	1980	0	0	0	0	0	0	1	5	17	2	1	1	2
	1981		0	0	0	0	0	0	4	6	2	0	0	1
	1982	0	0	0	0	0	0	1	4	9	5	0	0	2
	1983	0	0	0	0	0	0	0	0	0	0	2	0	0
	1984	0	0	0	0	0	1	0	0	0	0	0	0	0
	1986							1	1	8	10	1	0	3
	1987	2	0	0	0	0	0	6	3	57	1	2	0	6
STA	1982	0	1	1	0	0	0	0	1	4	2	1	0	1
34	1983	0	0	0	1	0	0	0	3	1	1	7	0	1
	1984	0	1	1	1	0	0	0	1	2	0	2	0	0
	1986							3	1	9	33	10	0	9
	1987	0	0	0	0	0	1	1	1	115	14	0	0	11

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=ASTERIDAE

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	0	0	0	0	0	0
19	1979	0	0	0	0	0	0	1	1	0	0	0	0	0
	1980	0	0	0	0	0	0	2	1	0	1	1	0	0
	1981		0	0	0	0	0	1	0	33	0	0	0	3
	1982	0	0	0	0	0	0	1	0	0	0	0	0	0
	1983	0	0	0	0	0	0	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	0	0	0	0
	1986							0	0	1	0	0	0	0
	1987	0	0	0	0	0	0	1	0	0	0	0	0	0
STA	1978	0		0	0	0	0	0	0	0	0	0	0	0
31	1979	0	0	0	0	0	0	4	5	0	0	0	0	1
	1980	0	0	0	0	0	0	6	0	0	0	0	0	1
	1981		0	0	0	0	0	1	0	7	0	0	0	1
	1982	0	0	0	0	0	0	0	0	0	0	0	0	0
	1983	0	0	0	0	0	0	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	1	0	0	0	0	0	0
	1986							0	0	0	0	0	0	0
	1987	0	0	0	0	0	0	1	0	0	0	0	0	0
STA	1978	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1979	0	0	0	0	0	0	1	0	1	0	0	0	0
	1980	0	0	0	0	0	0	1	1	0	1	0	0	0
	1981		0	0	0	0	0	4	3	2	0	0	0	1
	1982	0	0	0	0	0	0	0	0	0	0	0	0	0
	1983	0	0	0	0	0	0	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	1	1	0	0
	1986							0	0	0	1	0	0	0
	1987	0	0	0	0	0	0	1	0	0	0	1	0	0
STA	1982	0	0	0	0	0	0	0	0	0	0	0	0	0
34	1983	0	0	0	0	0	0	1	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	1	0	0	0	0
	1986							0	0	0	0	0	0	0
	1987	0	0	0	0	0	0	1	0	0	1	0	0	0

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=BALANUS SP.

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	4	1	1	5	0	0	0	0	1
19	1979	0	0	0	12	5	0	0	0	0	0	0	0	1
	1980	0	0	0	532	1	4	3	1	1	0	0	0	45
	1981		0	0	0	0	0	6	0	0	0	0	0	1
	1982	0	0	0	1	1	0	0	1	0	0	0	0	0
	1983	0	0	0	2	11	10	1	0	0	0	0	0	2
	1984	0	0	0	2	4	0	2	3	0	0	0	0	1
	1986							1	0	0	0	0	0	0
	1987	0	0	0	35	34	32	2	0	0	0	0	0	9
STA	1978	0		0	0	7	1	1	0	1	0	0	0	1
31	1979	0	0	0	4	10	1	0	1	1	0	0	0	1
	1980	0	0	3	182	0	2	1	1	0	0	0	0	16
	1981		0	0	0	1	0	12	1	1	0	0	0	1
	1982	0	0	0	1	6	2	0	1	0	0	0	0	1
	1983	0	0	0	0	5	7	1	1	0	0	0	0	1
	1984	0	0	0	3	11	1	3	11	0	0	0	0	2
	1986							1	0	0	0	0	0	0
	1987	0	0	2	21	50	6	13	1	1	0	0	0	8
STA	1978	0	0	0	0	1	0	0	0	0	0	0	0	0
04	1979	0	0	0	0	2	1	0	0	0	0	0	0	0
	1980	0	0	0	128	0	2	3	0	0	0	0	0	11
	1981		1	0	0	0	0	1	0	1	0	0	0	0
	1982	0	0	0	1	5	1	0	0	0	1	0	0	1
	1983	1	0	0	0	10	4	0	0	0	0	0	0	1
	1984	0	0	0	0	2	1	0	1	0	0	0	0	0
	1986							1	0	0	0	0	0	0
	1987	0	0	0	3	21	6	0	0	0	0	0	0	2
STA	1982	0	0	1	0	1	2	0	0	0	0	0	0	0
34	1983	0	0	0	1	3	1	0	0	0	0	0	0	0
	1984	0	0	0	1	4	1	0	3	0	0	0	0	1
	1986							0	0	0	0	0	0	0
	1987	0	0	0	10	7	6	0	0	0	0	0	0	2

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=HIATELLA SP.

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	3	28	3	270	1	1	1	0	29
19	1979	1	0	0	1	0	11	193	9	0	7	1	2	20
	1980	0	0	0	3	0	504	61	62	26	5	0	1	55
	1981		0	0	0	2	274	247	6	286	2	0	1	74
	1982	1	0	0	0	4	122	10	5	6	4	0	4	13
	1983	0	1	1	0	1	31	38	9	2	2	0	0	7
	1984	0	0	1	0	1	68	60	5	1	3	0	1	11
	1986							130	1	7	1	4	1	24
	1987	0	1	1	0	0	28	31	1	13	1	0	0	6
STA	1978	0		0	0	3	54	3	5	2	2	1	1	6
31	1979	0	0	0	0	2	80	83	1444	2	1	1	0	134
	1980	0	0	0	1	0	931	249	72	22	3	3	1	107
	1981		0	0	0	31	332	91	238	68	6	0	0	70
	1982	1	1	0	0	0	46	4	4	2	1	0	1	5
	1983	0	0	0	1	0	16	36	22	3	1	1	1	7
	1984	3	0	0	1	8	44	140	7	1	0	5	1	17
	1986							41	2	9	4	1	1	9
	1987	1	0	0	0	0	62	49	2	1	2	0	0	10
STA	1978	0	0	0	0	0	10	6	32	2	2	1	0	5
04	1979	1	0	0	0	0	62	47	27	4	11	1	0	13
	1980	0	3	0	1	0	67	48	50	14	2	2	0	15
	1981		0	0	0	7	377	302	5	56	4	1	0	68
	1982	0	1	0	0	2	24	12	29	14	2	0	0	7
	1983	0	0	0	0	1	36	12	24	1	1	1	0	6
	1984	0	0	0	0	2	30	39	6	3	1	2	1	7
	1986							55	3	3	2	1	4	11
	1987	1	2	0	0	0	73	227	22	54	1	2	0	32
STA	1982	1	0	0	1	7	65	6	34	16	5	2	0	12
34	1983	0	0	0	0	0	15	23	34	0	4	2	4	7
	1984	1	1	1	0	3	26	56	3	1	1	2	0	8
	1986							92	5	5	24	9	2	23
	1987	1	1	0	0	0	72	163	53	74	4	0	0	31

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=JASSA FALCATA

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	4	13	5	124	13	10	1	0	16
19	1979	0	0	0	0	1	2	46	9	0	2	0	20	7
	1980	2	0	0	1	1	2	10	18	38	25	5	8	9
	1981		0	0	0	1	3	5	8	231	145	9	14	38
	1982	6	0	0	0	1	5	12	7	76	34	12	4	13
	1983	0	0	0	1	0	0	3	59	19	40	5	17	12
	1984	1	1	1	0	1	7	25	35	11	40	9	4	11
	1986							4	5	36	3	3	1	8
	1987	0	0	0	0	3	3	46	23	10	44	13	9	12
STA	1978	0		0	0	3	29	7	79	7	4	1	1	12
31	1979	0	1	1	1	6	34	324	98	1	4	2	2	39
	1980	1	0	0	1	6	9	56	28	10	16	2	1	11
	1981		1	0	0	0	0	0	28	95	8	5	8	13
	1982	0	0	0	2	17	22	17	50	113	12	14	11	22
	1983	1	1	0	1	1	0	5	8	21	13	1	8	5
	1984	1	2	0	1	9	12	13	9	21	34	80	0	15
	1986							9	35	37	5	7	1	16
	1987	0	0	0	0	4	3	331	131	541	319	18	2	112
STA	1978	5	1	0	0	0	1	3	9	15	2	1	0	3
04	1979	0	0	0	0	1	3	3	13	1	4	3	1	2
	1980	1	0	0	0	1	1	36	0	23	40	7	1	9
	1981		0	0	0	0	0	0	11	5	79	74	66	21
	1982	116	0	0	0	0	1	1	5	45	38	25	11	16
	1983	1	1	1	0	0	2	2	22	8	16	33	38	10
	1984	1	1	0	0	3	7	12	22	50	52	35	4	15
	1986							0	2	1	4	1	5	2
	1987	0	0	0	0	0	1	14	18	8	22	32	3	8
STA	1982	14	0	0	1	1	1	1	1	12	13	28	2	6
34	1983	0	1	0	1	0	0	8	6	12	19	4	3	4
	1984	2	1	1	0	0	2	2	2	3	19	21	0	4
	1986							0	4	4	2	8	1	3
	1987	0	0	0	0	0	1	62	0	10	46	41	14	14

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=LACUNA VINCTA

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	1	0	0	0	0	0
19	1979	0	0	0	0	0	1	0	0	0	0	0	4	0
	1980	1	0	0	4	0	0	1	0	13	2	1	1	2
	1981		0	0	0	0	1	0	0	40	0	2	1	4
	1982	1	0	0	0	1	0	0	0	1	1	1	0	0
	1983	0	0	0	0	0	1	0	0	14	17	3	3	3
	1984	0	0	0	0	0	0	1	0	0	0	2	0	0
	1986							1	1	4	5	3	0	2
	1987	0	0	0	0	0	0	0	1	7	2	0	0	1
STA	1978	0		0	0	0	1	0	1	0	10	4	0	1
31	1979	0	0	1	0	0	6	7	11	1	3	1	0	2
	1980	0	0	0	1	0	0	1	0	16	3	5	1	2
	1981		0	0	1	0	6	0	31	21	7	1	4	6
	1982	0	0	0	0	0	1	0	0	1	0	0	1	0
	1983	0	0	0	0	0	0	0	0	7	3	1	1	1
	1984	1	0	0	0	0	1	0	1	0	0	12	0	1
	1986							2	3	3	3	0	0	2
	1987	0	0	0	0	0	0	1	2	13	5	0	0	2
STA	1978	0	0	0	0	0	0	0	0	0	0	1	1	0
04	1979	0	0	0	0	0	0	2	2	1	0	2	1	1
	1980	1	1	0	0	0	0	0	0	11	0	0	0	1
	1981		0	0	0	0	0	2	0	10	6	1	5	2
	1982	1	0	0	0	0	1	0	1	8	2	0	0	1
	1983	0	0	0	0	0	1	1	0	2	1	2	2	1
	1984	0	0	0	0	0	0	0	1	0	0	1	0	0
	1986							0	0	1	2	3	1	1
	1987	0	0	0	0	0	0	1	1	2	1	0	0	0
STA	1982	0	0	0	0	0	0	0	0	1	1	1	0	0
34	1983	1	0	0	0	0	0	0	0	1	5	3	1	1
	1984	0	0	0	0	1	0	0	0	0	0	4	0	0
	1986							0	0	2	4	2	1	1
	1987	0	0	0	0	0	0	0	0	1	2	0	0	0

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=MYTILIDAE

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	1	1		1	16	34	182	4155	10	30	0	1	422
19	1979	2	2	2	1	1	590	7765	356	25	74	80	109	817
	1980	11	5	1	52	4	70	4672	2492	3485	389	50	65	941
	1981		2	1	2	2	576	905	609	40363	370	34	93	3905
	1982	20	6	1	3	16	80	106	87	436	81	14	4	73
	1983	2	0	2	1	1	56	360	110	169	1283	53	18	171
	1984	6	19	1	0	3	4	1948	202	213	132	86	8	218
	1986							920	60	87	174	256	29	254
	1987	20	24	13	0	1	1	2734	59	151	91	90	3	265
STA	1978	2		0	3	16	120	253	295	26	60	7	1	74
31	1979	4	1	0	12	2	2152	28230	25610	37	24	148	22	4687
	1980	19	4	2	16	3	174	14207	6144	1000	335	133	74	1842
	1981		1	4	1	2	982	1493	3263	38229	481	47	396	4082
	1982	34	4	7	6	2	96	136	85	225	37	11	38	57
	1983	1	0	0	1	0	76	171	148	73	62	95	41	55
	1984	451	2	2	1	6	20	3762	355	98	23	747	6	456
	1986							811	83	198	838	54	20	334
	1987	8	14	1	1	6	4	12665	272	216	788	270	6	1187
STA	1978	2	4	0	0	1	32	70	36	4	12	3	5	15
04	1979	1	1	1	1	0	575	1637	669	43	52	40	20	253
	1980	4	24	2	8	14	14	3853	1073	768	110	30	21	493
	1981		2	0	0	0	277	481	68	18041	383	8	147	1764
	1982	10	3	0	10	5	28	118	63	325	38	6	3	52
	1983	1	2	0	1	1	161	54	599	36	23	29	33	78
	1984	11	7	2	0	18	12	956	159	68	5	16	5	105
	1986							305	54	29	37	38	23	81
	1987	45	74	0	0	0	1	6600	515	216	29	89	2	631
STA	1982	6	1	5	4	0	33	51	18	95	17	9	5	21
34	1983	2	1	1	1	0	34	100	161	42	250	83	50	60
	1984	56	10	2	1	1	7	1153	91	26	14	88	2	121
	1986							368	84	37	838	266	34	271
	1987	18	9	0	5	0	2	5594	1071	307	171	23	14	601

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=NUDIBRANCHIA

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	0	1	0	4	1	0
19	1979	0	0	0	0	0	0	2	16	0	0	8	0	2
	1980	0	0	0	0	0	0	15	4	16	26	1	0	5
	1981		0	0	0	0	0	30	1	49	6	5	0	8
	1982	0	0	0	0	0	0	3	2	71	1	1	0	7
	1983	0	0	0	0	1	1	3	5	74	1	0	1	7
	1984	0	0	0	0	0	1	0	1	17	98	0	0	10
	1986							2	0	5	2	0	0	1
	1987	0	0	0	0	0	1	3	1	1	0	2	0	1
STA	1978	0		0	0	0	0	0	0	0	2	0	0	0
31	1979	1	0	0	0	0	1	0	0	2	2	2	1	1
	1980	0	0	0	0	0	0	11	1	5	7	1	1	2
	1981		0	0	0	0	0	13	1	47	0	1	0	6
	1982	0	0	0	0	0	2	1	3	20	0	1	0	2
	1983	0	0	0	0	0	0	8	4	4	1	0	0	1
	1984	0	0	0	0	1	0	3	3	8	2	8	0	2
	1986							1	0	0	1	0	0	0
	1987	0	0	0	0	0	2	22	3	1	0	0	0	2
STA	1978	0	0	0	0	0	0	0	3	1	0	0	1	0
04	1979	0	0	0	0	0	0	0	1	0	2	1	5	1
	1980	0	0	0	0	0	0	39	0	20	2	0	0	5
	1981		0	0	0	0	0	1	26	8	43	0	0	7
	1982	0	0	0	0	0	0	23	5	267	7	1	0	26
	1983	0	0	0	0	0	5	1	4	0	2	1	1	1
	1984	0	0	0	0	0	0	1	1	2	0	1	1	0
	1986							4	1	3	1	1	0	1
	1987	0	0	0	0	2	0	1	1	0	0	0	0	0
STA	1982	0	0	0	0	0	0	1	1	28	1	1	0	3
34	1983	0	0	0	0	1	7	1	4	2	0	0	1	1
	1984	0	0	0	0	1	1	2	1	4	0	2	1	1
	1986							1	0	6	4	0	0	2
	1987	0	0	0	0	0	1	3	0	0	0	0	0	0

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=PONTOGENEIA INERMIS

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	0	0	1	0	0	0
19	1979	0	0	0	0	1	0	0	1	0	1	1	0	0
	1980	0	0	0	0	1	0	1	2	2	3	0	0	1
	1981		4	0	0	6	11	0	0	3	0	1	0	2
	1982	0	0	0	0	0	7	1	0	0	0	0	0	1
	1983	0	0	1	0	0	6	1	1	0	1	0	1	1
	1984	0	0	0	0	1	1	0	1	0	0	1	0	0
	1986							1	0	1	1	0	0	0
	1987	0	0	0	0	0	0	0	0	0	0	0	0	0
STA	1978	0		0	0	0	0	0	0	0	0	0	0	0
31	1979	0	1	0	0	16	1	0	0	0	2	1	1	2
	1980	0	1	2	1	3	3	2	0	0	1	0	0	1
	1981		0	0	0	33	17	5	0	0	0	1	0	5
	1982	0	0	0	1	1	6	0	0	1	0	0	0	1
	1983	0	0	1	13	0	9	1	3	0	0	0	0	2
	1984	0	0	0	0	8	1	1	2	0	1	1	0	1
	1986							1	1	0	0	1	0	0
	1987	0	0	0	0	1	0	0	0	0	0	0	0	0
STA	1978	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1979	0	0	0	0	0	0	0	0	0	0	0	0	0
	1980	0	0	0	0	1	1	0	1	3	0	0	0	0
	1981		0	0	0	0	0	0	0	0	0	0	0	0
	1982	0	0	0	0	0	1	0	0	3	0	1	0	0
	1983	0	0	0	0	0	8	2	0	0	0	0	0	1
	1984	0	0	0	0	1	1	0	0	2	1	0	0	0
	1986							1	1	1	1	0	0	0
	1987	0	0	0	0	0	0	0	0	0	0	0	1	0
STA	1982	0	0	0	0	0	2	0	0	1	0	0	1	0
34	1983	0	0	0	0	0	2	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	1	0	0	0
	1986							0	0	0	1	0	0	0
	1987	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX TABLE 3.3.4-1. (Continued)

SPECIES=STRONGYLOCENTROTUS DROEBACHIENSIS

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	2	0	2	0	0	0	0	0
19	1979	0	1	0	0	0	1	0	0	0	0	0	0	0
	1980	0	0	0	0	0	1	0	0	1	0	0	0	0
	1981		0	0	0	0	4	1	0	2	0	0	0	1
	1982	0	0	0	0	1	3	0	0	0	0	0	0	0
	1983	0	0	0	0	0	2	0	0	0	0	0	0	0
	1984	0	0	0	0	0	0	1	0	0	0	0	0	0
	1986							1	0	0	0	0	0	0
	1987	0	0	0	0	0	0	1	0	0	0	0	0	0
STA	1978	0		0	0	0	0	0	0	0	0	0	0	0
31	1979	0	0	0	0	1	3	1	0	0	0	0	0	0
	1980	0	0	0	0	0	0	1	0	0	0	0	0	0
	1981		0	0	0	0	0	0	0	0	0	0	0	0
	1982	0	0	0	0	0	4	0	0	0	0	0	0	0
	1983	0	0	0	0	1	0	1	0	0	0	0	0	0
	1984	0	0	0	0	0	1	1	0	0	0	0	0	0
	1986							0	0	0	0	0	0	0
	1987	0	0	0	1	0	0	2	0	0	0	0	0	0
STA	1978	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1979	0	1	0	0	0	1	0	0	0	0	0	0	0
	1980	0	0	1	0	0	0	0	0	0	0	0	0	0
	1981		0	0	0	0	1	0	0	1	0	0	0	0
	1982	0	0	0	0	1	2	0	0	0	1	0	0	0
	1983	1	0	0	0	0	4	0	0	0	0	0	0	0
	1984	0	0	0	0	0	1	1	0	0	0	0	0	0
	1986							2	0	1	0	0	0	0
	1987	0	0	0	0	0	0	0	0	0	0	0	0	0
STA	1982	0	0	0	0	0	1	0	0	1	0	1	0	0
34	1983	0	0	0	0	0	3	0	1	0	0	0	0	0
	1984	0	0	0	0	0	1	0	0	0	0	0	0	0
	1986							0	1	1	1	0	0	0
	1987	0	0	0	0	0	1	0	0	0	0	0	0	0

APPENDIX TABLE 3.3.4-2. PERCENT FREQUENCY OCCURRENCE (MEAN PER TWO REPLICATES) OF SELECTED COLONIAL SPECIES OCCURRING ON SHORT-TERM FOULING PANELS BY MONTH, STATION, AND YEAR. SEABROOK BASELINE REPORT, 1987.

SPECIES=DIATOMS[a]

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978													
19	1979													
	1980													
	1981		28	53	99	100	99	100	100	3	100	85	13	71
	1982	39	46	66	94	100	100	62	99	98	52	29	85	74
	1983	92	93	93	100	100	100	99	100	100	100	100	97	98
	1984	85	84	100	100	100	100	100	100	100	100	100	98	97
	1986							95	94	100	99	100	100	98
	1987	13	80	69	100	100	100	85	84	100	0	0	84	68
STA	1978													
31	1979													
	1980													
	1981		91	48	97	99	100	75	100	9	97	96	10	75
	1982	10	100	100	100	97	100	92	100	38	6	6	47	69
	1983	63	50	83	97	100	99	100	71	99	100	100	84	87
	1984	100	95	98	98	100	100	100	98	100	100	100	61	96
	1986							0	96	100	100	96	100	82
	1987	18	90	73	95	100	100	94	87	100	94	89	73	84
STA	1978													
04	1979													
	1980													
	1981		97	68	90	100	98	0	100	92	95	85	11	76
	1982	41	77	80	98	96	99	87	92	100	100	100	98	91
	1983	62	96	99	89	100	100	79	92	100	99	99	92	92
	1984	94	100	96	94	100	100	79	98	97	100	100	97	96
	1986							51	100	100	95	82	98	88
	1987	92	48	90	100	100	100	79	99	95	75	85	82	87
STA	1982	10	72	98	100	96	100	54	48	72	92	77	82	78
34	1983	94	94	97	96	99	98	100	96	100	100	99	97	97
	1984	100	92	96	100	100	100	100	61	99	100	100	70	93
	1986							97	100	100	100	100	100	100
	1987	78	92	84	98	100	100	93	98	98	100	93	68	92

[a]Diatoms were not evaluated for % frequency occurrence in 1978-1980 at Stations 19, 31 and 4.

APPENDIX TABLE 3.3.4-2. (Continued)

SPECIES=OBELIA SPP.

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	0	0	0	1	0	0
19	1979	0	0	0	1	1	1	6	0	2	0	18	0	2
	1980	0	0	0	0	0	0	33	0	0	0	0	0	3
	1981		0	0	0	0	0	0	0	0	0	0	0	0
	1982	0	0	0	0	0	4	1	0	8	1	0	0	1
	1983	0	0	0	0	0	0	6	0	0	0	0	0	0
	1984	0	0	0	0	0	1	0	0	0	0	0	0	0
	1986							0	0	0	0	0	0	0
	1987	0	0	0	0	0	1	13	0	0	0	0	0	1
STA	1978	0		0	0	0	0	0	0	0	0	1	0	0
31	1979	0	0	0	0	1	0	10	0	2	0	0	0	1
	1980	0	0	0	0	0	0	17	0	0	0	0	0	1
	1981		0	0	0	0	0	0	0	0	0	0	0	0
	1982	0	0	0	0	0	3	0	0	0	0	0	0	0
	1983	0	0	0	0	0	0	0	1	0	1	0	0	0
	1984	0	0	0	0	0	0	0	2	0	0	0	0	0
	1986							0	0	0	0	0	0	0
	1987	0	0	0	0	0	0	52	0	0	0	0	0	4
STA	1978	0	0	0	0	0	0	0	3	3	1	1	1	1
04	1979	0	0	0	0	0	1	15	23	0	2	20	0	5
	1980	0	0	0	0	0	0	68	1	0	0	0	0	6
	1981		0	0	0	0	0	0	0	0	0	0	0	0
	1982	0	0	0	0	0	0	0	6	100	16	0	0	11
	1983	0	0	0	0	1	4	1	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	0	7	0	1
	1986							0	0	0	0	0	0	0
	1987	0	0	0	0	0	3	19	0	0	0	0	0	2
STA	1982	0	0	0	0	0	1	0	0	0	2	0	0	0
34	1983	0	0	0	0	0	0	3	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	0	15	0	1
	1986							0	0	0	0	0	0	0
	1987	0	0	0	0	0	6	30	0	0	0	0	0	3

APPENDIX TABLE 3.3.4-2. (Continued)

SPECIES=TUBULARIA SP.

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL
STA	1978	0	0		0	0	0	0	58	30	13	0	0	9
19	1979	0	0	0	0	0	0	2	2	0	0	0	0	0
	1980	0	0	0	0	0	0	0	30	39	4	7	0	7
	1981		0	0	0	0	0	100	100	100	33	3	0	31
	1982	0	0	0	0	0	0	16	20	49	0	0	0	7
	1983	0	0	0	0	0	0	3	13	100	100	6	18	20
	1984	0	0	0	0	0	0	1	44	97	96	12	1	21
	1986							0	1	28	58	53	0	23
	1987	0	0	0	0	0	0	8	63	100	100	59	0	27
STA	1978	0		0	0	0	0	1	99	83	12	10	0	19
31	1979	0	0	0	0	0	0	78	0	0	0	0	1	7
	1980	0	0	0	0	0	0	0	38	3	4	1	0	4
	1981		0	0	0	0	0	0	100	100	71	42	6	29
	1982	0	0	0	0	0	0	0	10	1	0	0	0	1
	1983	0	0	0	0	0	0	2	0	2	3	0	1	1
	1984	0	0	0	0	0	0	0	1	50	9	95	1	13
	1986							0	0	20	0	0	0	3
	1987	0	0	0	0	0	0	21	12	100	90	15	0	20
STA	1978	0	0	0	0	0	0	1	0	0	1	1	0	0
04	1979	0	0	0	0	0	0	21	40	2	3	1	0	6
	1980	0	0	0	0	0	0	0	1	7	1	1	0	1
	1981		0	0	0	0	0	0	11	100	9	0	0	11
	1982	0	0	0	0	0	0	0	3	32	7	11	3	5
	1983	0	0	0	0	0	0	7	100	86	50	6	1	21
	1984	0	0	0	0	0	0	0	6	0	0	36	0	3
	1986							0	0	0	8	39	1	8
	1987	0	0	0	0	0	0	100	100	100	75	67	0	37
STA	1982	0	0	0	0	0	0	0	0	0	0	11	3	1
34	1983	0	0	0	0	0	0	4	84	100	100	34	14	28
	1984	0	0	0	0	0	0	0	0	16	9	90	0	10
	1986							0	3	14	95	100	0	35
	1987	0	0	0	0	0	0	98	100	100	100	2	0	33

APPENDIX TABLE 3.3.6-1. SUMMARY OF LEGAL LOBSTER CATCH AT THE DISCHARGE SITE FROM 1974 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

YEAR	MONTH JUN	JUL	AUG	SEP	OCT	NOV	YEARLY AVERAGE
1987	2.0	1.7	4.8	3.3	3.6	3.2	3.1
1986	3.6	6.8	7.1	6.7	8.9	12.3	7.2
1985	1.4	8.6	5.9	7.7	7.8	7.6	6.5
1984	2.3	1.8	11.0	4.3	10.7	9.0	6.9
1983	2.5	4.6	11.0	7.0	13.8	4.2	7.2
1982	2.1	9.6	9.7	7.6	10.0	8.5	7.9
1981	4.7	9.2	11.2	12.1	10.0	10.9	9.7
1980	2.9	4.5	12.5	12.2	6.2	7.7	7.7
1979	6.1	8.8	8.8	8.8	12.4	11.2	9.4
1978	7.1	4.0	12.8	14.6	11.4	9.8	10.0
1977	5.9	4.2	13.9	9.9	7.3	9.4	8.4
1976	3.3	8.8	12.4	7.5	9.2	10.1	8.6
1975	2.7	5.7	9.5	8.0	10.0	10.1	7.7
1974	ND	6.7	9.8	11.2	9.0	12.2	9.8
MONTHLY AVERAGE	3.6	6.1	10.0	8.6	9.3	9.0	

ND - No Data

[a]Catch per trip effort = legal catch from 15 traps per trip.

APPENDIX TABLE 3.3.7-1. SUMMARY OF *MYA ARENARIA* POPULATION DENSITIES FROM ANNUAL FALL SURVEYS IN HAMPTON-SEABROOK HARBOR, 1971 THROUGH 1987. SEABROOK BASELINE REPORT, 1987.

		NUMBER OF SAMPLES COLLECTED		MEAN DENSITY (No./ft²)		
LOCATION	YEAR	ADULTS	SPAT	SPAT (1 to 25 mm)	JUVENILES (26 to 50 mm)	ADULTS (>50 mm)
Flat 1	1971	18	18	48	6.8	2.1
	1972	18	18	110	8.1	3.3
	1973	36	18	44	2.5	1.3
	1974	64	18	2	3.7	2.1
	1975	57	18	31	0.8	1.1
	1976	49	18	580	>0.1	0.3
	1977	60	14	437	>0.1	0.2
	1978	63	14	209	1.4	>0.1
	1979	62	20	40	30.4	0.1
	1980	30	20	90	72.0	1.7
	1981	25	25	45	44.7	3.7
	1982	25	25	6	13.1	2.8
	1983	40	40	21	21.1	4.2
	1984	40	45	57	6.2	3.4
	1985	106	71	5	1.4	1.6
	1986	75	70	9	0.2	0.7
	1987	70	55	7	0.1	0.2
Flat 2	1971	9	9	91	4.8	3.8
	1972	9	9	152	2.2	1.4
	1973	18	9	136	3.8	1.1
	1974	25	9	0	1.3	1.3
	1975	25	9	5	0.0	0.5
	1976	19	9	198	>0.1	0.1
	1977	33	7	49	0.0	>0.1
	1978	29	7	8	3.9	0.2
	1979	32	9	31	3.5	0.2
	1980	40	25	253	3.9	2.2
	1981	25	25	519	1.0	0.9
	1982	15	25	7	0.2	0.9
	1983	40	25	19	4.4	5.4
	1984	40	25	25	0.9	1.7
	1985	51	25	21	>0.1	0.5
	1986	53	20	9	>0.1	0.3
	1987	55	20	13	>0.1	0.1

(continued)

APPENDIX TABLE 3.3.7-1. (Continued)

LOCATION	YEAR	NUMBER OF SAMPLES COLLECTED ADULTS	SPAT	MEAN DENSITY (No./ft²) SPAT (1 to 25 mm)	JUVENILES (26 to 50 mm)	ADULTS (>50 mm)
Flat 3	1971	6	6	74	4.7	4.6
	1972	6	6	39	1.6	0.4
	1973	12	6	8	3.6	2.2
	1974	16	6	1	0.7	1.5
	1975	17	6	1	0.0	0.5
	1976	24	5	321	>0.1	0.3
	1977	20	6	43	>0.1	>0.1
	1978	23	6	71	2.1	0.1
	1979	12	4	6	1.0	0.0
	1980	40	25	56	0.5	0.4
	1981	25	25	51	0.1	0.4
	1982	15	25	4	0.2	0.3
	1983	40	25	12	0.1	0.2
	1984	40	30	32	0.1	0.4
	1985	NS	25	12	NS	NS
	1986	NS	24	8	NS	NS
	1987	NS	25	9	NS	NS
Flat 4	1971	12	12	106	17.6	2.8
	1972	12	12	138	10.6	2.3
	1973	24	12	18	3.8	0.6
	1974	39	12	3	2.8	1.7
	1975	38	12	39	0.3	0.4
	1976	68	18	475	>0.1	>0.1
	1977	42	11	245	>0.1	>0.1
	1978	51	11	172	16.8	>0.1
	1979	66	18	97	36.3	0.6
	1980	25	25	96	47.2	3.2
	1981	25	25	236	49.4	2.3
	1982	25	25	24	12.3	2.2
	1983	25	25	45	2.8	1.0
	1984	25	25	82	1.0	0.9
	1985	36	25	16	0.3	0.6
	1986	38	30	12	0.2	0.2
	1987	40	20	12	0.3	0.2

(continued)

APPENDIX TABLE 3.3.7-1. (Continued)

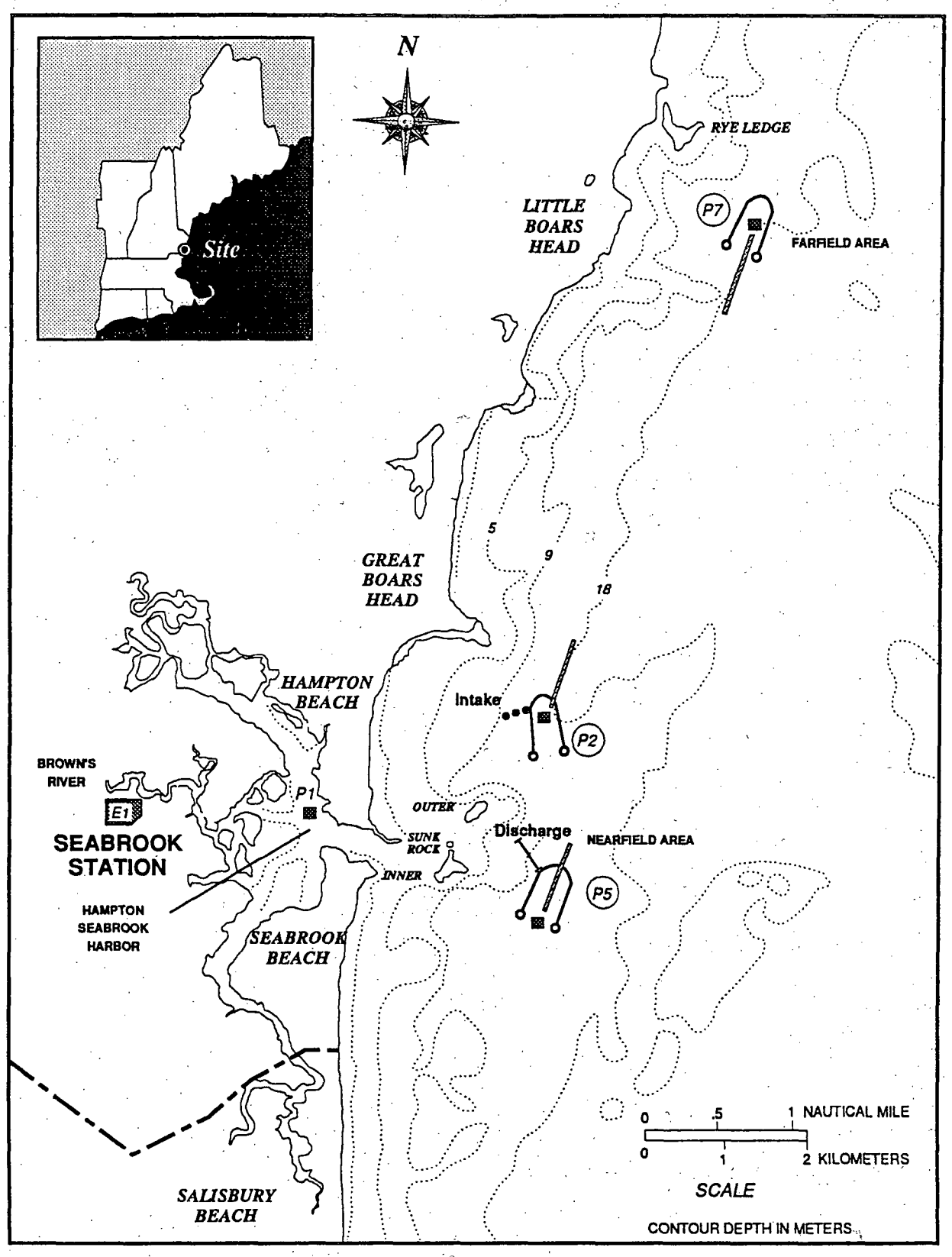
LOCATION	YEAR	NUMBER OF SAMPLES COLLECTED ADULTS	SPAT	MEAN DENSITY (No./ft^2) SPAT (1 to 25 mm)	JUVENILES (26 to 50 mm)	ADULTS (>50 mm)
Flat 5	1971	9	9	176	1.3	1.6
	1972	9	9	196	3.8	2.3
	1973	21	11	23	1.0	0.4
	1974	33	12	2	>0.1	0.1
	1975	20	8	5	0.0	>0.1
	1976	14	12	309	0.0	>0.1
	1977	38	9	64	>0.1	>0.1
	1978	38	7	32	4.8	>0.1
	1979	28	8	8	2.0	>0.1
	1980	40	20	65	2.2	0.8
	1981	25	25	409	0.3	0.7
	1982	15	25	43	>0.1	0.2
	1983	40	25	25	0.0	0.1
	1984	40	25	16	>0.1	0.1
	1985	NS	33	15	NS	NS
	1986	NS	35	7	NS	NS
	1987	NS	20	23	NS	NS
All Flats	1971	54	54	92	7.7	2.7
	1972	54	54	130	6.2	2.2
	1973	111	56	47	2.8	1.0
	1974	177	57	2	2.2	1.5
	1975	157	53	21	0.4	0.6
	1976	174	62	421	>0.1	0.2
	1977	193	47	207	>0.1	>0.1
	1978	204	45	123	6.3	>0.1
	1979	200	59	49	22.3	0.3
	1980	175	115	115	20.6	1.5
	1981	125	125	252	19.1	1.6
	1982	95	125	17	6.7	1.5
	1983	185	140	24	5.9	2.3
	1984	185	150	46	1.7	1.3
	1985	193	179	12	0.8	1.1
	1986	166	179	9	0.2	0.5
	1987	165	140	11	0.1	0.2

4.0 METHODS

4.1 GENERAL

Prior to 1975, the Seabrook Environmental Program involved studies of specific sites (e.g., the estuary, the discharge area, the intake area) or specific species (e.g., *Mya arenaria*) in order to (1) characterize their physical and/or biological environment and (2) assess impact of proposed plant design. The results of these studies were reviewed and discussed during the Environmental Protection Agency's hearings on Seabrook Station's open cycle cooling-water system (NAI 1977e; EPA 1977).

Since July 1975, the focus of the program has been to provide preoperational characterization of the environment in potentially impacted areas. Field and laboratory methods that were used for data collected during 1980 through 1987 were thoroughly described in the data reports for those years (NAI 1981c, 1981f, 1982a, 1982b, 1983a, 1984a, 1985a, 1986, 1987a, 1988). Methods used prior to 1980 were summarized and explained in detail in previous annual reports for Seabrook Environmental Studies (NAI 1976a, 1976b, 1977a, 1977b, 1977c, 1977d, 1978a, 1978b, 1979a, 1979b, 1979c, 1979d, 1979e, 1979f, 1980a, 1980b, 1980c, 1981a, 1981b, 1981c, 1981d, 1981e, 1981f). Plankton studies have been based on samples collected in the nearfield (intake) area and a farfield area (Rye Ledge) located beyond the influence of the Station's operation. In July 1986, sampling at a third station (P5) was resumed in the vicinity of the discharge (Figure 4.1-1); preoperational sampling had been conducted at P5 for various plankton programs from July 1977 through December 1981. Fish were sampled offshore by bottom trawls and gill nets near the discharge area and at two farfield sites, and by seining at three locations in the Hampton-Seabrook estuary (Figure 4.1-2). Marine algae and benthos were collected by divers at a series of stations stratified by depth near the intake/discharge area and in a farfield area (Table 4.1-1, Figure 4.1-3). Benthos in soft substrates were sampled along two transects in the estuary (Figure 4.1-4). Lobster (*Homarus americanus*), rock crab



▩ = microzooplankton, bivalve larvae and water quality stations

= macrozooplankton and ichthyoplankton stations

= lobster larvae stations

Figure 4.1-1. Plankton sampling stations. Seabrook Baseline Report, 1987

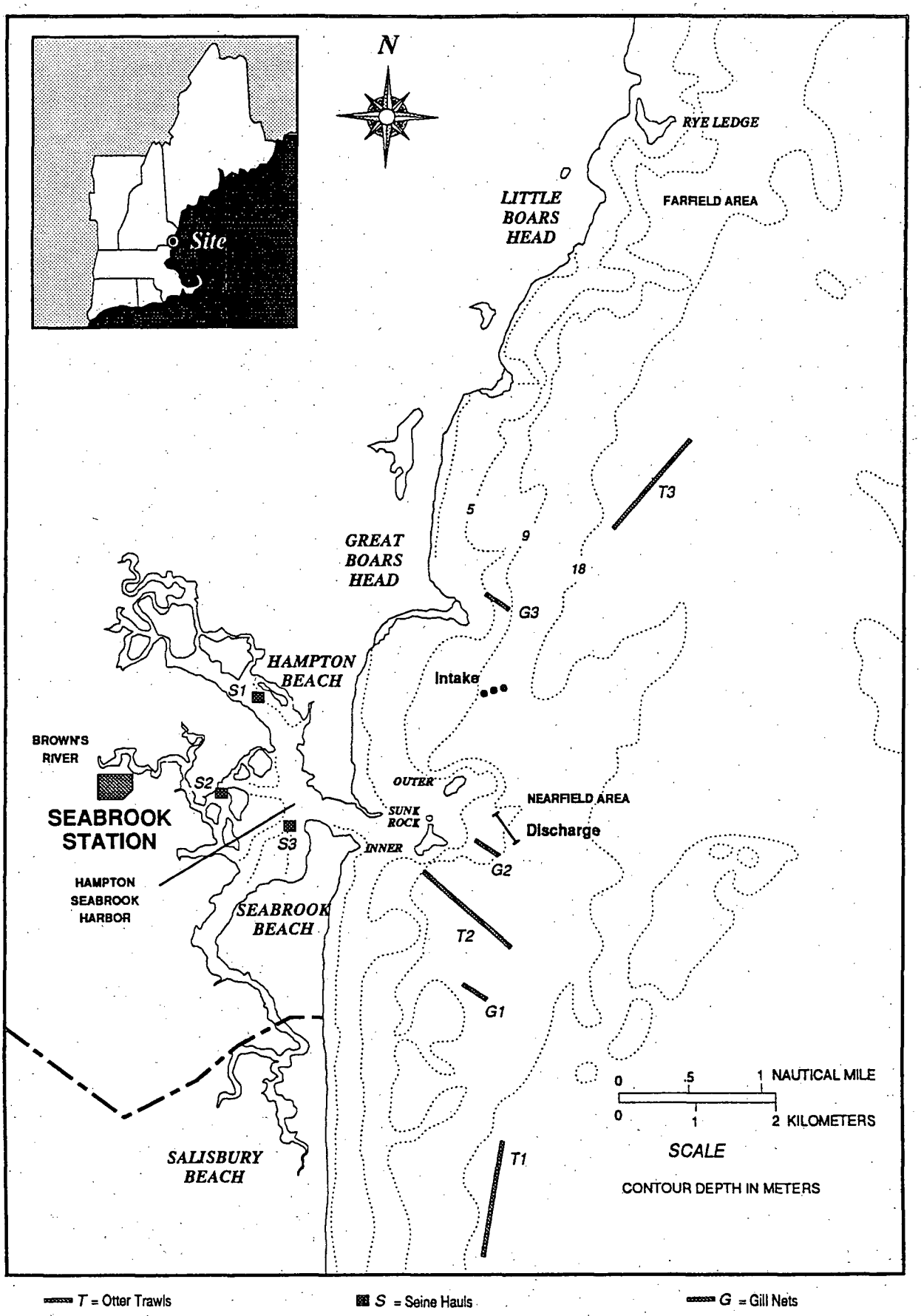
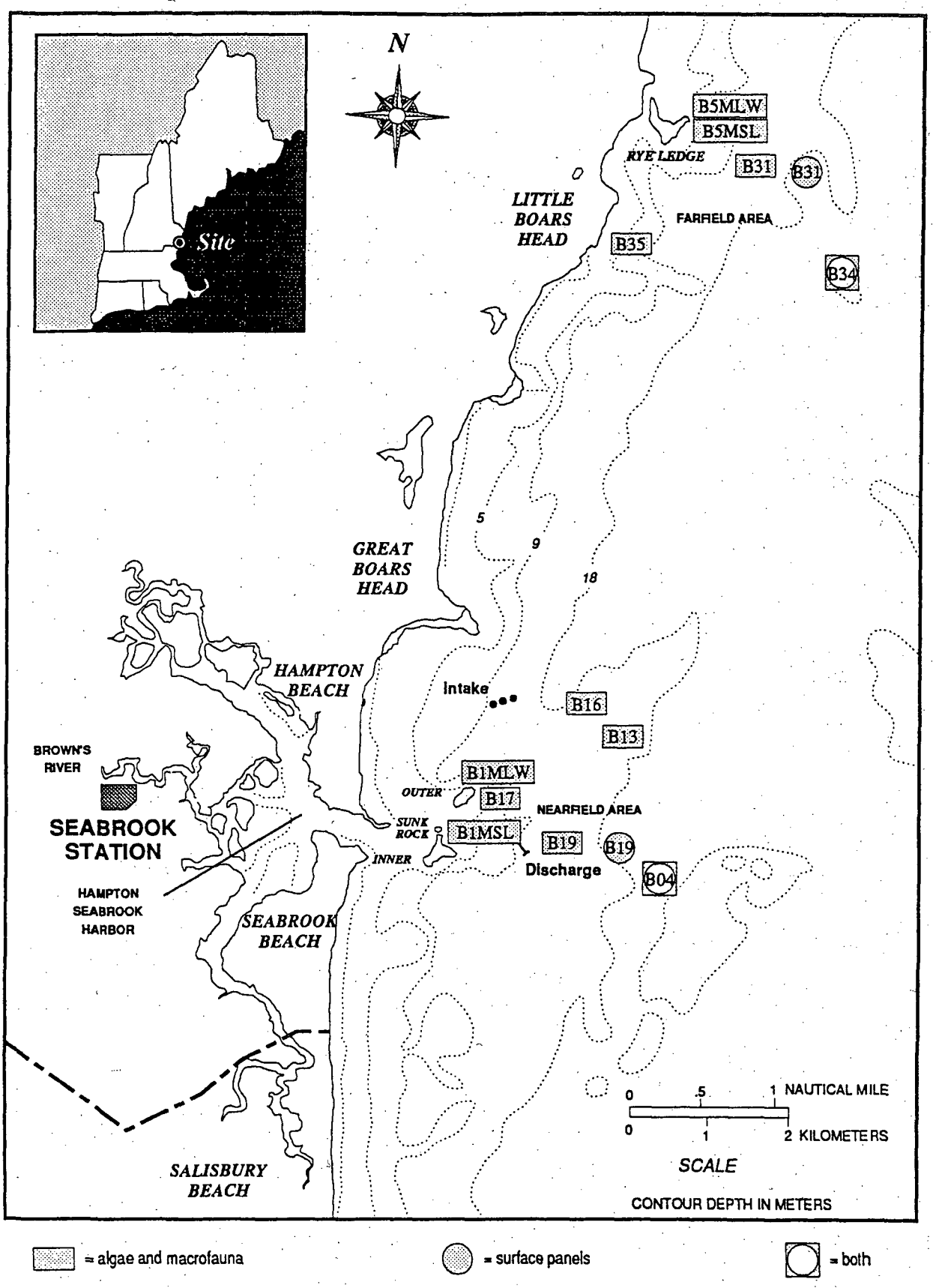


Figure 4.1-2. Finfish sampling stations. Seabrook Baseline Report, 1987.

TABLE 4.1-1. BENTHIC ALGAE AND MACROFAUNA STATION LOCATIONS AND DESCRIPTIONS. SEABROOK BASELINE REPORT, 1987.

DEPTH[a,b] m	ft	STATION	LOCATION LONGITUDE	LATITUDE	APPROXIMATE COMPOSITION OF HARD SUBSTRATES
4.6	15	17	70°47'37"	42°54'00"	Algae covered ledge (95%) and crustose covered ledge (5%)
4.6	15	35[c]	70°46'07"	42°57'22"	Algae covered ledge (85%) and boulders (15%)
9.4	31	31[c]	70°47'37"	42°58'04"	Algae covered rocks (30%) mussel beds (60%) and cobble (10%)
9.4	31	16	70°47'03"	42°54'16"	Algae covered ledge (75%) and mussel beds (25%)
12.2	40	19	70°47'13"	42°53'40"	Algae covered ledge and boulders (60%) and mussel beds (40%)
18.3	60	13	70°46'58"	42°53'54"	Algae covered ledge and boulders (40%) mussel beds (55%) and cobble (5%)
18.9	62	4	70°45'59"	42°53'23"	Mussel beds (70%) and algae covered ledge (30%)
21.0	69	34[c]	70°47'04"	42°54'23"	Mussel beds (60%) and algae covered ledge and boulders (40%)
0.3	1	1MLW	70°47'41"	42°53'56"	Algae covered ledge (90%) mussel bed (10%)
1.3	4	1MSL	70°47'46"	42°53'50"	Algae covered ledge (100%)
0.3	1	5MLW[c]	70°45'36"	42°58'19"	Algae covered ledge and boulder (90%) mussel bed (10%)
1.3	4	5MSL[c]	70°45'44"	42°58'12"	Algae covered ledge (100%)

[a]depth below mean low water, subtidal stations
[b]depth above mean low water, intertidal stations
[c]farfield stations



= algae and macrofauna = surface panels = both

Figure 4.1-3. Benthic marine algae and macrofauna sampling stations. Seabrook Baseline Report, 1987.

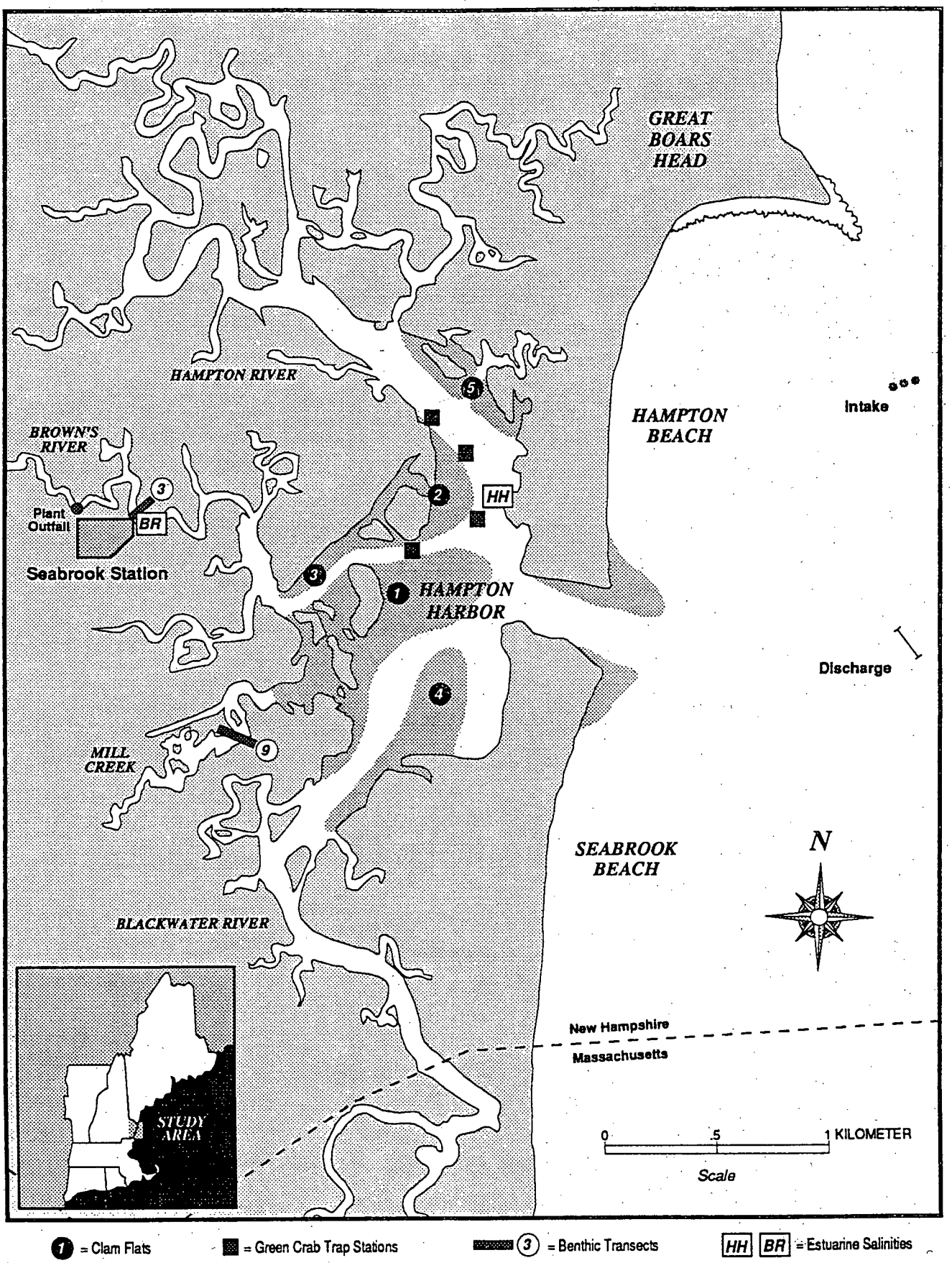


Figure 4.1-4. Hampton-Seabrook Estuary temperature/salinity, soft-shell clam (Mya arenaria), benthic transects and green crab (Carcinus maenas) sampling stations. Seabrook Baseline Report,1987.

(*Cancer irroratus*), Jonah crab (*C. borealis*) and green crab (*Carcinus maenas*) were collected in traps (Figures 4.1-4, 4.1-5). Soft-shell clams (*Mya arenaria*) were dug from five flats in the estuary (Figure 4.1-4), with farfield spat stations in Ipswich, MA and Ogunquit, ME (through 1984 only) (Figure 4.1-6).

A complete assessment of preoperational conditions was made in the 1984 Seabrook Baseline Report. The 1986 Baseline Report built on conclusions made in that report, updating results with two additional years of data for those programs which had been maintained without interruption. This 1987 Baseline Report adds another full year of preoperational data, further characterizing the natural biota of the area. Similar analytical methods, utilizing the entire historical data base, have been used wherever possible to maintain consistency.

Changes in a few of the programs in 1987 did occur. The continuous offshore monitoring program for temperature and salinity, and the phytoplankton and microzooplankton programs were discontinued. Refer to the 1986 Baseline Report for the results of those programs. The ichthyoplankton and bivalve larvae entrainment collections were discontinued after June 1987, because most of the latter half of the year there were not enough circulating water pumps operating to allow operation of the entrainment sampling system. This report summarizes the results of the entrainment program until sampling was discontinued.

Over the several years of this study there were some instances in which some sample types were collected for only part of a year, or discontinued for a whole year, due to program modifications (particularly in 1985 and 1986). This report does not include data from partial sampling years if they erroneously influence sample statistics. For example, annual means of macrozooplankton selected species were not calculated for 1986 because samples were not collected from January through June in that year (Table 3.1.3-6). However, these data could be used in discriminant analysis since samples are partitioned seasonally (Table 3.1.3-1). Data not presented in a

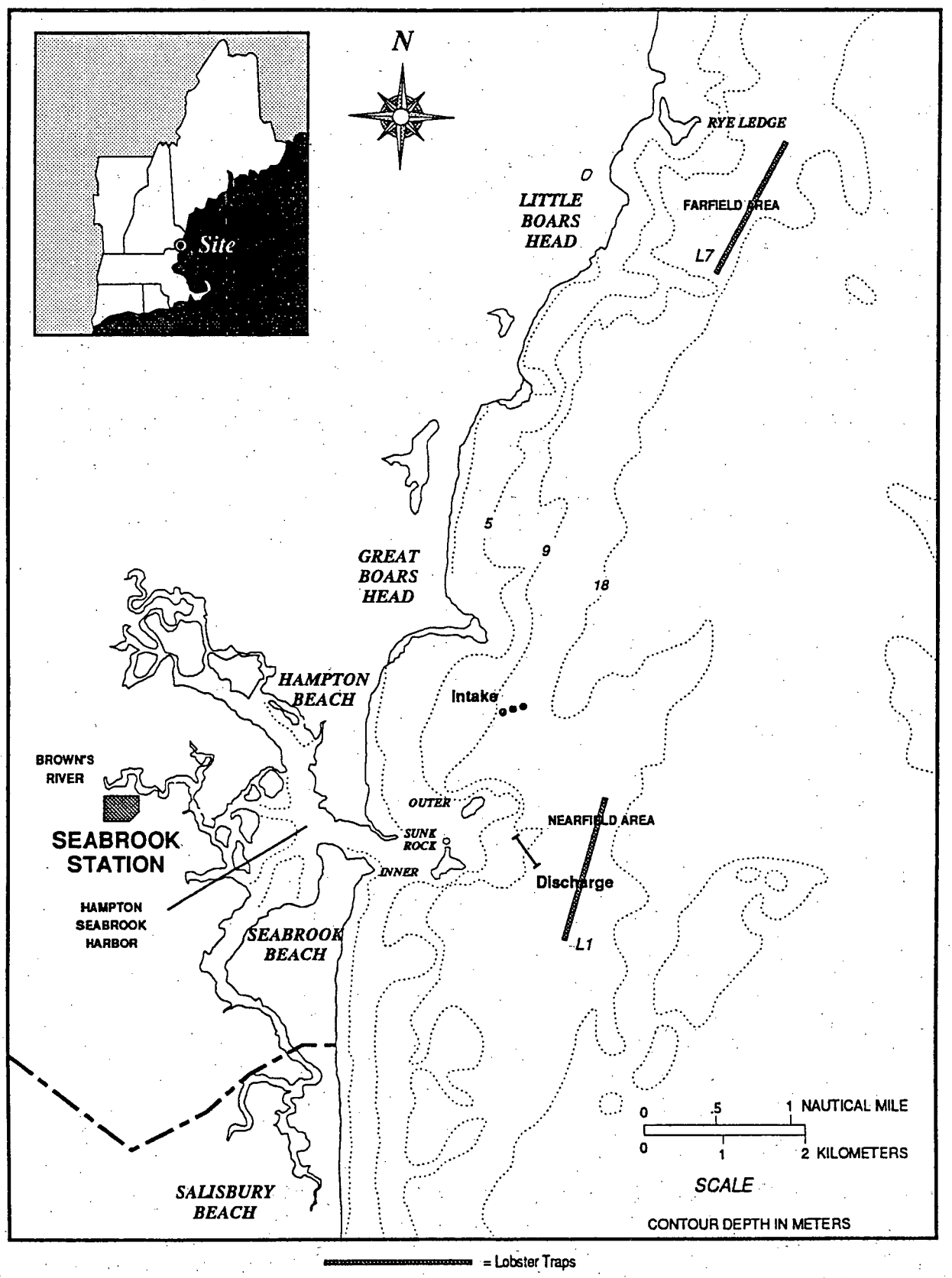
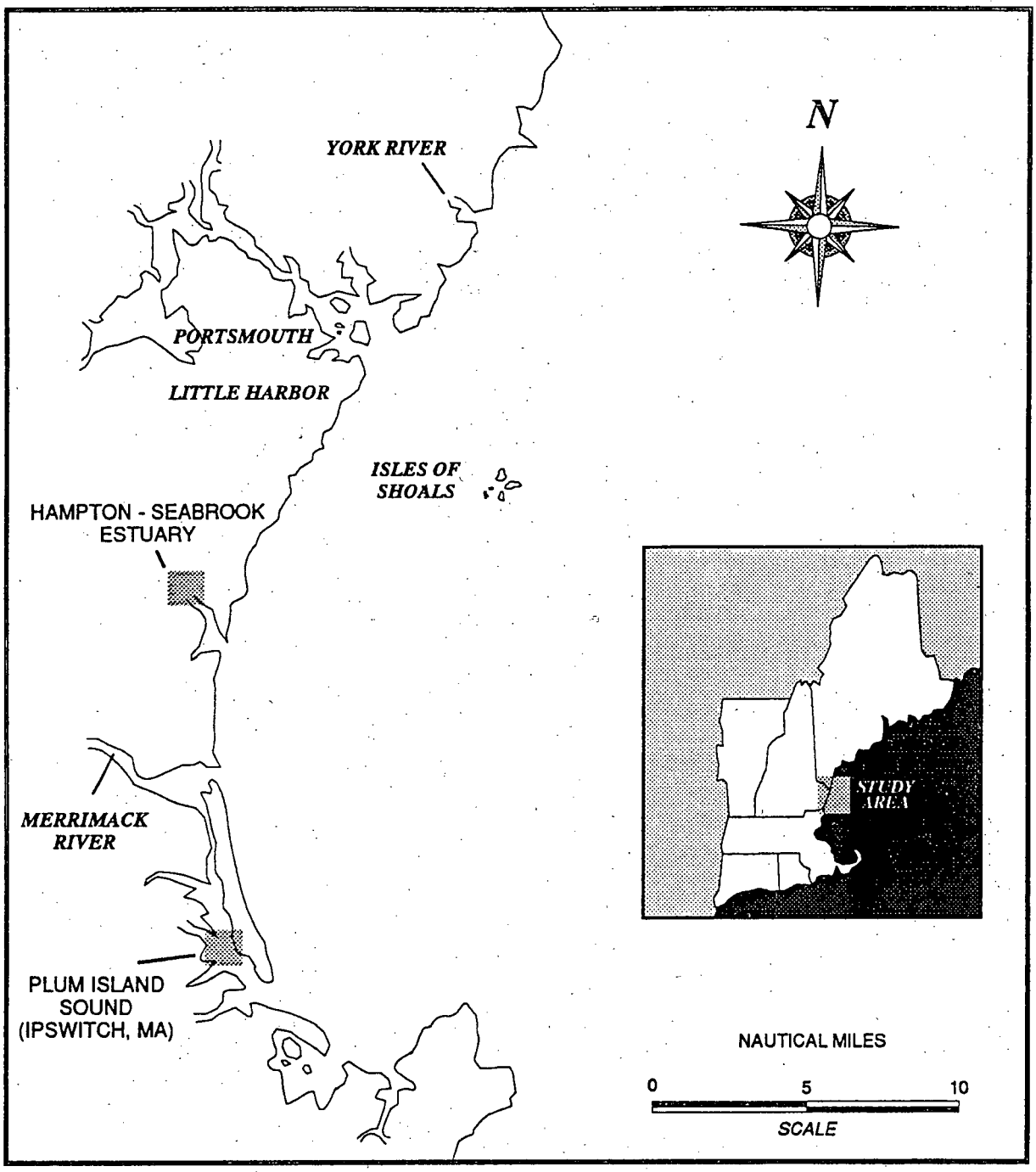


Figure 4.1-5. Locations of lobster and rock crab trapping areas. Seabrook Baseline Report, 1987.



STUDY SITES

Figure 4.1-6. Sampling sites for Mya arenaria spat. Seabrook Baseline Report, 1987.

table or figure means that they were either not collected or were incomplete for that period.

As in previous baseline reports, preoperational conditions in the Hampton-Seabrook area were examined in this report at the community and species levels, both useful indicators of environmental change. Community structure and its variation in time and/or space have been investigated in previous reports using numerical classification. Results presented in the 1984 Baseline Report form the basis against which future results (both preoperational and operational) will be compared. The 1985 through 1987 species assemblages were compared to those observed through 1984 either by using discriminant analysis or by using a variety of ranking techniques. Abundance of various key species (of numerical or commercial importance) previously identified as "selected species" were compared temporally or spatially using analysis of variance (ANOVA) or non-parametric techniques. In several cases, the size or growth of a selected species was examined in addition to abundance in order to provide a basis for detecting potential sublethal effects. These methods are effective in describing general patterns and magnitudes of variability that have occurred during the preoperational period. Once plant operation begins, population levels will be statistically compared to spatial and temporal patterns observed during the baseline period, and significant changes will be identified if they occur. For these comparisons, an analysis may focus on a single species or several species grouped together in a higher taxonomic category. Components of and rationales for species "complexes" were discussed in the 1984 Data Report (NAI 1985a).

4.2 COMMUNITY STRUCTURE

Techniques utilized for analysis of both spatial and temporal aspects of community structure are outlined in Table 4.2-1.

TABLE 4.2-1. SUMMARY OF COMMUNITY ANALYSES. SEABROOK BASELINE REPORTS, 1987.

COMMUNITY	PURPOSE OF ANALYSIS	ANALYTICAL METHOD	STATIONS	DATES	DATA CHARACTERISTICS [a]
Macrozooplankton (505 micron net)	Spatial comparison	Percent composition, percent frequency	P2, P5, P7	1/87 - 12/87	Mean of 3 replicate tows; all taxa included Wilcoxon's summed rank test for selected species
	Temporal comparison	Discriminant Analysis	P2	1/78-12/84, 7/86-12/87	Mean of 3 tows/date; excluded taxa with percent frequency ≤3% plus 9 general taxa out of 125
Fish Eggs (505 micron net)	Spatial comparison	Percent composition, percent frequency	P2, P5, P7	1/87 - 12/87	Mean of two tows; all taxa included
		Abundance	P2, E1	7/86 - 6/87	
	Temporal comparison	Discriminant Analysis	P2	1/76-12/87	Mean of 4 tows/date (Jan 76-Feb 83, except for non-selected species Jan-Dec 82: 1 tow); 2 tows (Mar 83-Dec 87) excluded taxa with total percent composition <0.1 (5 out of 16 taxa); excluded 26 sampling periods with <20 eggs in all replicates
Fish larvae (505 micron net)	Spatial comparison	Percent composition, percent frequency	P2, P5, P7	1/87-12/87	Mean of two tows; taxa with percent frequency ≥ 10% included
		Abundance	P2, E1	7/86-6/87	
	Temporal comparison	Discriminant Analysis	P2	1/76-12/87	Replicates treated as for eggs; excluded species with total percent composition <0.1 or frequency of occurrence <5% (27 out of 47 taxa); excluded 29 sampling periods with <20 larvae in all replicates
Demersal fish (otter trawl)	Spatial and temporal comparison	Catch statistics	T1, T2, 13	1/76-12/87	CPUE = /10 min tow; no transformation; all species combined by station, '76 - '86
		Percent composition			PERCENT: a) Dominant species grouped by year ('76 - '87) over all stations b) Dominent species grouped by station, all years combined

(continued)

TABLE 4.2-1. (Continued)

COMMUNITY	PURPOSE OF ANALYSIS	ANALYTICAL METHOD	STATIONS	DATES	DATA CHARACTERISTICS [a]
Pelagic fish (gill net)	Spatial and temporal comparisons	Catch statistics Percent composition	G1, G2, G3	1/76 - 12/87	CPUE = /24 hr. set; no transformation; a) depths (surface and buttom) and all species combined b) surface, mid, bottom nets, Feb, Jun, Oct. '80 - '87 combined PERCENT: a) Dominant species, surface and bottom and all stations combined by year, '76 - '87 b) Dominant species, surface and bottom separate, all stations and years combined c) Dominant species surface and bottom combined, grouped by station, all years combined
Estuarine fish (beach seine)	Spatial and temporal	Catch statistics Percent composition	S1, S2, S3	7/76 - 11/84 4/87 - 11/87 7/76 - 11/84 4/87 - 11/87	CPUE /haul; total catch by year and station for all species combined PERCENT: a) Dominant species grouped by year 1976-1984 and 1987 all stations combined b) Dominant species by station, all years combined.
Benthic Macroalgae (airlift)	Temporal/ spatial	Discriminant Analysis	4,34,13,16 19,31,1MLW 17,35,5MLW	August 1978 - 1987	Mean of replicates Replicates separate; biomass log (x + 1) transformed; all species included
Marine Benthic Macrofauna (airlift)	Temporal/ Spatial	Discriminant Analysis	17,19,31, 1MLW 34 4,16,13 35,5MLW	Aug 1978-1987 Aug 1980-1984; 1986-1987 Aug 1978-1984; 1986-1987 Aug 1982-1987	Mean of replicates; excluded non-colonial species with <25 occurrences or <150 individuals in sample, based on 1978-84 data. Stepwise discriminant analysis to reduce species to 32. 1978-1984 samples in groups according to numerical classification results; 1985-1987 samples placed in groups based on depth.

[a] All data log (x +1) transformed unless otherwise noted

Discriminant Analysis

The purpose of the discriminant analysis is to provide a means of characterizing or classifying new data with respect to historical (baseline) trends in community structure. It is a multivariate statistical technique that provides a quantitative evaluation of results of other classification analyses such as cluster analysis as well as a set of multivariate criteria that may be utilized to classify new data (Cooley and Lohnes 1971).

Discriminant analysis (SAS 1985a) develops a classification criterion for samples using a measure of distance between groups. Initially, samples are placed in groups either by simple examination or by an analysis such as numerical classification. The discriminant analysis produces weighting coefficients (linear discriminant function coefficients) that identify the variables (in this case, abundance or biomass of different species) which contribute most to differentiation of the preassigned groups. The analysis then evaluates the samples based on these criteria and calculates a probability of membership in each group.

Classification of new data with respect to historical (baseline) data can also be accomplished with discriminant analysis (Cooley and Lohnes 1971). This method was extensively discussed in NAI (1984b). Using the spatial and/or temporal groups defined for the historical baseline period (through 1984), a set of multivariate criteria are developed which are then used to classify new data (in this case, 1985-1987). Probability levels associated with group membership are also calculated. In this way, spatial and/or temporal assemblages which occurred in 1985-1987 are quantitatively compared to those described for previous years.

Data from each major community (macrozooplankton, fish eggs, fish larvae, algae, and marine benthos) were prepared in a similar fashion to that done for the 1984 Baseline Report community analysis prior to running the discriminant analysis. Details of the criteria used in eliminating rare species and sparse samples are shown in Table 4.2-1. Baseline collections

(through 1984) were placed in groups identified by the results of the multi-year cluster analysis (NAI 1985b). Discriminant analysis evaluated the species/collection matrix, reassigned the collections to the baseline groups, and calculated the probability level associated with group membership. A few differences in classification that arose between the two methods may be because discriminant analysis places less weight on abundant species than cluster analysis does. Discriminant analysis might characterize a group by ephemeral, nondominant species whereas cluster analysis might characterize the same group by its dominants.

In one case (subtidal benthos), the classification variables (species) outnumbered the samples being classified. A stepwise discriminant analysis was first performed to eliminate species that do not contribute to the discriminatory power of the model (SAS 1985a). The discriminant analysis used the resulting reduced species list to classify the historical data. The 1985-1987 data were then tested using the multivariate criteria developed for the historical data.

Ranking Methods

Rank dominance scores (RDS) were calculated for macrozooplankton abundances. The scores were calculated by ranking taxa by abundance within samples in descending order, summing across all samples, and standardizing the scores against the theoretical maximum. The following formula was used:

$$\text{RDS} = 100 \times \frac{\text{sum of ranks for all species over all samples}}{\text{theoretical maximum sum of ranks}}$$

This rank thus reflects both abundance and frequency of occurrence.

Spatial analysis of plankton and finfish data included ranking by percent composition. Percents were based on total abundances over the entire period being analyzed (January-December 1987). Apparent differences in ranks

(either RDS or percent) among macrozooplankton taxa were examined with a Wilcoxon's two-sample test (Sokal and Rohlf 1969; equivalent to Wilcoxon's sum of ranks test, SAS 1985a).

4.3 SELECTED SPECIES/PARAMETERS

Temporal and spatial differences for the selected species and water quality parameters were quantitatively evaluated for the preoperational period. Analytical techniques used in this evaluation are delineated in Table 4.3-1. Many of the selected species and physical/chemical parameters monitored in the Hampton-Seabrook area show year-to-year differences that are part of natural environmental variability. These among-year differences were assessed using analysis of variance or non-parametric techniques. Most of the organisms and physical/chemical parameters show seasonal patterns as well. These within-year patterns are shown graphically in plots of the mean over all years for each month. The monthly means are typically $\log_{10}(x + 1)$ transformed before plotting.

For many of the data sets, this year's tables comparing organism abundances among years or months show geometric means and confidence limits. These are calculated by (1) log (x+1) transforming the data, (2) calculating the mean and confidence limits of the transformed data, and (3) back-transforming to the original units. Geometric means are generally somewhat lower than arithmetic means (averages of untransformed data), with the difference between the two means being greater in data sets exhibiting a high degree of variability. An outlier in a data set, such as an unusually high abundance in a single sample, will have less influence on a geometric mean than on an arithmetic mean. Thus a geometric mean is, in effect, a weighted mean, in which extreme values are given less weight than are typical values. For data sets that require logarithmic transformation for statistical analysis, the geometric means faithfully portray the relationships within the data (among years, for example), whereas arithmetic means would sometimes show a different pattern than that detected by the analysis.

TABLE 4.3-1. ANALYSIS OF TEMPORAL AND SPATIAL PATTERNS IN SELECTED TAXA AND PARAMETERS: METHODS AND DATA CALCULATIONS. SEABROOK BASELINE REPORT, 1987.

METHOD	PARAMETER/TAXON, LIFESTAGE	PURPOSE OF ANALYSIS	STA-TIONS	DATES USED IN ANALYSIS	DATA MANIPULATIONS[a]
Estuarine Benthos	*Strebiospio benedicti* *Capitella capitata* Oligochaeta *Mya arenaria* *Nereis diversicolor* *Caulleriella* sp. B Total abundance No. of taxa	spatial comparisons of seasonal abundances	3, 9; 3MLW, 9MLW;	1978-1987 (except 1985)	$\bar{x}$ per sample period, log (x+1) abundance, paired t-test
Macrozooplankton	*Calanus finmarchicus* copepodites *Calanus finmarchicus* adults *Carcinus maenas* larvae *Crangon septemspinosa* larvae *Diastylis* sp. *Pontogeneia inermis* *Neomysis americana* Oedicerotidae Cirripedia *Temora longicornis* Total abundance	spatial comparison	P2, P7; P2, P5; P5, P7;	1/87-12/87	$\bar{x}$ per sample period; Wilcoxon's summed ranks test; RDS, percent composition

continued

TABLE 4.3-1. (continued)

METHOD	PARAMETER/TAXON, LIFESTAGE	PURPOSE OF ANALYSIS	STA-TIONS	DATES USED IN ANALYSIS	DATA MANIPULATIONS[a]
Ichthyoplankton	Winter flounder larvae Yellowtail flounder larvae American sand lance larvae Atlantic cod larvae Pollock larvae Atlantic mackerel larvae Hake larvae Atlantic herring larvae Cunner larvae	Temporal comparison among years in season of highest density	P2[b]	7/75-12/87 selected months	Log (X+1) mean abundance per sample period for months which together comprised over 90% of the total annual abundance, 1-way ANOVA, Waller-Duncan k-ratio t-test
Demersal fish (Otter trawl)	Winter flounder Yellowtail flounder Atlantic cod Hakes Rainbow smelt	temporal	T1,	1/76-12/87	CPUE (no. per haul), 1-way ANOVA, Waller-Duncan k-ratio t-test
Pelagic fish (Gill net)	Atlantic herring Pollock Atlantic mackerel	temporal	all stations combined	1/76-12/87	CPUE (no. per 24-hr set) 1-way ANOVA, Waller-Duncan k-ratio t-test
Esturine fish (Beach seine)	Winter flounder Rainbow smelt Atlantic silverside	temporal	all stations combined	1/76-12/84 1/87-12/87	CPUE (no. per seine trawl) 1-way ANOVA, Waller-Duncan k-ratio t-test

continued

TABLE 4.3-1. (continued)

METHOD	PARAMETER/TAXON, LIFESTAGE	PURPOSE OF ANALYSIS	STA-TIONS	DATES USED IN ANALYSIS	DATA MANIPULATIONS[a]
Marine Benthic Selected Species	Ampithoe rubricata, Nucella lapillus, Mytillidae spat	temporal and spatial comparison of abundance	1MLW 5MLW	5/78-11/87 5/82-11/87	abundance averaged over replicates, 3 dates per year, 1-way ANOVA among years Waller-Duncan K-ratio t-test
	Jassa falcata, Mytilidae spat		17 35	5/78-11/87 5/82-11/87	
	Asteriidae		17 35	5/81-11/87 5/82-11/87	
	Pontogeneia inermis, Mytilidae spat, Strongylocentrotus droebachiensis		19,31	5/78-11/87	
	Ampithoe rubricata, Nucella lapillus, Mytilidae spat	temporal and spatial comparison of length	1MLW,5MLW	5/82-11/87	Mean and confidence interval 5/82-11/87 calculated for each year and at nearfield and farfield station pairs
	Jassa falcata, Mytilidae spat, Asteriidae		17,35	5/82-11/87	
	Pontogeneia inermis, Mytilidae spat, Strongylocentrotus droebachiensis		19,31	5/82-11/87	
	Modiolus modiolus	spatial temporal	19,31 19,31	1980-1987 1980-1987	mean per sample period, Wilcoxon's summed ranks test, Kruskal-Wallis test

continued

TABLE 4.3-1. (continued)

METHOD	PARAMETER/TAXON, LIFESTAGE	PURPOSE OF ANALYSIS	STA-TIONS	DATES USED IN ANALYSIS	DATA MANIPULATIONS[a]
Epibenthic crustaceans	Homarus americanus Cancer irroratus Cancer borealis	temporal	L1	7/75-11/87	mean CPUE (per 15 traps) per month, no transformation, 1-way ANOVA, year, month
	Homarus americanus Cancer borealis Cancer irroratus	spatial	L1, L7	6/82-11/87	mean CPUE (per 15 traps) per month, no transformation, paired t-test, stations
Benthic macroalgae	Laminaria saccharina	spatial and temporal	17, 35	1982-1987	mean number per sample period, Wilcoxon's paired ranks
	Chondrus crispus	spatial and temporal	17, 35 1MLW, 5MLW	1982-1987	mean biomass, per sample period, log (x+1) transformation, 1-way ANOVA, years Paired t-test stations

[a] log (X+1) transformation unless otherwise stated for ANOVA.
[b] Ichthyoplankton: Station P3 collections made from 7/75-6/77; P2 from 7/77-12/86.

Differences in substrate, water mass movement, temperature, light penetration, depth, food availability, reproductive success or all of these can cause variation in species abundance and growth among stations or areas. As part of our experimental design, farfield stations beyond the influence of potential impact were established as "control" stations in areas as similar as possible to the nearfield areas. Any change observed during the operational phase at nearfield stations can be compared with these farfield areas to ascertain whether the change is occurring throughout the coastal area or just at the nearfield area. To evaluate spatial differences in the selected species, a paired t-test (nearfield vs. farfield stations) or the corresponding non-parametric test, the Wilcoxon signed ranks test, was used.

Analysis of Variance (ANOVA)

Analysis of variance was used to evaluate spatial or temporal variability in both abundance and length of selected species. Analysis of variance is a statistical technique which subdivides the total variability into portions attributable to different sources (Lentner 1972). In this study, the major sources of variability were (1) spatial, among stations or areas within stations, (2) temporal, among years, seasons, or sampling dates, and (3) residual, any variability not explainable by the first two sources. The actual analysis of variance differed according to design of the particular study type, but all sought to disprove the null hypothesis that the means of one or more populations were statistically equivalent.

Annual variability was generally evaluated by a one-way analysis of variance among years at a nearfield station. In some data sets that have been shown in previous baseline reports to exhibit no differences among stations (e.g., pelagic fish), or if stations are of essentially equal distance from the intake and discharge locations (e.g., estuarine fishes), data from all stations were combined. For demersal fish, the station nearest the discharge (T2) had several missing data points, so another station (T1) was used for the among-year ANOVA. For those data sets that exhibit a high

degree of within-year variability because of seasonal fluctuations (e.g., fish larvae), a subset of the data was chosen to represent the peak period, and samples from that period in each of the years were used in the analysis. In some cases the reduced data set still had a fairly high within-year variability, but this approach resulted in significance tests that compared favorably with two-way ANOVA designs (month x year) in terms of power, and avoided the possibility of difficult-to-interpret interaction terms which could hamper the ability to address the effect of primary interest (years).

Spatial comparisons were analyzed in some cases with a paired t-test. This is equivalent to a two-way ANOVA without replication, in which the second factor is blocks of time (i.e., dates) in which pairs of stations, nearfield and farfield, were sampled. This design removes the among-date variability that is common to both stations, providing greater discriminating power than if a one-way ANOVA (or the equivalent unpaired t-test) were used.

Analysis of variance and related parametric techniques make the following assumptions: (1) all samples are randomly collected, (2) samples come from a normally-distributed population, (3) error terms are normally and independently distributed, and (4) variances of samples are equal or homogeneous (Sokal and Rohlf 1969). Random and independent collection of samples is a function of experimental design. Normality of data was tested using the Kolomogorov-Smirnov test when sample size was greater than 50 and the Shapiro-Wilk statistic when sample size was 50 or less (SAS 1985b). Homogeneity of variances was tested using the F-max test (Sokal and Rohlf 1969). If one or both of these two assumptions was not met, the data were transformed and re-evaluated. In most cases, transformation of the data improved the distribution sufficiently to allow the use of analysis of variance. Logarithmic transformations were performed by adding 1 to the data used in the analysis (either for a replicate or average of replicates; see Table 4.3-1) and taking the base-10 logarithm. Square root transformations were accomplished simply by taking the square root of the data. Where sample sizes were unequal, a general linear model was used for the ANOVA (SAS 1985a).

Multiple Comparisons

If a significant difference among means was discovered using analysis of variance, The Waller-Duncan k-ratio t-test was used to test which means or groups of means were significantly different from each other. This test is less conservative than several other commonly used multiple comparisons tests (i.e., more likely to find significant differences between means). It was selected because more conservative tests failed in several cases to detect any significant differences among means even when the overall F-test of the ANOVA was highly significant.

Several types of non-parametric tests of significance were also used. Differences in ranks were assessed by using the Wilcoxon two-sample test (Sokal and Rohlf 1969; equivalent to Wilcoxon's sum of rank test, SAS 1985a) or the Kruskal-Wallis test (Sokal and Rohlf 1969). Wilcoxon's two-sample test is a ranking procedure by which two samples of unequal size can be compared. All data are ranked, then ranks are summed within samples. The differences between the summed ranks are compared using the Mann-Whitney U statistic when the larger sample size is ≤ 20 or Student's t value when sample size is > 20. The Kruskal-Wallis test was used as a non-parametric alternative to one-way ANOVA to test among-year differences or among-station differences. This procedure ranks all pooled data, then sums ranks within a group and compares differences using an H-statistic, distributed approximately as chi square (Sokal and Rohlf 1969).

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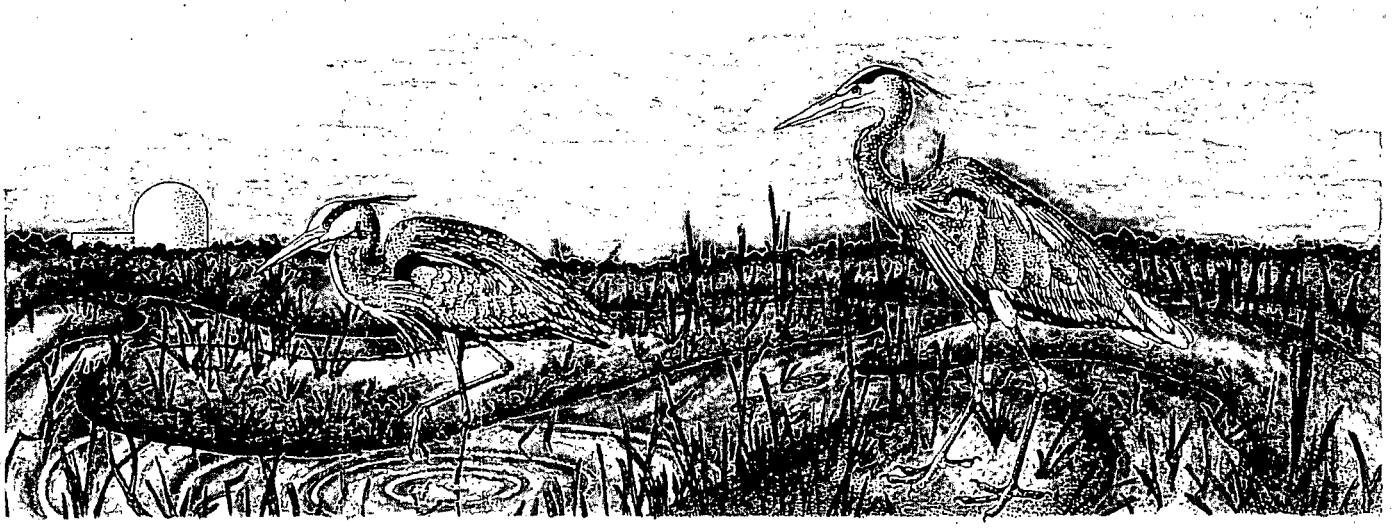
SEABROOK STATION
1990 ENVIRONMENTAL STUDIES
IN THE HAMPTON-SEABROOK AREA



A CHARACTERIZATION OF ENVIRONMENTAL CONDITIONS

New Hampshire
Yankee

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

R. Shea

SEABROOK ENVIRONMENTAL STUDIES, 1990
A CHARACTERIZATION OF ENVIRONMENTAL CONDITIONS IN THE HAMPTON-SEABROOK AREA DURING THE OPERATION OF SEABROOK STATION

TECHNICAL REPORT XXII-II

Prepared for

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NEW HAMPSHIRE YANKEE DIVISION
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TABLE OF CONTENTS

PAGE

PAGE

PAGE

LIST OF FIGURES

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

LIST OF TABLES

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

PAGE

LIST OF APPENDIX TABLES

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Seabrook Environmental Studies began in 1969 to monitor the balanced indigenous marine communities in preparation for assessing the effects of Seabrook Station Operation. Plant operation began on July 23, 1990. Seabrook Station operated at full power intermittently in August, for 2-3 weeks/month from September-November, then continuously in December.

The purpose of this first operational report is to document the impact of operation, if any, on the balanced indigenous population of shellfish, fish, and wildlife in the waters in and around Seabrook Station's intake and discharge. The optimal design of an impact assessment study ensures that a potential impact is delineated from naturally-occurring variability. The Seabrook Monitoring Program accomplishes this by (1) collecting data before and during operation to provide a "temporal" reference, and by (2) monitoring area of potential impact as well as areas outside the influence of the thermal plume to provide a "spatial" reference.

In each biological community, the experimental design of the monitoring program focuses on its most variable aspect. For example, the species distributions of plankton and pelagic fish change radically from season to season, but are generally similar within the study area. The sampling program collected data at least monthly to monitor seasonal trends in abundance at a nearfield and farfield area. For benthic macrofauna and macroalgae, seasonality tends to be less of an issue in comparison to the marked changes in species composition with depth and substrate. Benthic collections were made in the predominant substrate type, horizontal hard bottom ledge, along nearfield and farfield transects at regular depth intervals. The American lobster, soft-shell clam, and certain fish are of particular concern because of their commercial or recreational importance. Data on all life stages of these species were collected.

Evaluation of the potential for impacts from Seabrook Station took place in a systematic stepwise fashion. Information collected during 1990, particularly during the operational period (August-December) was compared to the historical data base. Potential operational effects could be ruled out if any of the following criteria were met:

1) Biological patterns observed in 1990 were similar to previous years at the nearfield stations.

2) Biological trends in 1990 differed from previous years, but were consistent in both nearfield and farfield areas, suggesting an area-wide phenomenon.

The evaluation of potential impacts focuses on the most likely source (intake, discharge).

1.2 INTAKE MONITORING

The goal of intake monitoring is to demonstrate that entrainment and impingement have not had an adverse effect on the biota. Seabrook Station employs a midwater intake, located 5 m above the bottom in 17 m of water. Zooplankton, ichthyoplankton, and finfish would be the organisms with the greatest potential for entrainment and impingement. Year-to-year variability of organisms, along with their seasonal fluctuations, and location in the water column affect the number of entrained/impinged organisms.

In-plant collection of entrained ichthyoplankton and bivalve larvae allows an estimation of the number of these groups that are entrained. Species composition of the entrained fish and bivalve larvae was similar to that collected in offshore tows. Numbers of entrained fish eggs and larvae were lower than would be expected based on estimates from offshore samples; certain taxa may avoid entrainment based on their preferred location in the water column.

Entrainment has had no demonstratable effect on the plankton communities at the intake station. Macrozooplankton, bivalve larvae, and ichthyoplankton egg and larvae communities at the intake station were similar to previous years in terms of species composition and abundance. Species composition of the microzooplankton community from mid-September to December in 1990 was unusual in comparison to collections made from 1978-84 and 1986, when microzooplankton were last collected. However, community composition was similar at all three stations, suggesting that this difference was not restricted to the nearfield area. Similarly, community composition in 1990 of holo- and meroplankton, and bivalve and ichthyoplankton larvae was statistically similar at the intake, discharge, and farfield areas. Tychoplankton, species that are associated with the substrate during most of their life but occasionally venture into the water column, continued to show nearfield-farfield spatial differences because of their affinity with the bottom substrate. Some of the ichthyoplankton egg taxa also showed spatial differences, but in 1990 these were evident only during the preoperational period. Most taxa did not exhibit reduced densities at the intake, indicating that there was no relationship to plant operation.

The number of adult fish lost from impingement has been low. In 1990, a total of 499 finfish and 4 lobsters were impinged. Demersal species, including lumpfish, pollock, longhorn sculpin, and windowpane were the most numerous species impinged. Lumpfish in particular tends to be associated with rocky areas or other structures; the intake structure may provide attractive habitat for this species. Pelagic species, even those that preferred the mid-water zone, were rarely impinged.

Trends in the adult finfish community were examined in light of the combined effects of egg and larval entrainment and adult impingement. Because of the widespread movements of pelagic fish, there is no valid reference area. Impact assessment instead focuses on a comparison of trends in 1990 to previous years. Two pelagic species showed catch

differences in 1990, but these differences appeared to be unrelated to plant operation. Catches of Atlantic mackerel were significantly higher in 1990 than previous years. As high catches were observed beginning in June, this difference appears to be unrelated to plant operation. Atlantic herring catches were substantially lower throughout 1990 continuing a trend of decreasing abundance, first noted in 1988. Diminishing catches of Atlantic herring have been observed both locally and regionally (NOAA 1991a). Aside from these two species, the pelagic fish community showed no differences in species distribution and abundance from previous years.

1.3 DISCHARGE MONITORING

1.3.1 Discharge Plume Monitoring

Potential impacts in the discharge plume are related to the threat of exposure to elevated temperature in surface and near-surface waters. Surface-dwelling organisms, phytoplankton and lobster larvae, are those most likely to be entrained in the discharge plume. Water temperatures at the plankton intake station in June and August-December were higher in 1990 than, on average, previous years. However, given the natural variability in water temperatures, temperatures throughout 1990 at the intake were statistically similar to previous years; furthermore there were no differences in water temperatures among the intake, discharge, and farfield stations. Continuously-monitored surface temperatures at the discharge were similar to a farfield reference station during the first two months of operation. The average monthly difference was less than 0.22°C. From August-December, discharge temperatures averaged 0.8-1.6°C higher on a monthly basis than those at the farfield station.

The phytoplankton species assemblage has historically shown little stability in terms of density level, community structure, and seasonal patterns. Collections in 1990, resumed after a three-year

hiatus, were markedly different than previous years. Total abundances at all three stations were consistently higher in 1990 when compared to the previous years' average. Colonial Cyanophyceae (blue-green algae) predominated during most of 1990 at intake, discharge, and farfield station. As these organisms were present prior to plant start-up, appear to be widespread in the Gulf of Maine (Balch *et al.* 1991), and occurred at both nearfield and farfield areas, their occurrence appears unrelated to plant operation. Aside from the colonial cyanophytes, the remaining taxa showed seasonal trends and abundance levels that were similar to previous years.

Of particular concern is the phytoplankter *Gonyaulax* sp., which produces paralytic shellfish poisoning (PSP), or red tide in this and other coastal areas. This organism usually reached toxic levels (as measured in *Mytilus edulis* meat by the State of New Hampshire) in May or June in Hampton Harbor, causing closure of flats to bivalve shellfish fishing for a period of one to seven weeks each year. In 1990, toxic levels of PSP were recorded in late May through June in Hampton Harbor at levels generally much lower than those observed prior to 1990.

Lobster larvae (Stages I-IV) have a strictly surface orientation. In coastal New Hampshire, successful recruitment of larvae is the single biggest factor in determining the level of adult catches. All stages were rare in the study area, generally occurring from June to October, with highest densities from late June through late August. Evidence suggests that waters off Hampton-Seabrook may be too cold for local production of lobster larvae, and those collected off Hampton-Seabrook may actually originate from elsewhere in the Gulf of Maine and from Georges Bank. In 1990, unusually large numbers of Stage I lobster larvae were caught in July, followed by exceptionally large numbers of Stage IV larvae in August. These unusual aggregations may have been associated with areas of water mass convergence, where lobster larvae have been known to accumulate. Higher-than-average surface temperatures may also have contributed to higher numbers of lobster larvas. As high

numbers of larvae were found at both nearfield and farfield areas prior to plant start-up, these events are not related to plant operation.

Subsurface fouling panels, located three meters below the surface, placed in the discharge plume area show the timing, type, and abundances of settling benthic organisms. Benthic recruitment and community development have shown a seasonal pattern that has been highly consistent from year to year. Historically, recruitment and settlment activities have been low in winter and spring but intensified from summer through fall. Seasonal patterns on surface panels in 1990 were similar to previous years. Differences occurred in the settlement level; abundance, biomass, and taxa richness (short-term panels) were higher than previous years, whereas community development (monthly sequential) biomass was lower. As these differences occurred at both nearfield and farfield areas, they are most likely unrelated to plant operation.

The intertidal and shallow subtidal area near Sunk Rocks is outside the immediate plume area, but might be exposed to slight elevations in temperature. Species composition of benthic macroalgae and macrofaunal communities in the intertidal and shallow subtidal areas changed with depth and substrate, but was highly similar among years. Community composition of intertidal and shallow subtidal macroalgae and intertidal macrofauna in 1990 was similar to previous years. The shallow subtidal macrofuana assemblage in 1990 was more similar to mid-depth assemblages than to shallow subtidal assemblages from previous years. High numbers of the barnacle *Balanus crenatus* contributed to the observed differences. Individual species showed significant variations in recruitment levels from year to year and among stations.

As the plant operated for only a few days before collections for benthic community analysis were made, it is unlikely that there are any plant-related differences. Differences either occurred at both nearfield and farfield stations or were not restricted to the operational period, with the exception of one case. Mytilidae at the nearfield

shallow subtidal station were significantly higher in abundance than previous years. As this result relies on only one collection (November) it cannot be definitively related to plant operation.

1.3.2 Benthic Monitoring

The mid-depth and deep subtidal areas were monitored to determine if, during operation of the circulating water system discharge, any discharge impacts resulted from increased detritus levels. Year-to-year differences in the macroalgae and macrofaunal communities have been small in comparison to variations with depth and substrate. The species composition was highly predictable and distinct for each depth zone. Benthic community collections in 1990 were similar to previous years. Since they were collected after only four days of commercial power generator, no differences were expected. Individual macrofauna species historically have shown significant differences among years in their annual abundance levels. Only one taxon, Mytilidae, showed a difference in 1990 that was restricted to the nearfield mid-depth station. However, increased abundance levels occurred throughout the year and were not restricted to the operational period.

The demersal fish community could be susceptible to a number of plant-related effects, including larval entrainment, adult impingement, and detrital effects on their primary food resource, benthic macrofauna. Because of distinct differences between the nearfield and farfield stations, potential plant effects were investigated separately for the two areas. While large numbers of commercial lobster traps have prevented sampling the nearfield station in September and October, making impact assessment during those months difficult; seasonal movements of the dominant species, which composed nearly 80% of the total catch, were found to be similar in 1990 to previous years. Lower catches of Atlantic cod and hakes in 1990 caused decreases in total catch. As diminished catches of these species occurred prior to plant operation, they are unrelated to plant operation.

Because of its commercial importance, the American lobster was monitored in the discharge area. Seasonal patterns in catches have been similar from year to year, affected by bottom temperatures that influenced molting and activity levels. Catches usually increased to a peak in August or September, then declined. Monthly lobster catches were consistently higher than average in 1990 at both discharge and farfield stations, reflecting trends observed throughout New England (NOAA 1991b). Since 1984, annual mean catch per unit effort of legal-sized lobsters has been below the 16-year average except in 1986. This apparent decline, a primary concern to lobstermen, was a result of natural variation in combination with the effects of the changes in the legal size limit instituted in 1984, 1989, and 1990 by the State of New Hampshire. Many lobsters that would have been of legal size under the old law were protected from harvest until their next molt. The increase in legal size in 1990 reduced catches to approximately 3% of the total catch, the lowest level observed since the beginning of the study.

Jonah and rock crabs are two other important epibenthic predators. Jonah crabs exhibited lower catches at the discharge area in 1990; however, these differences were first observed prior to plant operation and thus appear unrelated. Rock crabs have shown large fluctuations in annual catches. Higher-than-average catches in 1990 were due to large catches from June through August at both the discharge area and Rye Ledge. There was no evidence of plant-induced effects.

1.3.3 Estuarine Monitoring

Although the likelihood of a cooling water system operational impact on the Hampton-Seabrook estuary is low, temperature, salinity, benthos, fish, and the soft-shell clam were all monitored in the estuary.

Temperature and salinity both showed regular seasonal cycles. Maximum temperatures usually occurred in July with minima in January or

February. Salinity levels had a less distinct pattern, but were usually lowest in spring, a result of increased runoff, and highest in summer. Salinity levels in Browns River were high from 1980-1982, coincident with low precipitation levels and highest discharge volumes of tunnel dewatering through the Seabrook settling basin, which terminated in 1983. By 1986, salinity levels had returned to pre-1980 levels where they have remained since. The estuarine benthic community was highly variable in species composition and abundance, but predominantly composed of surface and subsurface deposit-feeding polychaetes. The number of species, total abundance, and abundance of some of the dominant species increased during the period when salinity levels were higher than average, but have returned to the levels observed prior to the tunnel dewatering discharge; no substantial changes to the benthic community were evident in 1990.

Estuarine fish included anadromous species as well as residents. Alewives and blueback herring pass into the estuary in spring, travelling upriver to spawn. Catch levels were affected by year class strength as well as water temperature and water level, which were influenced by rainfall and resulting runoff. Young-of-the-year and yearling rainbow smelt were occasionally and erratically caught in the estuary, but historically have never constituted a substantial portion of the total catch. In 1990, smelt composed 35% of the total catch, the result of large numbers of smelt in May and August. The predominant resident species has been Atlantic silverside, which made up over two-thirds of the total catch and nearly 90% during their most abundant period, August through November. Variations in abundance of this species was the single most important factor in year-to-year changes in total catch. Abundance of Atlantic silverside was lower in 1990 than average, continuing the trend of decreased abundances first observed in 1982.

The species of greatest concern in the Hampton-Seabrook estuary is the soft-shell clam. Density levels of spat, juveniles, and/or adults have been monitored in the estuary since 1969. Densities

of harvestable clams depend on a set of complex, interacting conditions. A successful set of spat is crucial, but this factor alone does not ensure high densities of harvestable clams. Once settled, survival of young-of-the-year clams depends on protection from its two main predators, green crabs and humans, as well as from disease. In 1976, a large spatfall throughout the estuary resulted in high densities of harvestable clams in 1980-1982. Increased levels of predation prevented recruitment of the highly successful spatfalls in 1980 and 1981. Light spatfalls from 1982-1988 in combination with an increase in predation have accounted for a precipitous decline in standing stock since 1983. In addition, neoplasia, a cell growth disease fatal to clams, has been detected from clams in Hampton estuary. This may also have contributed to the decline of harvestable clams. Experimental seeding of clam spat has been conducted in Hampton Harbor in 1987 and 1988 by the State of New Hampshire in one flat area was not successful. However, the possibility of augmenting the *Mya* population artificially must be factored into the monitoring program. Young-of-the-year settlement increased in 1989 and again in 1990. Survival of the 1989 year class at Flats 1 and 2 was evidenced by increased yearling densities. This may in part be due to decreased green crab catches and reductions in digging activities.

2.0 DISCUSSION

2.1 INTRODUCTION

2.1.1 General Perspective

Environmental studies for Seabrook Station began in 1969 and focused on plant design and siting questions. Once these questions were resolved, a monitoring program was designed which has examined the structure of all the major biological communities as well as the distribution, abundance, and size of selected species within each community. The goal was to assess the temporal (seasonal and yearly) and spatial (nearfield and farfield) variability that had occurred during the preoperational period. This report focuses on data collected since 1976 for fisheries studies and since 1978 for plankton and benthos studies as these years signify the beginning of a consistent preoperational sampling design.

Seabrook Station operation began intermittently in July and August, and continued for periods of approximately three weeks in September and October. After operation at 100% for less than a week at the beginning and end of November, the plant operated continuously for the month of December (Table 2.1-1). Although the plant was not generating power throughout 1990, the circulating water system was active throughout the twelve-month period.

The period beginning in August 1990 is considered the beginning of the operational period for the purposes of the environmental assessment of plant-related effects. Previous reports provided a perspective on the sources and magnitude of the naturally-occurring variability against which environmental conditions during operation would be compared. Identification of the level of variability, both spatial and temporal has been a critical component of this program, one which was a major focus for sampling design. The degree of variability has important implications for impact assessment. The rationale for

TABLE 2.1-1. NUMBER OF DAYS OF OPERATION AND AVERAGE DAILY FLOW OF SEABROOK STATION CIRCULATING WATER SYSTEM IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

MONTH	DATES OF 100% POWER GENERATION	NUMBER OF DAYS	DAYS OF CIRCULATING WATER SYSTEM OPERATION	AVERAGE DAILY FLOW (mgd)
Jan		0	31	324
Feb		0	28	564
Mar		0	31	563
Apr		0	30	563
May		0	31	562
June		0	30	563
Jul	23-26	4	31	582
Aug	7-12	6	31	588
	16-22	7		
	27-31	5		
Sep	1-19	19	30	588
Oct	4-27	24	31	590
Nov	5-9	5	30	590
	25-30	6		
Dec	1-31	31	31	589

focusing on specific sources of variability for each component of the monitoring program is discussed in the following section.

2.1.2 Sources of Baseline Variability

The optimal design of an impact study has four prerequisites that ensure that a potential impact is delineated from any naturally-occurring variability (Green 1979): (1) knowledge of the type, time and place of potential impact; (2) measurement of relevant environmental and biological variables; (3) monitoring before the potential impact occurs to provide a temporal control; (4) monitoring in an area unaffected by impact to serve as a spatial control. The experimental design of the Seabrook Environmental Program was structured to meet these prerequisites.

A basic assumption was that there are two major sources of naturally-occurring variability: (1) that which occurs among different areas or stations, i.e., spatial, and (2) that which varies in time, from daily to weekly, monthly or annually. In the experimental design and analysis, these studies focused on the major source of variability in each community type and then determined the magnitude of variability in each community (Figure 2.1-1). In certain communities, particularly planktonic, where circulation patterns provide a similar habitat throughout the area, spatial variability was found to be low in comparison to seasonal. The study design therefore focuses on frequent sampling to monitor seasonal trends generally at only one farfield and one or two nearfield stations. In other communities, particularly benthic, spatial variability has been higher than seasonal variability. Benthic sampling design has focused on the dominant substrate type in the discharge area, horizontal hard-bottom ledge, with paired nearfield and farfield stations representing the major depth zones. Finfish catches have shown both seasonal and spatial differences. Therefore, these studies make frequent (at least monthly) collections in the area of the discharge as well as farfield areas to the north and south.

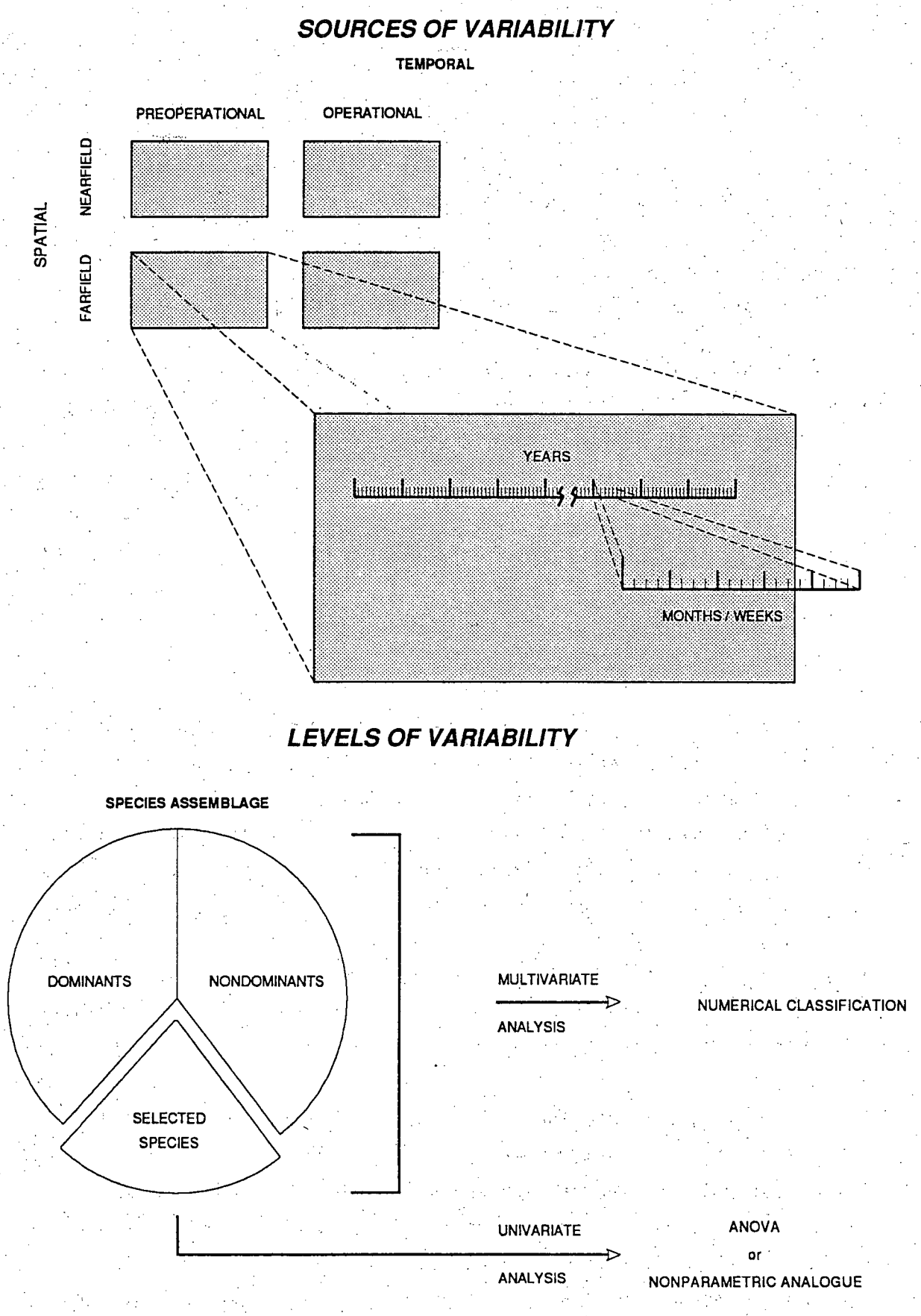


Figure 2.1-1. Schematic of sources and levels of variability in Seabrook Environmental Studies. Seabrook Operational Report, 1990.

Because the estuary is an aquatic nursery area and recreationally-important clam flat, baseline collections monitoring seasonal and annual patterns were also made there for operational phase comparison.

Biological variability can be measured on two levels: species and community. A species' abundance, recruitment, size and/or growth are important for understanding operational impact, if any. For this reason, these parameters were monitored for selected species from each community type. Species were chosen for more intensive study based on their commercial or numerical importance, sensitivity to temperature, potential as a nuisance organism, and habitat preference. In some cases, a selected species actually encompassed a complex of species grouped together in a higher phylogenetic category. Components of and rationale for species "complexes" were discussed in the 1984 Data Report (NAI 1985a). Overall community structure, e.g., the number and type of species, total abundance and/or the dominance structure, may also be affected by plant operation in a way not detectable by monitoring single species; therefore, the natural variation in community structure was monitored at the regular time intervals determined by early studies to be sufficient for this purpose.

Appropriate statistical methods must be used in conjunction with a well-planned experimental design in order to determine the sources and magnitude of variability. Temporal (annual) and spatial variability in species abundance and size were tested by using analysis of variance or nonparametric analysis that provide a means of evaluating the statistical significance of changes in the operational period. Spatial, seasonal, and annual variations in community structure were assessed with numerical classification or multivariate analysis of variance. Specific statistical designs are described in the Methods (Section 4.0).

Identification of the sources and levels of variability utilizing the methods discussed above has its ultimate focus on the sources of potential influence from plant operation, and the sensitivity of a

community or parameter to that influence (Table 2.1-2). Naturally, a community or species might be affected by more than one aspect of the cooling water system; however, the focus here is on the aspect of main concern. In general, intake (pumped) entrainment and impingement would potentially affect mainly plankton communities, including fish eggs and larvae, and juvenile and adult fish. If they occur, thermal effects from the discharge (e.g. plume entrainment) would most likely affect nearshore surface water quality, phytoplankton, lobster larvae, and intertidal and shallow subtidal benthos. Although no effects are anticipated in the estuary from the offshore discharge, fish and soft-shell clam populations have been monitored in that area to provide a baseline for operational phase comparisons. Bottom-dwelling organisms, including macrofauna, macroalgae, epibenthic crustaceans, and demersal fish, may be influenced by detritus potentially arising from moribund entrained plankton that is discharged with the cooling water. A previous impact assessment (NAI 1977e) has shown that the balanced indigenous community in the Seabrook study area should not be adversely influenced by the above factors. Results from the biological communities, species and environmental parameters sampled will be discussed in light of the feature of the cooling water system that has the greatest potential for affecting them.

2.1.3 Impact Assessment

The purpose of this report is to assess the impacts of the first several months of commercial operation of Seabrook Station on the aquatic biota of coastal waters of New Hampshire. Two impacts of concern, entrainment and impingement, were addressed with in-plant monitoring of the organisms entrapped in the circulating water system (CWS). The effects on the balanced, indigenous population of aquatic biota in the waters in the vicinity of the CWS intake and discharge structures were evaluated through continued monitoring at the stations established during the preoperational period and statistical comparison of the results on both the community and the species levels.

TABLE 2.1-2. SUMMARY OF BIOLOGICAL COMMUNITIES AND TAXA MONITORED FOR EACH POTENTIAL IMPACT TYPE. SEABROOK OPERATIONAL REPORT, 1990.

MONITORING AREA	IMPACT TYPE	SAMPLE TYPE	LEVEL MONITORED: COMMUNITY	LEVEL MONITORED: SELECTED SPECIES/ PARAMETERS
Intake	Entrainment	Microzooplankton	x	x
		Macrozooplankton	x	x
		Fish eggs	x	
		Fish larvae	x	x
		Soft-shell clam larvae		x
		Cancer crab larvae		x
	Impingement	Juvenile/Adult fish	x	x
Discharge	Thermal Plume	Nearshore water quality		x
		Phytoplankton	x	x
		Lobster larvae		x
		Intertidal/shallow subtidal macroalgae and macrofauna	x	x
		Subsurface fouling community	x	x
	Detrital Rain	Mid-depth/deep macrofauna and macroalgae	x	x
		Bottom fouling community		x
		Demersal fish	x	x
		Lobster adults		x
		Cancer crab adults		x
Estuary	Cumulative Sources	Estuarine temperature		x
		Soft-shell clam spat and adults		x
		Estuarine fish	x	x

The ability to determine whether operation of Seabrook Station has affected the "balanced, indigenous population" is dependent upon a systematic approach to impact assessment incorporating both temporal and spatial components (Figure 2.1-2). Potential operational effects could be ruled out if 1) 1990 results were similar to previous years or 2) 1990 differences were observed in both nearfield and farfield areas. In addition, other potential sources of change were investigated before concluding that plant operation affected the aquatic biota.

2.1.4 Sampling Location

Plankton and water quality studies have been based on samples collected in the nearfield (intake) area and a farfield area (Rye Ledge) located beyond the influence of the Station's operation. In July 1986, sampling at a third station (P5) was resumed in the vicinity of the discharge (Figure 2.1-3); preoperational sampling had been conducted at P5 for various plankton programs from July 1977 through December 1981. In addition, bivalve larvae were collected from Hampton Harbor (P1) starting in July 1986. Entrainment sampling was resumed in June 1990 for bivalve larvae and ichthyoplankton. Fish were sampled offshore by bottom trawls and gill nets near the discharge area and at two farfield sites, and by seining at three locations in the Hampton-Seabrook estuary (Figure 2.1-4). Marine algae and benthos were collected by divers at a series of stations stratified by depth near the intake/discharge area and in a farfield area (Table 2.1-3, Figure 2.1-5). Benthos in soft substrate was sampled along two transects in the estuary (Figure 2.1-6). Lobster (*Homarus americanus*), rock crab (*Cancer irroratus*), Jonah crab (*C. borealis*) and green crab (*Carcinus maenas*) were collected in traps (Figures 2.1-6, 2.1-7). Soft-shell clams (*Mya arenaria*) were dug from five flats in the estuary (two flats were dug only for spat starting in 1985) (Figure 2.1-6), with farfield spat stations in Ipswich, MA and in Ogunquit, ME (through 1984 only) (Figure 2.1-8).

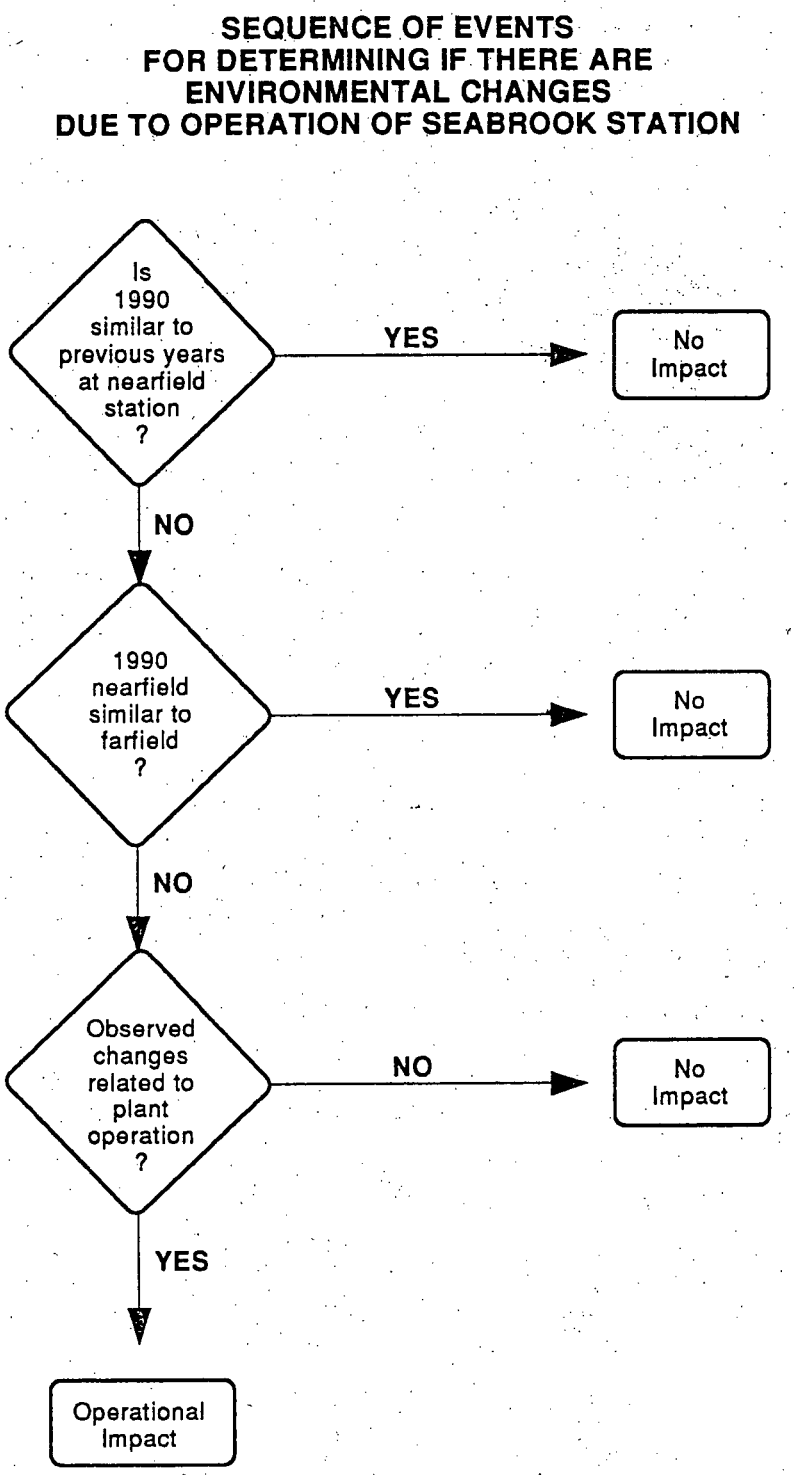
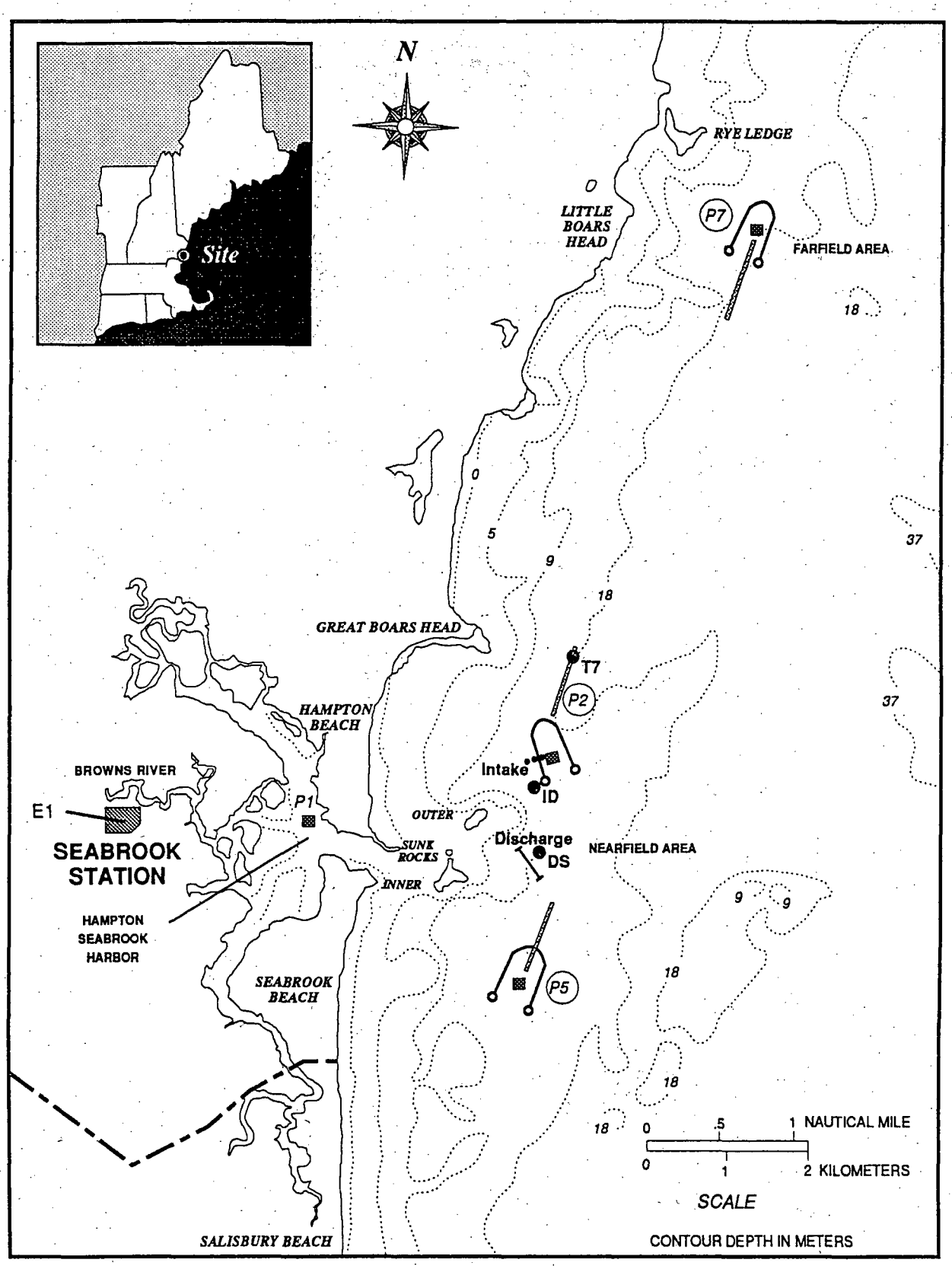


Figure 2.1-2. Sequence of events for determining if there are environmental changes due to the operation of Seabrook Station. Seabrook Operational Report, 1990.



▩ = bivalve larvae and water quality stations

= ichthyoplankton, phytoplankton and zooplankton stations

= lobster larvae stations

● = continuous temperature stations

E1 = Seabrook Entrainment Station

Figure 2.1-3. Plankton and water quality sampling stations. Seabrook Operational Report, 1990.

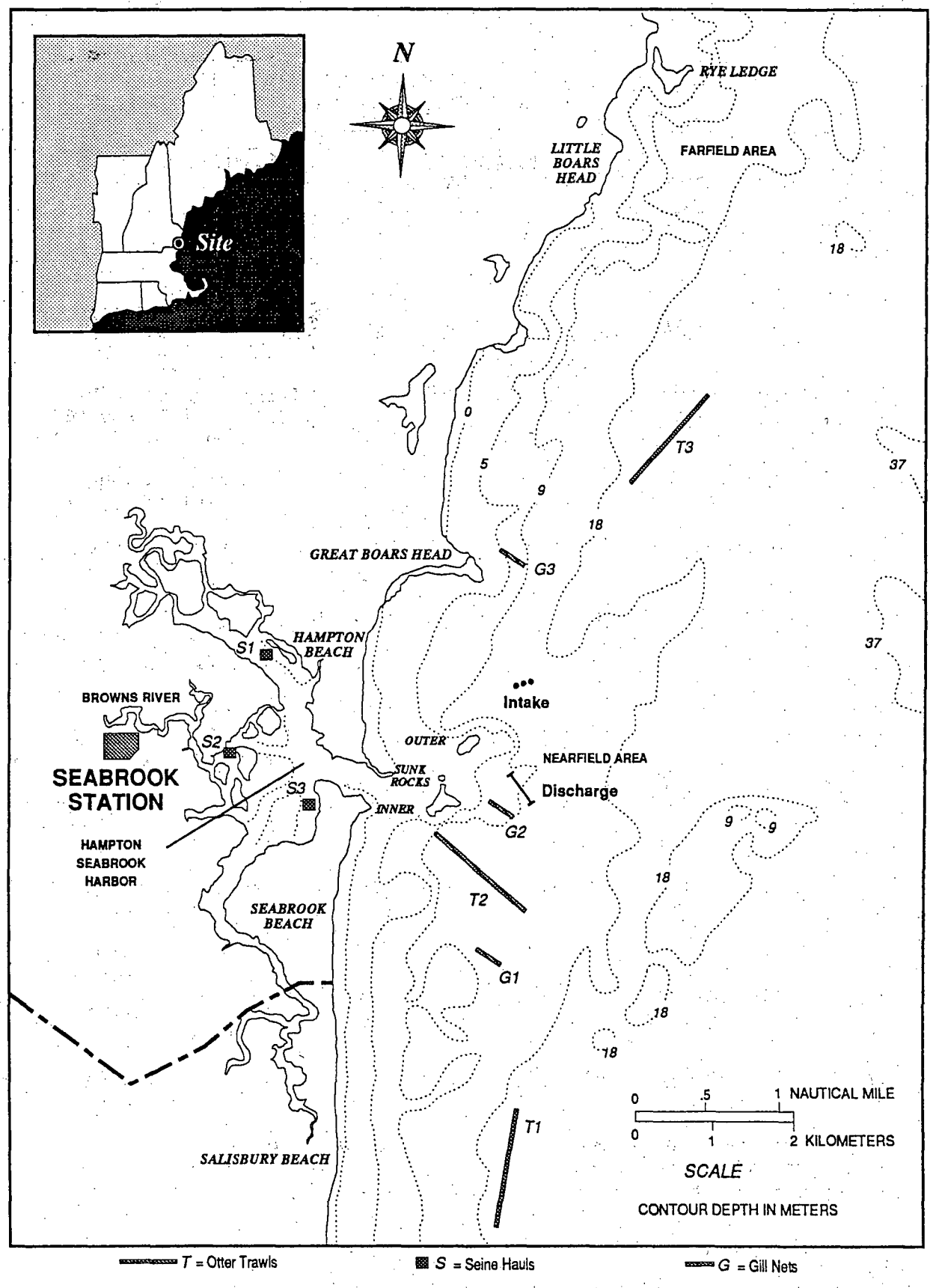


Figure 2.1-4. Finfish sampling stations. Seabrook Operational Report, 1990.

TABLE 2.1-3. BENTHIC ALGAE AND MACROFAUNA STATION LOCATIONS AND DESCRIPTIONS. SEABROOK OPERATIONAL REPORT, 1990.

DEPTH[a,b] m	ft	STATION	LOCATION LONGITUDE	LATITUDE	APPROXIMATE COMPOSITION OF HARD SUBSTRATES
4.6	15	B17	70°47'37"	42°54'00"	Algae covered ledge (95%) and crustose covered ledge (5%)
4.6	15	B35[c]	70°46'07"	42°57'22"	Algae covered ledge (85%) and boulders (15%)
9.4	31	B31[c]	70°45'29"	42°58'04"	Algae covered rocks (30%) mussel beds (60%) and cobble (10%)
9.4	31	B16	70°47'03"	42°54'16"	Algae covered ledge (75%) and mussel beds (25%)
12.2	40	B19	70°47'13"	42°53'40"	Algae covered ledge and boulders (60%) and mussel beds (40%)
18.3	60	B13	70°46'58"	42°53'54"	Algae covered ledge and boulders (40%) mussel beds (55%) and cobble (5%)
18.9	62	B04	70°45'59"	42°53'23"	Mussel beds (70%) and algae covered ledge (30%)
21.0	69	B34[c]	70°44'06"	42°57'23"	Mussel beds (60%) and algae covered ledge and boulders (40%)
0.3	1	B1MLW	70°47'41"	42°53'56"	Algae covered ledge (90%) mussel beds (10%)
1.3	4	B1MSL	70°47'46"	42°53'50"	Algae covered ledge (100%)
0.3	1	B5MLW[c]	70°45'36"	42°58'19"	Algae covered ledge and boulders (90%) mussel beds (10%)
1.3	4	B5MSL[c]	70°45'44"	42°58'12"	Algae covered ledge (100%)

[a] approximate depth below mean low water, subtidal stations
[b] approximate depth above mean low water, intertidal stations
[c] farfield stations

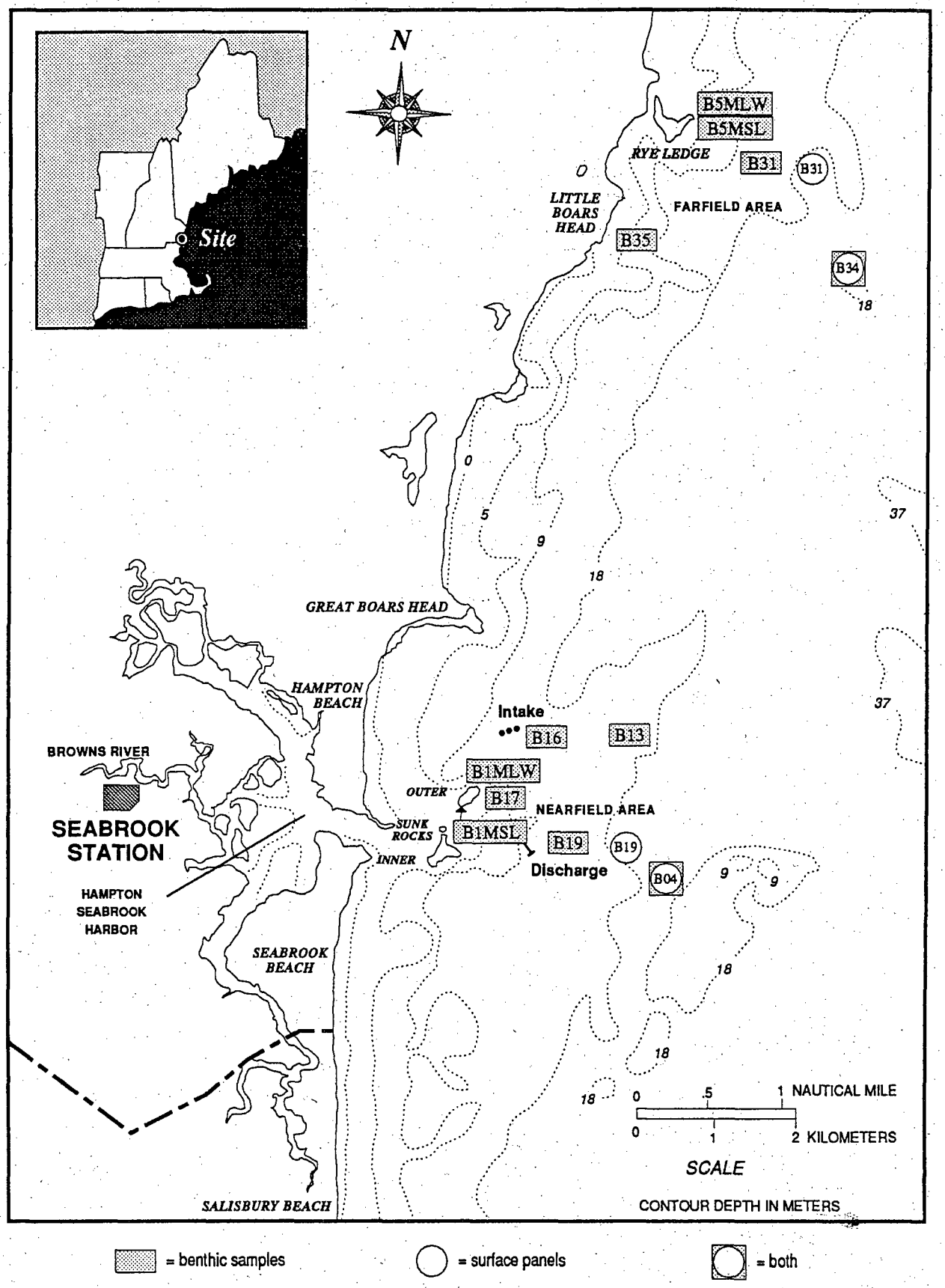
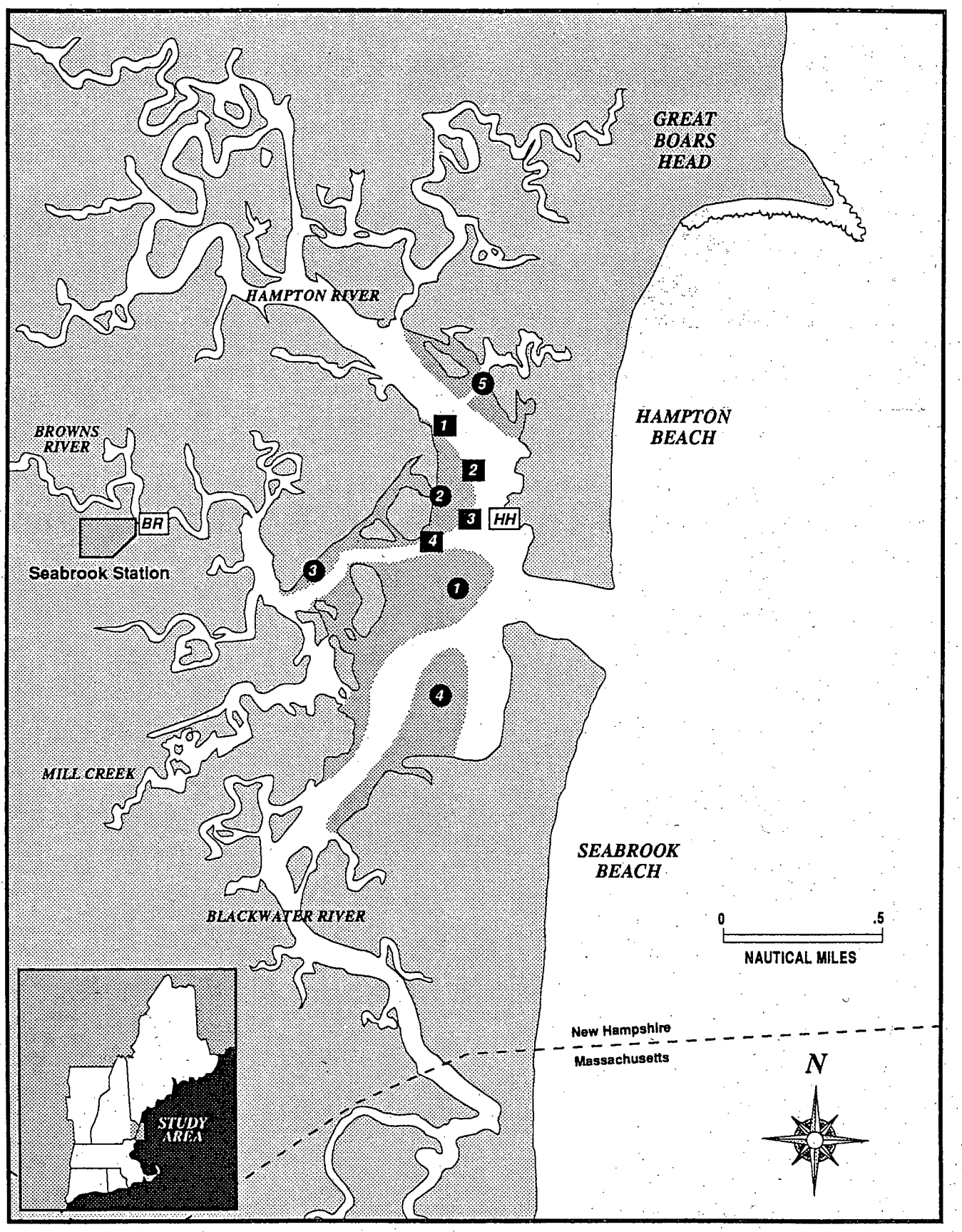


Figure 2.1-5. Benthic marine sampling stations. Seabrook Operational Report, 1990.



1 = Clam Flats 3 = Green Crab Traps HH BR = Estuarine Temperature/Salinities

Figure 2.1-6. Hampton-Seabrook estuary temperature/salinity, soft-shell clam *Mya arenaria* and green crab *Carcinus maenas* sampling stations. Seabrook Operational Report, 1990.

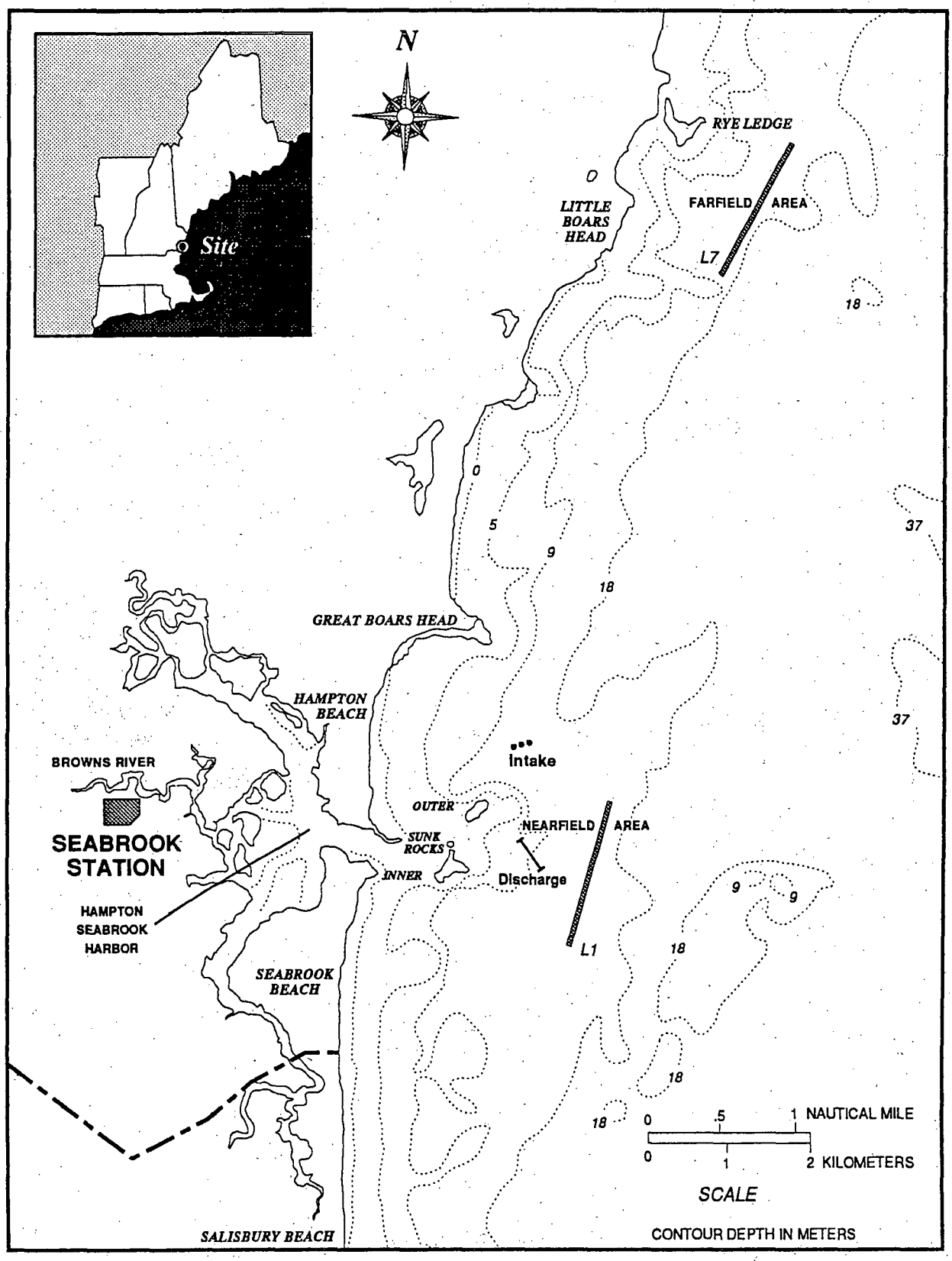
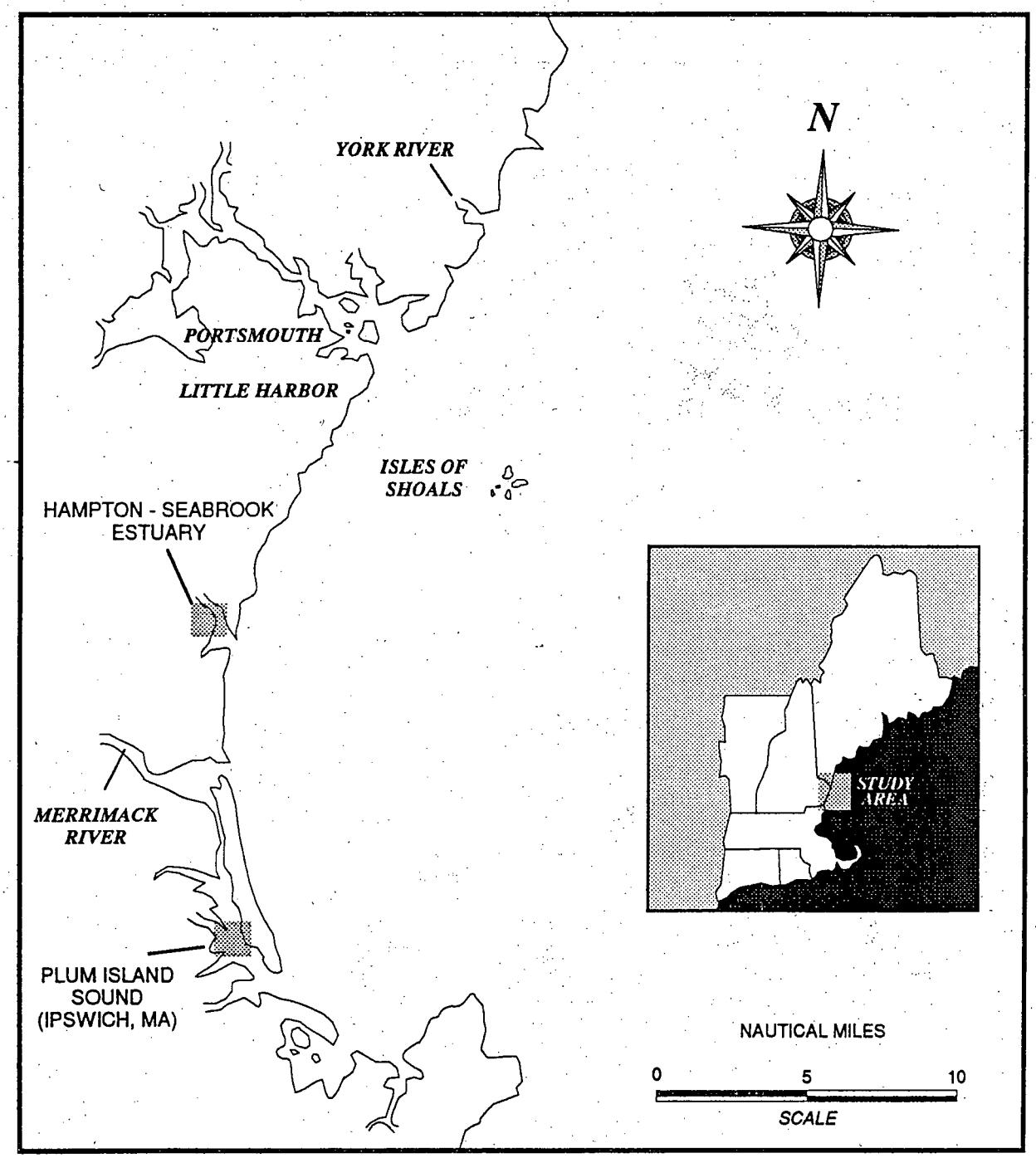


Figure 2.1-7. Locations of lobster and rock crab trapping areas. Seabrook Operational Report, 1990.



= study sites

Figure 2.1-8: Sampling sites for *Mya arenaria* spat. Seabrook Operational Report, 1990.

2.2 INTAKE AREA MONITORING

2.2.1 Plankton

The focus of monitoring plankton in the intake area was to evaluate the effect of entrainment on community structure and population levels. Due to their limited control of horizontal movements and broad vertical distribution in the water column, all types of planktonic organisms could be exposed to entrainment. Data on actual levels of entrainment are presented to quantify losses to the bivalve larvae and icthyoplankton communities and individual species. Comparisons of community structure and abundances of selected species in the nearfield area during the period of commercial power generation (August-December 1990) were made to both the farfield area in 1990 and the nearfield and farfield areas historically. These comparisons address the question of whether the balanced, indigenous population has been affected by the commercial operation of the plant.

An estimation of the number and type of plankton species affected by plant operation depends on (1) the time of year, and (2) the degree of yearly variability. Results from the community analysis give an indication of the number and type of species present (and thus entrainable) at any particular time of year. The selected species analysis enables a more precise estimate of the entrainable density for key species by examining their annual and seasonal variability. Knowledge of the within-year and among-year variability allows for more reliable estimates of impact than relying on samples taken in a single season and year.

2.2.1.1 Entrainment

Beginning in 1985, Seabrook Station operated its circulating water cooling system, although no power or heated discharge were produced until 1990. Entrainment samples were collected through June 1987. Since that time until 1990, the circulating water system had not

been operating at a frequency or capacity sufficient to warrant further sampling. Entrainment sampling was reinitiated in June 1990 for both bivalve larvae and ichthyoplankton.

Fish egg, larvae, and bivalve larvae communities entrained during the July 1986-June 1987 period were similar to those collected offshore, although the smaller sample volumes and less-frequent sample collection in the plant produced some expected differences. The top-ranked entrained fish egg and larvae and bivalve larvae species were similar to those from offshore collections (NAI 1990b). Abundances of most of the dominant species of eggs were lower in entrainment samples than in offshore samples, in some cases substantially so, due to the different depths represented by the two types of samples. The depth distribution of ichthyoplankton is typically uneven, particularly for eggs of some species, which are heavily concentrated near the surface or the bottom thus making them less susceptible to entrainment. Abundances of fish larvae and bivalve larvae were similar in in-plant and offshore collections in 1985-1986 (NAI 1990b).

The results of the in-plant sampling in 1990 confirmed observations made previously. Generally the relative abundance of both ichthyoplankton and bivalve larvae was similar between offshore (Station P2) and in-plant (entrainment) samples (Table 2.2-1), while several species of fish eggs were less abundant in the in-plant samples. Cunner larvae (not a dominant in previous comparisons) were much less abundant in the in-plant samples, reflecting this species' preference for the near-surface waters as demonstrated in diel studies of vertical stratification (NAI 1981b, 1981f). Abundances of bivalve larvae in in-plant samples averaged about 30% higher than in offshore samples, with differences species specific (Table 2.2-1). Although species were ranked the same in in-plant and offshore collections, *Heteranomia squamula, Modiolus modiolus* and *Hiatella* sp. appeared to be more commonly entrained, indicating that larvae of these taxa are not distributed homogeneously in the water column. In general, however, the species composition of the plankton likely to be entrained in Seabrook

TABLE 2.2-1. COMPARISON OF GEOMETRIC MEAN ABUNDANCES OF TOP-RANKED FISH EGG, FISH LARVAE, AND BIVALVE LARVAE TAXA COLLECTED OFFSHORE AT STATION P2 AND IN ENTRAINMENT SAMPLES AT SEABROOK STATION FROM JUNE THROUGH DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

DOMINANT SPECIES	ABUNDANCE[a] ENTRAINED (E1)	ABUNDANCE[a] OFFSHORE (P2)
Fish eggs[b]		
Cunner/yellowtail flounder	51	444
Rockling/hake	44	247
Windowpane	43	170
Hake	35	491
Atlantic cod/haddock/witch flounder	27	17
Atlantic mackerel	12	26
Atlantic whiting	8	11
Fourbeard rockling	7	9
Fish larvae[b]		
Cunner	9	178
Fourbeard rockling	6	25
Atlantic seasnail	6	1
Hake	2	13
Windowpane	2	4
Radiated shanny	2	3
Winter flounder	2	2
Atlantic whiting	1	7
Atlantic mackerel	<1	5
Bivalve larvae[c]		
Mytilus edulis	3621	3442
Heteranomia squamula	2633	1649
Modiolus modiolus	720	275
Hiatella sp.	594	245
Mya arenaria	9	11

[a]Based only on periods when entrainment and offshore samples were collected within several days of each other
[b]No./1000 m^3
[c]No./m^3

Station's circulating water system was similar to the offshore environment as measured by plankton sampling. Therefore, offshore sampling results can be used to give a rough estimation of species composition and abundance likely to be entrained.

An estimate of the total number of bivalve larvae and ichthyoplankton entrained during the period of in-plant sampling in 1990 is reported in Tables 2.2-2 and 2.2-3. Bivalve larvae entrainment was highest in June and July. *Mytilus edulis* was the predominant species subject to entrainment, along with *Modiolus modiolus* and *Heteranomia squamula*. Fish egg entrainment was highest in June and July; over 80% of the eggs were Atlantic mackerel and cunner/yellowtail flounder. Larval losses were heaviest from August to October, and the majority were cunner, fourbeard rockling, Atlantic seasnail, and Atlantic whiting.

Slightly less than 1,250 million fish eggs and 122 million fish larvae were estimated to be entrained from June to December in 1990. Entrainment losses estimated from in-plant collections were much lower than the estimates presented in the Summary Document (NAI 1977e), even when adjusted for the partial year of sampling and the use of only one unit instead of two. The annual loss of Atlantic mackerel was originally estimated to be 8.8 billion eggs, or 4.4 billion for 1 unit. If the 6-month estimate obtained for Atlantic mackerel (518.8 million) in 1990 is doubled, it is still much lower than the original estimate. Similarly, original estimates for winter flounder (0.158 billion), Atlantic mackerel (2.26 billion) and Atlantic menhaden larvae (0.331 million), are all 1-4 orders of magnitude higher than the preliminary estimates obtained in 1990 (Table 2.2-2). The entrainment loss originally estimated for soft-shell clam, 83 billion larvae per year (NAI 1977e) is an order of magnitude higher than the 8.1 billion estimated from 1990 in-plant collections during the period of maximum abundance (Table 2.2-2).

TABLE 2.2-2. ESTIMATED NUMBER OF BIVALVE LARVAE (in billions/month) ENTRAINED BY THE COOLING WATER SYSTEM AT SEABROOK STATION DURING JUNE-OCTOBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	JUN	JUL	AUG	SEP	OCT
Mytilus edulis	733.8	2,922.9	178.7	131.3	24.6
Modiolus modiolus	151.8	421.2	19.6	300.1	17.0
Placopecten magellanicus	0	0.4	0	0.2	<0.1
Heteranomia squamula	130.6	915.8	301.0	320.5	23.5
Spisula solidissima	25.0	27.6	4.1	9.9	2.4
Mya arenaria	1.3	2.4	0.1	2.5	1.8
Mya truncata	5.1	243.3	0.2	0.1	0.3
Hiatella sp.	232.4	594.4	24.6	22.5	2.7
Macoma balthica	0	26.4	0	0.1	0
Bivalvia	22.9	114.0	11.0	5.2	2.1
Teredo navalis	0	0	<0.1	0	0
Solenidae	28.7	27.4	3.6	0.8	0.6
TOTAL	1,331.6	5,295.8	543.0	793.2	75.0

TABLE 2.2-3. MONTHLY ESTIMATED NUMBERS OF FISH EGGS AND LARVAE (IN MILLIONS) ENTRAINED BY THE COOLING WATER SYSTEM AT SEABROOK STATION DURING JUNE-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

TAXON	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Eggs							
Atlantic mackerel	499.1	19.1	0.6	0	0	0	0
Cunner/Yellowtail flounder	380.4	105.0	4.7	0.2	0.1	0	0
Rockling/hake	86.1	10.2	15.4	1.6	0.7	0.2	0
Hake	6.2	10.9	17.6	2.2	0.4	0	0
Windowpane	13.5	10.0	8.8	4.0	0.1	0	0
Cod/witch flounder	16.3	5.3	2.2	1.3	0.7	0.4	0
Atlantic whiting	1.5	3.6	1.5	2.7	2.0	0.1	0
Fourbeard rockling	4.2	0.7	1.7	0.7	0.1	0	0
American plaice	2.3	0.3	0	0	0	0	0
Atlantic cod	0	0.2	0.4	0	0	0.9	1.0
Witch flounder	0	0	0.1	0.3	0	0	0
Cusk	0	0.1	0	0	0	0	0
Larvae							
Cunner	0	0.1	31.7	10.2	0.7	0	0
Fourbeard rockling	1.9	0.1	16.5	11.7	7.7	0	0
Atlantic seasnail	8.6	2.9	0.1	0	0	0	0
Atlantic whiting	0	0	0.3	4.4	3.0	0	0
Radiated shanny	4.6	0.1	0.1	0	0	0	0
Hake	0	0.1	1.4	2.0	1.3	0	0
Windowpane	0	0.1	0.7	2.0	1.0	0	0
Winter flounder	2.9	0.3	0	0	0	0	0
Atlantic herring	0	0	0	0	0	0.1	0.6
Unidentified	0	0	0.3	0.3	0.1	0	0
Lumpfish	0.6	0	0	0	0	0	0
Atlantic cod	0.5	0	0	0.1	0.1	0	0
American plaice	0.3	0.1	0	0	0	0	0
Witch flounder	0	0	0.3	0	0	0	0
Tautog	0	0	0.1	0.1	0.1	0	0
Atlantic mackerel	0.2	0	0	0	0	0	0
Pollock	0	0	0	0	0	0	0.2
Fourspot flounder	0	0	0	0.1	0.1	0	0
Rainbow smelt	0.2	0	0	0	0	0	0
Gulf snailfish	0.1	0	0	0	0	0	0
Goosefish	0	0	0.1	0	0	0	0
Atlantic menhaden	0	0	0.1	0	0	0	0
Yellowtail flounder	0.1	0	0	0	0	0	0
Snailfish	0.1	0	0	0	0	0	0

The question of whether the entrainment of these and other planktonic organisms has affected the balanced indigenous population is addressed in the following sections on community structure (Section 2.2.1.2) and selected species (Section 2.2.1.3).

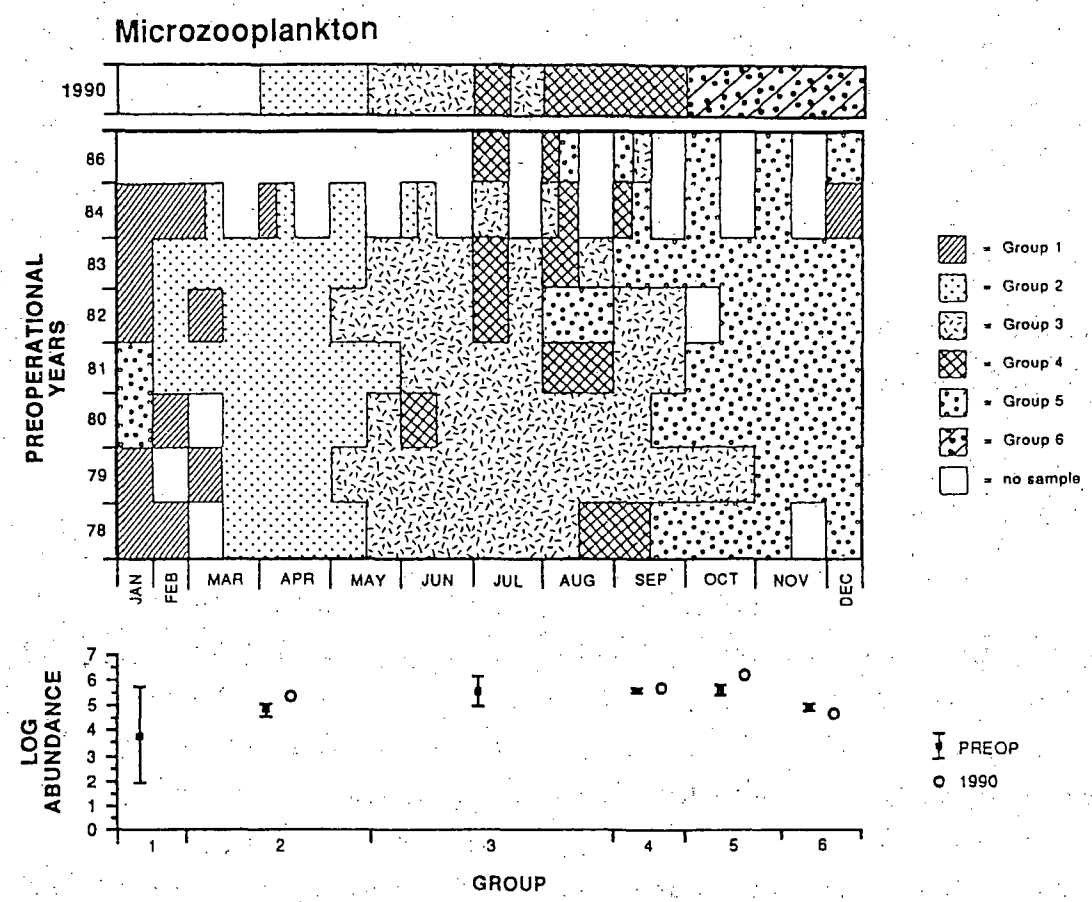
2.2.1.2 Community Structure

The purpose of examining the community structure of entrainable plankton is to determine whether operation of Seabrook Station has had an effect on the balanced indigenous population of planktonic organisms. Potential operational effects could be ruled out if the 1990 community was similar at the nearfield to previous years, or if 1990 differences were consistent throughout the area as demonstrated by MANOVA. Community composition in 1990 was compared to previous years using numerical classification. The community composition was considered unchanged if collections at the nearfield station in 1990 in a particular season were similar to the majority of samples from the same season from previous years, causing the analysis to group them together.

All of the planktonic communities discussed in this section had species assemblages that changed with season during the baseline period (Figures 2.2-1, 2.2-2, and 2.2-3). These groups were differentiated primarily on the distribution and abundance of dominant species; however, the relative abundance or even absence of other species was also a factor. The species entrained depend on the seasonal assemblage present at the time.

Microzooplankton

Microzooplankton exhibited several overlapping groups in spring and summer, indicative of both some year-to-year changes in community structure as well as a variable "transition period" in the late summer assemblage (Figure 2.2-1). The life cycles of the copepods *Oithona* sp. and *Pseudocalanus* sp. greatly influenced the structure of



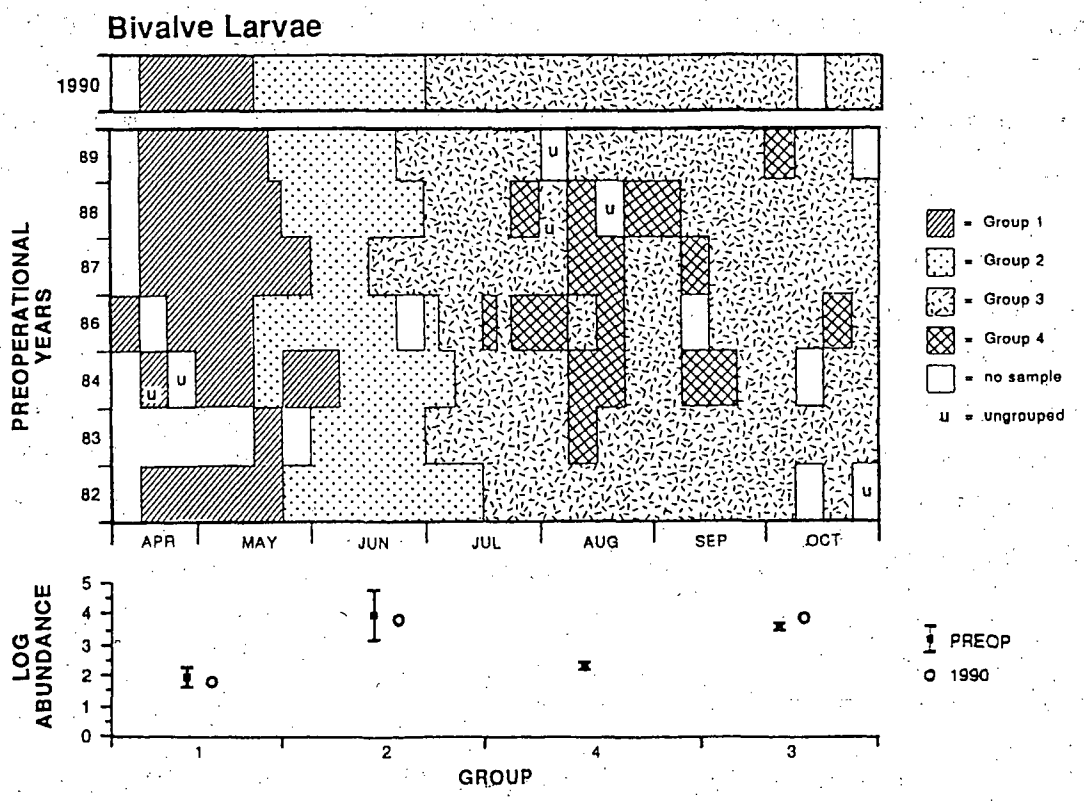


Figure 2.2-1. Months of occurrence and log (x+1) mean abundance (no./m ^{3}) in preoperational years and 1990 for seasonal groups formed by numerical classification of the microzooplankton and bivalve larvae collections. Seabrook Operational Report, 1990.

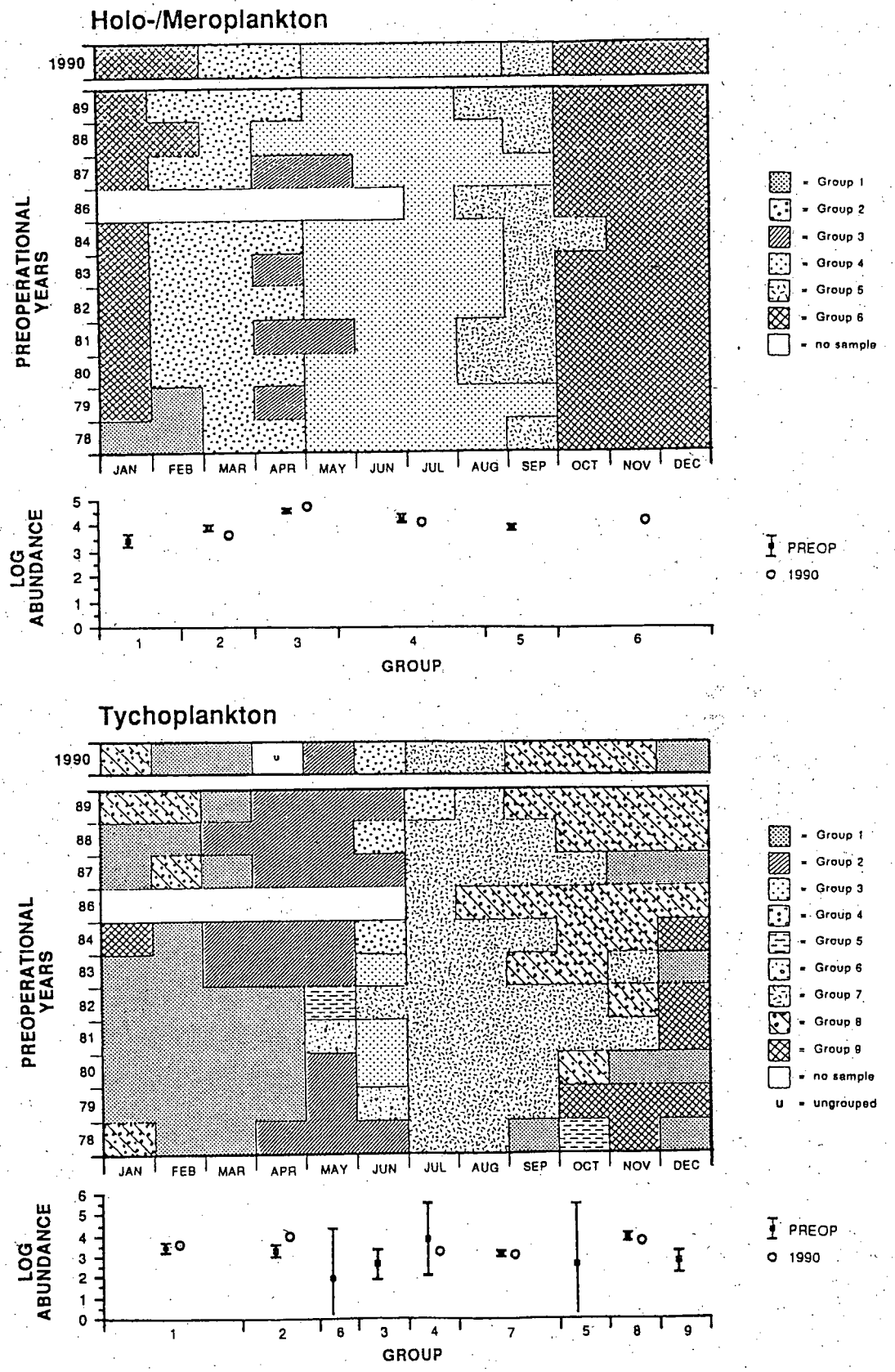


Figure 2.2-2. Months of occurrence and log (x+1) mean abundance (no./1000 m³) in preoperational years and 1990 for seasonal groups formed by numerical classification of the holo- and meroplankton and tychoplankton species of macrozooplankton collections. Seabrook Operational Report, 1990.

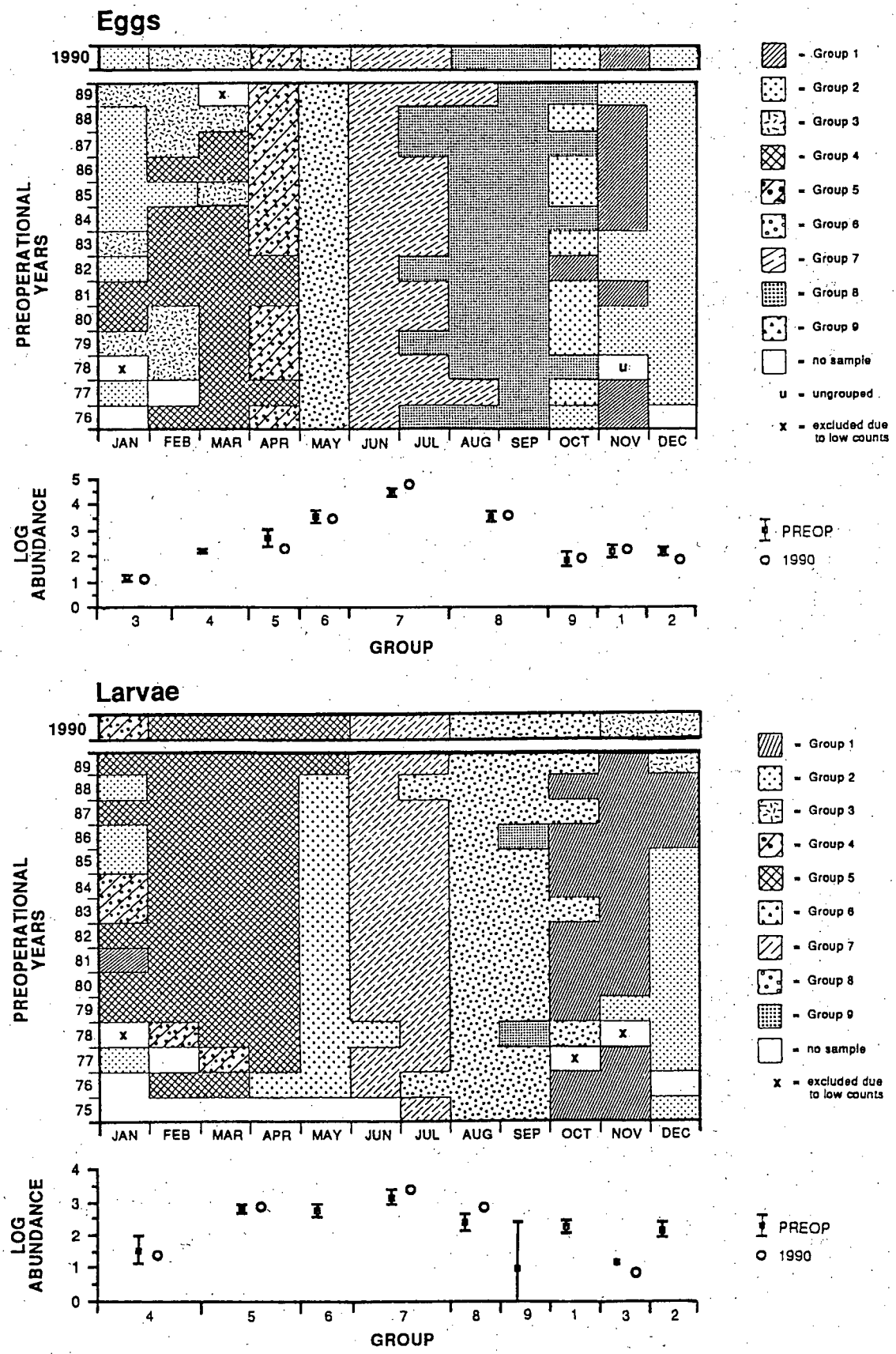


Figure 2.2-3. Months of occurrence and log (x+1) mean abundance (no./1000 m^3) in preoperational years and 1990 for seasonal groups formed by numerical classification of finfish eggs and larvae. Seabrook Operational Report, 1990.

the microzooplankton community. Other taxa, such as cirripedia larvae (spring), bivalve larvae (summer, fall) and tintinnids (fall, winter) characterized the community seasonally. From April through mid-September 1990, the microzooplankton community exhibited a seasonal progression similar to that observed between 1978 and 1986. During the remainder of 1990 most taxa were present at similar levels to previous years, although low numbers of bivalve larvae and the presence of rotifers and *Microsetella norvegica* in the fall made 1990 unusual, leading to the formation of a new group (6). As there were no significant differences in community structure between the nearfield and farfield stations in 1990 (Table 2.2-4), this transition in community structure is unlikely to be related to the operation of Seabrook Station. During 1990 there were no discernible impacts to the microzooplankton community in terms of species composition or abundance due to entrainment.

Bivalve Larvae

Seasonal variations in bivalve larvae community structure at nearfield Station P2 were consistent among years, including 1990 (Figure 2.2-1). *Hiatella* sp., *Mytilus edulis* and *Heteranomia squamula* were regular dominants characterizing the seasonal groups. Other species were typically abundant for shorter periods.

The similarity of the succession of taxa between 1990 and preoperational periods indicates that entrainment of bivalve larvae has not altered the composition of this assemblage in the vicinity of the plant. A comparison of species composition throughout 1990 among nearfield Stations P2 and P5 and farfield Station P5 further confirmed this conclusion (Table 2.2-4). There were no significant differences among these stations.

TABLE 2.2-4. SUMMARY OF NEARFIELD/FARFIELD (P2, P5 VS. P7) SPATIAL DIFFERENCES IN PLANKTON COMMUNITIES AND SELECTED SPECIES IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

COMMUNITY	DIFFERENCE BETWEEN NEARFIELD (P2 AND P5) AND FARFIELD (P7)
Microzooplankton	
Community	None
Selected species	None
Bivalve Larvae	
Community	None
Selected species	None
Macrozooplankton	
Community	Holoplankton/meroplankton - none Tychoplankton; nearfield > farfield
Selected species	*Neomysis americana* P2 > P5, P7
Ichthyoplankton Egg	
Community	Nearfield > farfield
Ichthyoplankton Larvae	
Community	None
Selected species	None

Macrozooplankton

In the past, the seasonal patterns of the macrozooplankton assemblage have been consistent (Figure 2.2-2), reflecting, primarily, the population dynamics of the dominant copepod species (holoplankton) modified by seasonal presence of larvae of benthic organisms (meroplankton)(NAI 1990b). The interannual variability in seasonal patterns of tychoplankton (taxa whose behavior includes movement between the substrate and the water column on a regular basis) was examined separately for this analysis (Figure 2.2-2). Holo- and meroplanktonic components of macrozooplankton assemblages have been distinct and consistent, showing high predictability from year-to-year. Seasonal succession of holo- and meroplankton assemblages in 1990 exhibited the same pattern observed in previous years. The copepods *Calanus finmarchicus* and *Centropages typicus* were consistently among the dominants. The greatest variability among years in terms of associations of species was evident in February and April. Variation in February could be due to relatively low abundances. The combined effects of freshwater flow and solar warming may affect the timing of the transition from winter to spring biological conditions, causing biological conditions in April to be unpredictable. Although both the holoplanktonic and meroplanktonic components of the macrozooplankton are susceptible to entrainment, there is no indication that these portions of the community have been significantly impacted. Community structure and abundance were similar at Station P2 in 1990 both to previous years and to the farfield area (Station P7).

Seasonal succession of tychoplankton species has shown greater variability than the holo- and meroplankton. With the exception of early spring and mid-summer, tychoplankton species composition has not been highly predictable and could resemble any of three or four patterns (Figure 2.2-2). However, it is highly likely that at any time of the year, either *Neomysis americana* or *Pontegeneia inermis* or both species will be a dominant. Seasonal changes in community structure largely reflected changes in abundance of these two species. April 1990 was

ungrouped, distinguished by unusually high abundances of *Mysis mixta* and *Gammarus lawrencianus* and seasonally typical abundances of other taxa.

Despite a highly variable seasonal succession of tychoplankton, it is evident that species composition in 1990 resembled that previously observed at Station P2. Comparisons to the farfield area confirmed previously noted (NAI 1990b) differences between the areas, i.e., that abundances of tychoplankton were greater in the nearfield than the farfield (Table 2.2-4). This pattern had been attributed to the more complex substrate of cobble and sand at the nearfield station compared to the uniformly sandy bottom at the farfield station. There is no indication that the tychoplankton assemblage has been affected by operation of the plant's circulating water system.

Ichthyoplankton (Fish Eggs and Larvae)

Fish egg assemblages in most months showed a predictable seasonal progression. There are two periods during the year (January-February and October) when it would be difficult to predict the planktonic fish egg community structure due to the high degree of variability among years (Figure 2.2-3). Seasonal succession of planktonic fish egg species composition and abundance in 1990 followed patterns previously observed and was most similar to the most recent preoperational years. Although spatial differences had not previously been investigated, there were differences in spatial distribution of fish eggs in 1990 when considering the entire year, while comparison among stations during the period of commercial operation (August-December) revealed no significant differences (Table 2.2-4). Differences were limited to a number of taxa that typically occur in the first half of the year. Abundances tended to be higher in the nearfield than the farfield, further suggesting they were not related to entrainment. Since the nearfield assemblage was similar in 1990 to preoperational years and species-specific vertical distribution of fish eggs tends to reduce their susceptibility to

entrainment, it is unlikely that this difference among stations is attributable to operation of Seabrook Station.

Seasonal assemblages of fish larvae could be divided into six major types based on their dominant taxa: fall (predominated by Atlantic herring), late fall-early winter (pollock, American sand lance, Atlantic herring), winter-spring (American sand lance), spring (winter flounder, snailfishes, radiated shanny, American plaice and American sand lance), late spring-early summer (Atlantic mackerel, cunner and fourbeard rockling) and late summer (cunner and fourbeard rockling). Variations in density of the major taxa, especially during transition periods (primarily November, December and January), caused small changes in species composition leading to the formation of overlapping "sub-groups". During most of 1990, seasonal patterns were similar to previous years (Figure 2.2-3). November and December 1990 collections were unusual in that they were represented by relatively low abundances of Atlantic herring, pollock and American sand lance larvae, resembling only December 1989 among the preoperational collections.

The 1990 ichthyoplankton community at Station P2 was compared to Stations P5 and P7 encompassing both the entire year and the August-December period representing commercial operation of the plant. In both cases, the nearfield and farfield communities were statistically similar (Table 2.2-4), indicating that the low abundances observed in November and December were not restricted to the intake area but were widespread. Thus, it is unlikely that these biological conditions reflected impacts due to entrainment of finfish larvae.

2.2.1.3 Selected Species

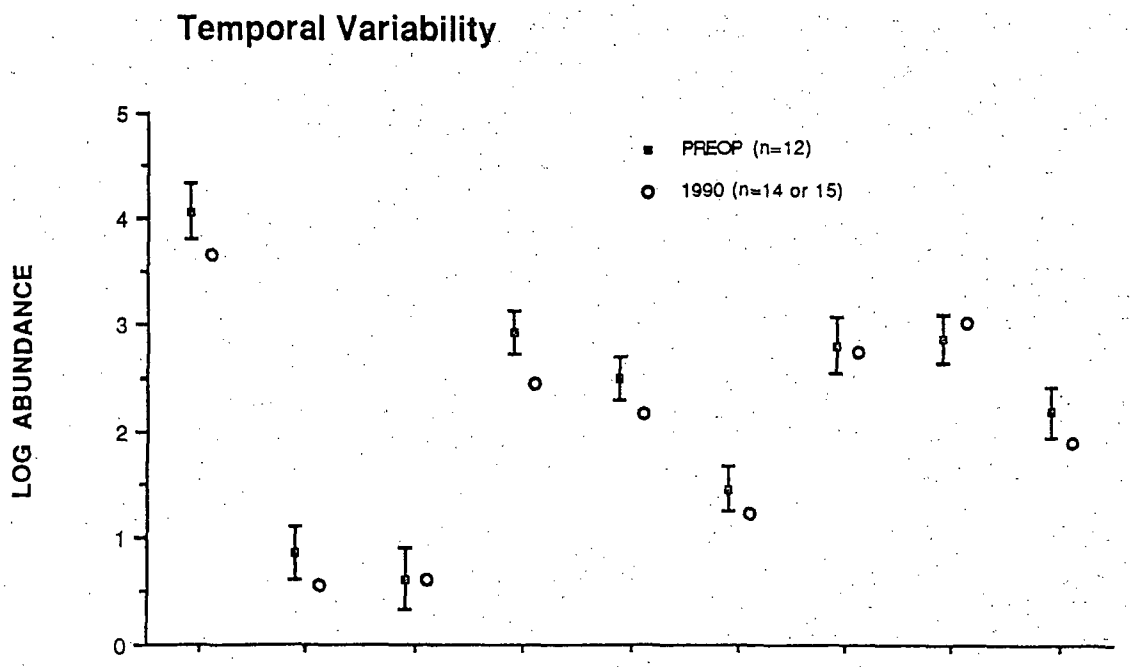
Eleven species with various lifestages from the pelagic zooplankton communities were designated as selected species. The existence of seven to twelve years of preoperational data allows an estimation of seasonal and annual variability. These species exhibited

different degrees of numerical importance; their relative contributions to their respective communities are shown in Figures 2.2-4 and 2.2-5.

The zooplankton selected species (including various life-stages) historically have constituted less than 40% of the overall abundances (Figures 2.2-4 and 2.2-5). In both the microzooplankton and macrozooplankton assemblages, other copepods typically have made as large or larger a contribution to overall abundances. In the microzooplankton, copepod nauplii and copepodites (unspeciated) have been extremely abundant. In the macrozooplankton, copepods other than the selected species have historically been dominant if averaged over the year; however, the noncopepod selected species have been dominants in certain seasons. All of the zooplankton selected species reached peak abundance in spring and summer, with the exception of *Neomysis americana*, which has been most abundant in fall through early spring.

Abundances of zooplankton selected species in 1990 were evaluated in relation to the preoperational years in both nearfield (Stations P2 and P5) and farfield (Station P7) using analysis of variance (Table 2.2-5). Both the entire year and the operational period from August through December were tested. It was typically the case that differences in abundances occurred between preoperational years as a whole and 1990. These differences, however, were not restricted to the nearfield area or to the period of commercial operation (August through December). Thus, there is no evidence through this initial period that commercial operation of the plant has significantly impacted populations of the zooplankton in the study area.

Two species of bivalves were also examined for trends in their larval stages (Figure 2.2-5, Table 2.2-5). Peak abundances of *Mytilus edulis* have historically occurred in early summer while *Mya arenaria* larvae have typically peaked in the August through September period. *M. edulis* has usually dominated the bivalve larvae collections and did so again in 1990. *M. arenaria* makes only a minor contribution to the total abundance of bivalve larvae (Figure 2.2-5). Abundances in the



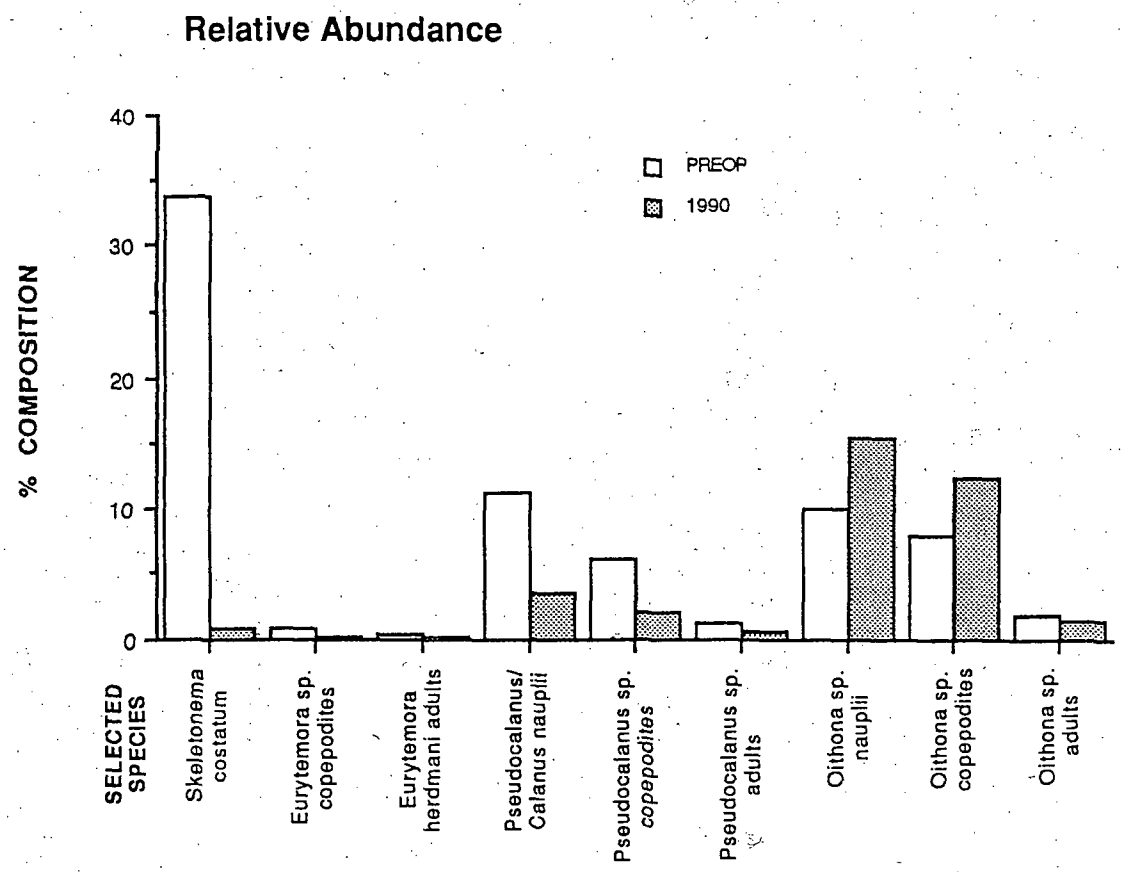


Figure 2.2-4. Mean log (x+1) abundance and 95% confidence interval, and percent composition for selected species of phytoplankton (cells/liter) and microzooplankton (no./m^3) at Station P2, 1978-1984 and 1990. Seabrook Operational Report, 1990.

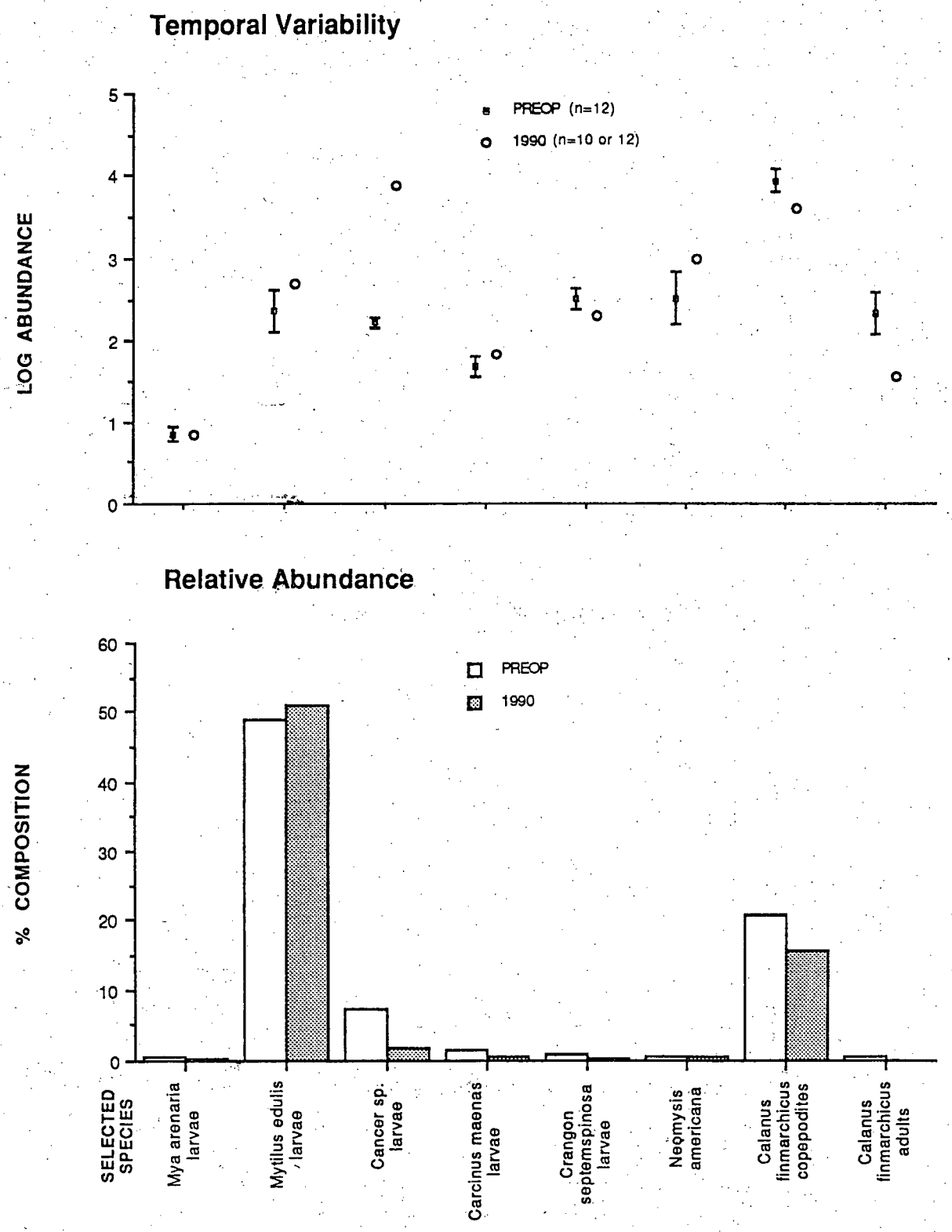


Figure 2.2-5. Mean log (x+1) abundance and 95% confidence interval, and percent composition for selected species of bivalve larvae (no./m^3) and macrozooplankton (no./1000 m^3),1978-1989 and 1990 at Station P2. Seabrook Operational Report, 1990.

TABLE 2.2-5. COMPARISON OF 1990 ABUNDANCES[a] OF SELECTED MICROZOOPLANKTON, BIVALVE LARVAE, MACROZOOPLANKTON AND ICHTHYOPLANKTON LARVAE, TAXA. SEABROOK OPERATIONAL REPORT 1990.

1990 SIMILAR	1990 DIFFERENT	RESTRICTED TO NEARFIELD?	RESTRICTED TO OPERATIONAL PERIOD?
Eurytemora herdmani adults	*Eurytemora* sp. copepodite	no	no
	Pseudocalanus/Calanus sp. nauplii		
Oithona sp. nauplii	*Pseudocalanus* sp. copedodites	no	no
	Oithona sp. copepodites	no	no
	Oithona sp. adults	no	no
Mya arenaria larvae	*Calanus finnarchicus* copepodites	no	no
Mytilus edulis larvae	*C. finmarchicus* adults	no	no
American sand lance larvae	*Crangon septemspirosa* post larvae	no	no
Atlantic cod larvae	*Neomysis americana*	no	no
	Winter flounder larvae	no	no
Atlantic mackerel larvae	Yellowtail flounder larvae	no	no
	Cunner larvae	no	no
	Hake larvae	no	no
	Atlantic herring larvae	no	yes

[a]Abundances of microzooplankton, bivalve larvae and macrozooplankton taxa were compared over the entire year and during the August through December operational period. Abundances of ichthyoplankton larvae were compared during their individual peak periods. Only Atlantic herring larvae peaks entirely within the August through December period.

nearfield (intake and discharge stations) were statistically similar to the farfield during both plant operation and preoperational periods. Neither species appears to have been impacted by commercial operation of the plant.

As a group, the selected species of fish larvae composed 80% of the total abundance and at least one species peaked in each season (Figure 2.2-6). Generally, each of the species was present for a brief but fairly consistent time period each year. Timing of abundance peaks in 1990 was consistent with previous years. Abundances of several species differed significantly from preoperational years (Table 2.2-5). Winter flounder, yellowtail flounder, and Atlantic herring larvae were less abundant in 1990 than in previous years. Cunner and hake larvae, on the other hand, were more abundant in 1990. None of these differences in abundance was restricted to the nearfield area.

Of the ichthyoplankton selected species, only Atlantic herring had its peak abundances during the August through December period corresponding to commercial operation of the plant. Abundances of this species during its peak were significantly lower than the mean of preoperational years. However, abundances were statistically similar between the nearfield and farfield areas throughout the preoperational and operational periods. The general trends of reduced larval abundances in 1987-1989, coupled with reduced adult catches locally and regionally, indicate that reduced abundances of this species in 1990 were not due to commercial operation of the plant.

2.2.2 Finfish

2.2.2.1 Impingement

Operation of the circulating water system, in terms of both the number of pumps and whether the system operated at all, has varied since operation of the circulating water system began in 1985. Fish entrained within the system and subsequently impinged upon the

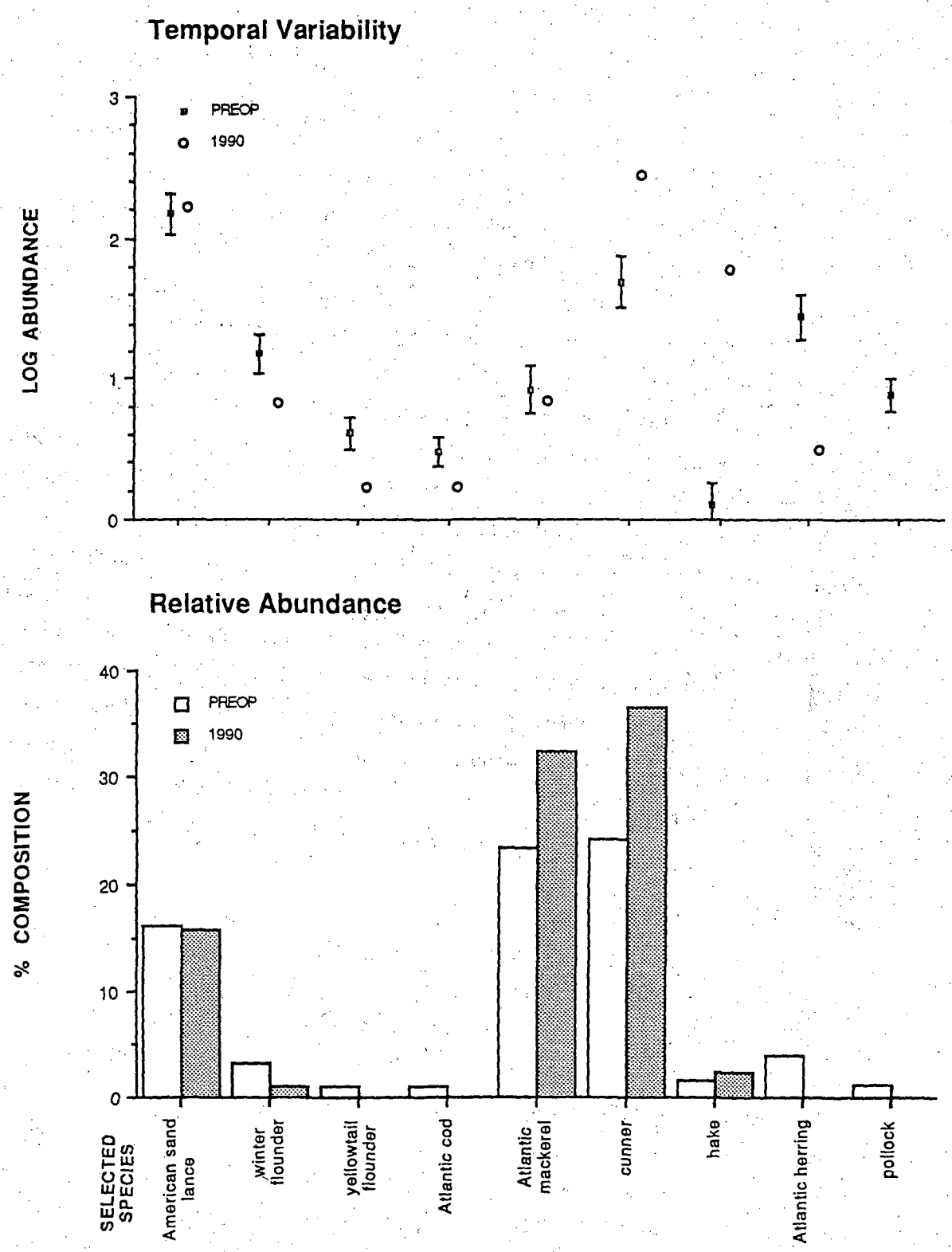


Figure 2.2-6. Mean log (x+1) abundance (no./1000 m³) and 95% confidence interval, and percent composition for selected species of fish larvae 1975-1989 and 1990 at Station P2. Seabrook Operational Report, 1990.

traveling screens have been collected by Seabrook Station personnel to determine operational impact. Initial estimates provided by station personnel based on 1985 data indicated that only one fish would be impinged per 50 million gallons of cooling water flow. During a five-month period in 1985, 970 individuals, representing 32 species, were collected from the circulating water system. These were dominated by grubby (*Myoxocephalus aenaeus*, 21%), snailfishes (*Liparis* sp., 21%), and longhorn sculpin (*Myoxocephalus octodecemspinosus*, 11%). During a seven-month period of circulating water system operation in 1986, 1212 individuals representing 35 species were collected. These were dominated by grubby (28%), windowpane (*Scophthalmus aquosus*, 12%), and longhorn sculpin (9%). The intake structure was cleaned of fouling organisms in 1986 and, subsequently, has been inspected annually to control biological growth. Intermittent operation of the circulating water system during 1987 resulted in a total impingement of 502 fish representing 21 species. Of these, longhorn sculpin, winter flounder (*Pseudopleuronectes americanus*), and windowpane made up 22%, 14%, and 13%, respectively, of those impinged. As the CWS operated intermittently and only at low capacities in 1988 and in 1989, fish impingement data were not collected.

The circulating water system operated regularly during 1990 (Figure 2.2-7). Over the entire year, 499 finfish, representing 31 species, were impinged (Results Section 2.2). This represents an impingement rate of less than one fish per 500 million gallons of cooling water flow or 1.4 fish per day. In addition, four lobsters were impinged. Lumpfish (*Cyclopterus lumpus*) and pollock (*Pollachius virens*) each represented 14% of the total finfish impinged. Longhorn sculpin represented 13% and windowpane, 10% of the total. Impingement was highest in May-June when lumpfish, windowpane and cunner (*Tautogolabrus adspersus*) were the most frequently impinged species and November-December when pollock, longhorn sculpin, herring (unspecified) and windowpane were caught. As in previous years, few pelagic species or individuals of pelagic species were impinged. Pollock was the primary exception, reflecting its tendency to be most abundant near the bottom.

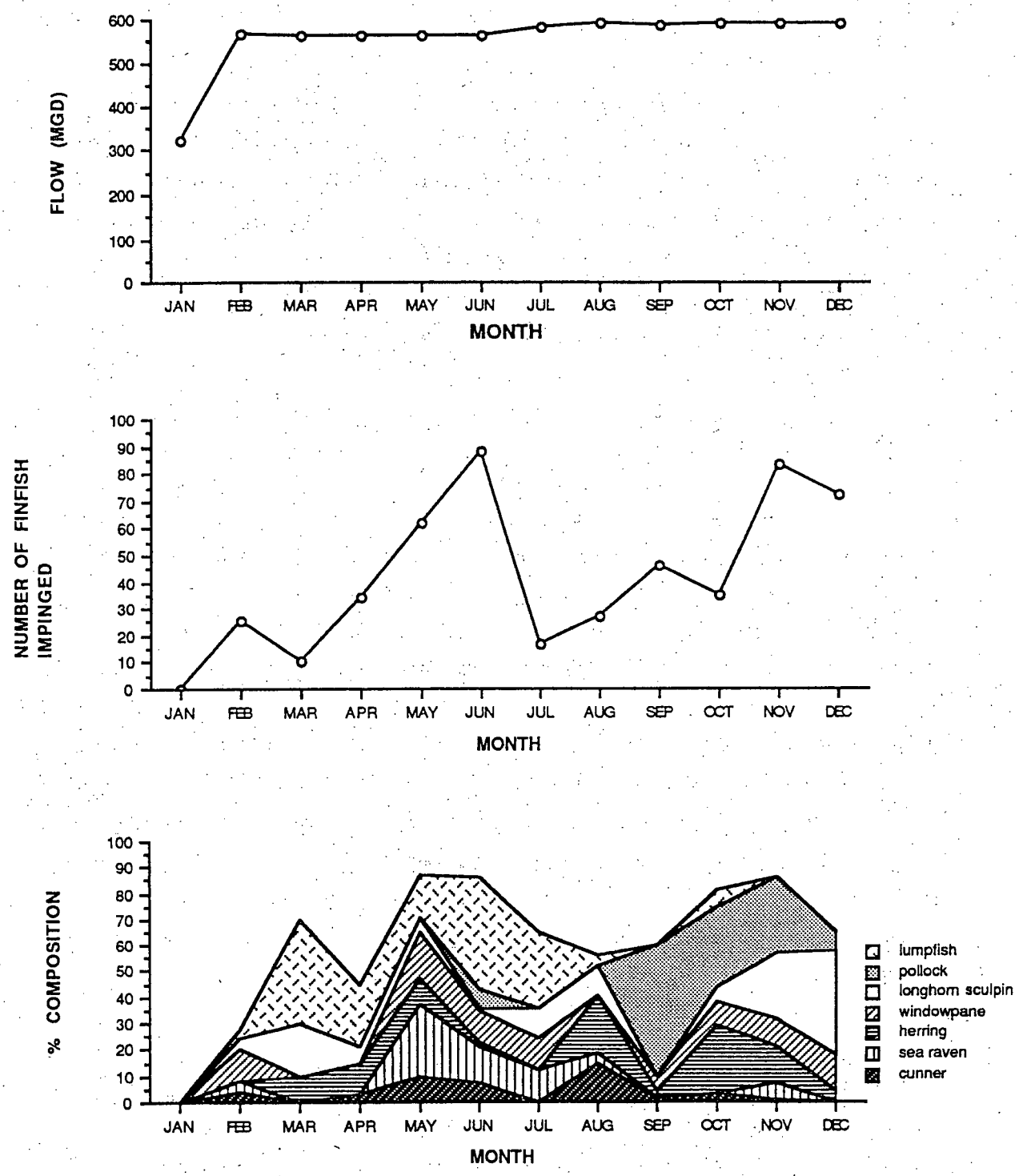


Figure 2.2-7. Flow rate (million gallons per day) of circulating water system and impingement of finfish during 1990. Seabrook Operational Report, 1990.

The low abundance of pelagic species from impingement collections suggests that the intake caps are performing as designed, minimizing entrapment. The species impinged are mainly demersal species; it is likely they are seeking cover at the intake structures, thus increasing the likelihood of swimming or being drawn into the intake tunnels. Impingement of even demersal species is low considering the overall impingement rate of 1.4 fish per day observed in 1990.

2.2.2.2 Pelagic Species

Taken together, the six dominant finfish species collected in gill nets have averaged 85% of the population (Figure 2.2-8). Effects of plant operations on pelagic fish populations in the study area should be visible by studying these species. The distribution of pelagic fish varied seasonally; two main seasonal groups of species, summer and winter, were identified in earlier studies utilizing numerical classification techniques (NAI 1982c). Prior to 1990, from September through April, Atlantic herring constituted from 64% to 93% of gill net catches, while in summer months (May-August), other migratory species such as Atlantic whiting (formerly known as silver hake) and Atlantic mackerel predominated (Figure 2.2-8). Pollock (predominantly age-two fish [NAI 1985b]) is a local resident that also made up a greater proportion of the pelagic nearshore community during summer.

No finfish were caught in gill nets in the early months of 1990, reflecting the sharp decline in the Atlantic herring population observed locally (Figure 2.2-8; Table 2.2-6) and regionally (NOAA 1991a). Catches of Atlantic herring were again low in the fall of 1990, resulting in relatively low total catches. As a result, relative contribution of the captured population was made up to a greater degree by other species. Pollock and Atlantic mackerel made up the majority of the catches between May and July. Atlantic whiting, typically abundant from June through August, was barely present in 1990. In August, spiny dogfish (*Squalus acanthias*) made up 80% of the catch. Butterfish

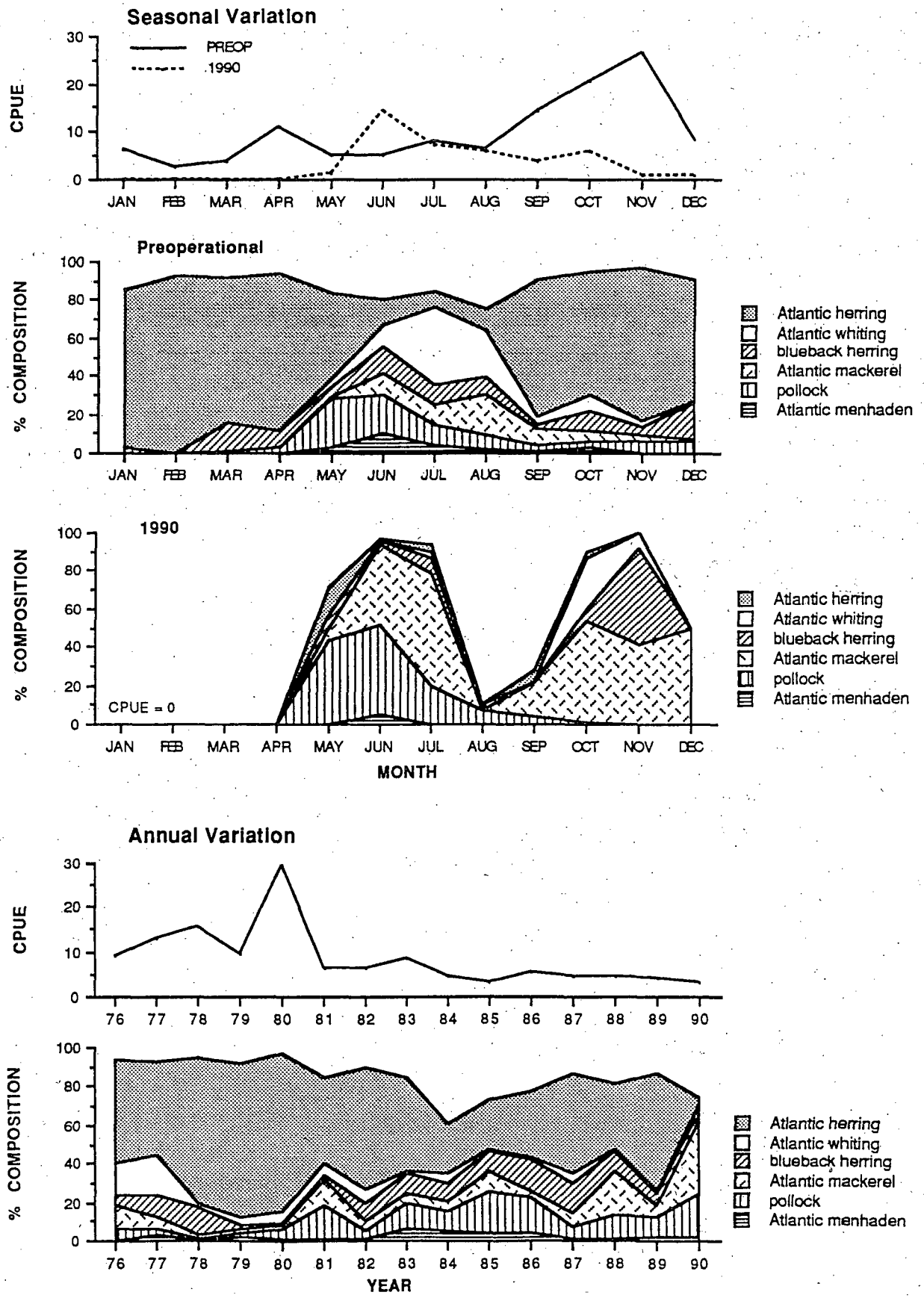


Figure 2.2-8. Seasonal and annual changes in composition and abundance of the pelagic fish community, based on catch per unit effort averaged over gill net Stations G1, G2, and G3, 1976-1989 and 1990. Seabrook Operational Report, 1990.

TABLE 2.2-6. COMPARISON OF 1990 ABUNDANCES[a] OF SELECTED PELAGIC FINFISH SPECIES. SEABROOK OPERATIONAL REPORT 1990.

1990 SIMILAR	1990 DIFFERENT	COMMENT
Pollock	Atlantic herring	• Lower throughout 1990; documented regional decline
	Atlantic mackerel	• Higher in 1990

[a]Abundances were compared over the entire year without distinguishing stations.

(*Peprilus triacanthus*) and bluefish (*Pomatomus saltatrix*) predominated in September, a period of below-average catches. In the fall, when Atlantic herring have usually been most abundant, Atlantic mackerel, blueback herring and Atlantic whiting composed the majority of the catch. Total catch in this period in 1990 was below average. Differences in community structure in 1990 can be attributed to regional changes in species populations (NOAA 1991a).

In every year, Atlantic herring has been the overall dominant pelagic fish in the area; however, it exhibited large annual abundance differences that were reflected in the annual percent composition (Figure 2.2-8). When catch per unit effort (CPUE) peaked in the study area in 1980, Atlantic herring composed 82% of the total catch. From 1984 through 1989, when total catches were at their lowest levels since the inception of the study, Atlantic herring constituted only 26-61% of the total catch (Figure 2.2-8). In 1990, Atlantic herring constituted only 3% of the pelagic fish collected, apparently reflecting a broad-scale trend (NOAA 1991a). Atlantic herring are known to show high variability in catches spatially as well as seasonally and annually (Bigelow and Schroeder 1953). Most of the fish collected off Hampton-Seabrook were yearlings, particularly those captured in the spring (NAI 1985b). Little is known about the habits of yearling herring, except that they seek out the warm waters of embayments in spring (Bigelow and Schroeder 1953).

The seasonal variability of the pelagic fish was found to be greater than annual variability (NAI 1990b). Most of the selected pelagic species had their peak abundance during a short but distinct period of time (Figures 2.2-8 and 2.2-9). Generally, variability among years has been low. The number of individuals that could be exposed to intake effects (impingement) would therefore be expected to vary substantially among seasons and, to a lesser extent, among years.

Areal differences are less important than temporal differences in evaluating potential plant effects on pelagic fishes. Because of

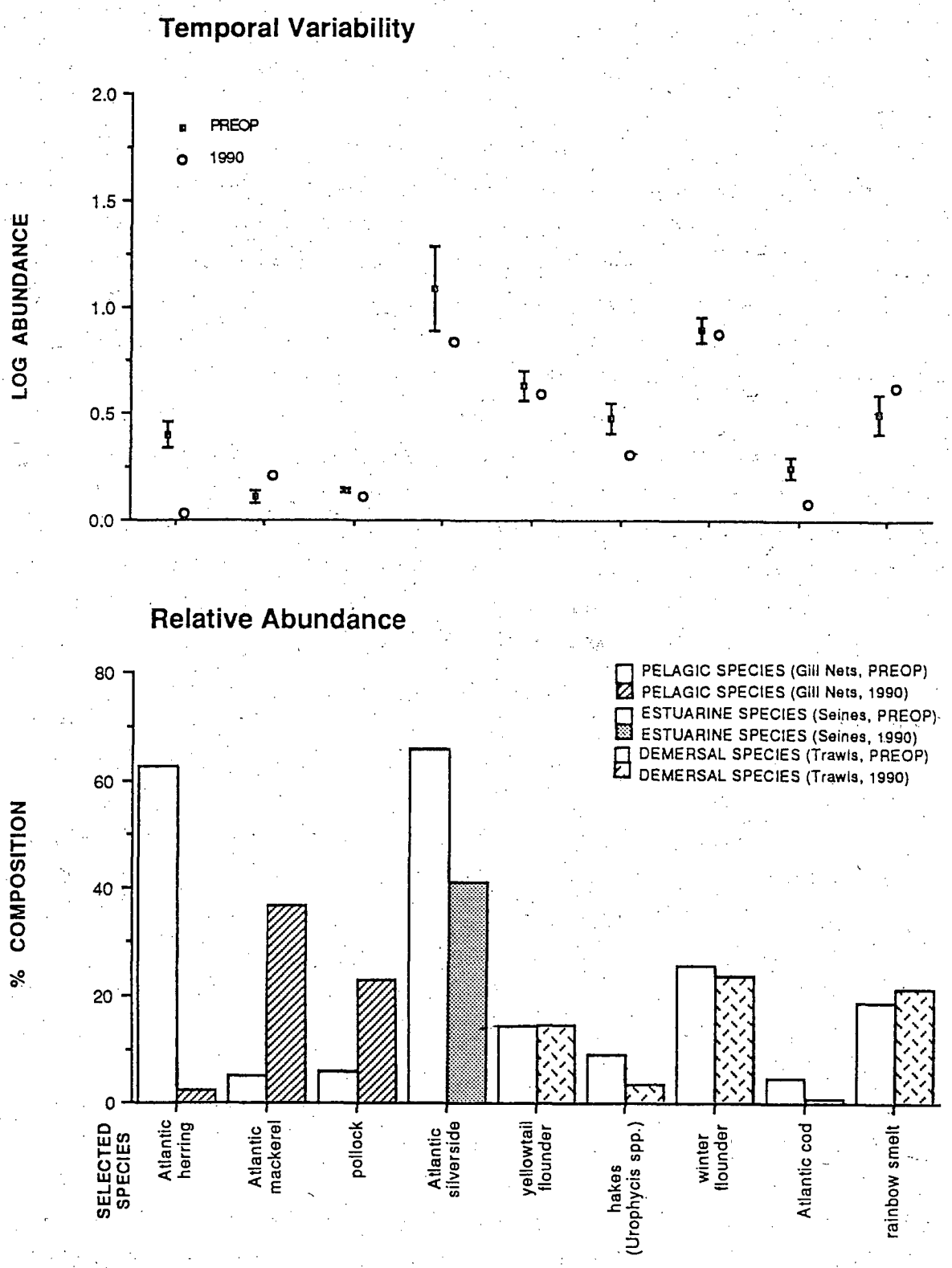


Figure 2.2-9. Mean log (x+1) abundance (catch per unit effort) and 95% confidence intervals, and percent composition for selected species of fish, 1976-1989 and 1990. Seabrook Operational Report, 1990.

their high degree of mobility, pelagic fish were not observed to be associated with any one habitat. As expected, relative abundances of the five most abundant taxa were very similar among stations, although catches tended to be lower at the southern station G1 (Section 3.2.2). Differences in the vertical distribution of these species may be important, however, because the intake structures are located at mid-depth, 5 m above bottom in 17 m of water. Historically, only one of the eight most abundant species, Atlantic menhaden, was consistently more abundant at the intake (mid-water) depth during the months sampled than at surface and bottom (Table 2.2-7). However, this species was only slightly more abundant at mid-depth than at the surface, and it only accounted for 2% of the pelagic fish in the study area. Atlantic whiting and pollock, and to a lesser extent alewife and rainbow smelt, were most abundant near the bottom. Atlantic herring, Atlantic mackerel and blueback herring were most abundant on the surface (Table 2.2-7). These species may be less vulnerable to intake effects. Despite historical trends, certain species occasionally had higher catches in the mid-depth area than in surface or bottom depths. In 1990, on those dates when all depths were sampled, alewife catches were highest in mid-water gill nets and catches of Atlantic mackerel in mid-water nets were higher in 1990 than any other species (Table 2.2-7), suggesting that these and other species could occasionally be more vulnerable to intake effects. However, these results indicated that the most abundant and frequently-occurring pelagic species did not show a preference for mid-depth distribution, verifying earlier results and the rationale for mid-water placement of the intakes (NAI 1975a). Furthermore, in-plant collections of finfish to date indicate that pelagic fish are not being encountered on the circulating water system screens in substantial numbers.

2.2.2.3 Demersal Species

The primary focus for assessment of operational effects of Seabrook Station on demersal finfish has been the impact of detrital

TABLE 2.2-7. CATCH PER UNIT EFFORT[a] BY DEPTH FOR THE DOMINANT GILL NET SPECIES OVER ALL STATIONS AND DATES WHEN SURFACE MID-DEPTH AND BOTTOM NETS WERE SAMPLED, PREOPERATIONAL YEARS (1980 THROUGH 1989) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

	DEPTH					
	SURFACE		MID-DEPTH		BOTTOM	
SPECIES	PREOP. YEARS	1990	PREOP. YEARS	1990	PREOP. YEARS	1990
Atlantic herring	5.3	0.1	2.9	0.1	1.9	0.1
Atlantic whiting	0.2	0.6	0.5	0.4	0.7	0.5
Atlantic mackerel	1.0	4.3	0.9	2.2	0.5	1.7
Pollock	0.2	0.0	0.2	0.0	1.2	4.4
Alewife	0.1	0.1	0.1	0.2	0.2	0.2
Blueback herring	0.8	0.3	0.3	0.2	0.5	0.1
Atlantic menhaden	0.6	0.5	0.7	0.6	0.2	0.0
Rainbow smelt	<0.1	0.0	<0.1	0.0	0.1	0.1

[a] number per one 24-hour set of one net (surface, mid-depth or bottom)

rain. This is discussed in Section 2.3.2.2. However, impingement studies have shown that certain species of demersal fish are susceptible to impingement. The low rate of impingement suggests that any changes to the demersal finfish community should not be attributable to impingement during plant operation. Of the demersal fish species impinged most frequently, abundances of several (winter flounder, Atlantic cod and hake) were examined by analysis of variance (reported in Section 2.3.2.2). There were no changes observed in catches of winter flounder in 1990 compared to preoperational years. Hakes and Atlantic cod were both relatively less abundant in 1990 but this occurred in both near-field and farfield areas and so is not attributable to impingement.

One of the most frequently impinged species, lumpfish (*Cyclopterus lumpus*), has not been caught routinely during the study. Although demersal, it tends to be associated with rocky areas or other structures rather than the open bottom. Thus the intake structures may provide attractive habitat for this species. Impingement of lumpfish was highly seasonal, occurring primarily in May and June (Figure 2.2-7). Most individuals were adults. The seasonality of impingement could be related to post-spawning movements (peak abundances of larvae occurred in May and June, NAI 1991). Thus the species appears to be less susceptible to impingement before or during its spawning period than after. Although a portion of the adult population may be lost through impingement, their spawning potential will have been realized, preventing magnified losses in future year-classes.

2.3 DISCHARGE AREA MONITORING

2.3.1 Plume Studies

2.3.1.1 Discharge Plume Zone

Because the discharge plume's largest exposure will be to surface and near-surface waters, the primary focus in this section will be on parameters or organisms in this part of the water column, namely phytoplankton, lobster larvae, and nearfield water quality parameters. Other organisms, such as pelagic fish and ichthyoplankton will, of course, have some exposure to the discharge plume, but it is assumed that entrainment and/or impingement are the more important issues for these organisms.

Water temperatures have shown distinct seasonal patterns that were important in driving biological cycles. Historically, surface and bottom temperatures, measured on a weekly basis and averaged monthly, reached their lowest points from January through March, then steadily increased from April to August; temperatures were generally highest from July to September (surface) or October (bottom) before beginning their fall decline (Figure 2.3-1). Surface temperatures had a more exaggerated seasonal cycle in comparison to bottom temperatures, with higher spring and summer temperatures.

Surface and bottom temperatures throughout the Hampton Seabrook area were higher than average in 1990 in June and from August to December (Figure 2.3-1). However, average monthly temperatures were statistically similar to previous years, and no differences were detected among intake, discharge, and farfield areas in 1990 (Figure 2.3-1, Results Section 3.1.1). These results indicate that the higher temperatures observed in 1990 were within the range of natural variability. Effects of plant operation on average monthly surface and bottom temperatures at Station P2 were not discernible.

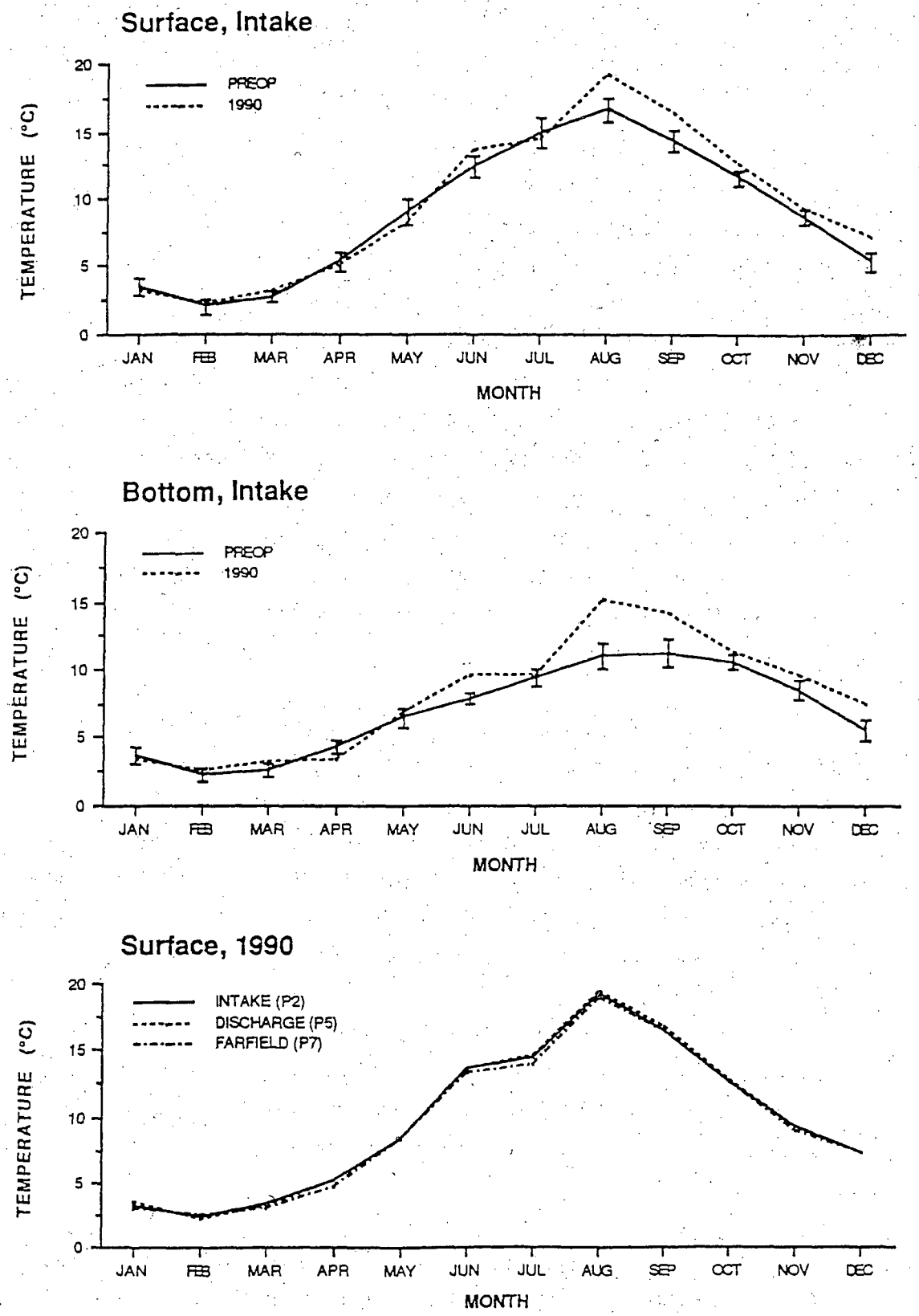


Figure 2.3-1. Monthly mean surface and bottom temperatures at nearfield Station P2, and 95% confidence intervals during preoperational period and in 1990, and mean monthly surface temperature at intake, discharge, and farfield stations. Seabrook Operational Report, 1990.

Temperature differences were noted in the continuously monitored temperature data supplied by YAEC. No consistent differences were observed in monthly averages of daily surface temperatures between the discharge station (DS, Figure 2.1-3) and farfield station T7 in July, August, and September; the average monthly differences were less than 0.22°C. From October-December, surface temperatures at the discharge station averaged 0.8-1.6°C higher than those that the farfield station (T7)(Table 2.3-1, Figure 2.3-2). At Station ID the nearfield station midway between the intake and discharge (Figure 2.1-3), average surface monthly temperatures were within 0.2°C of temperatures at farfield Station T7. Mid-depth and bottom temperatures at this near-field station were at most 0.3° higher than those at the farfield station; in most months, temperatures were actually higher at the farfield station (Table 2.3-1).

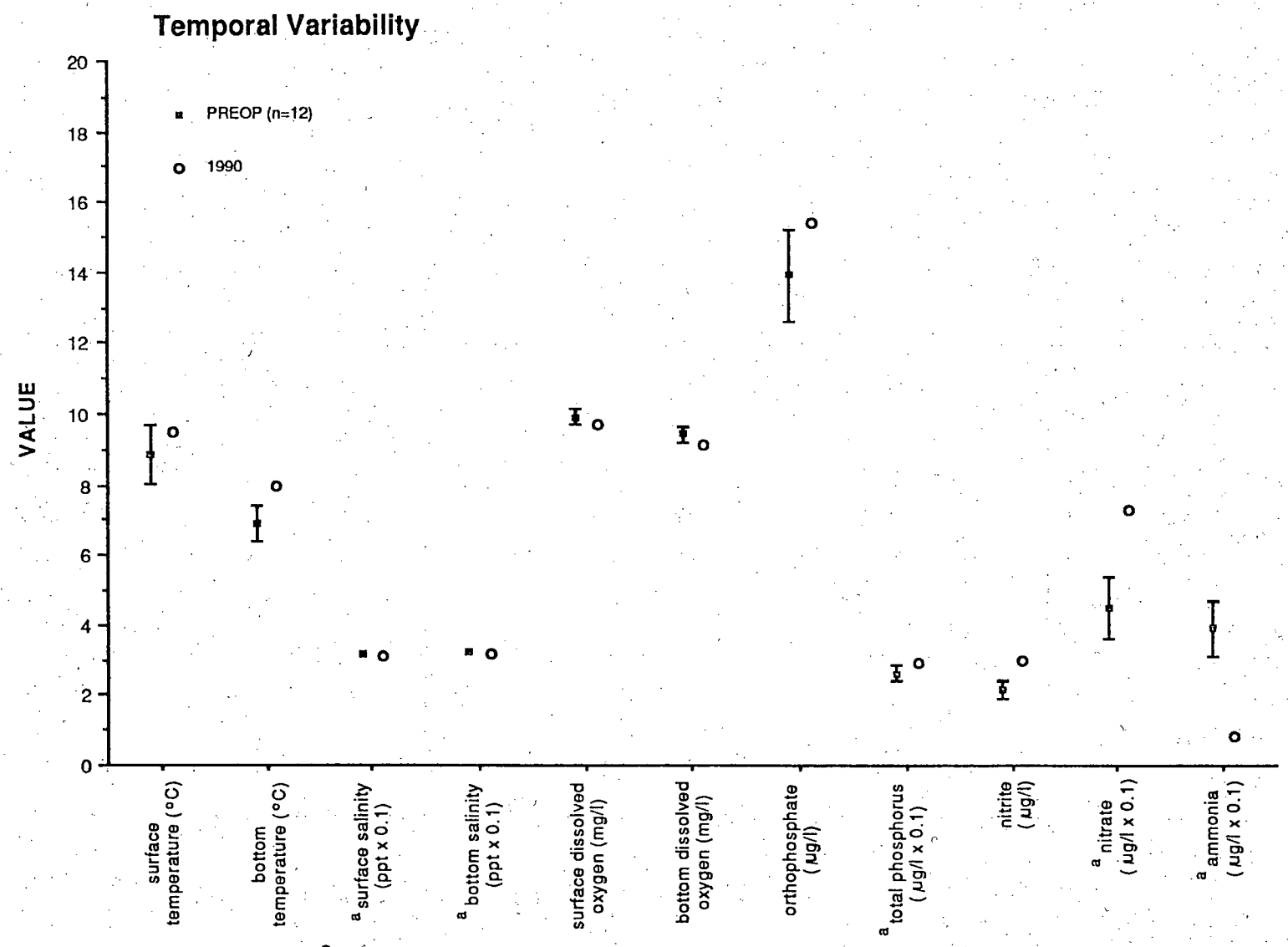
Historically, surface salinity values have been highest in winter and lowest in spring, a result of increased runoff. In 1990, salinity was lower than average from June-December (See Results Figure 3.1.1-4). Higher-than-average rainfall in April, May, August and October (Section 3.3.1) may have contributed to lower-than-average salinity in those months. However, the annual mean salinity in 1990 was similar to previous years (Figure 2.3.2).

Surface dissolved oxygen has had a seasonal pattern inversely related to temperature, with peak values in late winter and lowest values in fall. In 1990, seasonal patterns were similar to previous years, although values in September were lower than the average (See Section 3.1.1).

Nitrogen and phosphorus nutrients had more erratic cycles than temperature, salinity, and dissolved oxygen, but generally had lowest levels in summer and highest in fall and winter. Seasonal patterns and annual mean values of total phosphorus and orthophosphate in 1990 were slightly higher than previous years (Figure 2.3-2). Nitrite concentrations were unusual in 1990 in that they were much higher than average in

TABLE 2.3-1. MONTHLY MEAN TEMPERATURES (°C) AND TEMPERATURE DIFFERENCES BETWEEN DISCHARGE (DS) AND FARFIELD (T7) AT THE SURFACE, AND NEARFIELD (ID) AND FARFIELD (T7) STATIONS AT SURFACE, MID-DEPTH (8.5 m) AND BOTTOM (16.2 m) DEPTHS COLLECTED FROM CONTINUOUSLY MONITORED TEMPERATURE SENSORS. SEABROOK OPERATIONAL REPORT, 1990.

	DS-T7 SURFACE			ID-T7 SURFACE			ID-T7 MID-DEPTH			ID-T7 BOTTOM		
MONTH	DS	T7	DELTA T	ID	T7	DELTA T	ID	T7	DELTA T	ID	T7	DELTA T
JUL	14.54	14.63	-0.08	14.69	14.63	0.07	11.76	11.50	0.26	9.08	9.62	-0.54
AUG	18.16	18.36	-0.20	18.11	18.11	0.01	14.81	15.42	-0.61	13.26	13.14	0.12
SEP	16.31	16.09	0.22	16.22	16.06	0.16	14.06	13.94	0.12	12.14	12.31	-0.17
OCT	13.04	12.11	0.93	13.17	12.98	0.19	11.92	11.85	0.07	11.03	11.17	-0.14
NOV	10.24	9.44	0.80	9.38	9.39	-0.02	9.42	9.53	-0.11	9.49	9.91	-0.42
DEC	8.91	7.32	1.59	7.37	7.34	0.03	7.47	7.57	-0.11	7.43	7.96	-0.53



[a] For salinity, total phosphorus, nitrate, and ammonia values, multiply by 10.

Figure 2.3-2. Preoperational mean and 95% confidence limits, and 1990 mean for temperature (°C), salinity (ppt), dissolved oxygen (mg/1), and nutrients (µg/l) at Station P2. Seabrook Operational Report, 1990.

February, May, and October, but lower than average in July and August (See Results, Figure 3.1.1-7). The seasonal pattern of nitrate values was similar to previous years although concentrations were higher than average from January-May (See Results, Figure 3.1.1-7). Ammonia levels were below the detection limit of 10μg/l during most of 1990 (See Results, Figure 3.1.1-8). The annual average for nitrate and nitrite values in 1990 was higher than previous years, whereas ammonia was lower than average (Figure 2.3-2). These differences, however, were not statistically significant.

The phytoplankton community has shown the most seasonal and annual variability of any species assemblage studied in this program. Seasonal assemblages have changed rapidly and frequently, diminishing the suitability of the community for short-term impact assessment (NAI 1985b). Some elements of the phytoplankton community, however, have been relatively stable and predictable. Historically, total phytoplankton abundance has shown a predictable seasonal cycle, although abundance levels varied as much as two orders of magnitude among years (Figure 2.3-3). The spring bloom was typically initiated by increases in irradiance, and although the species composition varied from year-to-year, centric diatoms typically were among the first to appear (NAI 1985b). Abundances usually diminished with the depletion of growth-limiting nutrients (primarily nitrogen); development of the thermocline appeared to prevent the replenishment of nutrients from deeper waters and thus limit growth of spring dominants. A second (fall) peak usually occurred, coincident with the dissipation of the thermocline, which acted to replenish the nutrient supply in surface waters. In 1990, total abundance displayed a typical spring peak, but no fall peak was observed (Figure 2.3-3). Total abundances were higher than average in most months, and highly correlated among nearfield, intake and discharge, and farfield stations. This suggests that observed trends in phytoplankton abundance occurred on an area-wide basis.

Phytoplankton assemblages from 1978 to 1980 were similar, based on the predominance of *Skeletonema costatum, Rhizosolenia*

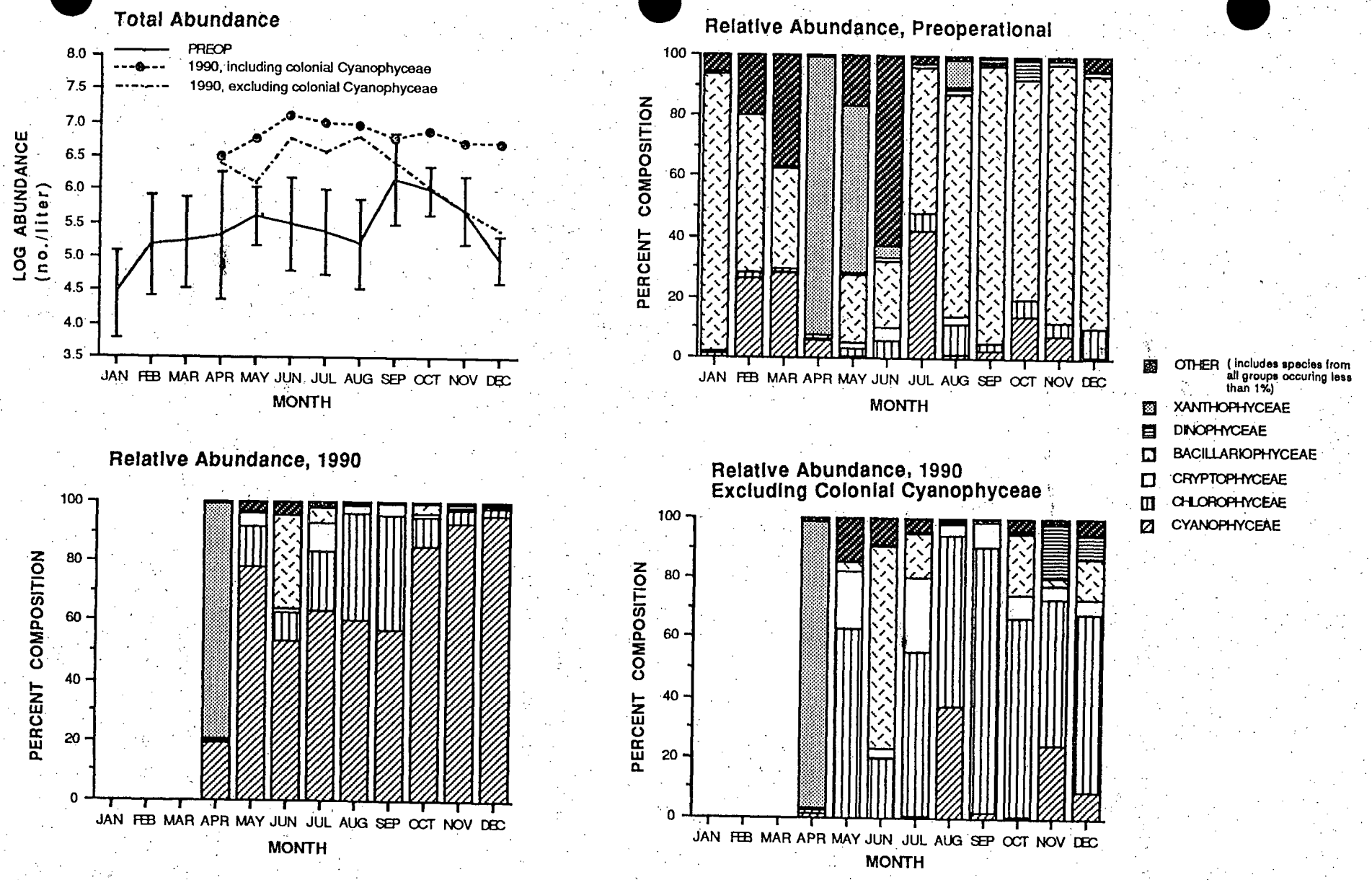


Figure 2.3-3. Monthly mean and 95% confidence intervals of total phytoplankton and relative abundance of the major phytoplankton groups during the preoperational period (1978-1984) and monthly mean in 1990 with and without Colonial Cyanophyceae. Seabrook Operational Report, 1990.

delicatula, and *Phaeocystis pouchetti*, while from 1981 through 1984, only *S. costatum* and *Chaetoceros* spp. were consistent dominants. The phytoplankton in 1986 was unusual in that there was an uncharacteristic July peak caused by bluegreens and *Leptocylindricus* spp. In the latter half of 1986, *S. costatum* and bluegreens predominated. No phytoplankton collections were made from 1987-1989. In 1990, colonial cyanophyceae (bluegreens) replaced diatoms (particularly *S. costatum*, but also *Leptocylindricus minimus* and *Nitzchia delicatissima*) as the overwhelming dominants (Figure 2.3-3). Diatoms appeared in significant numbers only in June and October. Other species displayed seasonal trends that were similar to previous years. *Phacocystis pouchetti* and *Chroomonas* sp. exhibited spring blooms, followed by filamentous and unicellular green algae.

The reason for the predominance of cyanophytes in 1990 is not known, but it may reflect a Gulfwide phenomenon. Abundances as high as 7×10^7 cells/l were observed in the central Gulf of Maine in the summer of 1988 and 1989 (Balch *et al.* 1991). High abundances of cyanophyceae have been linked to persistent vertical stratification, organic and inorganic nutrient enrichment, increased temperatures, and high amounts of photosynthetically-active radiation (Paerl 1988). Although nutrients were higher than average prior to the first collection of phytoplankton in April, temperatures were within the range of previous years, with no evidence of extraordinary stratification. Thus there is no obvious physical or chemical occurrence in 1990 that can be linked to the abundance of cyanophytes.

Cyanophyceae in some cases exhibit certain characteristics, such as high motility and production of resting cells (akinetes), that can provide them a competitive advantage (enabling them to bloom) over other groups of phytoplankton (Paerl 1988). Blooms of colonial cyanophytes have been cited as causing oxygen depletion, diminished water quality, increased turbidity, reduction of benthic flora and fauna due

to alterations in sediment conditions and reduction of the natural phytoplankton populations (Paerl 1988). These changes were not apparent in the study area.

Although abundances of colonial cyanophytes represented 66% of the total phytoplankton abundance from August to December 1990 (Table 3.1.2-1), abundances of most other dominant taxa were within the 95% confidence intervals of historical abundances (Results Table 3.1.2-2), suggesting that the phytoplankton assemblage has not been markedly altered. Number of taxa was similar to previous observations in all depth zones. There were no dramatic changes in the zooplankton or benthic communities that could be linked to the increased numbers of cyanophytes.

In 1990, as seen historically, no spatial differences were observed in the phytoplankton community either between intake (P2) and farfield (P7) areas or between intake (P2) and discharge (P5) areas (NAI 1985b, 1987b). In 1990, total abundances and chlorophyll *a* values were highly correlated among all three stations. Multivariate analysis of variance showed no significant differences among stations for the dominant taxa.

Skeletonema costatum was chosen as the selected phytoplankton species because of its consistent predominance during the baseline period. Historically, there has been a major peak in late summer or fall (see Results Figure 3.2.1-6) and in some years there was also a smaller peak in the spring (NAI 1981f, 1982a) or winter (NAI 1980c, 1983a). The characteristic fall peak was absent at all stations in 1990, causing significantly lower densities during the operational period. Because of highly-variable peak abundances, significant differences were detected among years and months although intake and discharge and farfield densities were statistically similar.

The phytoplankton species assemblage has shown little stability in terms of density level, community structure, or seasonal patterns.

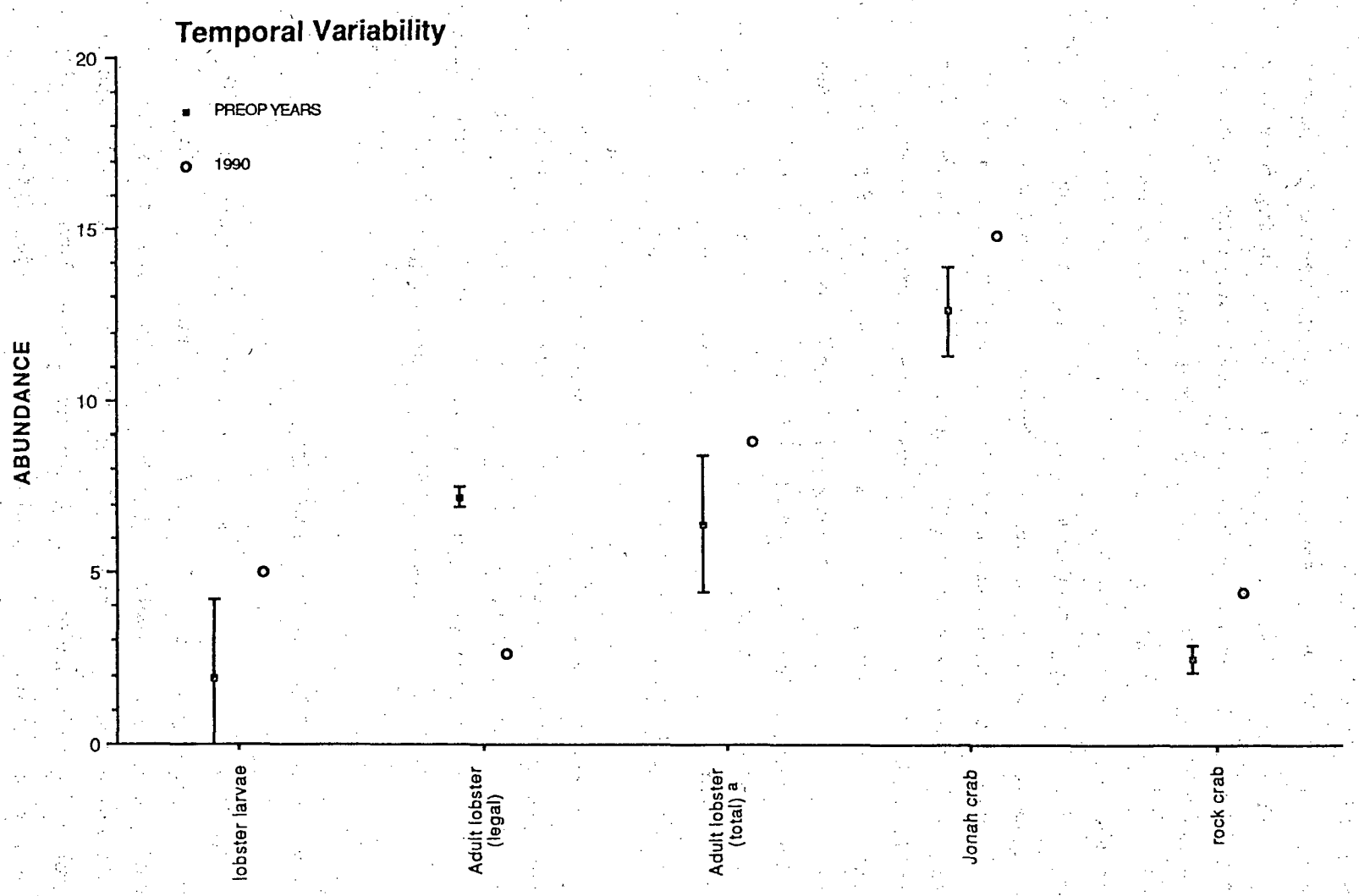
At best, only general trends are predictable, such as the occurrence of a spring peak. The seasonal species assemblage has changed markedly from year to year. 1990 was no exception to this pattern, with changes more marked than those noted in earlier years. There were no changes in community structure or abundances that were unique to the discharge or intake stations. Although differences in 1990 were more dramatic during the August-December time period, differences occurred throughout the year and do not appear to be related to plant operation.

Paralytic shellfish poisoning (PSP) is caused by high numbers of the diatom, *Gonyaulax* sp. PSP levels in *Mytilus edulis*, as measured by the State of New Hampshire and Massachusetts Department of Public Health (reported through 1984 only), have exceeded maximum levels allowable for human consumption every year from 1972 through 1989 (except 1987), usually for a period of 1-7 weeks (NAI 1987b; 1989a, 1990a). In 1972, toxic levels were present in Hampton Harbor for a period of 16 weeks. Although Hampton Harbor flats have been closed each summer since 1976 to soft-shell clam diggers for conservation reasons, high PSP levels have caused the closure of the harbor to all bivalve shellfish digging for several weeks each summer as well. Peak values in most years occurred in May or June, coinciding in Hampton Harbor and the farfield area, Essex, MA (through 1984, when data from both sites were collected). In 1990, elevated levels of PSP were recorded in late May through June, similar to previous years at levels generally lower than previous years (See Results, Figure 3.1.2-5).

Of the shellfish in the area with planktonic lifestages (*Cancer* crabs, lobster, and soft-shell clams), only lobster larvae Stages I-IV have strictly a surface orientation, typically found in the top few centimeters of water. The seasonality and variability of *Cancer* sp. larvae and *Mya arenaria* larvae were discussed in the intake area monitoring section. Successful recruitment of lobster larvae is the biggest factor in determining the level of adult lobster catches in subsequent years (Harding et al. 1983). Lobster larvae collected off Hampton-Seabrook probably originate from warm waters in the Gulf of

Maine and Georges Bank (Harding et al. 1983) and are driven into the area by a combination of winds and nontidal currents (Grabe et al. 1983). Temperatures in the study area are typically not warm enough to allow planktonic development (Harding et al. 1983), reinforcing the idea that this area is probably not important in the production of lobster larvae. Lobster larvae, which were rare throughout the study area, have typically been recorded from the first week in June to the second week in October, with peaks frequently occurring in the mid-summer months (Figure 2.3-4 and Results Figure 3.3.6-1). In 1990, lobster larvae first appeared in early June, at all three stations, similar to previous years. Maximum abundances have occurred over an eight-week period between late June and late August, during the period of maximum surface temperatures. Historically, abundances of all life stages have been very low, averaging <2 per 1000 square meters (Figure 2.3-4). From 1978-1989, stage I and IV larvae have predominated, and stage II and III have been extremely rare. Densities at both the farfield station (P7) and discharge station (P5) were usually higher than at the intake station (P2). In 1990, an unusually large catch of Stage I lobster larvae occurred in July, over 10/1000 m^2 at all three stations, followed by an exceptionally large catch of over 60/1000 m^2 Stage IV larvae in August. Higher than average surface water temperatures throughout the Hampton-Seabrook area may have enhanced the survival of lobster larvae. In addition, unusually large aggregations of lobster larvae have been associated with convergence areas or shallow sea fronts, where different water masses meet. These areas are the result of wind-induced down-welling coupled with influences of tides and river discharges, which form visible accumulations of foam and debris (Cobb 1983). It's uncertain whether the large numbers of lobster larvae were caused by higher temperatures or convergence of water masses. However, since the timing of these incidents occurred at both near- and farfield areas, it is unlikely that these were related to plant operation.

Subsurface (-3 m) "fouling" panels placed in the projected inner and outer discharge plume area and at farfield areas, show the types, timing and abundances of shallow subtidal organisms that can



[a] For CPUE of total lobsters, multiply by 10.

Figure 2.3-4. Preoperational mean (1975-1989) (no./1000 m^2, lobster larvae; catch per 15-trap effort adult lobsters and crabs) and 95% confidence limits and 1990 mean for lobster larvae, adult lobsters and crabs at the discharge site. Seabrook Operational Report, 1990.

settle on bare substrates. Short-term panels, exposed for one month, allow estimation of recruitment levels while monthly sequential panels, exposed for 1-12 months, show the development of the fouling community (Figure 2.3-5). Total biomass, abundance of noncolonial fauna, and richness of faunal taxa showed seasonal patterns that were highly consistent from year-to-year and between nearfield and farfield areas, reflecting the increase in settling activity in summer and fall. The development of the fouling community in 1990 followed the basic seasonal progression observed in previous years although several differences are notable. Recruitment abundances, taxa richness, and biomass (panels located at inner plume stations only) measured on short term panels were significantly higher in 1990 than previous years, whereas community development biomass (monthly sequential panels) was lower (Figure 2.3-5; Table 2.3-2). Changes in the settling population were due to increased numbers of mytilids, which increased biomass as well as provided additional substrate for other organisms. As these differences occurred at both nearfield and farfield areas, and began before plant start-up, they are unrelated to plant operation.

The species assemblage colonizing fouling panels at the discharge station has shown seasonal changes that were relatively consis-tent from year to year, particularly from June to December. In 1990, the settling community at the discharge station in the latter half of the year was similar to those of previous years (Figure 2.3-6).

2.3.1.2 Intertidal/Shallow Subtidal Zone

An area outside of the immediate surface plume area that is being monitored for potential plume effects is Sunk Rocks. Intertidal (MSL and MLW) and shallow subtidal (-4.6 m) stations that are representative of the area were monitored on Outer Sunk Rocks (nearfield) and at a reference area at Rye Ledge. Community comparisons have historically focused on August collections when all organisms are identified and enumerated. Operational impact assessment in 1990 for the benthic

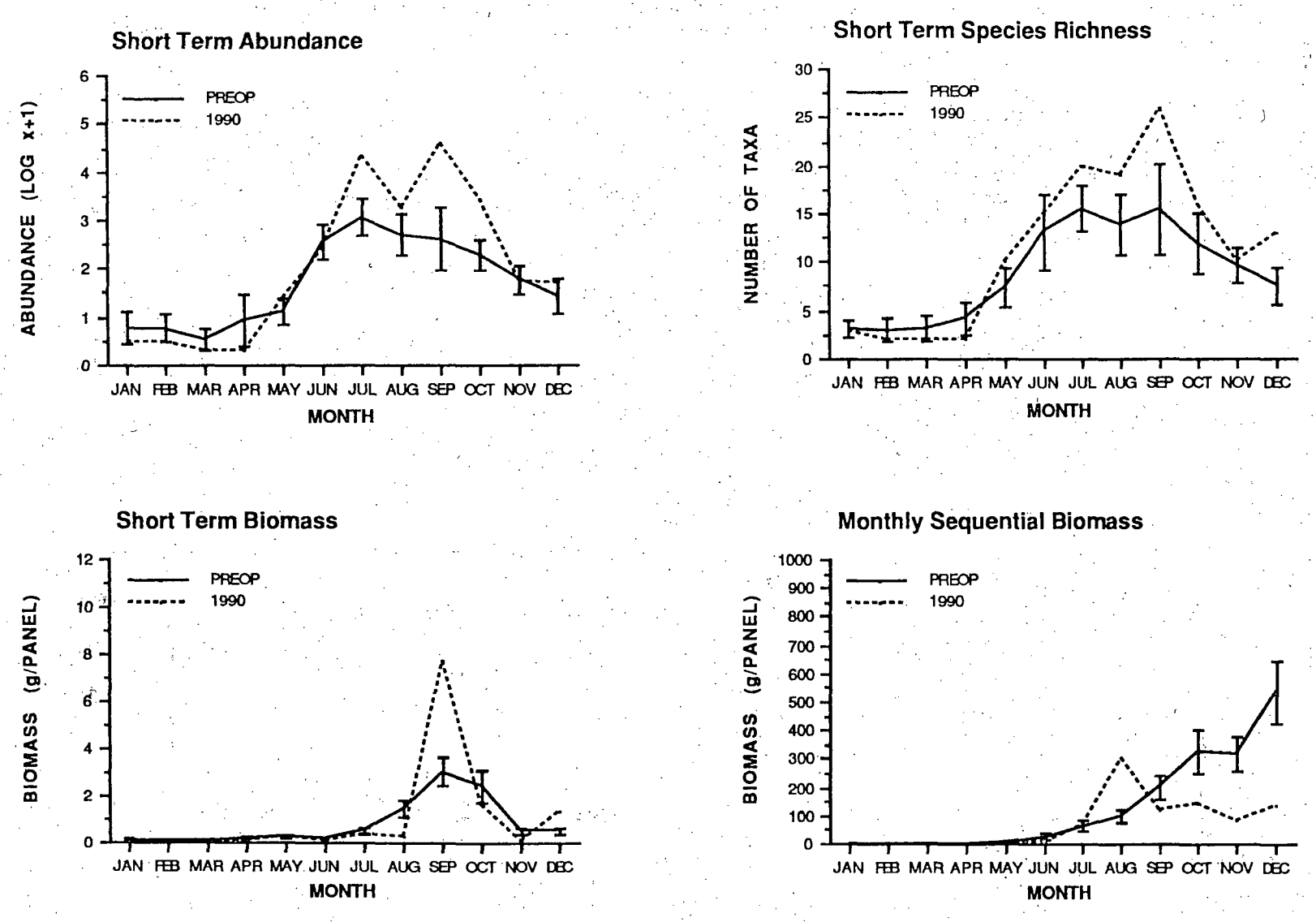


Figure 2.3-5. Seasonal patterns of settlement and growth of fouling organisms during the preoperational period and in 1990 as indicated by noncolonial abundance, species richness, and biomass from monthly sequential panels set at discharge Station B19. Seabrook Operational Report, 1990.

TABLE 2.3-2. SUMMARY OF DIFFERENCES IN COMMUNITY PARAMETERS MEASURED AT INTERTIDAL, SHALLOW SUBTIDAL, MID-DEPTH, AND DEEP BENTHIC STATIONS AND IN THE SURFACE FOULING COMMUNITY. SEABROOK OPERATIONAL REPORT, 1990

ZONE	STATIONS	1990 SIMILAR? GROUP[a]	1990 SIMILAR? PARAMETER[b]	1990 DIFFERENT? GROUP[a]	1990 DIFFERENT? PARAMETER[b]	NEARFIELD, FARFIELD SIMILAR?
Intertidal	Sunk Rocks Farfield			Algae	Richness	No
					Biomass	No
				Fauna	Richness	No
					Abundance	No
Shallow subtidal	Sunk Rocks Farfield	Algae	Richness			
			Biomass			
		Fauna	Richness			
			Abundance			
Mid-depth	Intake Discharge Farfield	Algae	Richness, intake	Algae	Richness discharge, farfield	No
			Biomass, discharge		Biomass, intake, farfield	Yes
		Fauna	Richness, intake	Fauna	Richness	No
					Abundance	Yes
Deep	Intake Discharge Farfield	Algae	Richness	Algae	Biomass discharge	No
			Biomass, intake			
		Fauna	Richness	Fauna	Abundance	Yes
Surface Fouling Community	Discharge, inner plume outer plume; Farfield	ST	Biomass outer plume, farfield	ST	Richness	No
					Abundance	No
					Biomass, inner plume,	No
					outer plume, nearfield	Yes
				MS	Biomass	No

[a]Algae = macroalgae; Fauna = macrofauna; ST = short term panels; MS = monthly sequential panels
[b]Richness = number of taxa; Biomass = total biomass, all taxa combined; Abundance = total number of organisms

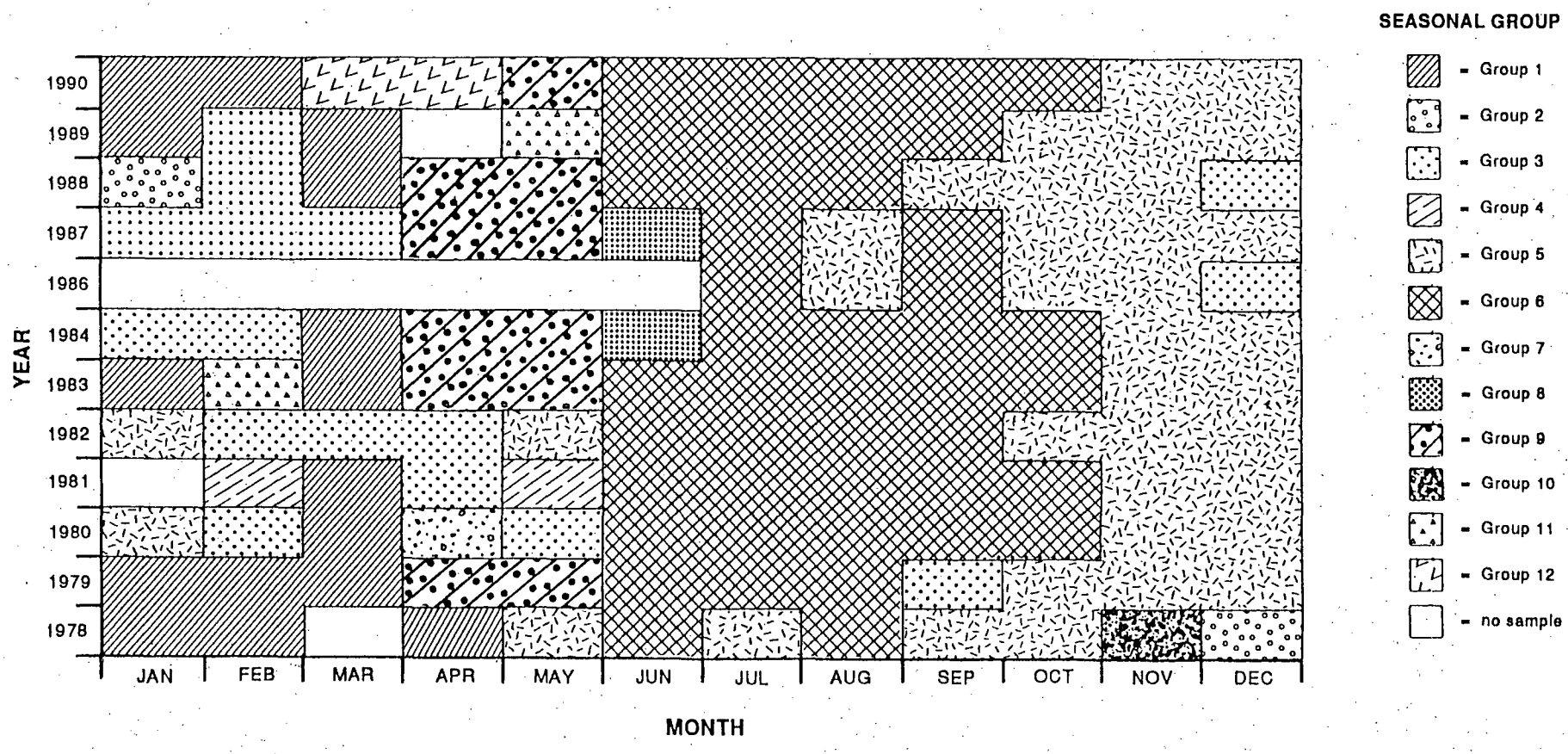


Figure 2.3-6. Seasonal groups formed by numerical classification of log (x+1) noncolonial abundances from short-term surface panels from Station B19 collected from 1978-1984 and July 1986-December 1990. Seabrook Operational Report, 1990.

community utilizes data collected after limited commercial operation (Table 2.1-1). Any differences observed in 1990 are, therefore, unlikely to be related to plant operation.

Benthic community structure within the intertidal/shallow subtidal area was assessed in several ways. The number of species (richness) and total abundance or biomass estimates obtained in 1990 were statistically compared to previous years. Potential operational effects could be ruled out if 1990 results were similar to previous years, 1990 differences were consistent throughout the area (i.e., at nearfield and farfield station pairs), or results in 1990 in the nearfield area were similar to previous years even though they may not have been similar at the farfield area. Community composition in 1990 was compared to previous years using numerical classification. The community composition was considered unchanged if collections in 1990 at a particular station were similar to the majority of samples from the same station from previous years, causing the analysis to group them together.

The community parameters met the criteria established for demonstrating no operational impact. Although macrofauna and macroalgae taxa richness and abundance or biomass at intertidal stations showed differences in 1990, these differences occurred at both nearfield and farfield areas (Table 2.3-2). Macrofaunal and macroalgae community parameters at shallow subtidal stations were statistically similar to previous years.

Benthic algae and macroinvertebrate collections taken annually in August at Stations B1MLW and B5MLW (intertidal) and Stations B17 and B35 (shallow subtidal) have exhibited species assemblages that were consistent and highly similar from year to year at each station (Figure 2.3-7). Each annual collection at a station was grouped (by numerical classification) with the majority of those collected in other years at the same station (Results Sections 3.3.2 and 3.3.3). In 1990, community composition of intertidal and shallow subtidal macroalgae collections

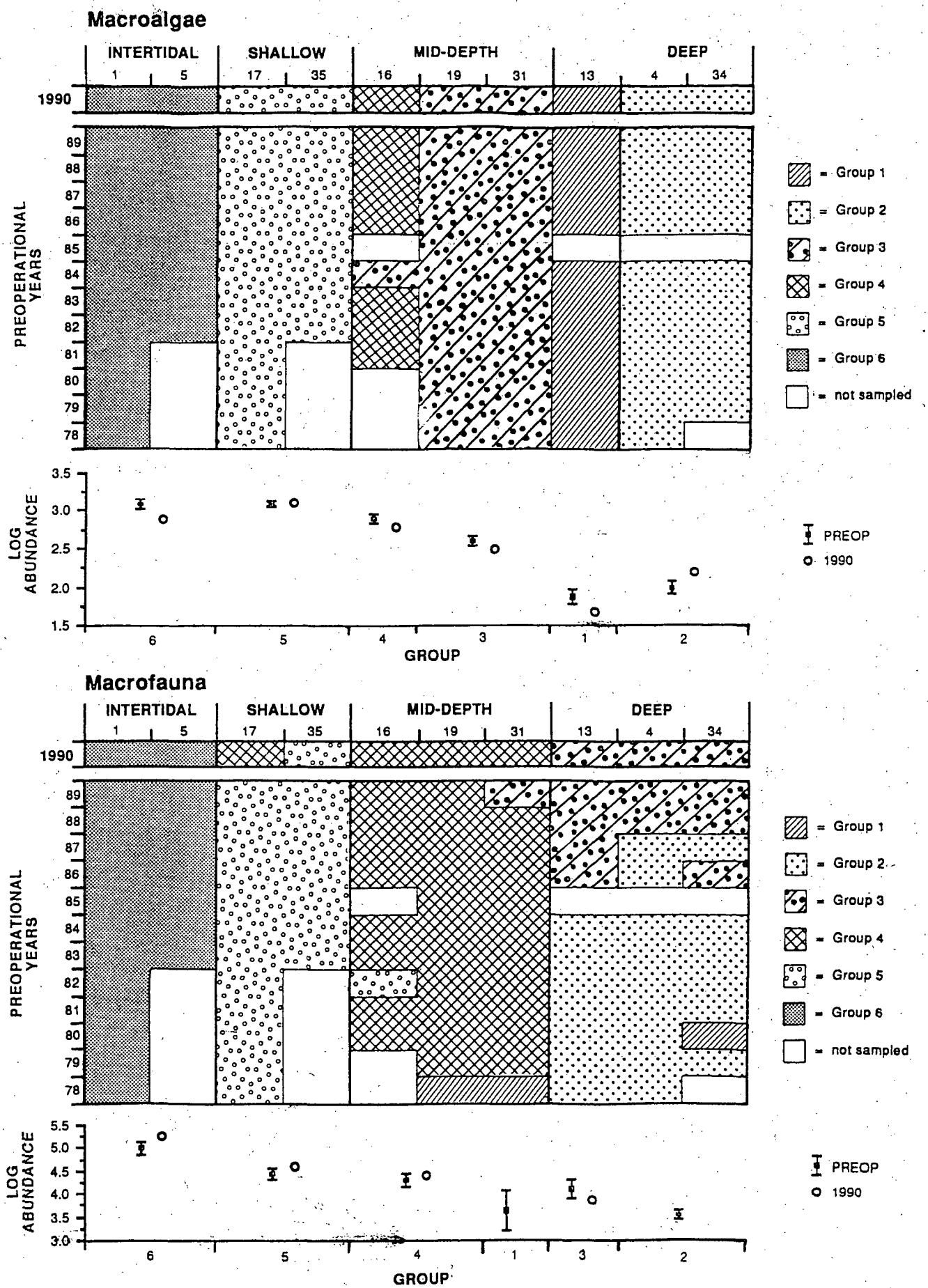


Figure 2.3-7. Similarity and abundance or biomass of macroalgae and macrofauna species assemblages in 1990 compared to the preoperational years. Seabrook Operational Report, 1990.

and intertidal macrofauna collections was similar to previous years. For the first time since 1978, the shallow subtidal macrofaunal assemblage at the nearfield station (B17) was more similar in 1990 to mid-depth regions than to previous shallow subtidal collections. High numbers of *Balanus crenatus* probably contributed to the similarity ofthis station to mid-depth areas. Macrofauna density levels in intertidal and shallow subtidal groups in 1990 were higher than previous years, due to increased mytilid density, which occurred at nearfield and farfield areas. Algae biomass in the shallow subtidal area in 1990 was similar to the preoperational mean. However, the intertidal group biomass in 1990 was lower than the historical average, due to decreased amounts of *Chondrus crispus*. This difference was observed at the reference station as well as the nearfield station.

Fourteen benthic taxa were selected for more intensive monitoring because of their trophic position, abundance and commercial or recreational value (Table 2.3-3). Parameters monitored included abundance (all taxa), size (fauna only), and reproductive status (epibenthic crustaceans). All life stages of the commercially-important taxa were studied. Some of these taxa were monitored in the Sunk Rocks area while others were examined as part of the discharge or estuarine studies.

Algal selected species showed no evidence of operational impact. Biomass of the dominant algae *Chondrus crispus* in 1990 in the shallow subtidal zone was similar to previous years (Figure 2.3-8). In the intertidal zone, biomass was lower in October at both stations (Table 2.3-4). This resulted in lower relative abundance in 1990 than previous years (Figure 2.3-8). Quantitative counts of the dominant kelp, *Laminaria saccharina*, were much lower than recorded in previous years at the nearfield station. However, lower counts were also recorded in April and July, prior to the operational period (Table 2.3-4).

TABLE 2.3-3. SELECTED BENTHIC SPECIES AND RATIONALE FOR SELECTION. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES (COMMON NAME)	LIFESTAGE[a]	RATIONALE
Macroalgae		
Laminaria saccharina (kelp)	A	Habitat (canopy)-forming primary producer
Chondrus crispus (Irish moss)	A	Habitat (understory)-forming primary producer; sporelings may be heat sensitive
Benthic Invertebrates		
Ampithoe rubricata (amphipod)	J,A	Intertidal/shallow subtidal community dominant (formerly)
Jassa marmorata (amphipod)	J,A	Intertidal/shallow subtidal community dominant
Pontogeneia inermis (amphipod)	J,A	Subtidal, ubiquitous community dominant
Nucella lapillus (dog welk)	J,A	A major intertidal predator of *Mytilus edulis*
Asteriidae (starfish)	J	Predator, community dominant
Strongylocentrotus droebrachiensis (green sea urchin)	J,A	Potentially destructive herbivore
Dominant Bivalves		
Mytilus edulis (blue mussel)	L,S,A	Habitat former; spat may be heat sensitive
Mya arenaria (soft-shell clam)	L,S,A	Recreational estuarine species; larvae entrainable
Epibenthic Crustaceans		
Carcinus maenas (green crab)	L,J,A	A major predator of soft-shell clam spat
Cancer borealis (Jonah crab)	L,J,A	Important predator and prey
Cancer irroratus (rock crab)	L,J,A	Important predator and prey
Homarus americanus (American lobster)	L,J,A	Commercial species; larvae plume-entrainable

[a]A = adult; J = Juvenile; L = Larvae; S = Spat

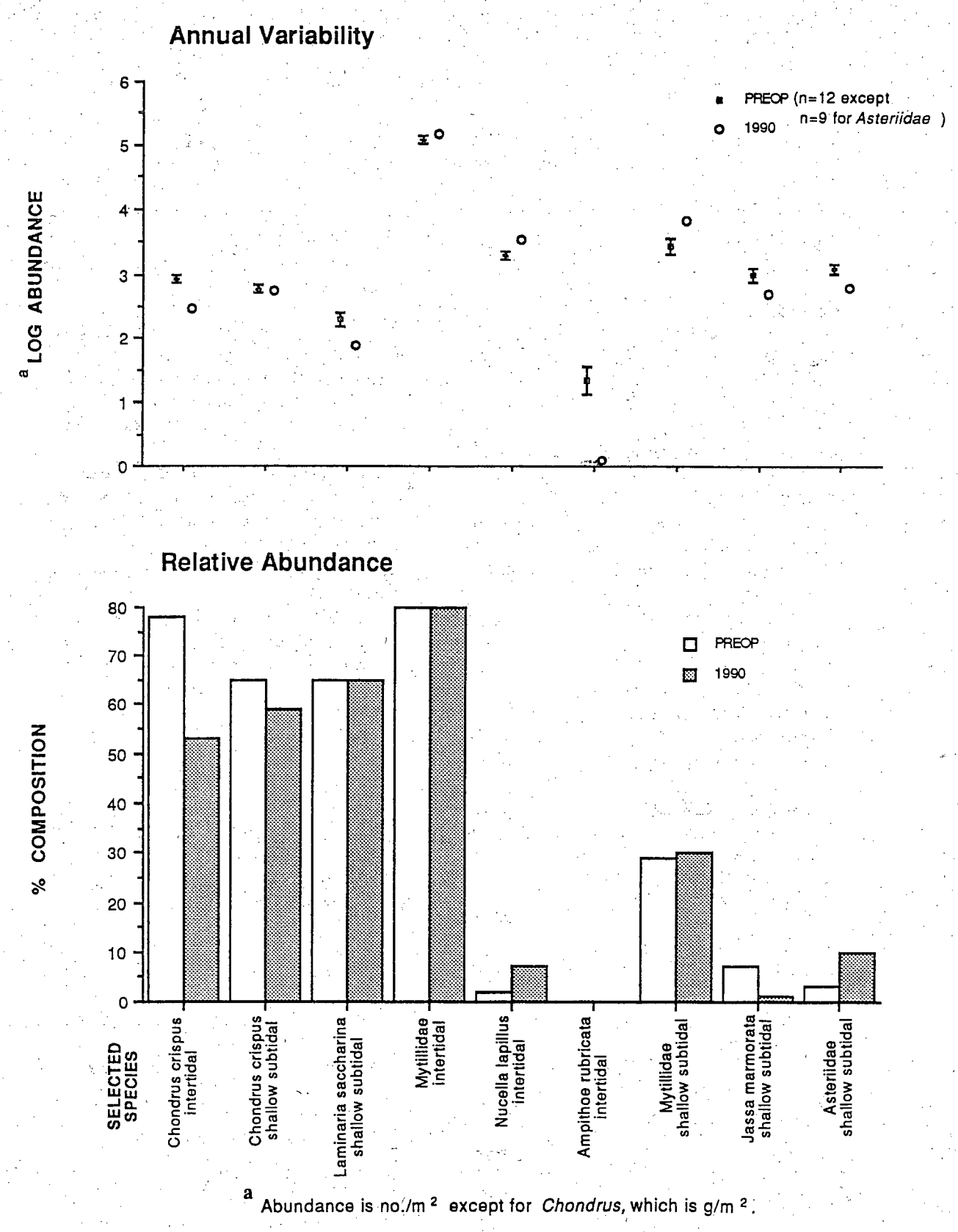


Figure 2.3-8. Nearfield (Sta. B1MLW & B17) annual variability (95% confidence limits) of log (x+1) biomass (g/m 2) or abundance (no./m2) and percent composition for selected intertidal and shallow subtidal species of algae (triannual collections) and benthos (August only) during the preoperational period and in 1990. Seabrook Operational Report, 1990.

TABLE 2.3-4. COMPARISON OF 1990 ABUNDANCES OR BIOMASS LEVELS OF SELECTED INTERTIDAL AND SHALLOW SUBTIDAL MACROALGAE AND MACROFAUNAL TAXA. SEABROOK OPERATIONAL REPORT, 1990.

1990 SIMILAR[a]	1990 DIFFERENT[a]	RESTRICTED TO NEARFIELD?	RESTRICTED TO OPERATIONAL PERIOD?
Chondrus crispus (S)	*Ampithoe rubricata* (I)	yes	no
Jassa marmorata	Asteriidae (S)	no	no
(ST,M;ST,D)	*Jassa marmorata* (S)	no	no
	Mytilidae (I)	no	no
	(S)	yes	yes
	(ST,M)	no	N/A
	(ST,D)	yes	N/A
	Nucella lapillus (I)	no	no
	Chondrus crispus (I)	no	yes
	Laminaria saccharina	yes	no

[a]Based on results of Analysis of Variance or Wilcoxan's Summed Ranks tests.

I = Intertidal
S = Shallow subtidal
ST,M = Short-term panels, mid-depth
ST,D = Short-term panels, deep

Differences in 1990 for the majority of macrofauna species occurred either at both nearfield and farfield stations, or were not restricted to the operational period (November), suggesting that they were not related to plant operation (Table 2.3-4). In one instance, one taxon did not meet these criteria. Mytilidae collected in the shallow subtidal zone occurred in significantly higher densities at the nearfield station in November. Since this result is based on only one sample during the operational period, additional information will be necessary to evaluate potential operational effects.

2.3.1.3 Estuarine Zone

Environmental studies in Hampton Harbor estuary include monitoring physical parameters (temperature and salinity), fish populations, benthic macrofauna, and juvenile and adult soft-shell clams (*Mya arenaria*). The estuary has been monitored to determine the effects, if any, of the settling pond discharge since 1978. This included any possible effects of tunnel dewatering, which added large volumes of ocean water to Browns River through 1983. Current estuarine monitoring efforts are conducted to identify any potential effects from either settling pond discharge or Seabrook Station operation. One of the main environmental issues in the Hampton-Seabrook estuary related to plant operation is whether the offshore intake and discharge will impact the adult clam population in Hampton Harbor. The probability of impact from the most-likely source, entrainment of *Mya* larvae, is small (NAI 1977e); this is discussed in Section 2.2.2. Effects on juvenile and adult *Mya* are evaluated by comparing population estimates developed for 1990 with those from previous years.

Temperature and salinity, monitored in Hampton Harbor and Browns River since 1978, provide valuable information for interpreting biological phenomena. Maximum temperatures usually occurred in July, with minima in January or February (Figure 2.3-9). Temperatures generally followed this pattern in 1990 but were higher than average in

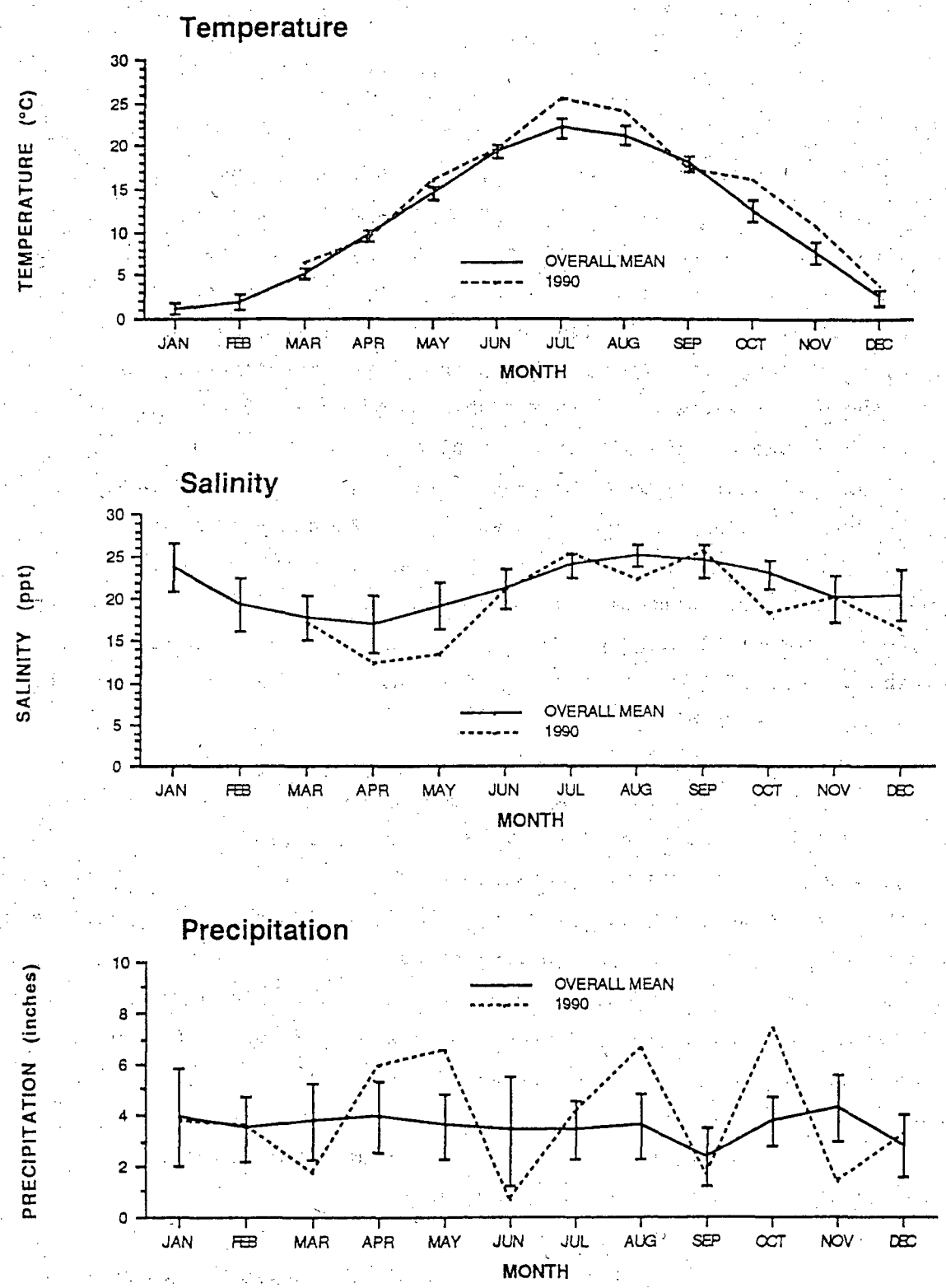


Figure 2.3-9. Monthly means and 95% confidence limits for seawater surface temperature and salinity taken at low tide in Browns River over the entire study period (May 1979-December 1989) and in 1990, and precipitation measured in Boston, MA, from 1978-1990. Seabrook Operational Report, 1990.

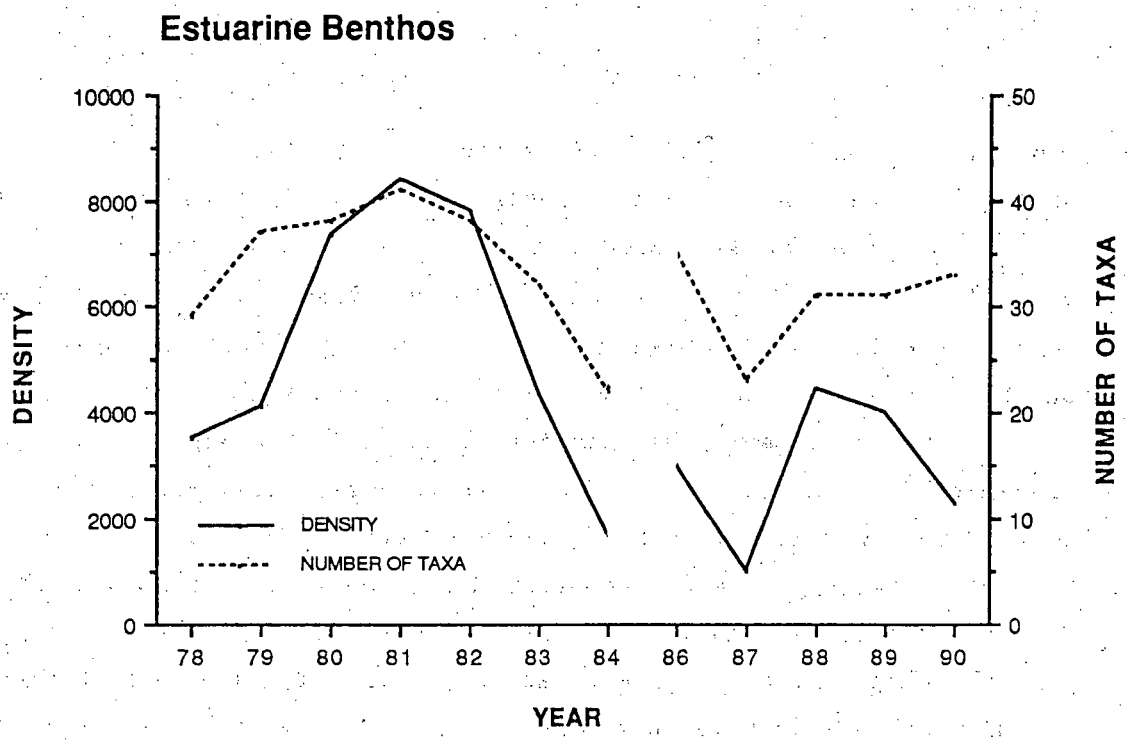
July-August and again in October-November. Salinity had a less distinct seasonal cycle than did temperature, but was usually lowest in spring, coincident with increased runoff. Heavy rains in April and May of 1990, and again in October, led to lower-than-average salinities during these months (Results, Section 3.3.1, Figure 2.3-9). In Browns River, average annual salinity values remained high for a three-year period from 1980-1982, coinciding with low precipitation and highest discharge volumes from the settling basin. This was the period when the maximum de-watering of the cooling tunnels took place, and the salinity of the settling pond's discharge water was relatively high, approximately 25 ppt. After discharge volumes decreased in 1983 and precipitation returned to pre-1980 levels, salinity levels dropped, averaging 18-20 ppt through 1990. Hampton Harbor salinities, which were not as susceptible to these influences because of the influx of a large volume of offshore waters, showed higher salinity and lower year-to-year variability than Browns River.

The benthic macrofaunal community in Mill Creek (Station 9) and Browns River (Station 3) was typical of New England estuaries. The species composition was also consistent with that from other estuaries on the East Coast (Watling 1975; McCall 1977; Whitlatch 1977; Santos and Simon 1980). Surface and subsurface deposit feeders predominated, including opportunistic polychaetes such as *Streblospio benedicti* and *Capitella capitata*, with suspension feeders and omnivores forming an important component. The most numerous species inhabiting estuaries are those that are resistant and resilient to the natural changes in the physical environment, such as fluctuating temperature, salinity, dissolved oxygen, and sediment grain size.

In Mill Creek and Browns River, the biological parameters measured were highly variable seasonally and annually, with total abundance, numbers of taxa, and most of the dominant species significantly different among years and between stations. This is typical of this physically heterogeneous habitat. Some of this variability was related to changes in salinity. The combination of lower precipitation

and higher levels of discharge from the settling basin from 1980 to 1982 apparently caused higher and less-variable salinities in Browns River. At the same time, total abundance and number of taxa increased (Figure 2.3-10), along with densities of *Streblospio benedicti* and *Capitella capitata* at that site. Higher salinity levels probably enhanced the habitat for more stenohaline species, and at the same time, opportunistic polychaetes invaded the changing habitat. Following an increase in precipitation and decrease in discharge volumes, these parameters dropped to their lowest point in 1984; however, they had returned to pre-1980 levels by 1986. Since that time, species richness and total density have been variable, in part attributable to periods of low salinity caused by heavy precipitation and runoff, especially during recruitment periods (Figure 2.3-10). In 1990, salinity was lower than average and was associated with lower numbers of taxa. Total density in 1990 was similar to previous years.

Important estuarine fish include both diadromous species as well as residents. Three anadromous fish species occur seasonally in the estuary: rainbow smelt in winter, and alewives and blueback herring ("river herring") travelling to upper reaches of local rivers to spawn in the spring. Rainbow smelt were an important but highly variable (both seasonally and annually) constituent of the demersal fish community at the entrance to the estuary (T2), composing approximately 20% of the total catch historically and in 1990 (see Section 2.3.2.2). The absence of smelt in trawls from April through November reflects their movement farther offshore. Historically, in spring and summer, sparse and erratic numbers of young-of-the-year and yearling smelt have been caught in the estuary (Figure 2.3-11), but no one age group (based on length-frequency) has been consistently dominant (NAI 1985b). Since 1976, rainbow smelt have never composed a substantial portion of annual seine catches, averaging only 3% of the total catch (Figure 2.3-11). In 1990, high numbers of rainbow smelt moved into the estuary in May and again in August, leading to higher-than-average total catches and relative abundances in these months (Figure 2.3-11). Average smelt catches in 1990 were the highest observed to date, composing 35% of the



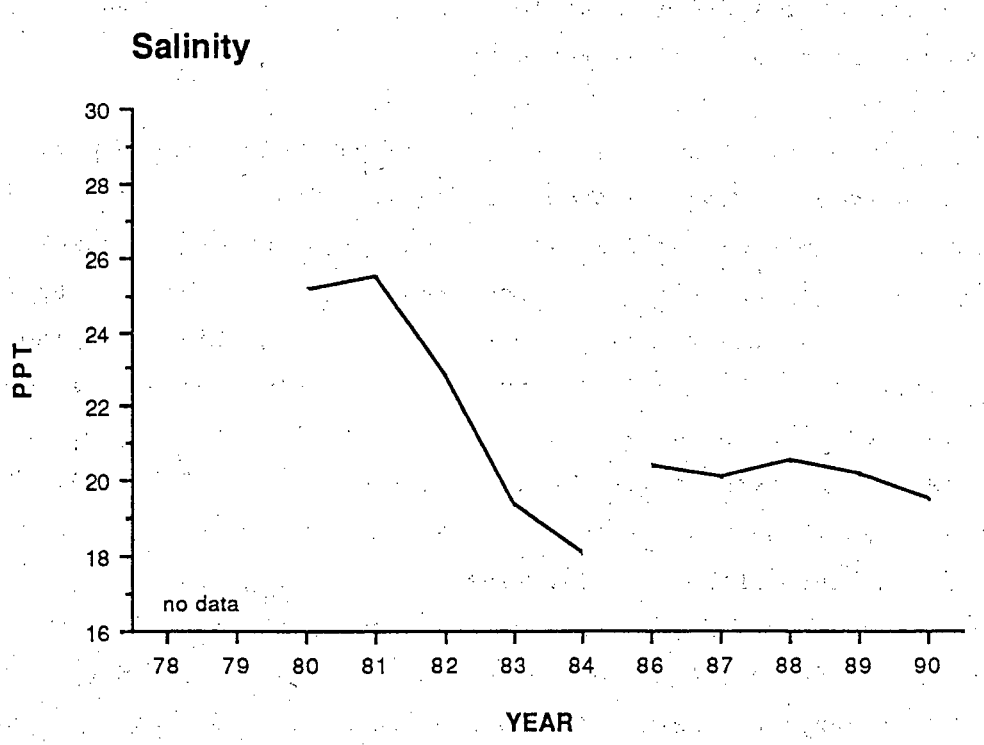


Figure 2.3-10. Annual geometric mean density (no./m^2) and mean number of taxa per station of estuarine benthos (1978-1984; 1986-1990), and annual mean salinity (1980 -1984; 1986-1990), at Browns River. Seabrook Operational Report, 1990.

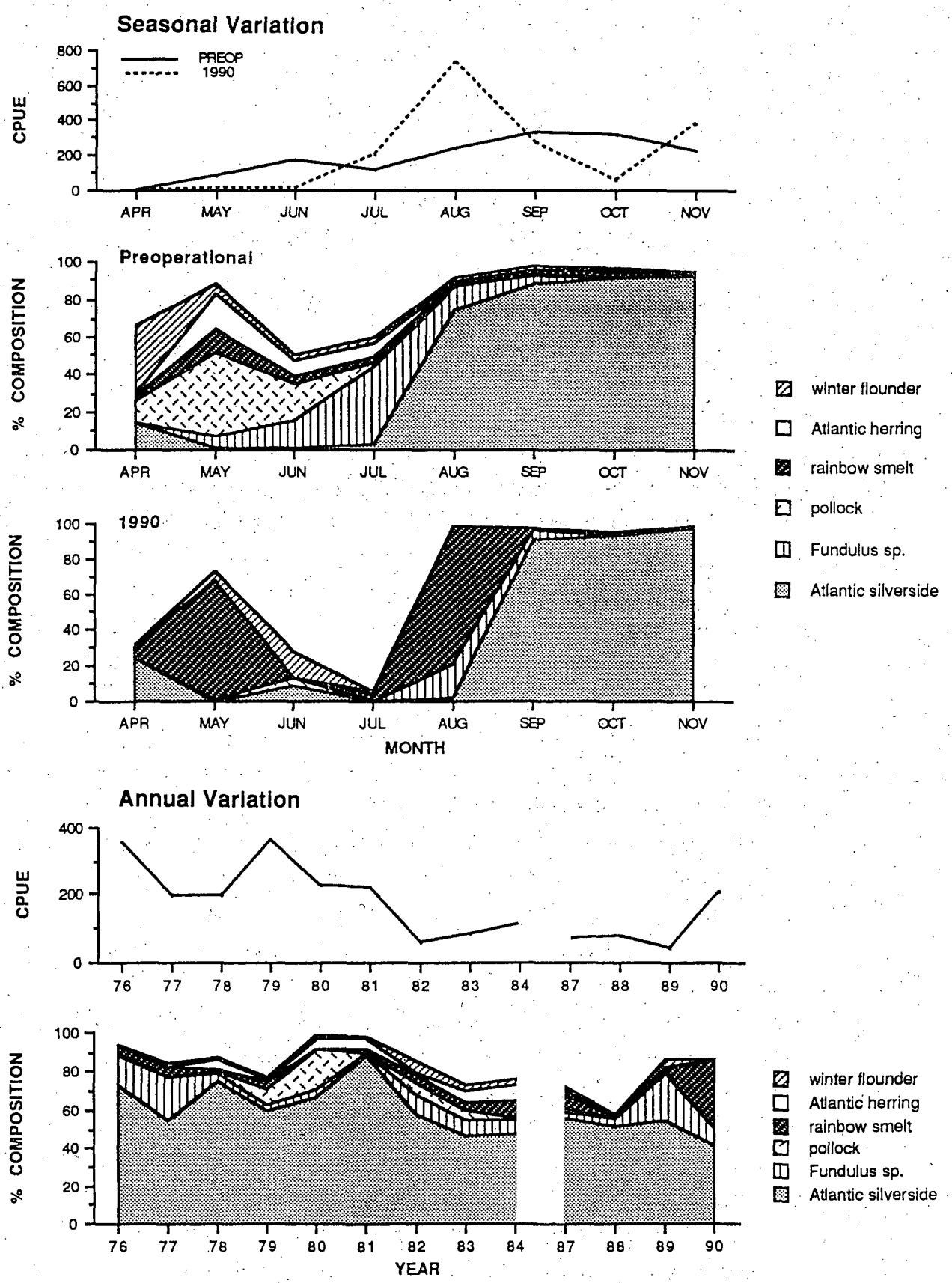


Figure 2.3-11. Seasonal and annual changes in composition and total abundance of the estuarine fish community, based on catch per unit effort averaged over beach seine Stations S1, S2 and S3, during the preoperational period (1976-1984 and 1987-1989) and in 1990. Seabrook Operational Report, 1990.

total catch (Figure 2.2-6, 2.3-11). Since increased abundances of smelt were for the most part due to higher catches prior to commercial operation, they are not related to plant operation.

River herring (*Alosa* spp.), which includes alewife and blueback herring, occasionally appeared in large numbers in Hampton Harbor, especially at the Browns River Station. In the Taylor River, the size of the river herring run has been variable, depending on year class strength, whereas the timing of the run depended on water temperature and level, which in turn was influenced by rainfall and runoff (NAI 1985b). In the estuarine sampling program, these species constituted only about 5% of the total catch (1978-1989). No alewives or blueback herring were caught in the estuary in 1989. In 1990, blueback herring were caught in low numbers in the estuary in the fall, but no alewives were collected (see Results Section 3.2.2).

Another species that uses the estuary is winter flounder. This species undergoes onshore/offshore migration, depending on the time of year (Bigelow and Schroeder 1953). Juveniles (ages one and two, based on length-frequency analysis) have been the main constituent in the estuary, primarily collected during the spring and summer (NAI 1985b). Recruitment was evident by the occurrence of young-of-the-year size classes. Winter flounder have composed only a small portion of the estuarine fish assemblage, averaging only 2% since 1976 (Figure 2.3-11). Their relative abundance was highest in April, when total catch is lowest. In 1990, winter flounder catches were lower than average throughout the year (see Section 3.2.2).

The dominant resident species in the estuary has historically been Atlantic silverside, which typically composed from just under 50% to nearly 90% of seine catches during the baseline period (1976-1989) during their period of greatest abundance, August to November (Figure 2.3-11). This trend continued in 1990, with one exception. High rainbow smelt catches in August reduced the relative importance (percent composition) of silversides. The population historically has been

composed primarily of yearling fish but the occurrence of young-of-the-year size classes in spring has indicated recruitment (NAI 1985b). The year-to-year variation in silverside catch has been the main cause of the observed variation in the total annual catch in beach seines for all species combined. Total catches were high from 1976-1981 (200-360 fish/haul) and much lower from 1982-1989 (40-115 fish/haul) (Figure 2.3-11). Inceased total catch in 1990 was in large part due to increased numbers of silversides in comparison to 1989 levels. However, given the high annual variability in silverside catches, 1990 were statistically similar to previous years levels, although lower than average (See Results, Section 3.2.2).

Since the Hampton-Seabrook estuary contains the majority of New Hampshire's stock of the recreationally-important species *Mya arenaria*, an extensive sampling program (initiated in 1969) has been undertaken in order to characterize the natural variability in the population for all lifestages. Of the potential impact types, larval stages will be most susceptible to intake effects and therefore are discussed in that section (Section 2.2.1). Spat settlement densities appear to bear no relationship to the abundance or periodicity of *Mya* larvae in the nearshore waters (NAI 1982b). It would appear that *Mya* veliger behavior (i.e. their "readiness" or competency to settle) combined with the timing of favorable currents may be more important to settlement success than sheer numbers of larvae in the water column. Such conditions apparently existed in 1975, 1976, 1977, 1980, 1981 and 1984 when high young-of-the-year spat densities indicated successful recruitment at Flat 1 (Figure 2.3-12) and other flats. The 1976 year class in particular provided an important and rejuvenating recruitment to the local population as shown by the high densities of 13-25 mm (yearling and older) spat clams in 1977 and 1978 (Figure 2.3-12). In 1989, young of the year settlement densities throughout Hampton Harbor were again higher than previous levels. This level of settlement was sustained into 1990 at Flats 2 and 4 and showed further increases at Flat 1 (Figure 2.3-12). Survival of the 1989 year class at Flats 1 and 2 is suggested by increased densities of the 13-25 mm spat in 1990.

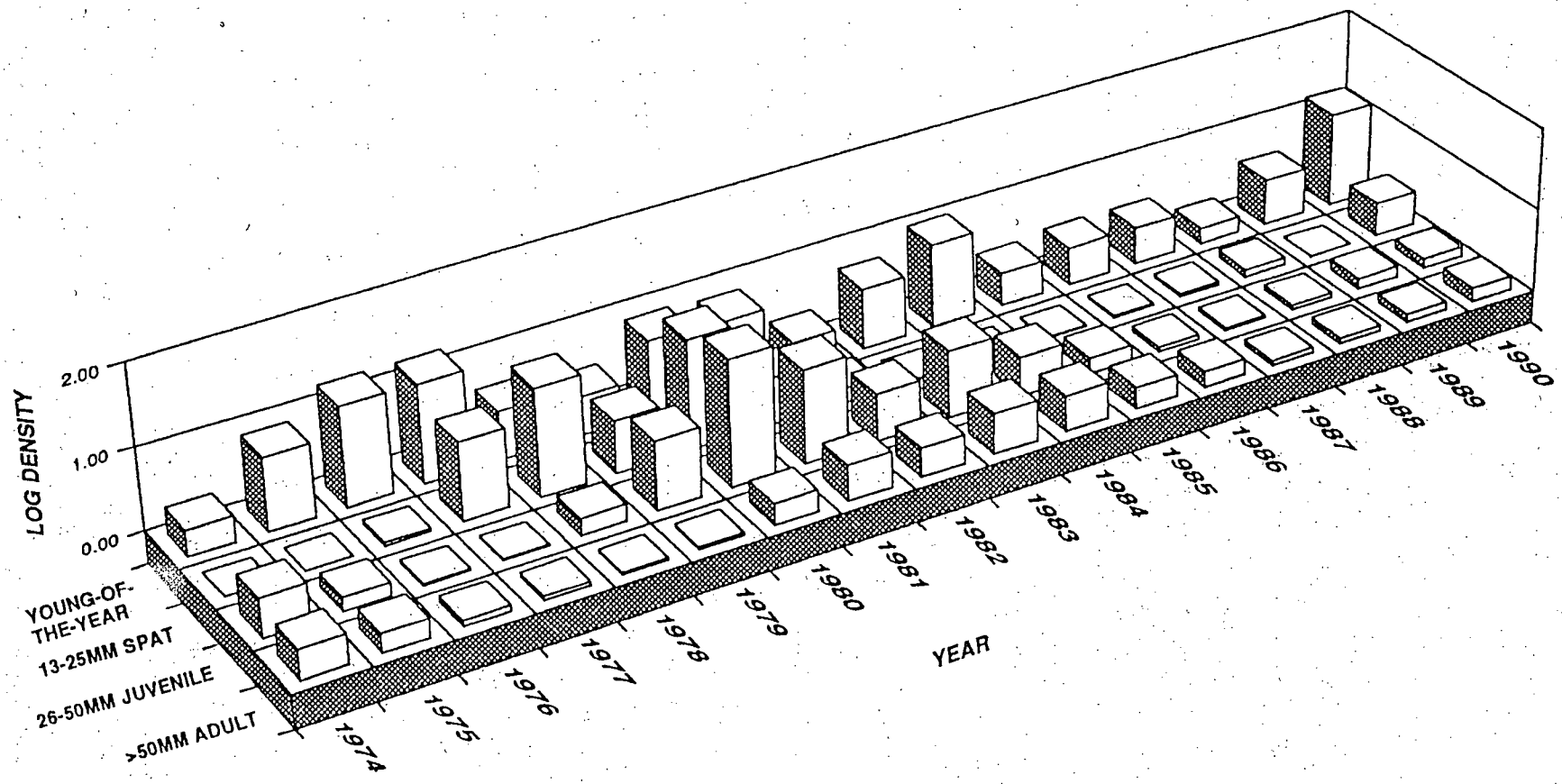


Figure 2.3-12. Annual log (x+1) mean density (number per square foot) of young-of-the-year (1-5 mm), spat (13-25 mm), juvenile (26-50 mm) and adult (>50 mm) *Mya arenaria* at Hampton- Seabrook Harbor Flat 1 from 1974-1990. Seabrook Operational Report, 1990.

Once settled, survival of young-of-the year *Mya* depends on both the level of predation from its two main predators, the green crab and human clam diggers, and the absence of diseases such as neoplasia. Despite relatively heavy densities of young-of-the year in 1980, 1981, and 1984 on Flat 1, recruitment to yearling clams was minimal (Figure 2.3-12). This pattern was replicated throughout the estuary. Predation by green crabs, whose densities began to increase in 1980 and from 1983-1989 remained much higher than previous years, may have virtually eliminated the first and second year-class (Figure 2.3-13). Dramatically decreased green crab catches in 1990 may have enhanced the survival of spat and juveniles, in part contributing to increased densities at Flat 1 (spat only) and Flat 4 (spat and juveniles)(Figures 2.3-12,13).

Human predation is also an important factor in the level of harvestable clams, and causes additional mortality to unharvested adults as well as spat and juveniles by disturbance. Digging activity declined sharply from 1982 to 1985 with a small increase in 1986 as clam diggers switched among the flats within the estuary in an effort to harvest clams. Digging activity resumed its decline in 1987 and continued to fall through 1989, when flats were closed due to coliform contamination (Figure 2.3-13). The standing stock had declined precipitously from 1983 through 1987, lagging trends in digging activity by one year. In 1988, the decline of adult standing stock leveled off while the number of adult licenses continued to decrease. Harvestable clam densities began to increase at Flat 4 following closure of all of the flats to any digging activities, while standing stock at the other flats remained unchanged. However, for the entire area, harvestable clams have increased steadily since 1987, most likely due to the reduced digging pressure along with reduced numbers of green crabs.

Finally, the presence of disease has an undetermined effect on *Mya* recruitment and survival. Neoplasia, a cell growth disease fatal to *Mya*, was detected at Hampton Harbor Flats 1 and 2 in studies conducted in 1986 and 1987 (Hillman 1986, 1987). Presence of neoplasia in 1987 coincided with dramatic decreases in juvenile and adult densities at

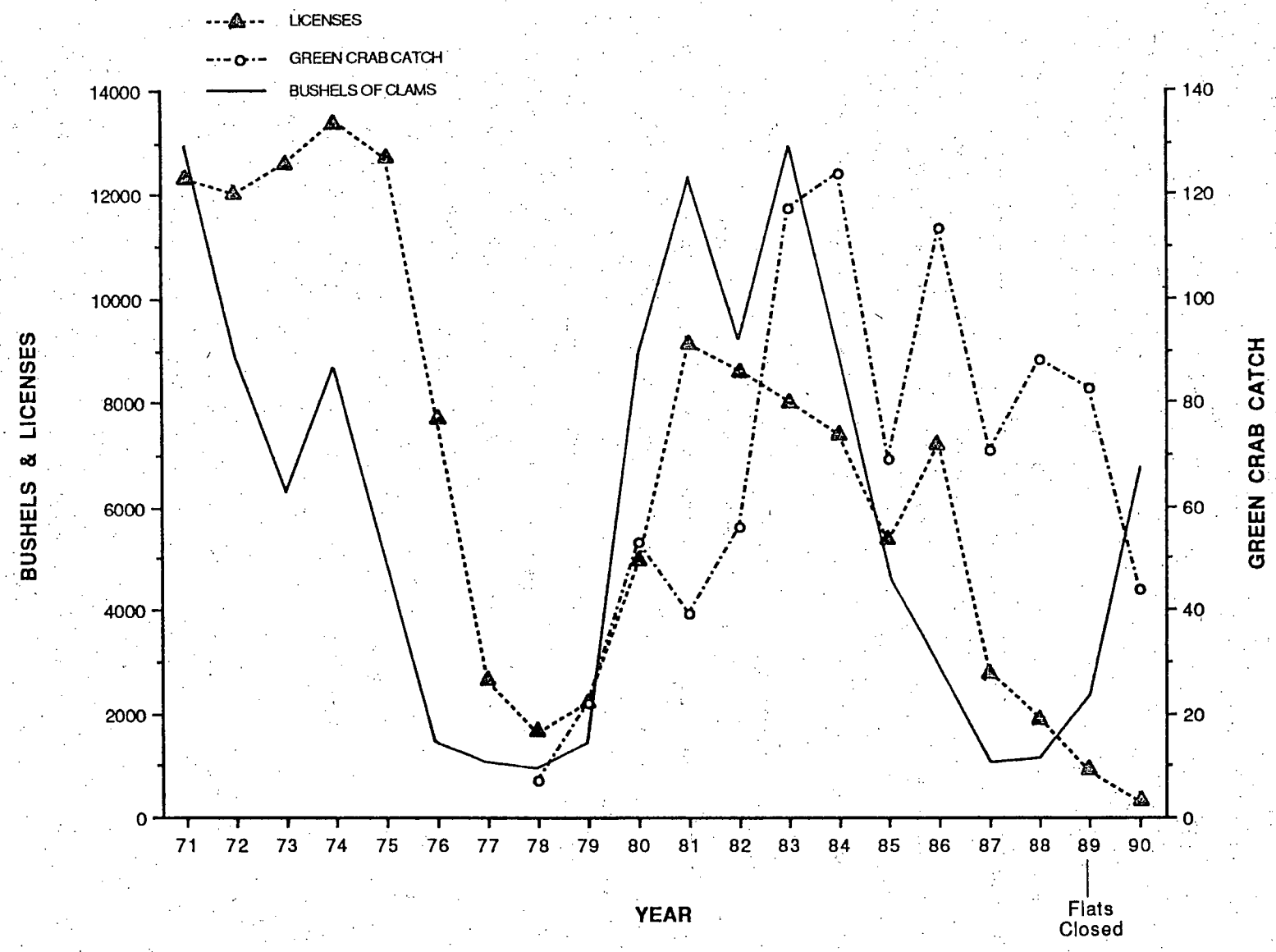


Figure 2.3-13. Number of adult clam licenses issued, the adult clam standing crop (bushels), 1971-1990, and green crab catch in fall, 1981-1990 in Hampton-Seabrook Harbor. Seabrook Operational Report, 1990.

Flats 1 and 2, while Flat 4 densities, where no neoplasia were found, remained unchanged. The magnitude of the effect of this disease on the clam population is unknown.

Increases in young-of-the-year recruitment in 1990, along with continued survival of yearling spat, suggest that there are no adverse effects from plant operation, including settling pond discharge or offshore entrainment. The ability to assess impact in adult clams in Hampton estuary will depend on close monitoring of all of the factors important to recruitment and predation. One of these factors is clam seeding by the State of New Hampshire. Seeding activities during 1987 and 1988 on Hampton Harbor tidal flats did not result in measurably increased spat densities. Thus, it appears that predation levels and disease are currently the most important factors in determining the standing crop of harvestable clams.

2.3.2 Benthic Monitoring

2.3.2.1 Macroalgae and Macrofauna

Monitoring of the benthic organisms (macroinvertebrates, algae, demersal fish, and epibenthic crustaceans) was established to determine the extent of change (if any) to the community structure in this zone as a result of plant operation. Changes could be manifested by (1) the enhancement of detritivores and suspension feeders, (2) the increased attraction of benthic feeders caused by locally-increased food supply, and/or (3) impact on organisms sensitive to the increased detritus resulting from moribund entrained organisms.

Mid-depth and deep (10-20 m) benthic communities, including macroalgae, macrofauna, and bottom panels, were sampled to monitor the preoperational benthic community. Year-to-year variations in community structure were small in comparison to variations related to depth and substrate. The macroalgae community was highly similar among years, although less so than in the intertidal and shallow subtidal areas.

Species composition of collections in the mid-depth and deep subtidal areas during 1990 was similar to those taken at the same station in previous years (Figure 2.3-7 and Section 3.3.2). In 1990, plant start-up began less than a week before macroalgae and macrofaunal community collections were made. Thus, 1990 collections are not expected to show changes resulting from plant operation.

Species composition of the macroalgae community in mid-depth and deep areas was similar to previous years (Figure 2.3-7). Total biomass of the mid-depth station groups in 1990 was similar to previous years. Deep discharge (B04) and farfield (B34) group biomass was lower in 1990 than in previous years, whereas deep intake (B13) station biomass was higher than previous years (Figure 2.3-7).

Macrofauna community composition at mid-depth station in 1990 was similar in mid-depth regions to previous years; the assemblage at deep stations was similar to the assemblage collected in the last 2-3 years (Figure 2.3-7). Heavy *Balanus crenatus* sets have differentiated the deep stations in recent years from the deep water assemblage collected prior to 1988. Station group densities in 1990 were similar to previous years.

Other community parameters underscored the stability of the benthic community. The majority of changes noted in 1990 occurred at both nearfield and farfield areas. Taxa richness of both algae and macrofauna in 1990 was statistically similar to previous years at the mid-depth intake station and deep areas. Differences in macrofaunal and macroalgae taxa richness at the mid-depth discharge station were also observed in the farfield area (Table 2.3-2).

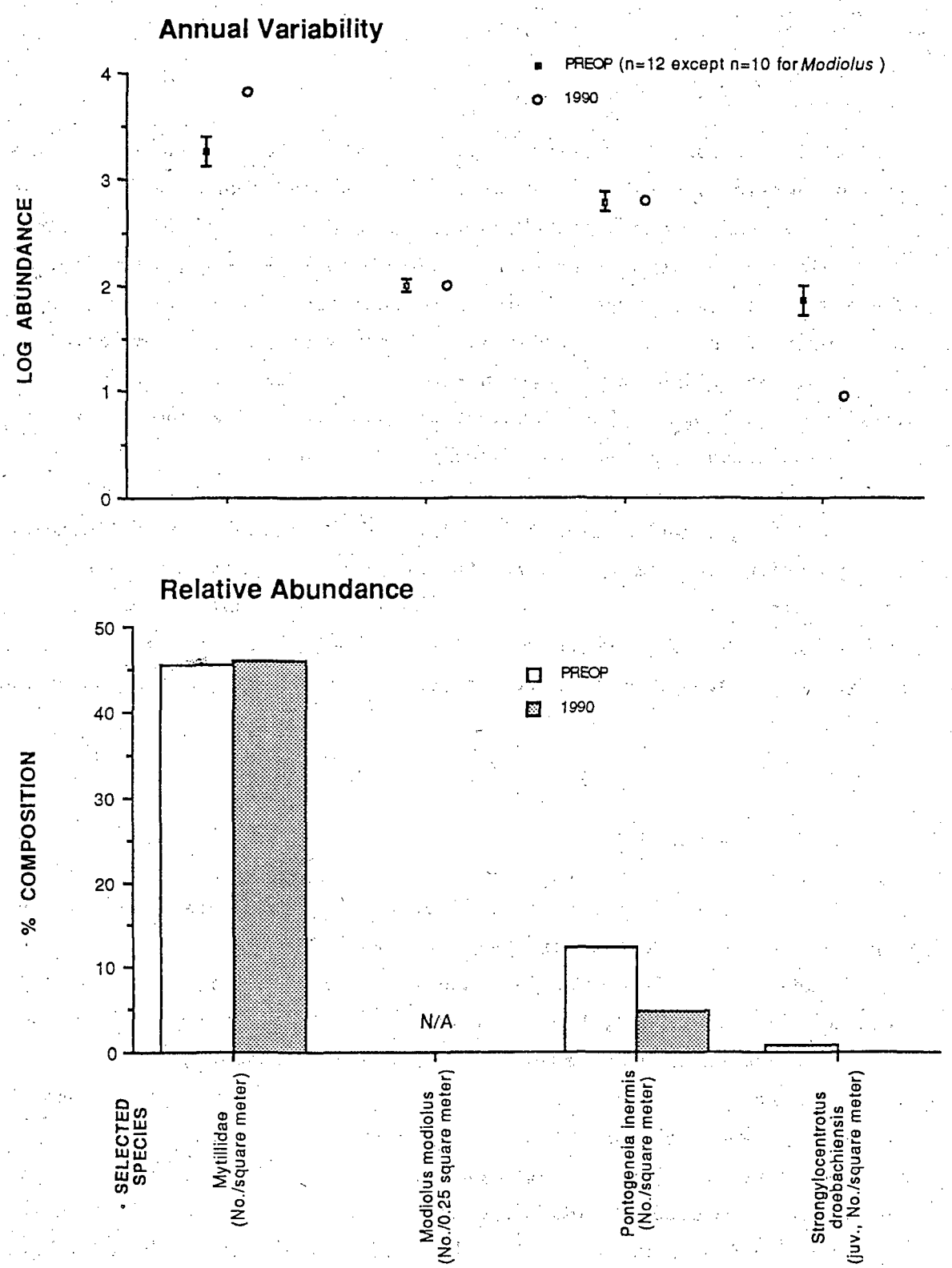
Patterns in abundance and size distribution in selected benthic species were only slightly less predictable than community characteristics. Historically, abundances have varied among years and between nearfield and farfield stations (NAI 1990b). 1990 abundances of two taxa, amphipod *Pontogeneia inermis* and mussel *Modiolus modiolus*,

were similar to previous years (Figure 2.3-14). Abundances of mytilids were higher in 1990 at the discharge station, and lower at the farfield station, whereas green sea urchins were more abundant in 1990 at both nearfield and farfield areas (Table 2.3-5, Figure 2.3-14). However, these differences occurred before plant operation began, and thus appear to be part of the natural variability among years. In particular, green sea urchin densities showed evidence of a long term cycle. 1990 densities, although higher than 1988 and 1989 densities, were lower than the preoperational average (see Results, Section 3.3.5).

Length measurements have historically been a stable indicator of population recruitment and growth, showing low variability among years. Mytilids were larger than average at the discharge station, but within the range of previous years. Amphipod *Pontogeneia inermis* and the green sea urchin were similar in size to previous years (see Section 3.3.5).

2.3.2.2 Demersal Fish

Demersal fish that inhabit or feed in the nearshore area are important not only because of their predominance in the food chain but also because of their commercial value. As would be expected with any bottom-oriented species, the nearshore population of demersal fish show spatial differences associated with substrate and location relative to Hampton Harbor. Of the farfield stations, T1 has a sandy bottom and T3 has sand mixed with cobble and shell debris. The nearshore discharge station T2 is mainly sand. Station T2, located off the mouth of Hampton Inlet, is influenced by tidal flow from the estuary, which often causes the accumulation of drift algae. The algae, combined with heavy lobster fishing in the area, has decreased gear effectiveness and has even prevented trawling activities in some months. For this reason, potential effects of operation are investigated separately for the nearshore Station T2 and the more distant stations (T1 and T3), which are similar and thus combined for this assessment.



N/A = Percent composition not computed in instances where only a single species is collected.

Figure 2.3-14. Preoperational mean (1978-1989) and 95% confidence limits and 1990 mean of log (x+1) abundance (no./m^2) and percent composition for selected benthic species at mid-depth nearfield station. Seabrook Operational Report, 1990.

TABLE 2.3-5. SUMMARY OF SIMILARITIES OF ABUNDANCES OF SELECTED TAXA IN MID-DEPTH REGIONS IN 1990 COMPARED WITH PREVIOUS YEARS. SEABROOK OPERATIONAL REPORT, 1990.

1990 SIMILAR[a]	1990 DIFFERENT[a]	SIMILAR TREND AT NF/FF[a]	RESTRICTED TO OPERATIONAL PERIOD[a]
Pontogeneia inermis	Mytilidae	no	no
Modiolus modiolus	*Strongylocentrotus droebachiensis*	yes	no
Rainbow smelt	Atlantic cod	yes	no
Winter flounder	Hakes	yes	no
	Yellowtail flounder	yes	no
	Lobster (total catch)	yes	no
	Lobster (legal-sized)	yes	no
	Rock crab	yes	no
	Jonah crab	no	no

[a]Based on results of Analysis of Variance or Wilcoxon's summed ranks tests.

Total catches in the demersal fish community showed evidence of a multiple-year cycle. Total catches steadily increased from 1977-1981, declined from 1981 through 1985, generally increased through 1988, and decreased in 1990 (Figure 2.3-15). Catches from August-December, the period of operation in 1990, paralleled the trends for the entire year. Thus the decrease in total catch in 1990 was not restricted to the operational period. Seasonally, catches were usually lowest from January through March or April, but the occasional appearance of rainbow smelt increased total winter catches as occurred at T2 in 1990. Total catch was highest in summer and fall at T1 and T3, and somewhat earlier at T2 (Figure 2.3-15). Seasonal patterns of total catch in 1990 were similar at T1 and T3, but catches were lower than average at these stations. The seasonal pattern of total catch at T2 was slightly different in 1990 from previous years. Catches were lower than average from March through June, then increased due to high catches of winter flounder. Large numbers of lobster traps prevented trawling at T2 in September and October.

Historically, six taxa composed close to 80% of total near-shore otter trawl catches both across months and years (Figure 2.3-16). The spatial, seasonal, and annual variability of these dominant species had a strong influence on the community structure. The relative importance of dominant species often showed year-to-year fluctuations (Figure 2.3-16). Proportions of hakes, Atlantic cod, and rainbow smelt varied by five to tenfold among years. Yellowtail flounder and winter flounder were more stable constituents, with lower year-to-year variability. In 1990, hakes and cod had lower relative abundance than any previous year. Catches of these species throughout 1990 were significantly lower than all previous years at all three stations (Figure 2.2-6; Table 2.3-5). Rainbow smelt catches were higher than average in 1990 but statistically similar to previous years. Skates were also relatively more abundant, on average, than in previous years.

The demersal fish community at T2 changed with the seasonal movements of the dominant species. The presence of rainbow smelt and,

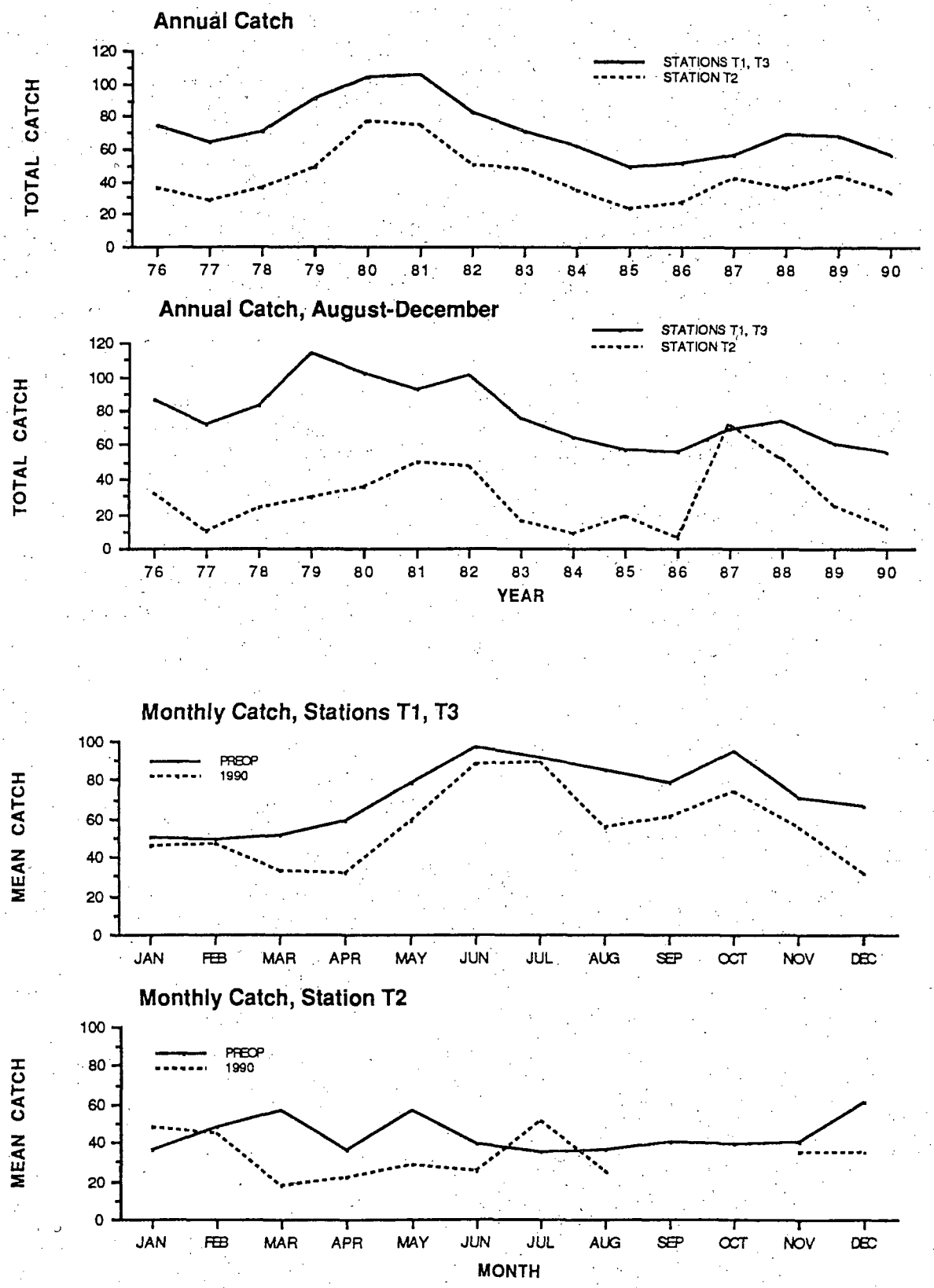


Figure 2.3-15. Total annual and monthly catch of demersal species at Stations T1 and T3 combined and Station T2 during the preoperational period (1976-1989) and in 1990. Seabrook Operational Report, 1990.

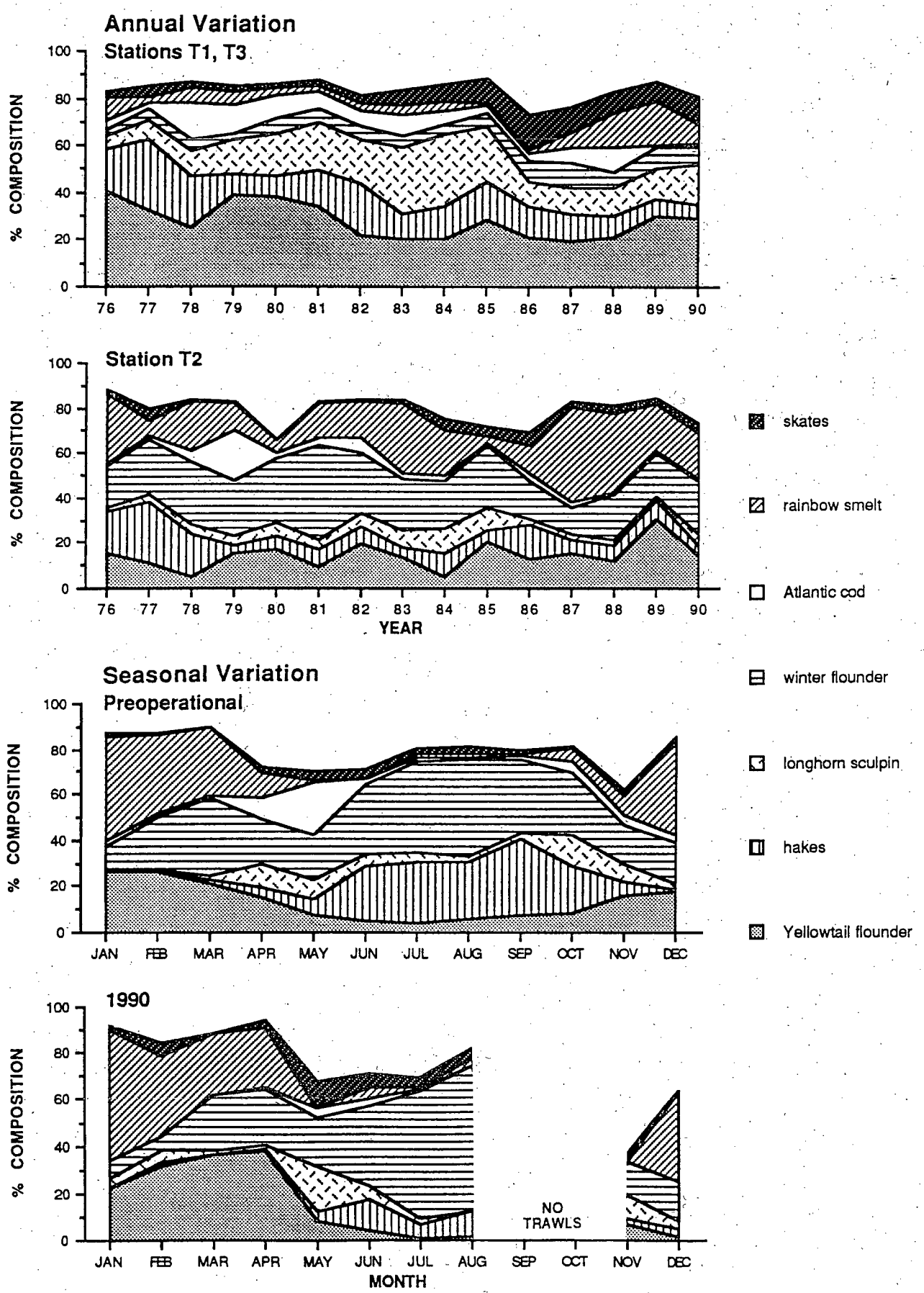


Figure 2.3-16. Seasonal and annual changes in relative abundance of the demersal fish community, based on mean catch per unit effort at otter trawl Station T2 during the preoperational period (1976-1989) and in 1990. Seabrook Operational Report, 1990.

to a lesser extent yellowtail flounder, in winter (December-March) differentiated the community from the remainder of the year, when hakes (red, white, and spotted) predominated (Figure 2.3-16).

The age structure of the fish population can also be a factor contributing to abundance variability. Based on 1983 and 1984 length-frequency data and age-size information from the literature, the dominant age group collected at the nearfield trawl station (T2) was determined. As with most of the pelagic and estuarine fish collected in this study, the majority of fish collected with otter trawls were juveniles. Yellowtail flounder and rainbow smelt were predominantly young-of-the-year, whereas the majority of Atlantic cod were ages one and two. Only hakes and winter flounder had no dominant age class, although presence of young-of-the-year for these as well as the other taxa indicated the timing of recruitment. Knowledge of the age structure of the population and use of age and growth parameters (NAI 1985b) can be used to better understand spatial and temporal changes in the demersal fish population.

Spatial differences are an important consideration with demersal fish. Historically, farfield Stations T1 and T3 have been similar in overall catch per unit effort (NAI 1990b). Communities have been dominated by the same species, although longhorn sculpin were more important at T3, while yellowtail flounder were more important at T1 (Section 3.2.2.1). The nearfield station (T2) was unique, with total CPUE (averaged over all years) reaching only 60% of that at farfield stations (Figure 2.3-15). This may be due in part to decreased sampling efficiency from accumulated drift algae and interference from lobster traps. Historically, winter flounder and rainbow smelt (together) composed 45% of the overall catch at T2, compared with 11-12% at the farfield stations (Figure 2.3-16). These species were relatively more abundant at the farfield stations in 1990 (15-19%) than previous years, but their relative abundance remained less than half that at T2 in 1990 (45%). Most of the differences in total catch and species composition

can be attributable to the previously mentioned differences in substrate and location with respect to Hampton Harbor.

Changes in the demersal fish community in 1990 were mainly the result of significantly decreased abundances of Atlantic cod and hakes. This is consistent with historical trends, as demersal fish catches have shown substantial variations among years. Since catches of these species were diminished throughout the year at all three stations, the differences appear unrelated to plant operation.

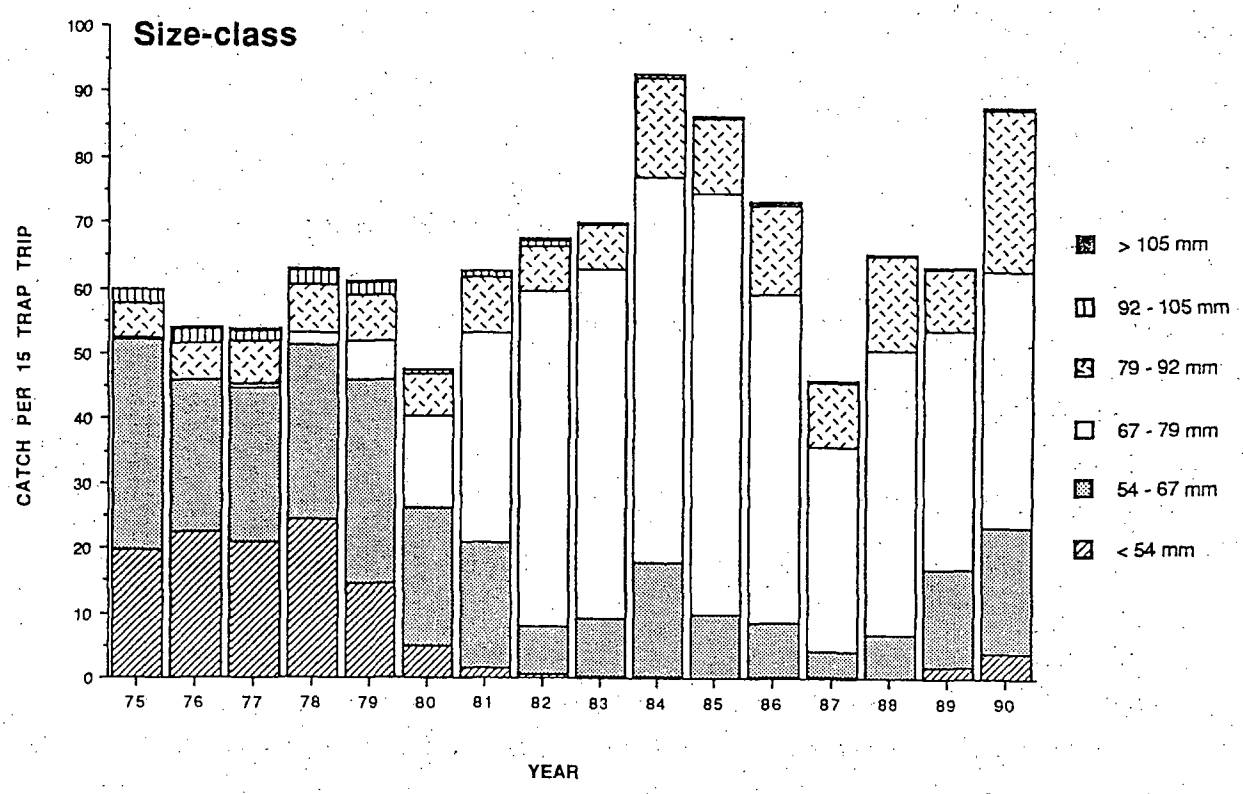
2.3.2.3 Epibenthic Crustacea

Because of its commercial importance, all life stages of the American lobster have been studied over the last 12-16 years. Annual catches of adult lobsters ("Total catch") averaged between 46 and 93 per year for a 15-trap fishing effort. Catches were highest during late summer and fall, from August-November. Seasonal trends of lobster catches in 1990 were similar to previous years, but monthly catches were consistently higher than average at both nearfield and farfield stations (Section 3.3.6). Higher than average bottom temperatures may, in part, be responsible for higher catches. Temperature acts not only to increase activity (and thus the likelihood of being caught [Dow 1969]) but also affects seasonal movements (Campbell 1985). Increased lobster catches were reported in 1990 both in New Hampshire and throughout New England (NOAA 1991b). Variations in catches of legal-sized lobsters, a primary concern to lobstermen, were a result of natural variation combined with the effects of increases in the legal size limit in 1984, 1989, and 1990. Effects of the first increase in the legal size limit in 1984 (from 3 1/8" [79.4 mm] to 3 3/16" [81.0 mm]), reduced the proportion of legal-sized lobsters from an average of 14% (1975-1983) to 8% (1984-1988). A second increase in the legal size limit (to 3 7/32" [81.8 mm]) in 1989 coincided with a 50% decrease in legal catches to 5% of total catch. The increase in legal size in 1990 to 3 1/4 in (82.6 mm) further reduced legal catches to 3% of the total catch.

Size class distributions reflect changes in the legal size limits. Since 1981, 67-79 mm lobsters have predominated in trap catches. Numbers of lobsters measuring 79-92 mm, as well as their proportions, were higher in 1990 than in 1984-1989, which in turn were higher than previous years. This probably reflects the increased protection from fishing pressure caused by size limit changes (Figure 2.3-17).

Jonah (*Cancer borealis*) and rock (*C. irroratus*) crabs are collected along with lobsters in the trapping program. Jonah crab catches have shown an increasing trend. Catches at the discharge area were higher from 1985-1987 than previous years; in 1988 and 1989, annual catches surpassed all previous years. 1990 catches, however, were lower than the past two years, but higher than the average for the study period (1982-1990; Figure 2.3-16). Increased catches occurred in July and August. Jonah crab catches at Rye ledge in 1990 were lower than average in all months that collections were made, but within the range of previous years. Although Jonah crabs were statistically different in 1990 only at the discharge area, differences were first observed prior to plant start-up. Thus, 1990 differences are unrelated to plant operation.

Rock crabs are less prevalent than their congener in the study area, probably because of their preference for sandy substrate (Jefferies 1966). Catches in 1989 were the highest observed to date, at both the discharge area and Rye Ledge. In 1990, catches were still higher than average at both stations (Figure 2.3-4), but were lower than the peak catches observed during the previous year. Higher than average catches in 1989 and 1990 were due to large catches from June through August.



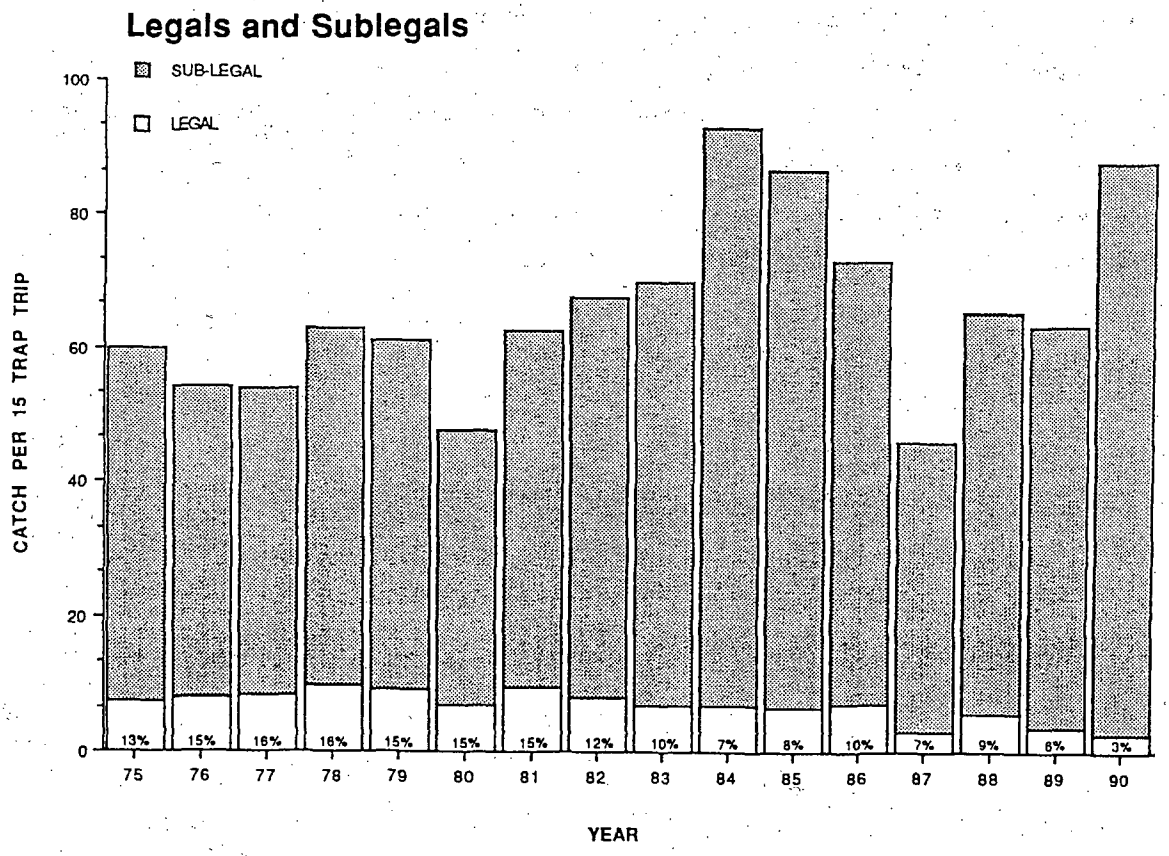


Figure 2.3-17. Size class distribution of lobsters and catches of legal and sublegal-sized lobsters at the discharge station, 1975-1990. Seabrook Operational Report, 1990.

3.0 RESULTS

3.1 PLANKTON AND WATER QUALITY PARAMETERS

Plankton and water quality programs of the Seabrook environmental studies have included water quality sampling, phytoplankton, microzooplankton, bivalve larvae, and macrozooplankton. The plankton and water quality programs presented in this 1990 operational report are those for which sampling was conducted during 1990: water quality (Section 3.1.1), phytoplankton (3.1.2), microzooplankton (3.1.3), bivalve larvae (3.1.4), and macrozooplankton (3.1.5). Results from entrainment sampling for bivalve larvae are also presented.

3.1.1 Water Quality Parameters-Seasonal Cycles and Trends

Three physical (temperature, salinity and dissolved oxygen) and five chemical (orthophosphate, total phosphorus, nitrite-nitrogen, nitrate-nitrogen and ammonia-nitrogen) parameters were monitored over a 13-year period to assess their temporal variability. A farfield station (P7) was added in 1982 to provide a reference area. With the exception of ammonia, parameters exhibited cycles with one or two peaks annually.

Water temperature was monitored in the nearfield both continuously and from discrete samples collected weekly, twice-weekly, or monthly during the plankton cruises. Historically, monthly mean values derived from both sampling methods have been similar (NAI 1980c, 1980d, 1981f, 1982a, 1984a, 1985a). Surface water temperatures were strongly influenced by solar irradiation, with temperature peaks lagging irradiance peaks by one month (NAI 1985b). Bottom temperatures (depth 16 meters at MLW) showed truncated peaks which lagged one to three months behind surface peaks. Since 1978, highest temperatures at Station P2 have occurred in July or August at the surface, and from August to October at the bottom (Figure 3.1.1-1). In 1990, peak surface and bottom temperatures occurred in August and were above the preoperational average. Surface and bottom water temperatures remained above

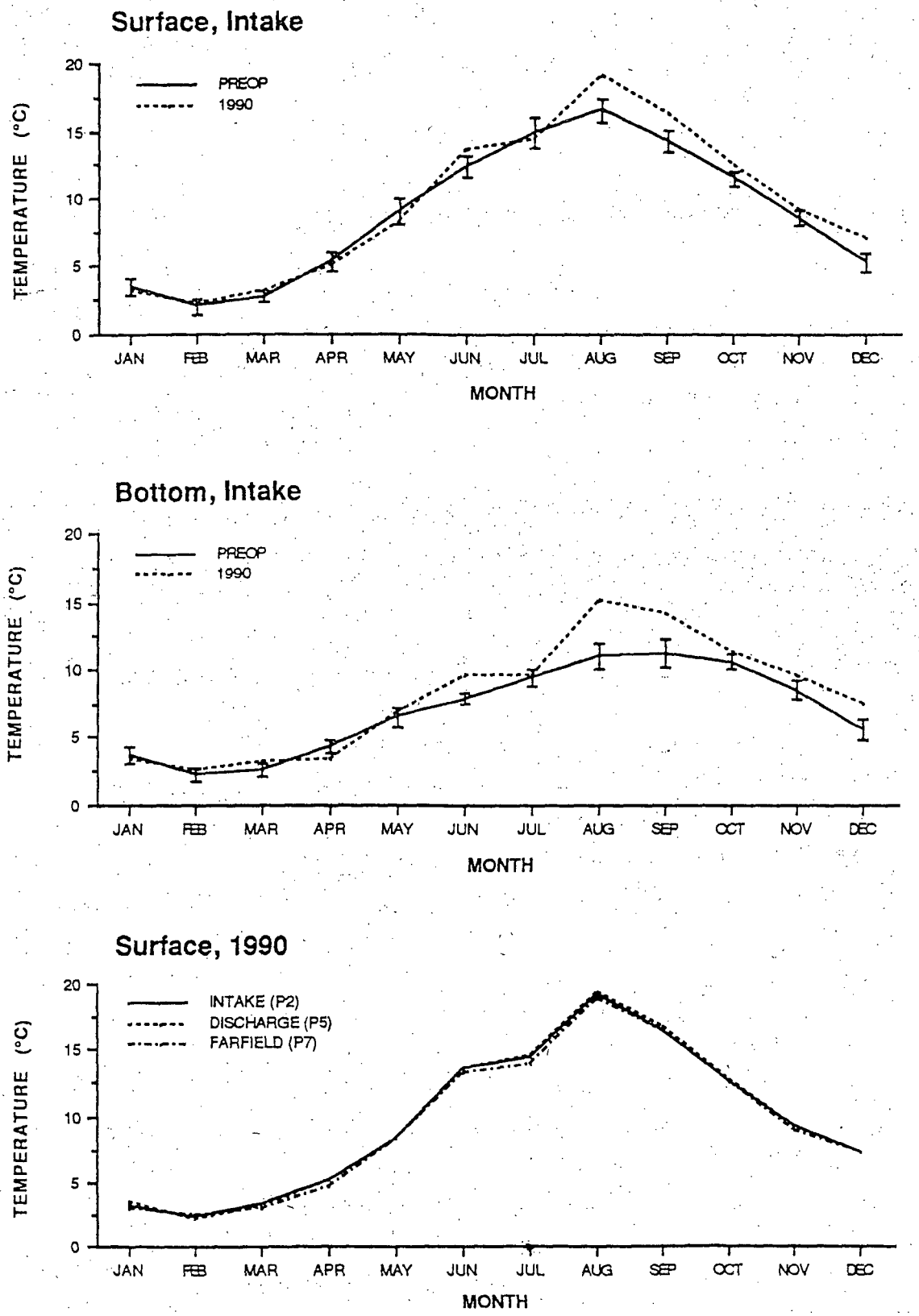


Figure 3.1.1-1. Surface and bottom temperature (°C) at nearfield Station P2, monthly means and 95% confidence intervals over all years, 1978-1989 and monthly means at Stations P2, P5, and P7 in 1990. Seabrook Operational Report, 1990.

average for the remainder of the year (Figure 3.1.1-1) resulting in annual mean temperatures that were higher than the preoperational average (Table 3.1.1-1). However, 1990 nearfield temperatures were statistically similar to previous years for both the entire year and during the operational period (August-December; Table 3.1.1-2).

In 1990, temperatures were monitored at the intake (P2), discharge (P5), and farfield stations (P7). Monthly mean surface temperatures were statistically similar at all three stations both for the entire year and for the operational period (Table 3.1.1-2). There were no discernible differences in seasonal patterns among the three stations (Figure 3.1.1-1).

Continuous temperature data were provided by YAEC from stations located near the intake (T7) and discharge (DS) areas. Monthly averages of daily surface temperatures at the discharge station (Figure 3.1.1-2) were similar to those at intake station T7 in July, August, and September. From October-December, surface temperatures at the discharge station averaged 0.8-1.6°C higher than those at station T7 (Figure 3.1.1-2).

Temperature differences between surface and bottom waters show the seasonal trend in development and dissipation of the thermocline. Historically, vertical temperature differences were minimal (<1°) from January through March and November-December (Figure 3.1.1-3). Vertical temperature differences have been most pronounced (at least 3°C) from May through October. Thermocline development in 1990 was similar to previous years, although temperature differences were less than the preoperational average from June through September. Thermocline dissipation in 1990 during the operational period (August-December) was similar to previous years.

Other water quality parameters were also monitored at Station P2, P5 and P7 during fortnightly plankton cruises. As in previous

TABLE 3.1.1-1. ANNUAL MEANS AND COEFFICIENTS OF VARIATION FOR WATER QUALITY PARAMETERS MEASURED DURING PLANKTON CRUISES AT NEARFIELD STATION P2, 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

	ANNUAL MEAN (AND COEFFICIENT OF VARIATION)													
PARAMETER	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	PREOP	1990
Temperature (°C)														
surface	8.37 (66.93)	8.76 (57.85)	8.76 (57.86)	8.72 (63.34)	8.88 (53.02)	9.58 (53.74)	8.94 (55.72)	9.73 (54.55)	9.31 (49.57)	9.12 (57.80)	8.55 (60.23)	8.87 (62.74)	8.86 (56.45)	9.52 (59.32)
bottom	6.61 (55.62)	6.36 (47.96)	7.05 (52.76)	7.37 (59.11)	7.36 (46.03)	7.32 (44.43)	6.93 (45.04)	8.03 (47.81)	7.58 (40.42)	6.39 (45.95)	6.46 (45.36)	6.54 (56.56)	6.92 (47.91)	7.97 (54.23)
Salinity (ppt)														
surface	31.68 (3.33)	31.82 (3.84)	32.17 (2.64)	31.89 (2.16)	31.84 (3.47)	31.04 (4.39)	30.68 (4.93)	32.15 (2.26)	31.68 (2.44)	30.65 (6.76)	31.74 (2.36)	31.48 (3.56)	31.57 (3.89)	31.09 (4.44)
bottom	32.24 (1.65)	32.47 (2.77)	32.42 (1.52)	32.32 (1.41)	32.41 (2.01)	31.92 (2.12)	31.77 (1.83)	32.50 (1.54)	32.20 (1.77)	31.48 (2.66)	32.26 (1.40)	32.12 (1.83)	32.18 (0.11)	31.86 (3.01)
Dissolved Oxygen (mg/l)														
surface	10.28 (10.80)	10.02 (13.39)	10.27 (11.17)	9.90 (12.70)	9.60 (11.15)	9.48 (7.73)	10.01 (12.06)	9.67 (10.42)	9.88 (11.03)	9.89 (9.92)	9.72 (11.01)	9.72 (10.73)	9.87 (10.86)	9.67 (12.16)
bottom	10.07 (8.86)	9.69 (14.67)	9.85 (14.28)	9.43 (17.90)	9.25 (16.17)	8.98 (11.99)	9.32 (13.56)	9.17 (15.36)	8.96 (13.52)	9.73 (11.64)	9.07 (16.54)	9.07 (14.60)	9.37 (14.11)	9.11 (15.82)
Orthophosphate[d] (µg/l)	9.58 (29.99)	9.75 (52.59)	10.12 (76.10)	11.82 (30.83)	17.02 (55.54)	19.23 (44.47)	14.29 (56.06)	--[b] --	--[c] --	18.08 (45.25)	16.80 (45.24)	14.08 (60.89)	13.93 (55.11)	15.42 (59.48)
Total phosphorus[d] (µg/l)	32.50 (40.09)	15.12 (63.09)	31.96 (77.68)	22.50 (33.93)	24.61 (28.66)	25.83 (35.05)	24.17 (40.43)	--[b] --	--[c] --	33.36 (40.30)	28.80 (34.03)	27.92 (36.99)	26.70 (48.50)	29.17 (34.16)
Nitrite[d] (µg/l)	2.12 (46.11)	1.71 (66.58)	3.17 (59.59)	2.92 (53.13)	2.30 (68.34)	2.05 (54.34)	1.02 (98.08)	--[b] --	--[c] --	1.48 (98.00)	2.50 (60.43)	1.67 (81.24)	2.17 (68.42)	2.96 (80.08)
Nitrate[d] (µg/l)	52.08 (116.61)	38.33 (101.24)	48.33 (111.88)	45.42 (94.41)	37.17 (137.89)	51.83 (106.62)	36.75 (117.47)	--[b] --	--[c] --	44.42 (132.17)	49.50 (111.11)	67.62 (100.99)	45.16 (112.71)	73.33 (85.28)
Ammonia[d] (µg/l)	51.46 (120.96)	47.42 (42.93)	104.17 (48.73)	36.25 (64.73)	<30.00[a] --	27.32 (115.96)	16.57 (70.82)	--[b] --	--[c] --	53.33 (61.54)	20.30 (145.32)	<10 --	39.26 (105.70)	<10 (56.86)

[a] Below detection limits (30 µg/l) of methods used in 1982.
[b] Not measured in 1985.
[c] Measured July through December 1986 only.
[d] Collected one meter below surface.

TABLE 3.1.1-2. RESULTS OF ANALYSIS OF VARIANCE OF WATER TEMPERATURES COMPARED AMONG STATIONS P2, P5, AND P7 IN 1990 AND AMONG YEARS AT STATION P2 FROM 1978-1990 AND COMPARISONS OF SALINITY, DISSOLVED OXYGEN AND NUTRIENTS AMONG STATIONS IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

			JANUARY-DECEMBER			AUGUST-DECEMBER		
PARAMETER	DEPTH	SOURCE	df	SS	F	df	SS	F
Temperature	Surface	Station	2	1.88	0.97 NS	2	0.87	0.98 NS
	Bottom	Station	2	0.07	0.99 NS	2	0.48	0.97 NS
	Surface	Year	12	30.95	1.00 NS	12	38.25	0.99 NS
	Bottom	Year	12	48.86	0.98 NS	12	59.61	0.74 NS
Salinity	Surface	Station	2	0.27	0.05 NS	2	0.36	0.06 NS
	Bottom	Station	2	1.41	0.31 NS	2	3.29	0.49 NS
Dissolved oxygen	Surface	Station	2	0.26	0.10 NS	2	0.17	0.31 NS
	Bottom	Station	2	0.98	0.23 NS	2	1.00	0.59 NS
	Surface	Year	13	8.32	0.53 NS	13	6.39	1.09 NS
	Bottom	Year	13	19.30	0.83 NS	13	14.72	1.53 NS
Orthophosphate	Surface	Station	2	<0.01	0.20 NS	2	<0.01	0.10 NS
Total phosphate	Surface	Station	2	<0.01	0.64 NS	2	0	0.00 NS
Nitrite	Surface	Station	2	<0.01	0.23 NS	2	<0.01	0.48 NS
Nitrate	Surface	Station	2	<0.01	0.12 NS	2	<0.01	0.06 NS
Ammonia	Surface	Station	2	<0.01	1.10 NS	2	<0.01	0.92 NS

NS = Not Significant ($p>0.05$)
df = degrees of freedom
SS = sum of squares

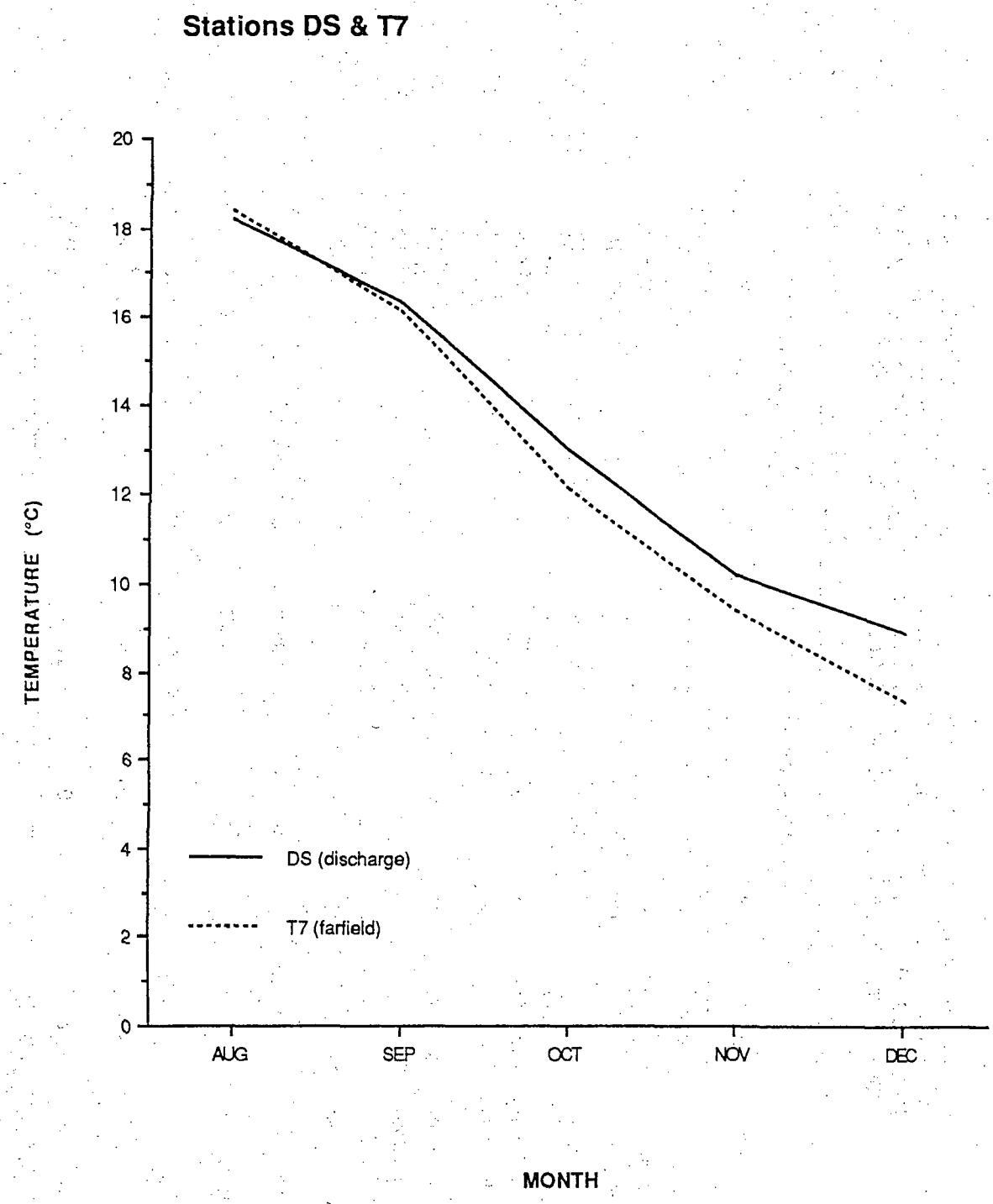


Figure 3.1.1-2. Comparison of monthly averaged continuous temperature (°C) data collected at discharge (DS) and farfield (T7) stations during commercial operation, August-December 1990. Seabrook Operational Report, 1990.

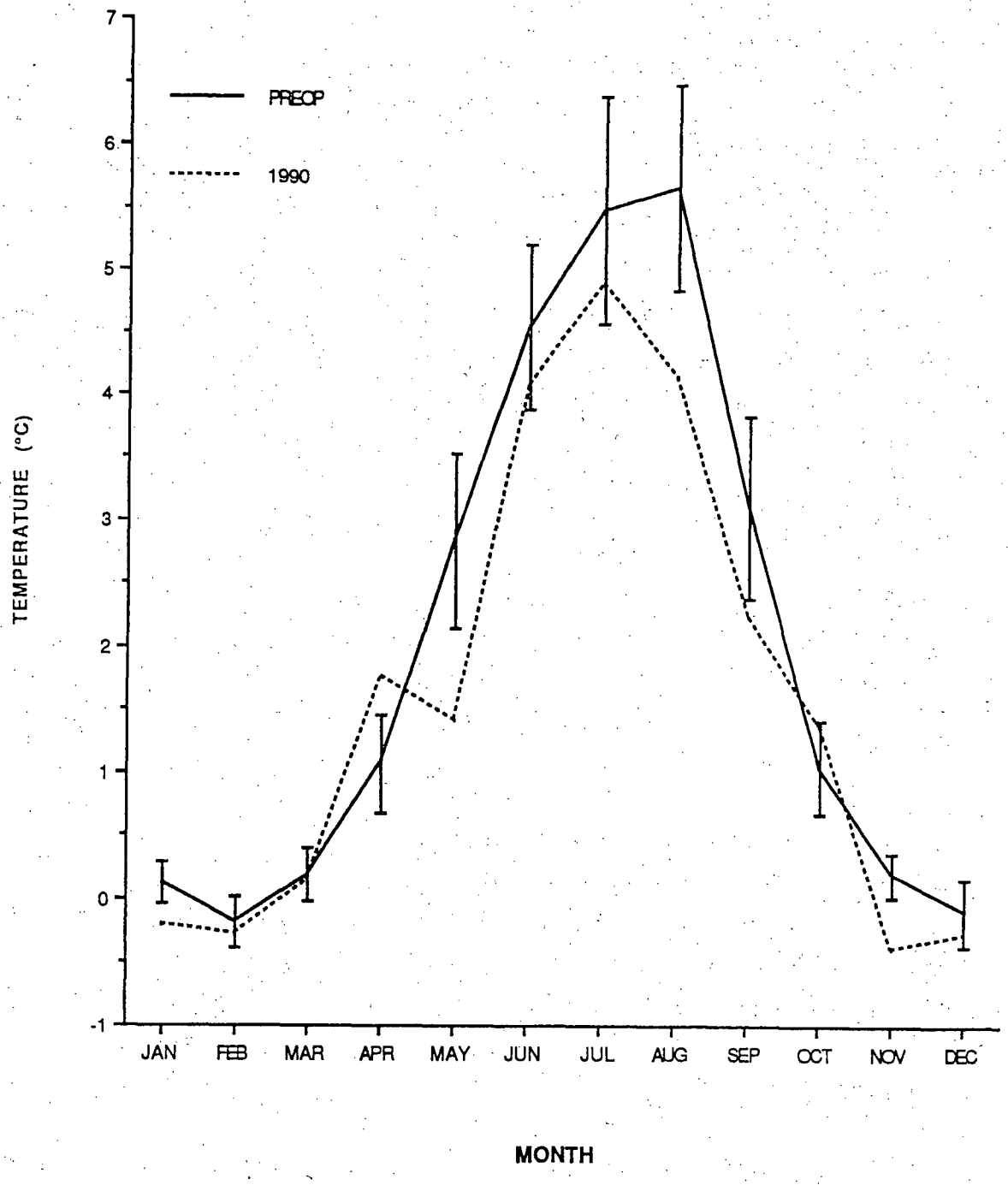
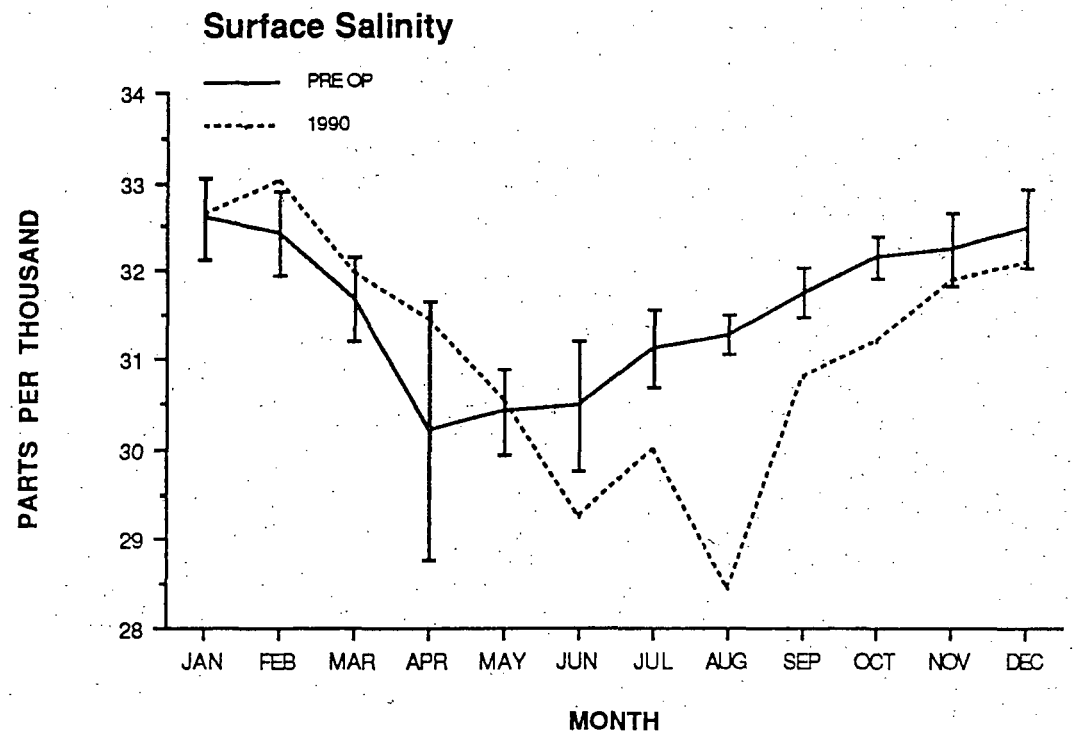


Figure 3.1.1-3. Monthly mean difference and 95% confidence limits between surface and bottom temperatures (°C) at nearfield Station P2 over all years from 1978-1989 and monthly means in 1990. Seabrook Operational Report, 1990.

years, surface salinities in 1990 began to decline in February (Figure 3.1.1-4). Low salinity levels usually occurred in April or May, but were not observed until June in 1990, when surface salinity was well below the preoperational average. This may be attributable to above average precipitation for April and May (Section 3.3.1). The low surface salinity observed in June was followed by a small increase in July and then dropped sharply in August (Figure 3.3.1-3), coincident with higher-than-average precipitation in July and August (Section 3.3.1). The August salinity was the lowest ever observed for this month at Station P2. Surface salinities then steadily climbed through the remainder of the year, but continued to be slightly below the preoperational average. Annual fluctuations in bottom salinities followed roughly the same pattern as surface salinities, although the magnitude of differences was not as pronounced. The annual mean surface and bottom salinities were below the preoperational average for the thirteen-year period, but within the range of annual means. No significant differences in salinity occurred among Stations P2, P5 and P7 in 1990 (Table 3.1.1-2).

Historically, surface and bottom dissolved oxygen peaked in late winter (February-April) and decreased to lowest levels in fall (August-November) (Figure 3.1.1-5). Seasonal trends in 1990 were similar, although the fall nadir in September was lower than the preoperational average. Dissolved oxygen patterns were similar at Stations P2, P5 and P7 as evidenced by the results of analysis of variance (Table 3.1.1-2).

Historically, orthophosphate and total phosphate did not show evidence of a strong seasonal cycle. Values were lowest in summer, (May-September), during the presence of the thermocline (Figure 3.1.1-6). The seasonal variation of orthophosphate and total phosphorous in 1990 was comparable to previous years, although values above and below the preoperational average were observed. No spatial differences were found for either parameter in 1990 (Table 3.1.1-2). Peaks in ortho-



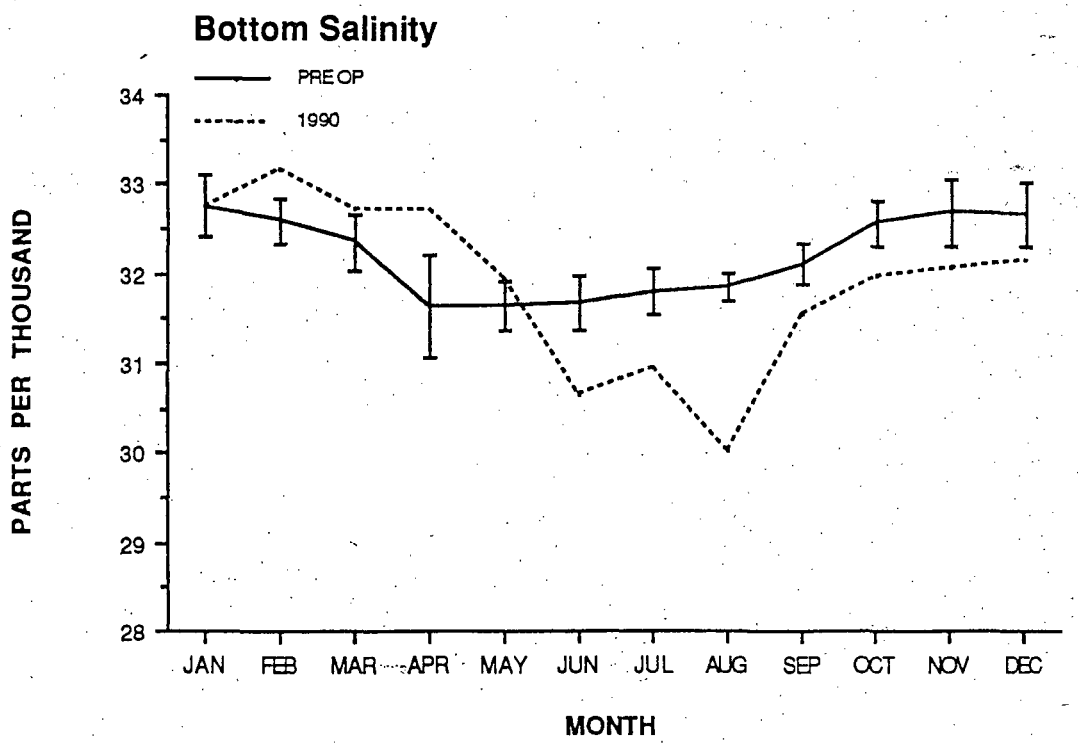
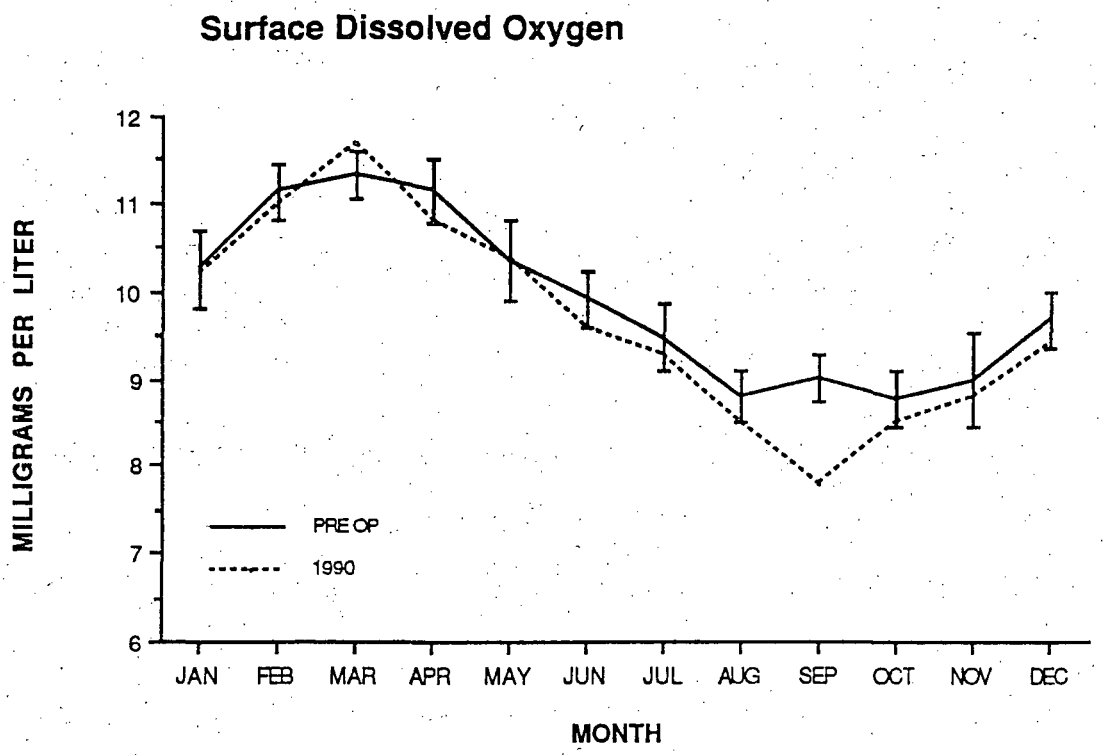


Figure 3.1.1-4. Surface and bottom salinity (ppt) at nearfield Station P2, monthly means and 95% confidence intervals over all years, 1978-1989, and monthly means for 1990. Seabrook Operational Report, 1990.



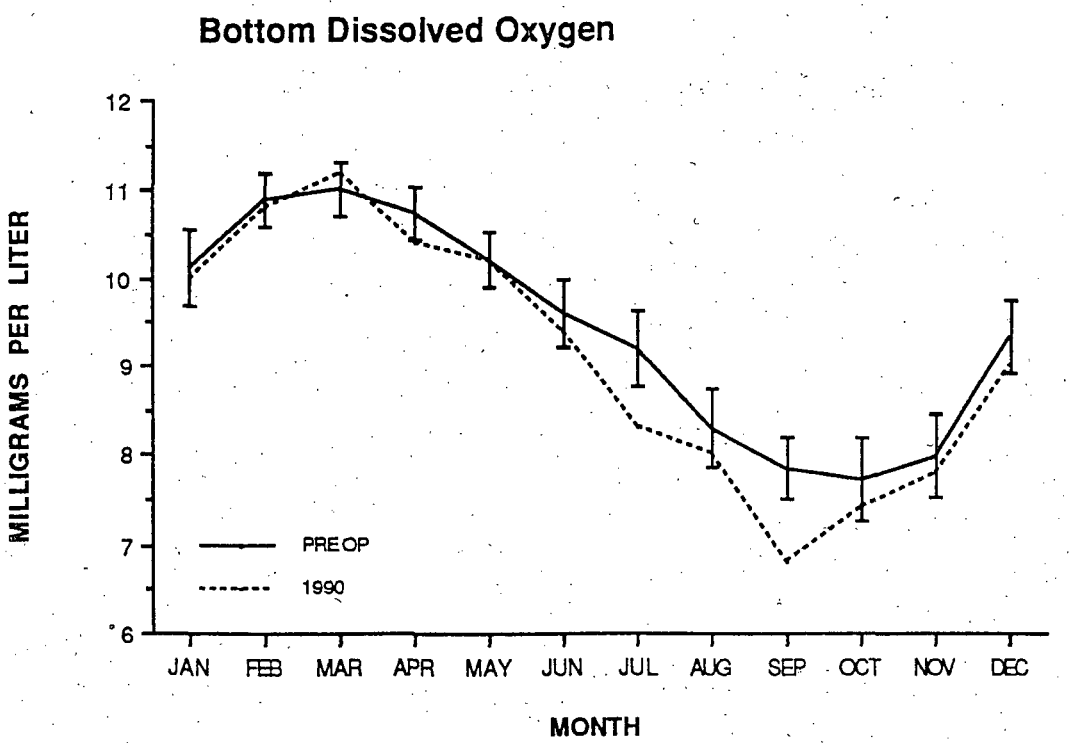
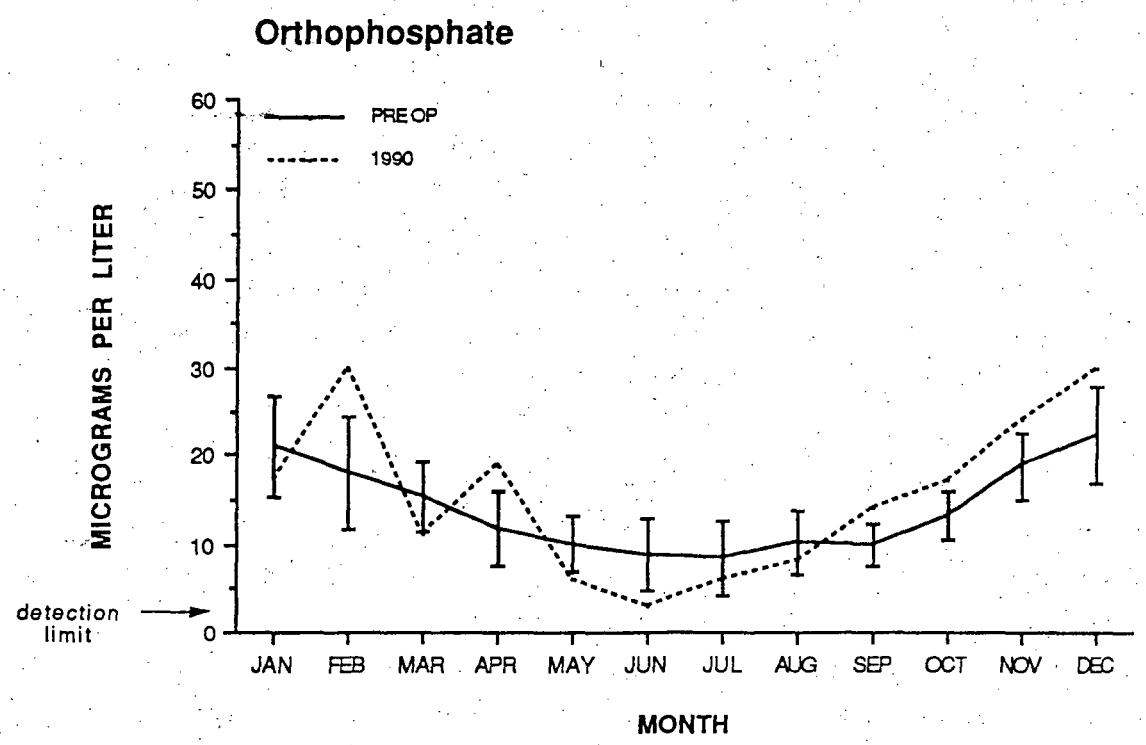


Figure 3.1.1-5. Surface and bottom dissolved oxygen (mg/L) at nearfield Station P2, monthly means and 95% confidence intervals over all years, 1978-1989, and monthly means for 1990. Seabrook Operational Report, 1990.



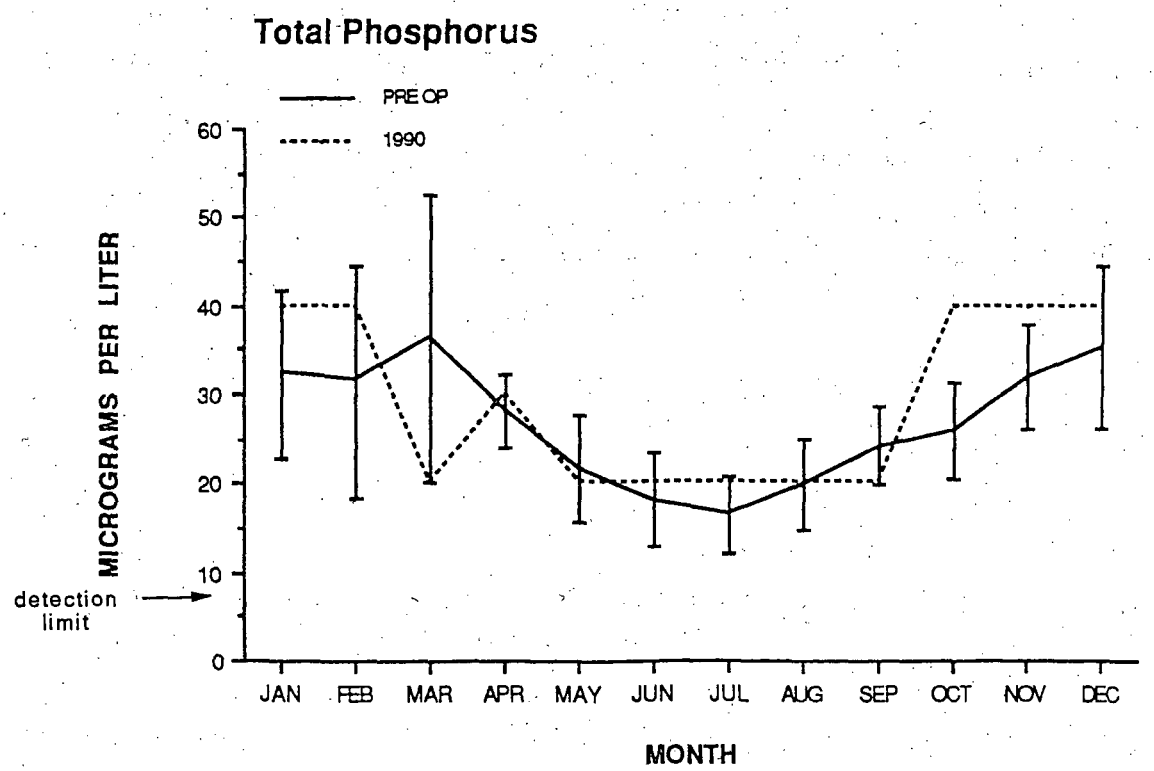


Figure 3.1.1-6. Surface orthophosphate and total phosphorus (µg P/L) at nearfield Station P2, monthly means and 95% confidence intervals over all years from 1978-1984 and 1986-1989, and monthly means for 1990. Seabrook Operational Report, 1990.

phosphate concentration in 1990 occurred in February and April, and were consistently above the preoperational average from September through December. Values for orthophosphate in March, May and June 1990 were somewhat lower than the mean for previous years. Concentrations of total phosphate for the year stayed generally within the 95% confidence limits, but were elevated in October and November (Figure 3.1.1-6).

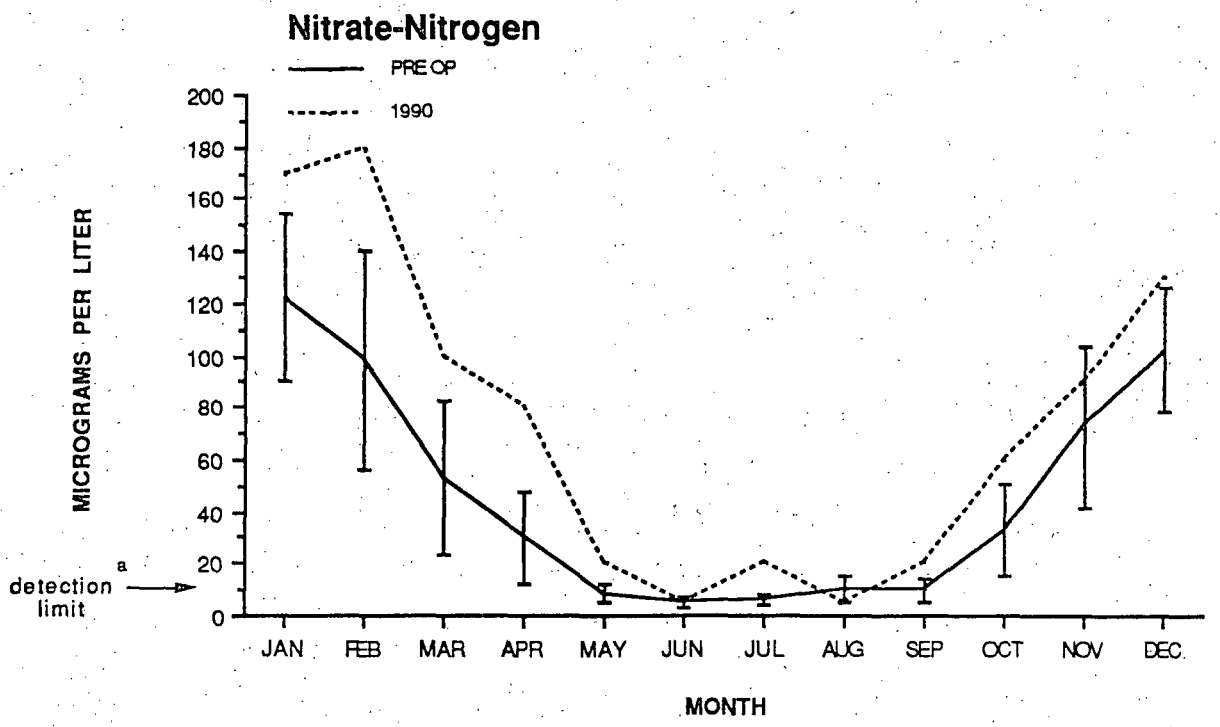
Nitrate levels at station P2 have historically shown a strong seasonal cycle. Values typically steadily decreased from January to May, remained low through September, then steadily increased for the remainder of the year. The seasonal nitrate cycle in 1990 approximated the preoperational average, with the yearly low occurring in June. However, higher-than-average nitrate values were observed from January through May, and in September and October. Ammonia and nitrite levels historically have not shown a strong seasonal pattern. Nitrite values fluctuated widely in 1990, and higher-than-average values were observed in February, May and October (Figure 3.1.1-7). In 1990, ammonia concentrations were below the analytical detection limit (10 μg/l) for seven months of the year (January through March, June through August and November) and below the preoperational average during the remaining months (Figure 3.1.1-8). Concentrations of all nitrogen nutrients were similar among Stations P2, P5 and P7 in 1990 (Table 3.1.1-2).

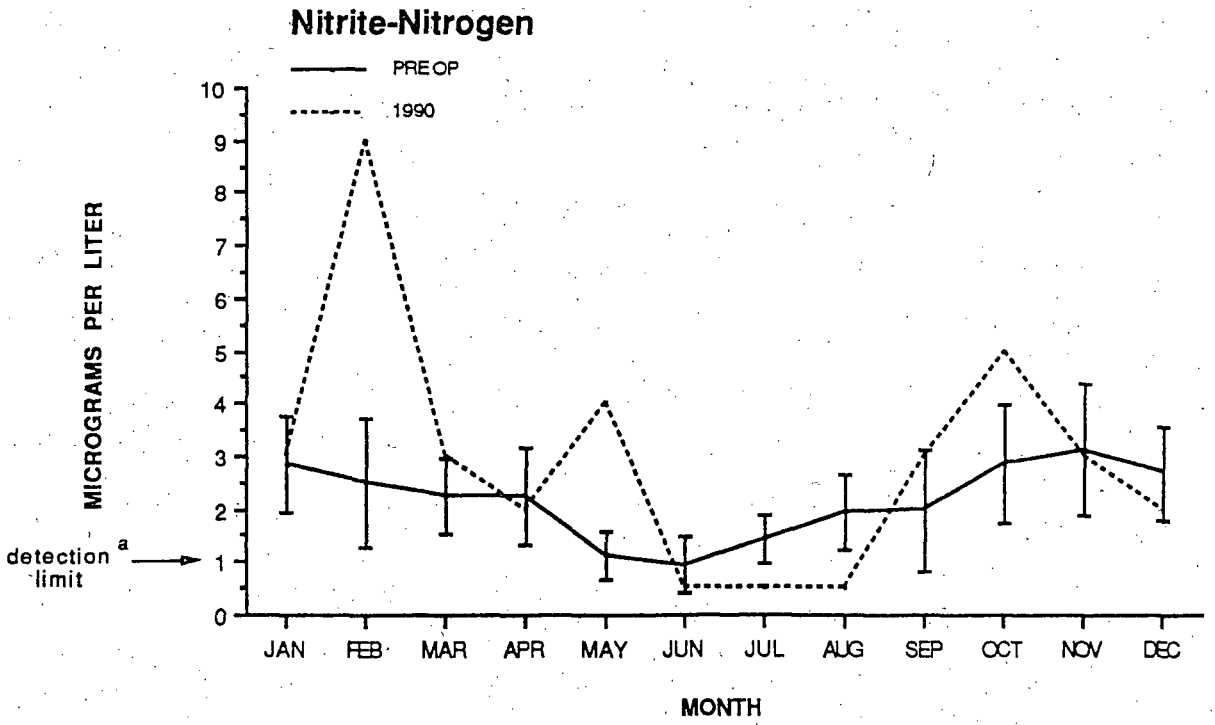
3.1.2 Phytoplankton

3.1.2.1 Total Community

Temporal Characteristics

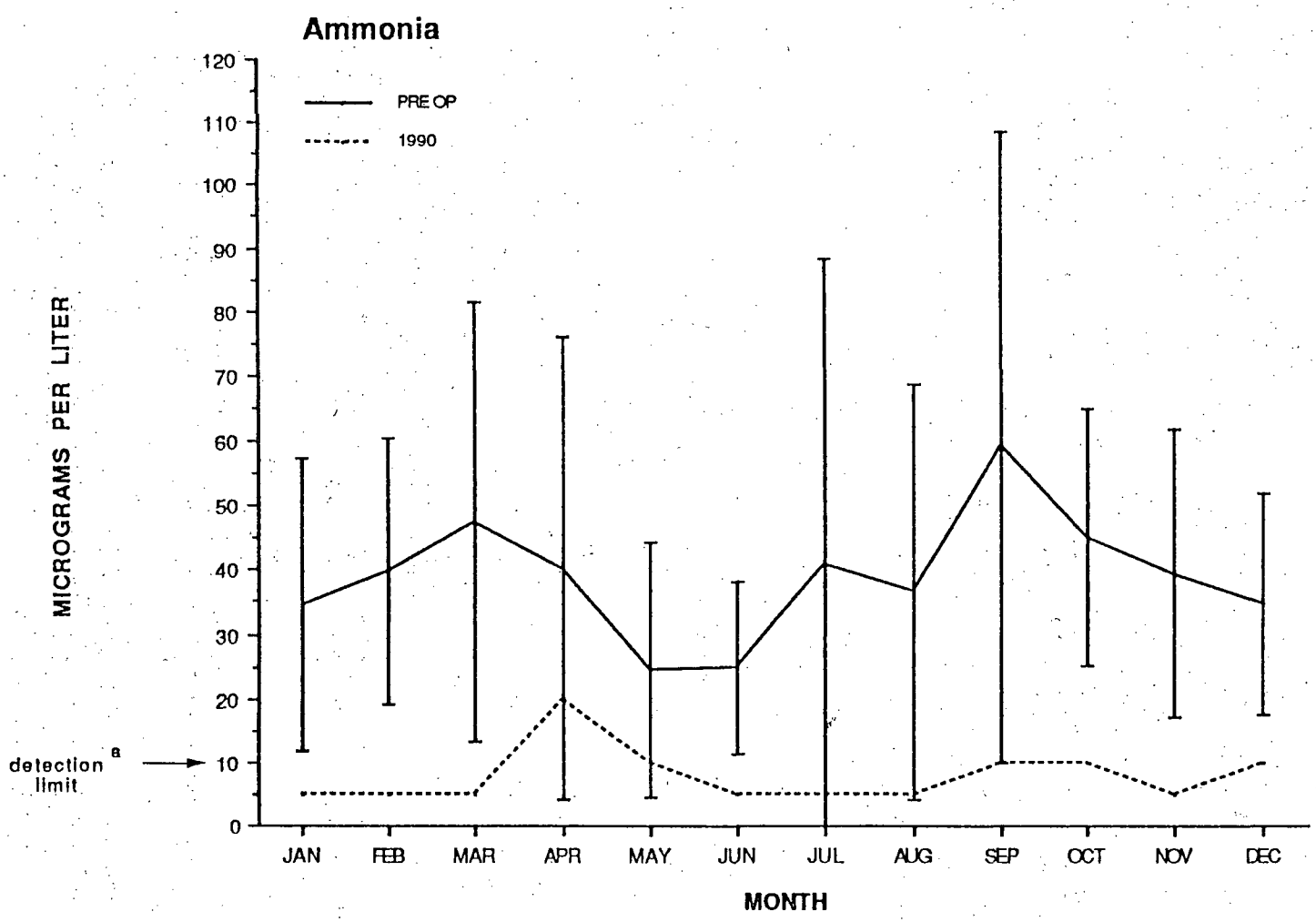
During the preoperational years, mean total phytoplankton abundance exhibited a bimodal annual cycle with spring and fall maxima and summer and winter minima (Figure 3.1.2-1; refer to Figure 3.1.2-1 of NAI 1985b). In 1990, the spring peak occurred in June, one month later than in preoperational years, and a fall peak was not observed at all. Total abundance was higher in 1990 than during the preoperational





[a] For the purpose of calculating monthly means, data points reported as "below detection limit" were given a value of one-half the detection limit.

Figure 3.1.1-7. Surface nitrite-nitrogen and nitrate-nitrogen (µg N/L) at nearfield Station P2, monthly means and 95% confidence intervals over all years from 1978-1984 and 1986-1989, and monthly means for 1990. Seabrook Operational Report, 1990.



[a] For the purpose of calculating monthly means, data points reported as "below detection limit" were given a value of one-half the detection limit.

Figure 3.1.1-8. Surface ammonia-nitrogen (µg N/L) at nearfield Station P2, monthly means and 95% confidence intervals over all years from 1978-1984 and 1986-1989, and monthly means for 1990. Seabrook Operational Report, 1990.

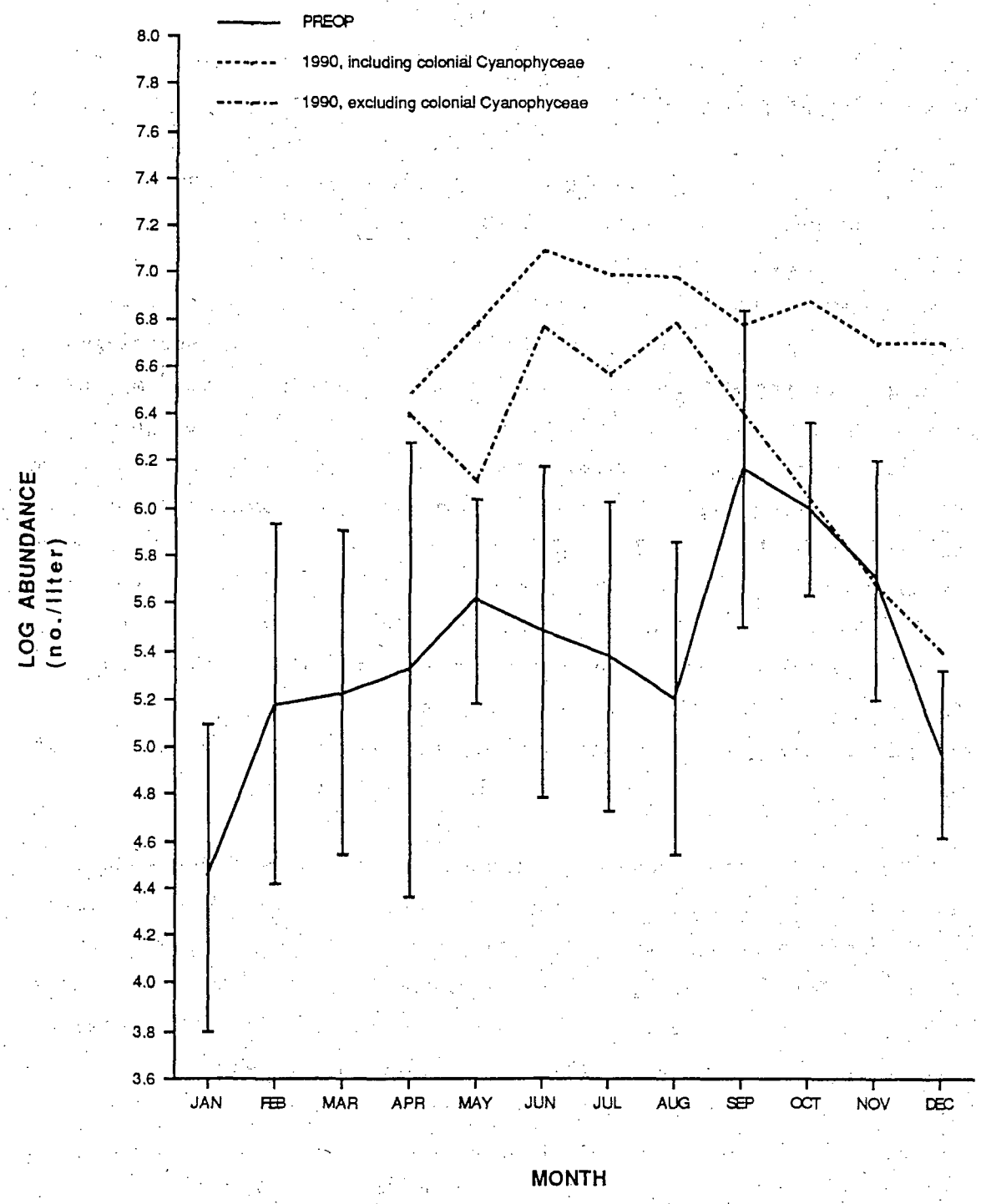


Figure 3.1.2-1. Log (x+1) abundance (no./l) of total phytoplankton at nearfield Station P2; monthly means and 95% confidence intervals over all preoperational years (1978-1984) and monthly means with and without colonial Cyanophyceae for 1990. Seabrook Operational Report, 1990.

period, with 1990 monthly total abundance values generally above the upper bound of preoperational 95% confidence intervals (Figure 3.1.2-1).

For the months of August through December, the number of species composing 1% or more of total abundance varied from only five in 1990 to as many as fourteen in 1981 (Table 3.1.2-1). *Skeletonema costatum* was consistently dominant in the preoperational period, accounting for approximately 10-90% of the phytoplankton assemblage during these years. In 1990, however, *Skeletonema costatum* composed less than 1% of the total assemblage. Colonial Cyanophyceae replaced *Skeletonema costatum* as the most abundant taxon in 1990, accounting for 66% of the assemblage. Colonial Cyanophyceae were absent from preoperational samples between 1978 and 1983, and accounted for less than 0.1% of the assemblage in 1984, but contributed 13% of the total abundance in 1986. Other species that were dominant in some years during the preoperational period include flagellate algae (54% in 1983), and *Rhizosolenia delicatula* (69% in 1979), while in 1990, unicellular and flagellate algae, filamentous Cyanophyceae, and *Chroomonas* sp. were all abundant, each accounting for more than 1% of total abundance.

The mean abundances of taxa dominant in 1990 are generally quite different compared to preoperational years. In 1990, five taxa each comprised greater than 1% of the total abundance. These taxa were, as noted above: colonial Cyanophyceae, unicellular algae, flagellated algae, filamentous Cyanophyceae, and *Chroomonas* sp. (a cryptophyte). Mean abundances of each of these taxa during August-December in preoperational years were at least two orders of magnitude lower than during the same months in 1990 (Table 3.1.2-2), and in each case, the lower 95% confidence level for the 1990 means were above the upper bound of the preoperational 95% confidence levels. Confidence intervals of 1990 abundances of other relatively abundant taxa generally overlapped confidence intervals for the preoperational periods. This indicates that abundances in 1990 for these taxa were within the previously observed range of natural variability.

TABLE 3.1.2-1. PERCENT COMPOSITION OF SPECIES BY YEAR FOR PHYTOPLANKTON DATA
DATA IS SUBSET FOR 1990 OPERATIONAL PERIOD - AUGUST - DECEMBER.
SEABROOK OPERATIONAL REPORT, 1990.

	90	86	84	83	82	81	80	79	78
CYANOPHYCEAE;COLONIAL	65.75	13.46	0.02						
ALGA; UNICELLULAR	19.70	0.05	0.00	1.17		1.14			0.04
CYANOPHYCEAE;FILAMENTOUS	8.18		0.02	0.01					
ALGA; FLAGELLATE	2.56	3.28	4.19	54.27	15.31	7.67	1.18		
CHROOMONAS SP.	1.89				4.63	0.08	0.22	0.07	0.02
SKELETONEMA COSTATUM	0.56	66.22	72.53	10.15	48.64	28.85	88.40	10.39	62.61
PROROCENTRUM MICANS	0.38	0.03	0.14		0.36	0.78	0.06	7.36	0.04
LEPTOCYLINDRUS DANICUS	0.13	0.04	4.24	0.09					
LEPTOCYLINDRUS MINIMUS	0.12	2.09	3.07	0.58	13.38	1.47			
BACILLARIOPHYCEAE	0.07	0.03	0.01	0.43	1.73	0.79	0.52	0.03	3.91
CENTRALES	0.06	1.08	0.26	6.29					
PENNALES	0.04	0.17	0.15	0.85					
RHIZOSOLENIA DELICATULA	0.03	0.27	0.69	2.32	0.01	1.37	3.60	68.76	22.15
PERIDINIUM SP.	0.02		0.00		0.19	1.23	0.00	0.14	0.00
NAVICULA SP.	0.02		0.01	0.78		0.01			
THALASSIONEMA NITZSCHIOIDES	0.02	0.54	0.54	1.62	10.64	0.37	2.02	0.02	8.54
CHAETOCEROS SP.	0.01	0.82	0.85	0.79	0.92	1.32	0.14	0.03	0.05
NITZSCHIA DELICATISSIMA	0.01	1.38	0.69	0.05	0.28	19.86	0.80	0.71	1.05
GYMNODINIUM SP.	0.01				0.01	1.28			
EUGLENALES	0.00		0.02	0.30	0.51	2.40	0.01	0.02	0.01
NITZSCHIA SERIATA	0.00	0.03	0.97	0.10	0.40	0.53	1.33	1.32	0.03
RHIZOSOLENIA FRAGILISSIMA		6.19	1.22	7.99	0.00	9.92			
MERISMOPEDIA SP.		1.35							0.02
THALASSIOSIRA SP.		1.31	0.96	1.08	0.04	1.40	0.09	0.07	
DINOPHYCEAE		1.04	3.23	4.21	0.08	0.18			
NITZSCHIA LONGISSIMA		0.06	0.12	0.15	0.06	0.22	0.39	0.06	1.07
RHIZOSOLENIA SP.		0.01	0.00	0.01	1.08	0.01			
CERATAULINA BERGONII		0.00	5.70	1.16		0.01	0.00		0.03
CERATIUM FURCA			0.01		0.45	0.97	0.00	0.03	
RHIZOSOLENIA STOLTERFOTHII			0.00	0.82	0.13				
ASTERIONELLA GLACIALIS			0.00	1.68	0.00	0.00	0.14	0.02	0.16
GYRODINIUM SP.				0.32	0.05	0.50	0.01	1.23	0.01
CYANOPHYCEAE				0.05		13.59			
THALASSIONEMA SP.					0.05	2.43			
PHAEOCYSTIS POUCHETII								7.45	
PLEUROSIGMA ANGULATUM								1.69	0.00
ALL	99.56	99.45	99.65	97.27	98.93	98.37	98.92	99.40	99.73

TABLE 3.1.2-2. PREOPERATIONAL AND OPERATIONAL GEOMETRIC MEAN ABUNDANCE[a] AND CONFIDENCE INTERVAL FOR PHYTOPLANKTON TAXA OCCURRING BETWEEN AUGUST AND DECEMBER AT STATION P2. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	PREOPERATIONAL YEARS[b]		1990[c]	
	$\bar{X}$	CI	$\bar{X}$	CI
Cyanophyceae; colonial	0.64	0.52	6.63	0.14
Alga, unicellular	1.21	0.53	5.78	0.77
Cyanophyceae; filamentous	0.13	0.19	4.89	1.14
Alga, flagellate	3.35	0.68	5.00	0.58
Chroomonas sp.	1.36	0.53	4.83	0.69
Skeletonema costatum	4.71	0.38	3.22	2.42
Rhizosolenia fragilissima	1.76	0.68		
Leptocylindrus minimus	2.01	0.69	2.82	2.14
Nitzschia delicatissima	2.38	0.63	1.22	2.09
Merismopedia sp.	0.21	0.31		
Thalassiosira sp.	2.33	0.59		
Centrales	1.43	0.61	3.55	0.40
Dinophyceae	2.07	0.62		
Chaetoceros sp.	2.47	0.52	0.71	1.97
Thalassionema nitzschioides	2.94	0.58	1.94	2.21
Cerataulina bergonii	0.99	0.51		
Leptocylindrus danicus	0.66	0.45	1.71	2.91
Nitzschia seriata	2.15	0.60	0.60	1.66
Rhizosolenia delicatula	3.04	0.65	0.78	2.16
Asterionella glacialis	0.95	0.47		
Pennales	1.22	0.52	2.24	2.54
Rhizosolenia stolterfothii	0.44	0.35		
Navicula sp.	0.60	0.37	3.09	0.16
Bacillariophyceae	2.96	0.42	3.48	0.64
Rhizoselenia sp.	0.89	0.44		
Euglenales	1.57	0.52	1.67	1.90
Cyanophyceae	0.66	0.52		
Thalassionema sp.	0.49	0.40		
Gymnodinium sp.	0.56	0.44	1.24	2.10
Peridinium sp.	1.03	0.47	1.93	2.23
Ceratium furca	1.00	0.43		
Prorocentrum micans	2.29	0.51	3.40	2.43
Phaeocystis pouchetii	0.27	0.38		
Pleurosigma angulatum	0.35	0.35		
Gyrodinium sp.	1.22	0.51		
Nitzschia longissima	2.27	0.48		

[a]Log transformed means and 95% confidence intervals in cells/liter.
[b]Sample size = 40 (five months by eight years)
[c]Sample size = 5

Just as total abundance was shown to vary over the year in Figure 3.1.2-1, the relative abundance of individual taxa also varies throughout the year. During the preoperational period, phytoplankton species succession generally followed patterns described by Margalef (1958, northwest coast of Spain) and Lillick (1940, Gulf of Maine cited in NAI 1985b). Both studies demonstrated that nutrient supply was the main determinant of succession and that temperature was important insofar as it worked to enhance or restrict nutrient supplies within thermal strata (NAI 1985b). Margalef (1958) proposed the following seasonal cycle of taxa replacement within the community: 1) small-celled species in the spring, capable of rapid division due to a high surface area-to-volume ratio, succeeded by 2) larger flagellates and diatoms with a lower turnover rate, followed by 3) large motile forms (flagellates and dinoflagellates) during the period of highest thermal stratification.

Succession of phytoplankton assemblages during the preoperational period at the Seabrook sampling locations was similar to that described by Margalef (Figure 3.1.2-2; NAI 1985b). The spring bloom during the preoperational period was initiated by different taxa from year to year; centric diatoms (Bacillariophyceae, especially *Thalassiosira* sp., *Chaetoceros* sp., and *Skeletonema costatum*) were most often the first to appear in high densities (see Table 3.1.2-2 of NAI 1985b). Small flagellates and colonial blue-green algae were also among the spring dominants. Large vernal blooms of *Phaeocystis pouchetii* (a member of the Xanthophyceae group, or yellow-brown algae) occurred in five of the seven preoperational years. By midsummer, dinoflagellates (Dinophyceae) appeared in high numbers. Diatoms (Bacillariophyceae) reached their highest densities in the fall due largely to blooms of *Skeletonema costatum* and other diatoms. Overall, during the preoperational period diatoms were the most abundant group from August through the winter until February. The Xanthophyceae (*Phaeocystis pouchetii*) were most abundant in the spring, while during summer all groups were well represented.

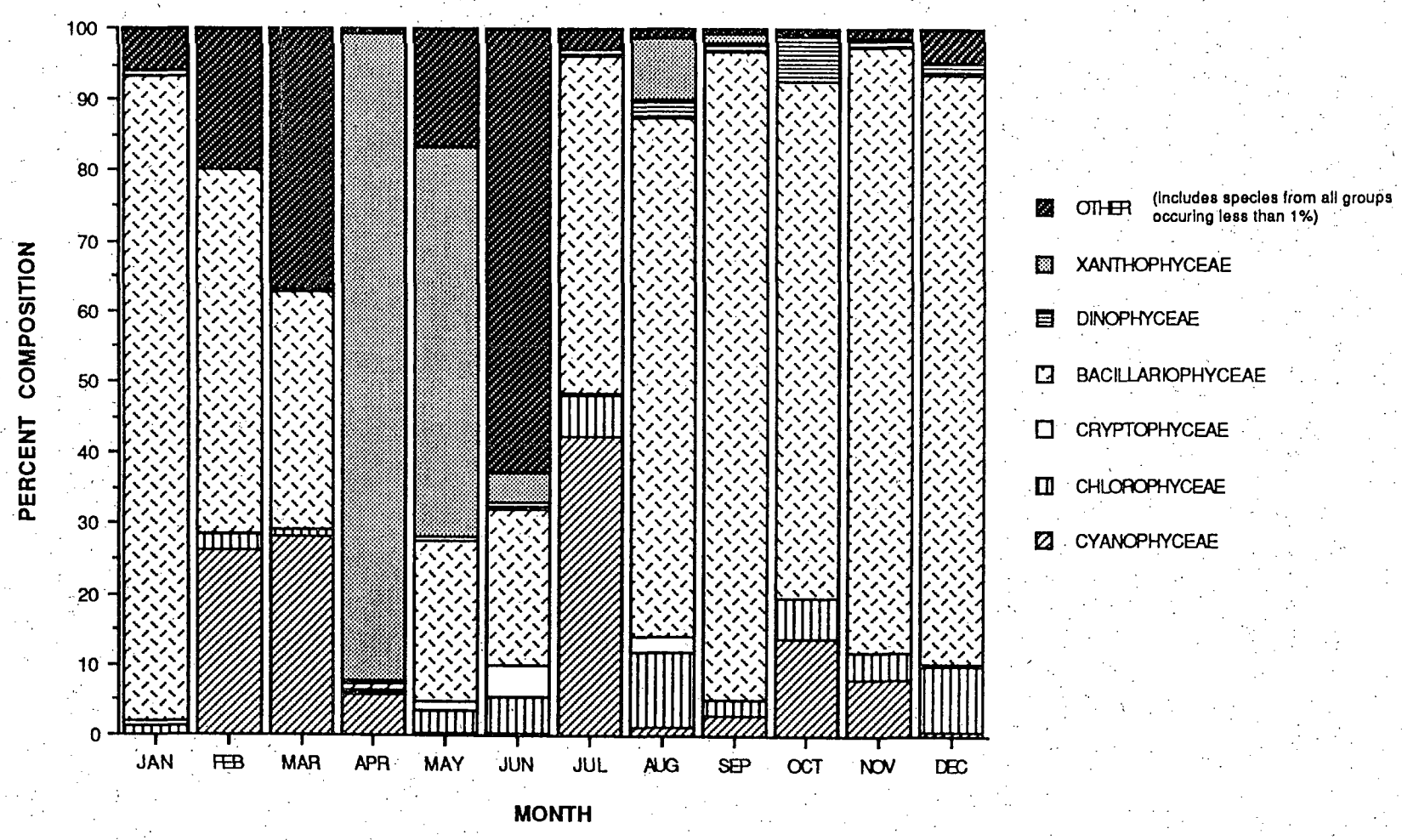
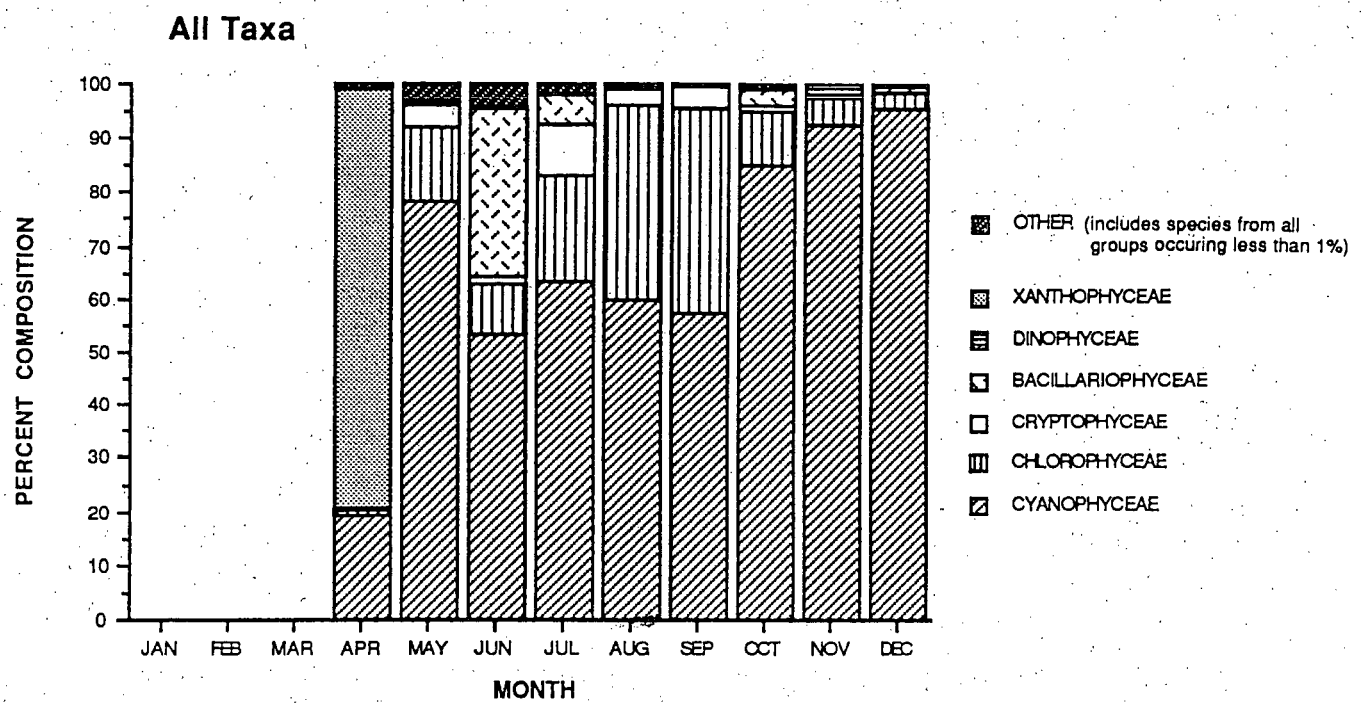


Figure 3.1.2-2. Seasonal succession of the major phytoplankton groups (percent composition) during the preoperational years (1978-1984) at nearfield Station P2. Seabrook Operational Report, 1990.

Based on yearly mean abundance, colonial Cyanophyceae added substantially to the total abundance and were the overwhelmingly dominant taxon in 1990 (Table 3.1.2-1), perhaps reflecting a regional pattern. In transects across the Gulf of Maine Balch *et al.* (1991) observed abundances of cyanophyceae ranging from 2 - 7 x 10^7 cells/l in the summer of 1988 and 1989. High densities of colonial cyanophytes have been reported in several other areas of New England: Woods Hole Harbor at $2x10^6$-$3.6x10^8$ cells/l (Waterbury, *et al.* 1979); Narragansett Bay at 10^6 cells/l; Rhode Island shelf at $3x10^5$ cells/l and Georges Bank at 10^8 cells/l (Johnson and Sieburth 1979); Montsweag Bay ME at $1.6x10^5$ cells/l (McAlice and Jones 1978). Only McAlice and Jones (1978) reported the relationship of the cyanophyte to the rest of the phytoplankton assemblage. The cyanophyte bloom lasted for several months in Montsweag Bay, ME (McAlice and Jones 1978). The colonial cyanophyte (reported as *Microcystis* sp.) dominated that phytoplankton assemblage, but co-occurred with a typical and diverse group of other phytoplankton species. Similarly, the phytoplankton assemblage, excluding colonial Cyanophyceae, observed in 1990 in the coastal waters of New Hampshire resembled the preoperational assemblage in terms of abundance and species composition (Figure 3.1.2-3).

Phaeocystis pouchetii exhibited a spring bloom in 1990, as was observed in previous years. Later in the spring the Chlorophyceae (green algae, here consisting of filamentous and unicellular taxa) appeared, and remained one of the dominant groups for the rest of the year. Cryptophyceae (flagellated algae, consisting primarily of *Chroomonas* sp.) and filamentous Cyanophyceae (in addition to colonial taxa) were also abundant in the summer. Unlike the preoperational period, where diatoms were an important group for most of the year, they composed a substantial proportion of the assemblage only in June (primarily *Leptocylindrus minimus* and *Nitzschia delicatissima*) and in October (*Skeletonema costatum*) and to a lesser degree in July and December. The appearance of large numbers of *Skeletonema costatum* in the fall was, however, characteristic of the preoperational period.



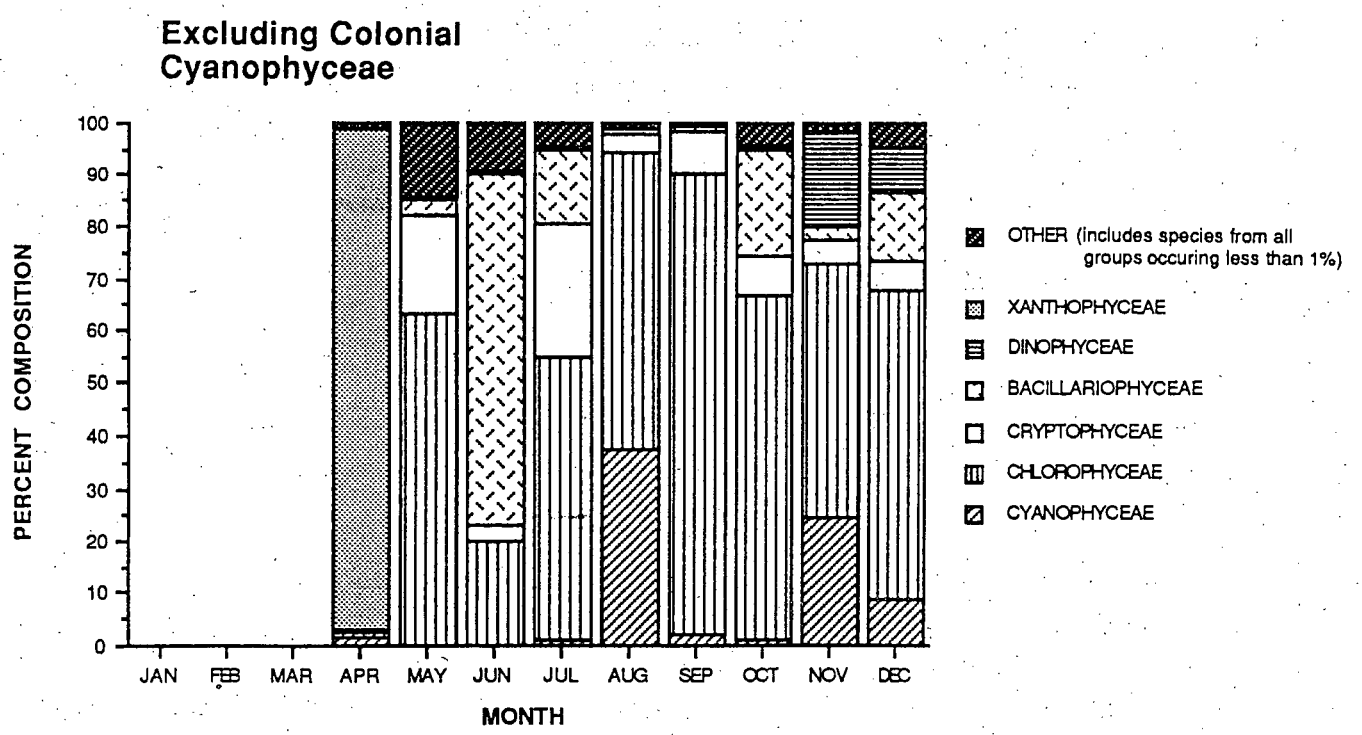


Figure 3.1.2-3. Seasonal succession of the major phytoplankton groups (percent composition) during 1990, all taxa and excluding colonial Cyanophyceae at nearfield Station P2. Seabrook Operational Report, 1990.

Nearfield and Farfield Assemblages

Percent composition and frequency of occurrence of most dominant species have been similar in the nearfield and the farfield, for both the preoperational and operational periods (Table 3.1.2-3). Historical analyses of the correlations in total abundances between stations have shown that there is a strong correlation ($r > 0.800$) between stations P2 and P7 (NAI 1985b). For the period of April through December 1990, total phytoplankton abundance showed a significant correlation ($r > 0.700$) at alpha = 0.05 between stations P2 and P5, and between P5 and P7. The correlation of total abundance between stations P2 and P7 was also significant, although not as strong as the other two comparisons ($r = 0.544$).

Differences in individual taxon abundances between stations during 1990 were also analyzed using a multivariate analysis of variance procedure (MANOVA) (Table 3.1.2-4). The following taxa were selected for inclusion in the analysis: colonial Cyanophyceae; filamentous Cyanophyceae; Chlorophyceae; *Chroomonas* sp.; *Leptocylindrus minimus; Phaeocystis pouchetii; Nitzschia delicatissima*; and *Skeletonema costatum*. These were the dominant taxa (relative abundance greater than 1%) for the period of April to December. *Phaeocystis pouchetii* and Chlorophyceae species represented less than 1% of total abundance between August and December and therefore were not tested. For both the April to December and August to December periods, no significant differences in abundances among the three stations were detected.

Chlorophyll *a* Concentrations

Chlorophyll *a* concentrations may, in general, be used as a measure of phytoplankton standing crop, although the issue is complicated by the varying amounts of chlorophyll *a* contained in different phytoplankton species. During the preoperational period, chlorophyll *a* concentrations showed a bimodal pattern, with peaks in spring and fall

TABLE 3.1.2-3. RELATIVE ABUNDANCE (%) OF PHYTOPLANKTON SPECIES OCCURRING IN FREQUENCIES OF 1% OR GREATER DURING AUGUST-DECEMBER OF THE PREOPERATIONAL YEARS (1978-1986) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

	1978		1979		1980		1981		1982		1983		1984		1986			1990		
SPECIES	P2	P5	P2	P5	P2	P5	P2	P5	P2	P7	P2	P7	P2	P7	P2	P5	P7	P2	P5	P7
Cyanophyceae; filamentous																		8	2	5
Bacillariophyceae	4	2			<1	<1	1	1	2	3										
Nitzschia delicatissima	1				1		20	29					1	1	1	1	1			
Nitzschia longissima	1		1			1		12												
Rhizosolenia delicatula	22	25	69	63	4	5	1				2	3	1	1						
Skeletonema costatum	63	66	10	14	88	79	29	3	49	28	10	4	72	58	66	63	64	1	1	
Thalassionema nitzschioides	8	6			2	5			11	18	2	1	<1	1	<1		1			
Gyrodinium sp.			1	1																
Nitzschia seriata			1	1	1	2	<1						1	2						
Phaeocystis pouchetii			7	9																
Pleurosigma angulatum			2	2																
Prorocentrum micans			7	8			1	<1											1	
Alga; flagellate					1	5	8	12	15	17	54	61	4	7	3	5	8	3	3	3
Chroomonas sp.						1			5	4								2	2	2
Alga; unicellular							1	2			1							20	18	17
Ceratium furca							1													
Chaetoceros sp.							1	1	1	1	1		1	1	1	1	1			
Cyanophyceae							14	10				<1								
Euglenales							2	8	<1	4										
Gymnodinium sp.							1	3												
Leptocylindrus minimus							1	1	13	21	1	1	3	3	2	2	2			
Peridinium sp.							1	1												
Rhizosolenia fragilissima							10	10			8	3	1	1	6	7	12			
Thalassionema sp.							2	1												
Thalassiosira sp.							1	1			1	1	1	1	1	2	2			
Rhizosolenia sp.									1	1										
Asterionella glacialis											2	6								
Centrales											6	9		1	1	1	2			
Cerataulina bergonii											1		6	9						
Dinophyceae											4	3	3	6	1	1	2			
Navicula sp.											1	1								
Pennales											1	1								
Rhizosolenia stolterfothii											1									
Leptocylindrus danicus													4	5						
Oscillatoria sp														3						
Merismopedia sp.															1	3	2			
Cyanophyceae; colonial															13	12	1	66	72	70
Chaetoceros danicus																				1

TABLE 3.1.2-4. RESULTS OF MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA) COMPARING PHYTOPLANKTON COMMUNITY STRUCTURE AT STATIONS P2, P5 AND STATION P7 DURING 1990. SEABROOK OPERATIONAL REPORT, 1990.

NO.OF SPECIES[a]	NO. OF STATIONS	PERIOD	STATISTIC	df	F
8	3	Apr-Dec	Wilk's criterion	16,50	0.52 NS
			Pillai's trace	16,52	0.52 NS
			Hotelling-Lawley trace	16,48	0.53 NS
8	3	Aug-Dec	Wilk's criterion	12,22	0.74 NS
			Pillai's trace	12,24	0.71 NS
			Hotelling-Lawley trace	12,20	0.77 NS

[a]Analysis included these numerically dominant taxa:
Cyanophyceae, colonial
Cyanophyceae, filamentous
Chlorophyceae
Chroomonas sp.
Leptocylindrus minimus
Phaeocystis pouchetii
Nitzschia delicatissima
Skeletonema costatum

(Figure 3.1.2-4). Concentrations followed a somewhat different pattern in 1990, although spring and fall peaks are apparent. The two highest concentrations were observed in March and in November; smaller peaks were apparent in May-June and in September, as occurred during the preoperational period. Chlorophyll *a* concentrations were consistently higher in the preoperational period than in 1990, although 1990 concentrations were contained within the wide preoperational confidence intervals. These differences in concentrations may reflect the dominance of Bacillariophyceae during the preoperational period, and the dominance of Cyanophyceae which contain less chlorophyll, in 1990.

Chlorophyll *a* concentrations in 1990 were similar among the three stations, as indicated by moderate to high correlation coefficients (Table 3.1.2-5).

PSP Levels

PSP toxicity levels in *Mytilus edulis*, as provided by the State of New Hampshire, have shown a strong seasonal pattern of extreme values occurring during the late spring and early summer during the preoperational period (Figure 3.1.2-5). The preoperational data also show a small peak in toxicity levels occurring in August. In 1990, elevated PSP levels were recorded in late May through June, although these levels were generally much lower than those observed prior to 1990.

3.1.2.2 Selected Species

Skeletonema costatum was chosen as a selected species because of its historic omnipresence and overwhelming dominance during much of the year. During the preoperational period, abundances were slightly bimodal in nature, showing a small peak in the spring (varying from year-to-year from February to May) and a major peak in the late summer

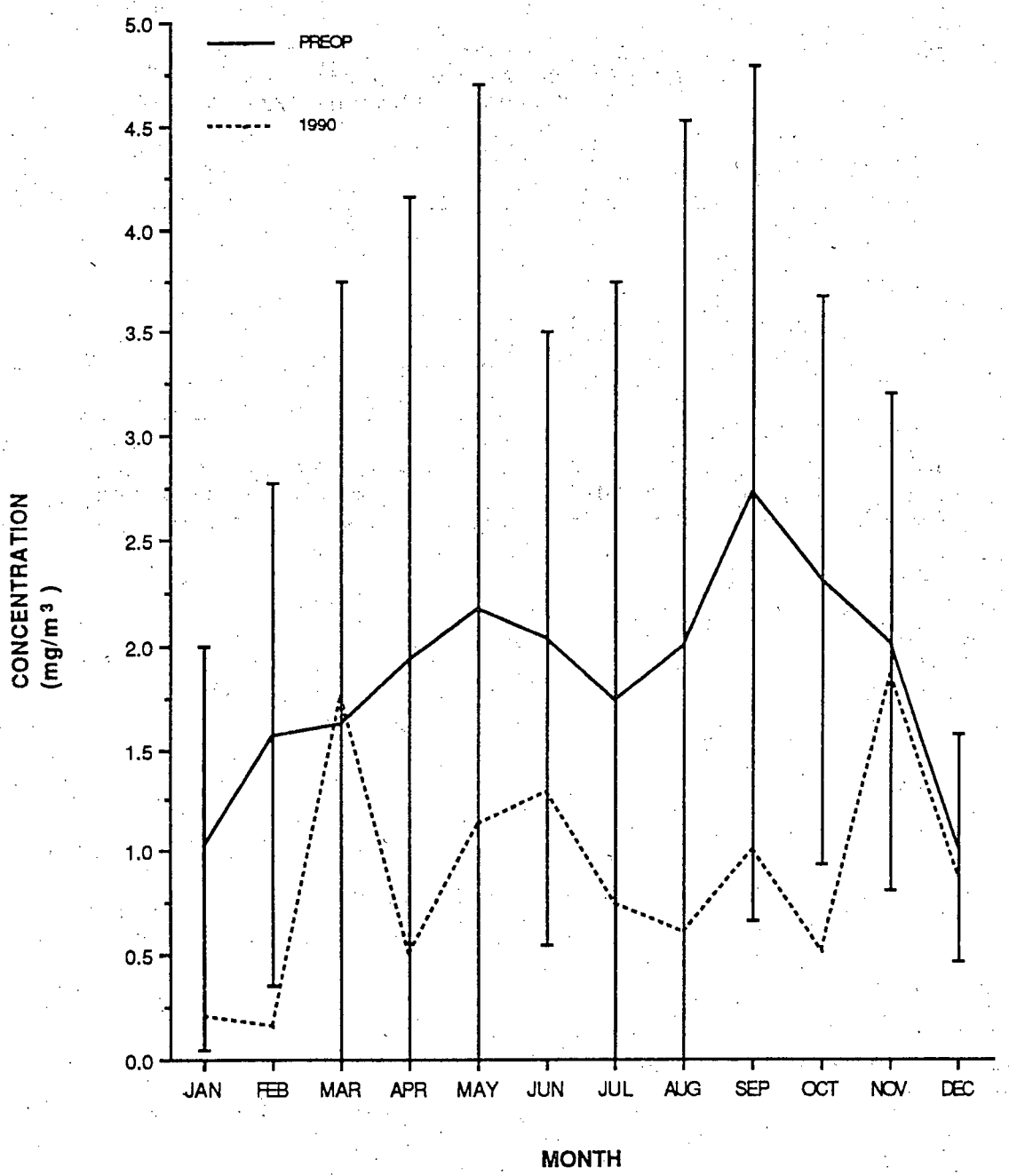


Figure 3.1.2-4. Mean monthly chlorophyll a concentrations and 95% confidence intervals over all preoperational years (1978-1984) and monthly means in 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

TABLE 3.1.2-5. CORRELATION COEFFICIENTS FOR CHLOROPHYLL *a* CONCENTRATIONS AT STATIONS P2, P5, AND P7 IN 1990. SEABROOK OPERATIONAL REPORT,1990.

	P5	P7
P2	0.9113	0.7831
P5		0.7162

All correlations statistically significant at alpha = 0.05; coefficients (r) of 0.600-0.800 indicate moderate correlation and coefficients greater than 0.800 indicate high correlation.

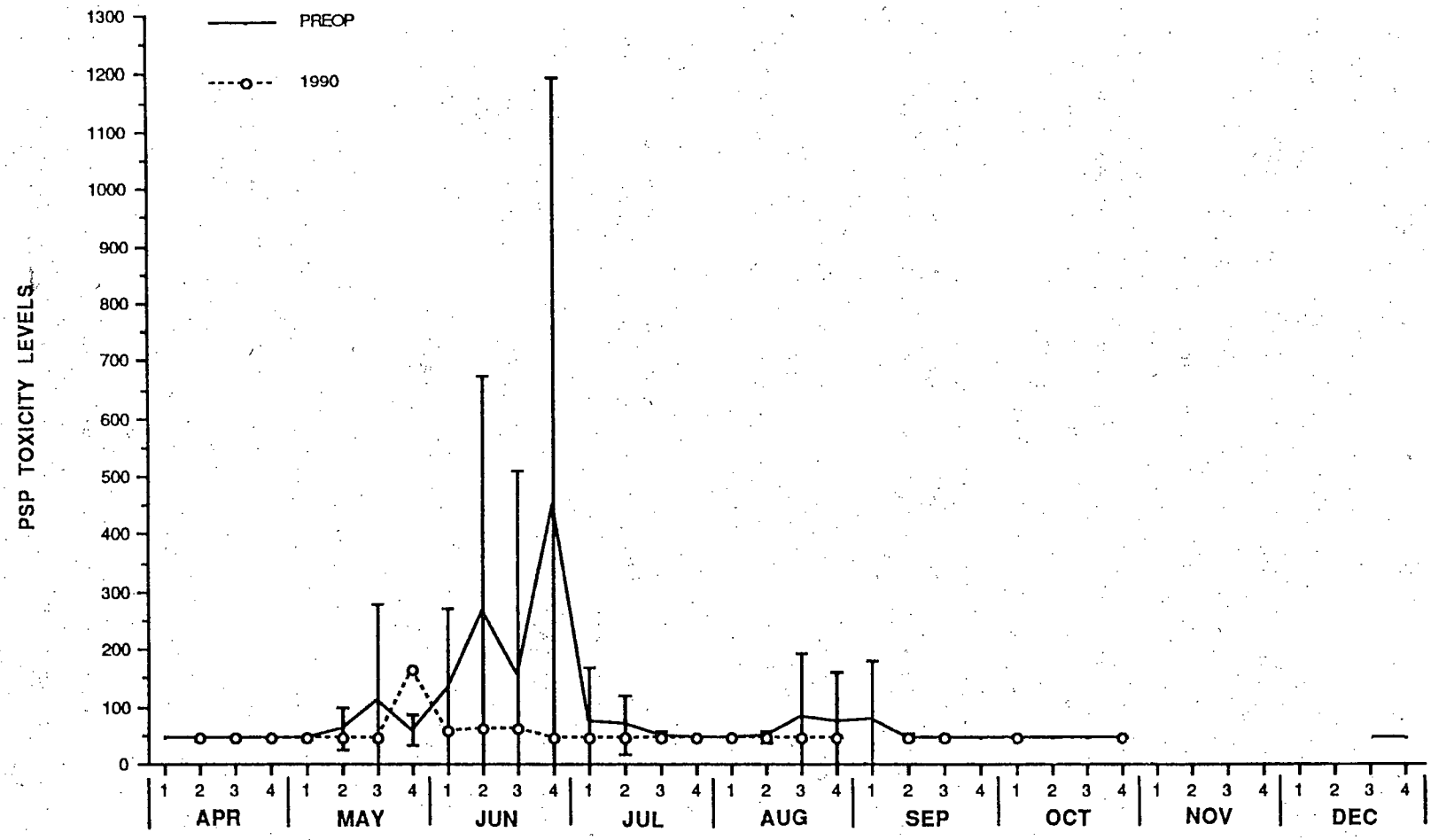


Figure 3.1.2-5. Mean and 95% confidence intervals of weekly paralytic shellfish poisoning (PSP) toxicity levels in *Mytilus edulis* in Hampton Harbor over all preoperational years(1978-1984) and mean levels in 1990. Seabrook Operational Report, 1990.

or fall (varying from August to October). This pattern was somewhat different in 1990 (Figure 3.1.2-6 and Table 3.1.2-6). A large peak in abundance was observed in June; in October, the peak was very consistent with historical trends. An analysis of variance procedure (ANOVA) was structured to examine the following characteristics of *Skeletonema costatum* abundances during the preoperational and operational periods:

a) Preop-Op tests differences in abundances between the preoperational and operational periods, regardless of station, and will detect whether operational period falls within historical variability;

b) Station tests differences in abundances among Stations P2, P5 and P7, regardless of sample date, and will detect whether there has been a consistent relationship in abundances spatially;

c) Year (Preop-Op) tests differences in abundances among years nested within preoperational and operational periods, regardless of station, and will detect whether any year or years are unique;

d) Month (Preop-Op) tests differences in abundances among months nested within preoperational and operational periods, regardless of station, and will detect whether there is a consistent seasonal pattern; and

e) Preop-Op X Station tests differences in abundances between the main effects of preoperational and operational periods and station and will detect whether the relationship in abundance among stations has been consistent between preoperational and operational periods.

These results are summarized in Table 3.1.2-7. During the April to December period, significant differences in *Skeletonema costatum* abundances were shown to exist between the preoperational years and 1990 (Preop-Op), among years (Year (Preop-Op), and among months (Month (Preop-Op)). For the August to December period, a significant difference was shown to exist between preoperational and operational abundances (which is noted in Figure 3.1.2-6), and significant differences were again noted among years and among months. No differences in abundances were apparent among stations in either the April-December or August-December time frame. The relationship among stations in terms of

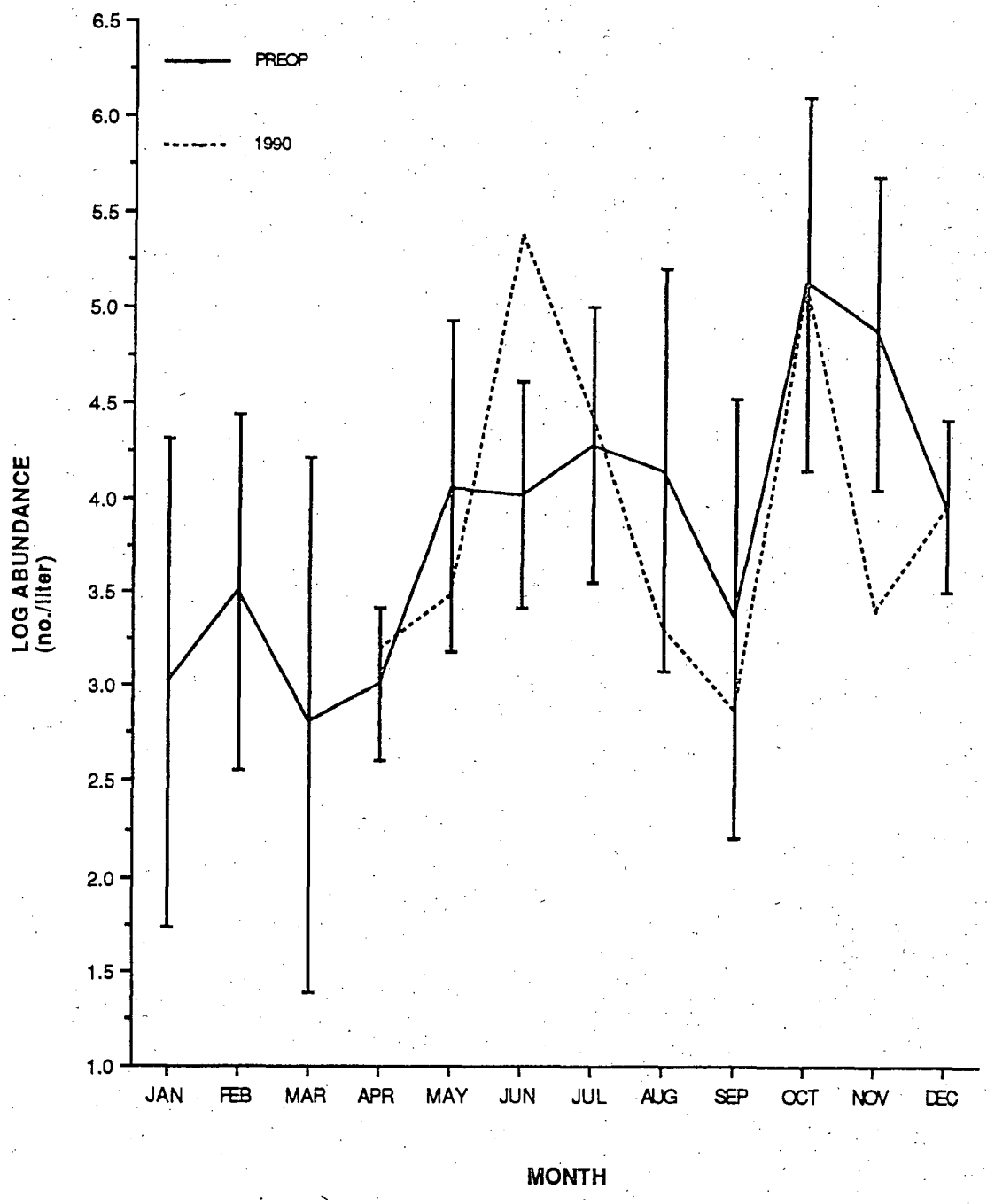


Figure 3.1.2-6. Log (x+1) abundance (no./l) *Skeletonema costatum* at nearfield Station P2; monthly means and 95% confidence intervals over all preoperational years (1978-1984) and monthly means for 1990. Seabrook Operational Report, 1990.

TABLE 3.1.2-6. PEAK FALL ABUNDANCES OF *SKELETONEMA COSTATUM* IN SURFACE WATERS AT THE NEARFIELD STATION P2 DURING PREOPERATIONAL YEARS (1978-1984, 1986) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

MONTH OF MAXIMUM OCCURRENCE	MEAN ABUNDANCE IN CELLS/LITER								
	1978	1979	1980	1981	1982	1983	1984	1986	1990
August				2.4×10^6		1.2×10^5			
September		2.7×10^5	2.2×10^6		9.2×10^5		4.5×10^6	8.7×10^6	
October	2.6×10^6								1.3×10^5

TABLE 3.1.2-7. RESULTS OF ANALYSIS OF VARIANCE[a] COMPARING NEARFIELD (STATIONS P2 AND P5) AND FARFIELD (STATION P7) *SKELETONEMA COSTATUM* ABUNDANCES DURING PREOPERATIONAL YEARS (1978-1986) AND 1990 AND STATIONS P2, P5 AND P7 DURING 1990. SEABROOK OPERATIONAL REPORT, 1990.

SOURCE OF VARIATION	APRIL - DECEMBER df	SS	F	AUGUST[b] - DECEMBER df	SS	F
A. SPATIOTEMPORAL VARIATION, 1978-1986 AND 1990						
Preop-Op[c]	1	7.79	6.96**	1	16.22	14.59***
Station[d]	2	4.49	2.01 NS	2	1.48	0.67 NS
Year (Preop-Op)[e]	7	26.51	3.38**	7	18.11	2.33*
Month (Preop-Op)[f]	16	98.77	5.51***	8	37.94	4.26***
Preop-Op X Station[g]	2	1.00	0.44 NS	2	0.24	0.11 NS
Error	165	153.44		75	83.40	
B. SPATIAL VARIATION, 1990						
Station[h]	2	1.97	0.57 NS	2	0.87	0.28 NS
Error	24	41.55		12	18.83	

[a]Based on twice monthly sampling periods.
[b]Commercial operation began in August 1990.
[c]Preoperational (1978-1986) versus operational period, regardless of area.
[d]Station P2 versus Station P5 versus Station P7, regardless of sample date.
[e]Year nested within preoperational and operational periods, regardless of area.
[f]Month nested within preoperational and operational periods, regardless of area.
[g]Interaction between the main effects of sample period and station.
[h]Station P2 versus P5 versus P7, regardless of sample period.

NS = not significant ($p>0.05$)
* = significant ($0.05\geq p>0.01$)
** = highly significant ($0.01\geq p\geq 0.001$)
*** = very highly significant ($0.001\geq p$)

abundance of *S. costatum* did not vary between preoperational years and 1990 (Table 3.1.2-7, Preop-Op X Station).

An additional analysis was constructed to evaluate the differences in abundances among Stations P2, P5, and P7 in 1990, with all dates pooled. No significant differences in abundances either during the entire year or the August-December operational period were detected (Table 3.1.2-7).

3.1.3 Microzooplankton

3.1.3.1 Total Community

Seasonal Characteristics

Temporal variability in species abundances and taxonomic composition of the nearshore microzooplankton community (surface and bottom samples combined) at Station P2 (Figure 2.1-2) for all pre-operational (1978-1984 and 1986) and operational (1990) collections was examined using cluster analysis. Numerical classification grouped individual sampling dates into six major groups that corresponded with the seasonal cycle (Figure 3.1.3-1). Comparison of the specific dates included within each cluster group indicated that there were moderate differences among years. The most pronounced variation occurred during late summer and fall of preoperational years where cluster groups included a number of "outlying collections" (i.e., a collection date separated by more than two weeks from the rest of the seasonal group) (Figure 3.1.3-2). Collections from 1990 generally clustered into groups containing corresponding dates from the preoperational period, although the fall/winter collections were identified as a separate cluster group from preoperational dates. Preoperational and operational periods were similar in the rank order of numerically dominant taxa identified from each cluster group (Table 3.1.3-1); these taxa accounted for at least 80% of the total mean abundance within each cluster. Differences among groups, in large measure, were attributed to seasonal variability in the

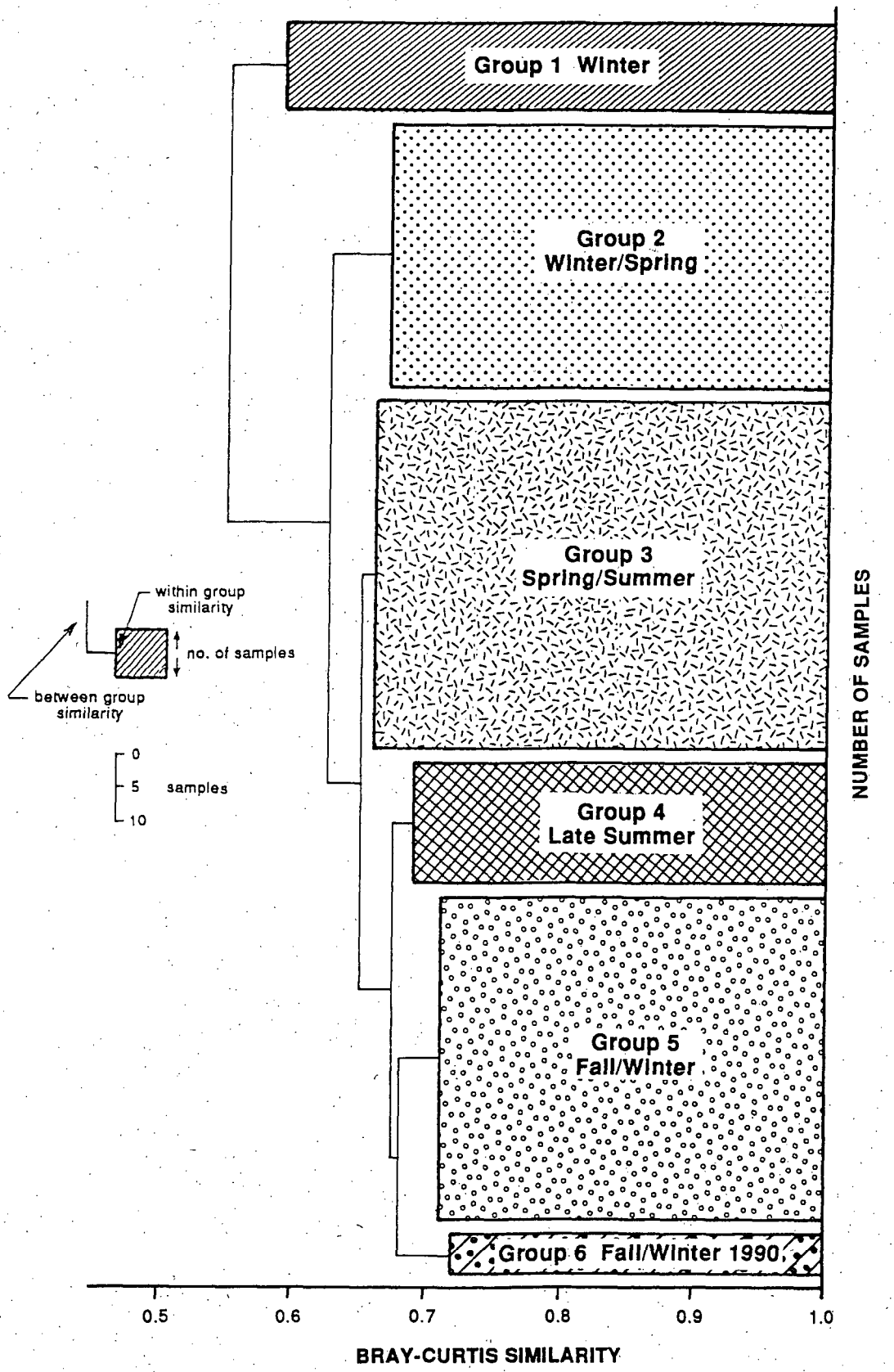


Figure 3.1.3-1. Dendrogram formed by numerical classification of log (x+1) transformed microzooplankton abundances (no./m^3) at Seabrook nearfield Station P2, 1978-1984, July -December 1986, and April-December 1990. Seabrook Operational Report, 1990.

TABLE 3.1.3-1. GEOMETRIC MEANS OF MICROZOOPLANKTON ABUNDANCE (NO./m^3), 95% CONFIDENCE LIMITS, AND NUMBER OF SAMPLES FOR DOMINANT TAXA OCCURRING IN SEASONAL CLUSTER GROUPS IDENTIFIED BY NUMERICAL CLASSIFICATION OF COLLECTIONS AT NEARFIELD STATION P2, 1978 - 1985, JULY - DECEMBER 1986, AND APRIL - DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

GROUP	DOMINANT TAXA	1978-1984, 1986 LOWER C.L.	MEAN	UPPER C.L.	N	1990 MEAN	N
1. Winter (0.59/0.56)[a]	Copepoda nauplii	124.75	252.1	508.40	13	--	--
	Oithona sp.	177.65	361.9	736.13		--	--
	Pseudocalanus sp.	57.30	121.7	257.29		--	--
	Pseudocalanus/Calanus nauplii	96.64	220.1	499.55		--	--
2. Winter/Spring (0.67/0.62)	Cirripedia larvae	130.33	214.8	353.47	36	66.8	3
	Copepoda nauplii	604.17	863.0	1232.63		949.5	
	Oithona sp.	974.97	1391.6	1986.06		1382.6	
	Polychaeta larvae	180.15	248.6	342.54		34.0	
	Pseudocalanus sp.	217.22	323.5	481.40		222.4	
	Pseudocalanus/Calanus nauplii	541.79	802.2	1187.43		418.7	
3. Spring/Summer (0.66/0.65)	Bivalvia veliger larvae	1768.55	2966.0	4973.92	48	499.7	4
	Copepoda nauplii	3530.56	4922.6	6863.21		9665.3	
	Oithona sp.	5203.95	6434.9	7957.01		17510.2	
	Pseudocalanus sp.	1438.74	1980.0	2724.87		509.4	
	Pseudocalanus/Calanus nauplii	2252.00	3087.8	4233.69		1301.8	
4. Late Summer (0.69/0.68)	Bivalvia veliger larvae	210.25	467.2	1036.79	13	862.3	5
	Copepoda nauplii	1090.87	2406.7	5308.35		1744.3	
	Oithona sp.	2957.31	5219.6	9211.79		4069.8	
	Pseudocalanus sp.	1105.19	1934.7	3386.42		459.7	
	Pseudocalanus/Calanus nauplii	1272.29	2403.2	4538.73		246.9	
	Temora longicornis	87.37	235.5	631.92		914.0	
5. Fall/Winter (0.71/0.68)	Bivalvia veliger larvae	132.95	204.5	314.40	48	not repre-	
	Copepoda nauplii	848.49	1176.4	1630.98		sented	
	Oithona sp.	1646.20	2146.7	2799.23			
	Pseudocalanus sp.	275.78	376.3	513.16			
	Pseudocalanus/Calanus nauplii	579.34	760.6	998.41			
	Tintinnidae	71.85	154.1	329.35			
6. Fall/Winter '90 (0.72/0.68)	*Centropages* sp. copepodites	not represented				181.6	5
	Copepoda nauplii					1349.2	
	Microsetella norvegica					162.9	
	Oithona sp.					2239.0	
	Pseudocalanus sp.					272.2	
	Pseudocalanus/Calanus nauplii					306.9	
	Rotifera					133.9	
	Tintinnidae					250.3	

[a]within group similarity/between group similarity
[b]no samples collected on these dates

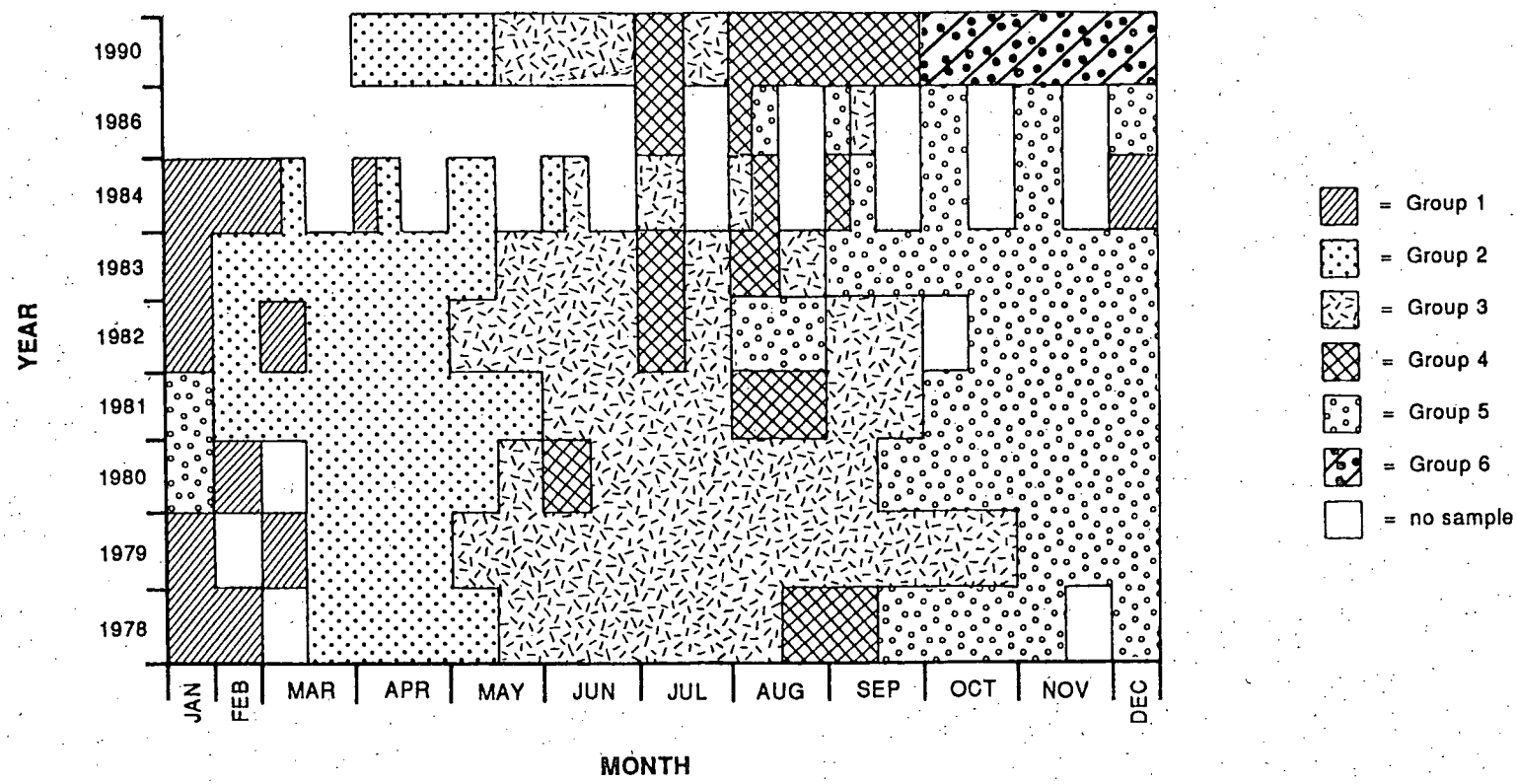


Figure 3.1.3-2. Seasonal groups formed by numerical classification of log (x+1) transformed microzooplankton abundances (no./m^3) at Seabrook nearfield Station P2, 1978-1984, July-December 1986, and April-December 1990. Seabrook Operational Report, 1990.

abundances of these dominant taxa. Seasonal groups identified by cluster analysis generally encompassed collection periods with similar temperature regimes, particularly with respect to the depth and intensity of the thermocline (NAI 1985b).

Within-cluster group similarities were fairly high (0.587 - 0.723) indicating that the microzooplankton community structure was fairly constant among the dates comprising each group (Figure 3.1.3-1). Between-group similarities were also reasonable high (0.556 - 0.677) due to the consistent occurrence and relatively high densities throughout much of the year of the same dominant taxa (i.e., Copepoda nauplii, *Oithona* sp., *Pseudocalanus* sp., and *Pseudocalanus/Calanus* nauplii; Table 3.1.3-1).

As noted above, seasonal patterns in the microzooplankton community structure were largely delineated by changes in both total abundance and the dominance structure of numerically important taxa. Lifestages of the copepods *Oithona* sp. and *Pseudocalanus* sp., and *Pseudocalanus/Calanus* nauplii were the most abundant organisms in virtually every cluster group during both pre-operational and operational periods (Table 3.1.3-1). The winter microzooplankton (Group 1) was characterized by fewer dominant taxa with moderate abundances. In the late winter through early summer (Groups 2 and 3), population densities of copepods (*Oithona* sp., *Pseudocalanus* sp., *Pseudocalanus/Calanus* nauplii, and Copepoda nauplii) increased substantially. Abundances of the microzooplankton assemblage peaked during the summer (Groups 3 and 4) when copepod densities were at their highest and benthic species (particularly bivalves) contributed large numbers of individuals to the meroplankton. Among-year differences in the dates assigned to cluster groups 3, 4 and 5 (summer-fall) were more apparent than for the other seasons because of the large number of dominant taxa with highly variable densities (Figure 3.1.3-2). The dominant copepods continued to maintain moderate populations throughout the fall and into winter (Groups 5 and 6) while densities of most other taxa declined. The fall of 1990 (Group 6) differed from earlier years in the subdominance of

rotifers, *Microsetella norvegica* and *Centropages* sp. copopodites in addition to the typical fall dominants (Table 3.1.3-1). The between group similarity of 0.68 between groups 5 and 6 is a relatively high value indicating that distinctions between the two groups are subtle.

In summary, the microzooplankton community structure at Station P2 has been fairly consistent throughout this study, with the greatest annual variability evident during the summer and fall when both abundances and number of dominant species were highest. Although the microzooplankton community varied in the fall of 1990 from preoperational years, the differences were due to increased abundances of several taxa while the typical species maintained their predominance. There were no other differences noted between pre-operational and operational periods. The community structure was influenced primarily by the population dynamics of the copepods *Oithona* sp. and *Pseudocalanus* sp. and by the production of early lifestages (nauplius larvae) of other copepods. Other taxa (including Polychaeta, Bivalvia, and Tintinnidae) exerted less influence on overall community structure.

Spatial Patterns of Microzooplankton Abundances

Spatial variation (i.e., among-stations differences) in the microzooplankton community structure was examined separately for both the preoperational and operational periods, with abundances averaged over depth. Comparison of total microzooplankton densities from 1982 to 1984 using Wilcoxon's two-sample test (Sokal and Rohlf 1969) revealed no significant differences between Stations P2 and P7 (NAI 1985b). Although some numerically important taxa exhibited large differences in rank order or percent composition between stations, their individual abundances were also not significantly different (NAI 1985b).

A multivariate analysis of variance (MANOVA) was performed using the April-December 1990 abundances of 34 numerically important

taxa from Station P2, P5, and P7. Species composition and abundances were not significantly different among these stations (Table 3.1.3-2).

In summary, statistical evaluation of the spatial variation in microzooplankton community structure, as measured by abundance data among sampling stations, found no significant differences either during preoperational years or during 1990.

3.1.3.2 Selected Species

The copepods *Pseudocalanus* sp. and *Oithona* sp. were selected for in-depth analysis in the microzooplankton program because of their dominant roles in the community. Their abundance and low trophic level make them important members of the marine food web. *Eurytemora herdmani* has been reported to be an abundant coastal copepod in the northern region of the western Atlantic (Katona 1971) and as such, may be particularly sensitive to perturbations in the local temperature regime. Lifestages of these taxa were identified whenever possible to develop an understanding of the dynamics of population recruitment cycles. In some cases, however, the possible presence of congeneric species made it impossible to routinely identify all lifestages to species level. Nevertheless, information on lifestages of these genera is included in this report to present as complete a picture as possible. Temporal (seasonal and annual) and spatial (horizontal and vertical) variability of the above-mentioned species is characterized. Even though some vertical differences in abundance did exist, temporal characteristics are described for surface and bottom collections combined.

Eurytemora sp.

During the preoperational period, *Eurytemora* sp. copepodites at Station P2 were present in low numbers for most of the year, generally exhibiting short-term peak abundances in early to mid-summer (Figure

TABLE 3.1.3-2. RESULTS OF MULTIVARIATE ANALYSIS OF VARIANCE COMPARING MICROZOOPLANKTON COMMUNITY STRUCTURE AT STATIONS P2, P5, AND P7 IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

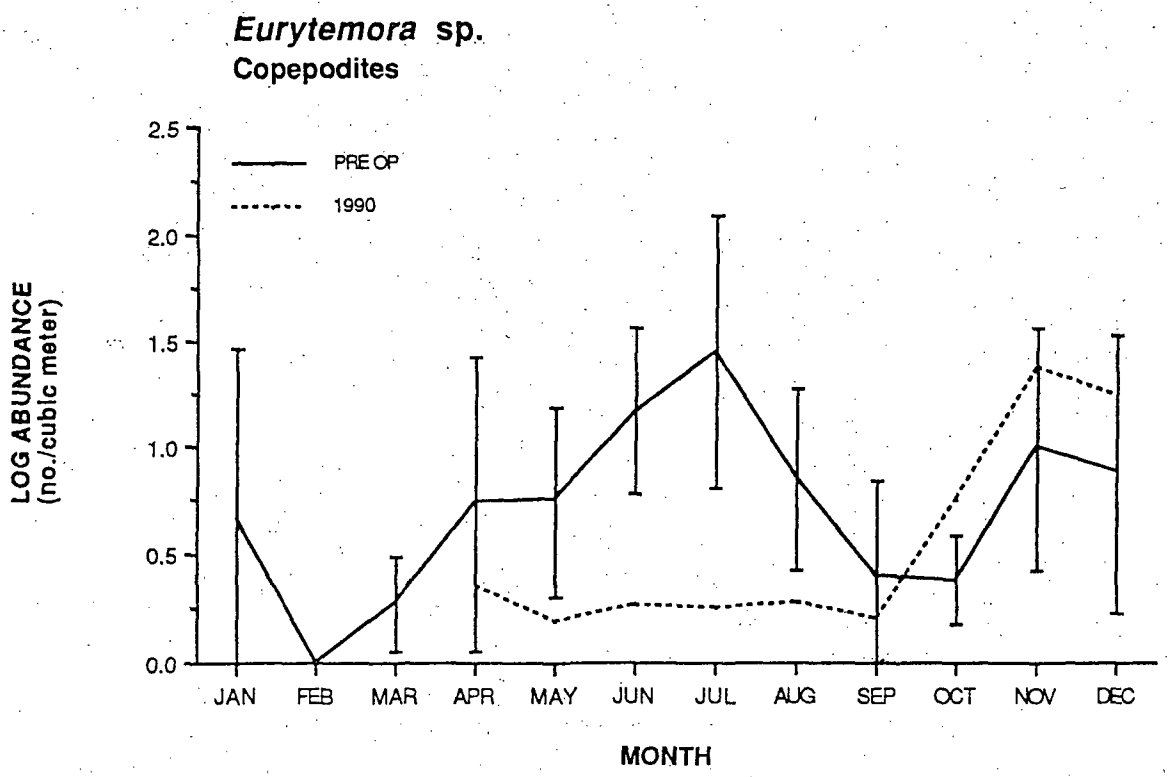
NUMBER OF SPECIES	NUMBER OF STATIONS	STATISTIC	df	F
34	3	Wilk's criterion	68,30	0.6880 NS
		Pillai's trace	68,32	0.6714 NS
		Hotelling-Lawley's trace	68,28	0.7092 NS

NS = Not significant

3.1.3-3). An additional smaller fall peak was often recorded, especially in 1983 (NAI 1984b), when the highest annual mean abundance for copepodites was recorded (Table 3.1.3-3). Annual geometric means ranged from 1.7 copepodites/m^3 in 1982 to 16.6 copepodites/m^3 in 1983, averaging 6.1 copepodites/m^3 during the preoperational period (1978-1984). *E. herdmani* adults typically occurred in lower numbers than copepodites and were almost absent from the plankton samples at Station P2 from December through April during the preoperational years (Figure 3.1.3-3). Peak abundances occurred during one or more months from May through September and usually coincided with peak copepodite abundances. Annual geometric means were highly variable ranging from 0.9 adults/m^3 in 1979 and 1982 to 10.5 adults/m^3 in 1983, and averaged 3.1 adults/m^3 over the preoperational period (Table 3.1.3-3).

Earlier studies indicated that *Eurytemora* sp. copepodite and *E. herdmani* adult populations in Hampton Harbor and the Nearfield Station P2, underwent similar seasonal cycles, but during the spring the estuarine population was much larger (NAI 1978b, 1979b). These observations suggest that recruitment to the coastal population may be supplemented by the estuarine population. Other sources of recruitment in the spring might be maturation of, and subsequent reproduction of, overwintering copepodites (Figure 3.1.3-3) or hatching of diapause (overwintering) eggs.

In 1990, *Eurytemora* sp. copepodite densities did not exhibit the historic early to mid-summer peak and were well below the preoperational average from May through August (Figure 3.1.3-3). However, a late fall peak was evident and was slightly higher than the mean for the preoperational years. The 1990 geometric annual mean for copepodites (2.5/m^3) was below the overall mean for the preoperational years but was within the range of mean values for individual years (Table 3.1.3-3). *E. herdmani* adults followed the same general seasonal trend in 1990 as during the preoperational years. Values were lower than the preoperational mean in July and greater than the preoperational mean in August,



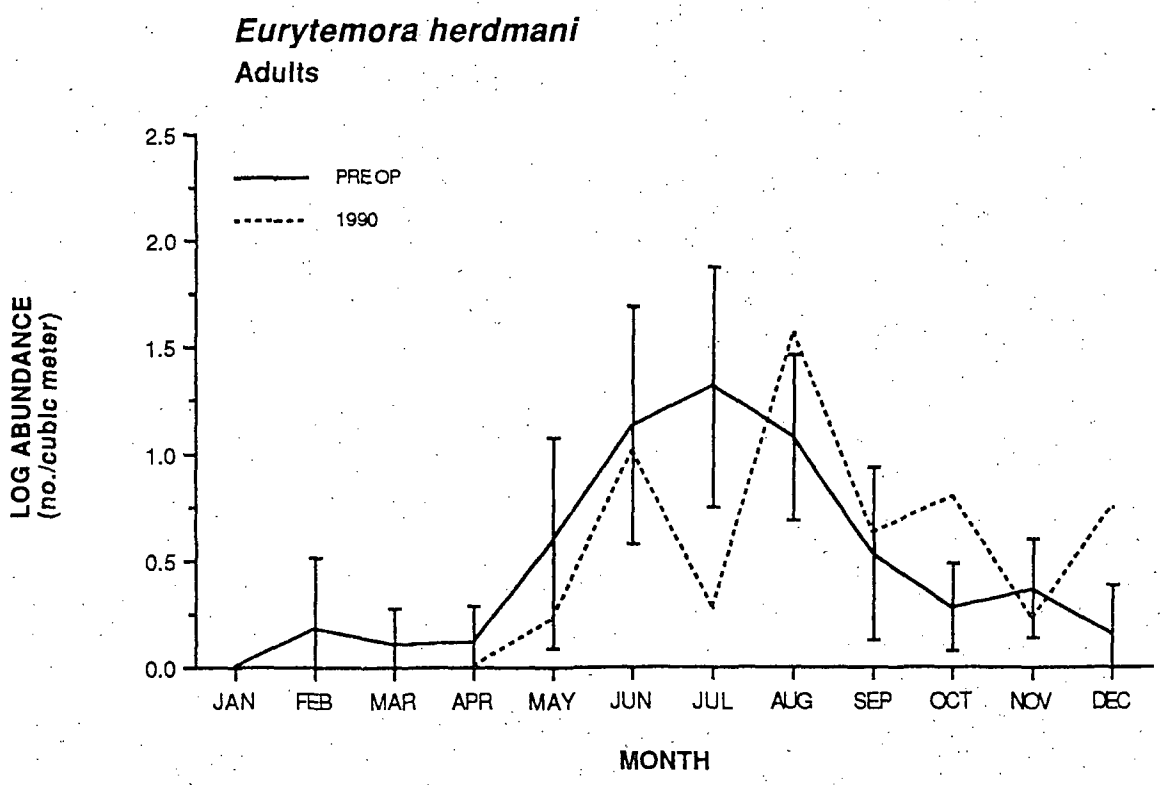


Figure 3.1.3-3. Log (x+1) abundance (no./m^3) of *Eurytemora* sp. copepodites and *Eurytemora herdmani* adults; monthly means and 95% confidence intervals over all preoperational years (1978-1984 and 1986) and monthly means for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

TABLE 3.1.3-3. GEOMETRIC MEAN (NO/M^3) BY YEAR, PREOPERATIONAL MEAN AND 95% CONFIDENCE LIMITS AND OPERATIONAL YEAR MEAN (1990) OF SELECTED MICROZOOPLANKTON SPECIES AT STATION P2 (APRIL-DECEMBER). SEABROOK OPERATIONAL REPORT, 1990.

	YEAR							PREOPERATIONAL YEARS			
SPECIES/LIFESTAGE	1978	1979	1980	1981	1982	1983	1984	MEAN	UPPER CONFIDENCE LIMIT	LOWER CONFIDENCE LIMIT	1990
Eurytemora sp. copedodites	4.0	6.1	9.7	10.6	1.7	16.6	3.2	6.1	12.0	2.8	2.5
Eurytemora herdmani adults	1.3	0.9	4.9	7.0	0.9	10.5	3.1	3.1	7.0	1.1	3.0
Pseudocalamus/Calanus sp. nauplii	832.3	1209.0	789.1	1068.2	1577.3	520.5	365.9	822.7	1307.7	517.5	274.3
Pseudocalanus sp. copepodites	396.5	453.2	177.6	260.0	645.4	336.7	167.1	314.2	496.5	198.7	148.9
Pseudocalanus sp. adults	22.4	33.7	23.7	22.2	72.8	37.7	12.0	28.0	46.8	16.6	15.8
Oithona sp. nauplii	401.6	993.4	301.6	1122.4	1482.5	775.2	292.4	643.1	1188.3	347.8	562.7
Oithona sp. copepodites	662.9	1798.3	614.5	651.0	1263.3	755.1	301.9	753.2	1274.0	445.1	1069.4
Oithona sp. adults	71.2	151.2	134.8	263.4	330.3	225.0	69.3	153.3	270.1	86.8	76.5

October, and December (Figure 3.1.3-3). The geometric annual mean in 1990 was virtually identical to the geometric mean for all preoperational years (Table 3.1.3-3).

Results of the two-way ANOVA on *Eurytemora* copepodites showed that differences in abundances between 1990 and the preoperational years were very significant for the April through December collections (Table 3.1.3-4, Preop-Op). Although abundances in 1990 were significantly lower than preoperational densities, the area (nearfield vs farfield) and interaction terms were not significant, indicating densities were generally lower throughout the area. Differences in annual and seasonal densities were also significant (Table 3.1.3-4, year (Preop-Op) and month (Year (Preop-Op)) indicating high variability among years and months. Results of the two-way ANOVA on *E. herdmani* adult densities during April through December were not significant for either temporal or spatial effects.

During the months of plant operation (August through December) the results of the ANOVA on *Eurytemora* copepodite and adult densities were not significant for either temporal or spatial effects or their interactions. This indicates that the population in the vicinity of the intake was not quantitatively different from the one in the farfield area.

Pseudocalanus sp.

Historically, *Pseudocalanus/Calanus* sp. nauplii were present year-round at Station P2 (Figure 3.1.3-4), and were among the numerical dominants of the microzooplankton community in all seasons except winter (Table 3.1.3-1). Seasonal peak abundance was attained during mid-summer. Annual geometric means at Station P2 ranged during the preoperational period from 366 nauplii/m^3 in 1984 to 1577 nauplii/m^3 in 1982, and averaged 823 nauplii/m^3 (Table 3.1.3-3). *Pseudocalanus* sp. copepodites and adults were also present throughout the year with peak

TABLE 3.1.3-4. RESULTS OF THE TWO-WAY ANALYSIS OF VARIANCE OF LOG (X+1) TRANSFORMED DENSITY (NO/m^3) AMONG PREOPERATIONAL YEARS (1982-1984 & 1986) AND OPERATIONAL YEAR (1990), AREA (NEARFIELD VS. FARFIELD) AND THEIR INTERACTIONS FOR SELECTED MICROZOOPLANKTON SPECIES. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES/ LIFESTAGE	SOURCE OF VARIATION[a]	APRIL - DECEMBER df	SS	F	AUGUST - DECEMBER df	SS	F
Eurytemora sp. copepodite	Preop-Op	1	4.09	14.49***	1	0.34	1.25 NS
	Year (Preop-Op)	3	14.27	16.84***	3	10.75	13.12***
	Month (Year (Preop-Op))	37	47.40	4.54***	20	25.48	4.67***
	Area	1	0.43	1.53 NS	1	0.92	3.36 NS
	Preop-Op X Area	1	0.03	0.09 NS	1	0.13	0.48 NS
	Error	142	40.10		81	22.12	
Eurytemora herdmani adult	Preop-Op	1	0.54	2.29 NS	1	0.37	1.52 NS
	Year (Preop-Op)	3	11.52	16.33***	3	4.32	5.99***
	Month (Year (Preop-Op))	37	47.39	5.45***	20	15.76	3.27***
	Area	1	0.23	0.99 NS	1	0.54	2.23 NS
	Preop-Op X Area	1	<0.01	0.01 NS	1	0.08	0.34 NS
	Error	142	33.38		81	19.51	
Pseudocalanus/Calanus sp. nauplii	Preop-Op	1	6.10	29.94***	1	8.40	40.66***
	Year (Preop-Op)	3	6.86	11.22***	3	0.90	1.45 NS
	Month (Year (Preop-Op))	37	36.58	4.85***	20	14.48	3.50***
	Area	1	0.03	0.15 NS	1	0.08	0.38 NS
	Preop-Op X Area	1	0.20	0.98 NS	1	0.22	1.05 NS
	Error	142	28.96		81	16.74	
Pseudocalanus sp. copepodite	Preop-Op	1	8.59	41.54***	1	2.63	12.18***
	Year (Preop-Op)	3	6.67	10.75***	3	1.25	1.93 NS
	Month (Year (Preop-Op))	37	37.67	4.93***	20	9.35	2.17**
	Area	1	0.05	0.25 NS	1	0.13	0.61 NS
	Preop-Op X Area	1	0.08	0.41 NS	1	0.02	0.08 NS
	Error	142	29.35		81	17.46	
Pseudocalanus sp. adult	Preop-Op	1	13.21	43.38***	1	5.43	18.96***
	Year (Preop-Op)	3	7.54	9.20***	3	0.66	0.77 NS
	Month (Year (Preop-Op))	37	53.20	5.27***	20	26.68	4.66***
	Area	1	0.19	0.70 NS	1	0.20	0.71 NS
	Preop-Op X Area	1	0.17	0.63 NS	1	0.14	0.50 NS
	Error	142	38.78		81	23.20	

(continued)

TABLE 3.1.3-4. (Continued)

SPECIES/ LIFESTAGE	SOURCE OF VARIATION[a]	APRIL - DECEMBER df	SS	F	AUGUST - DECEMBER df	SS	F
Oithona sp. nauplii	Preop-Op	1	0.14	0.81 NS	1	0.74	4.72*
	Year (Preop-Op)	3	9.07	18.09***	3	1.54	3.28*
	Month (Year (Preop-Op))	37	27.42	4.43***	20	10.54	3.36***
	Area	1	0.23	1.37 NS	1	0.09	0.56 NS
	Preop-Op X Area	1	0.02	0.14 NS	1	0.14	0.89 NS
	Error	142	23.76		81	12.70	
Oithona sp. copepodite	Preop-Op	1	1.17	8.50**	1	0.05	0.40 NS
	Year (Preop-Op)	3	10.74	25.96***	3	2.54	6.80***
	Month (Year (Preop-Op))	37	35.86	7.03***	20	5.42	2.17**
	Area	1	0.12	0.86 NS	1	0.04	0.33 NS
	Preop-Op X Area	1	0.08	0.56 NS	1	0.09	0.69 NS
	Error	142	19.57		81	10.10	
Oithona sp. adult	Preop-Op	1	7.40	37.96***	1	10.25	83.25***
	Year (Preop-Op)	3	10.73	18.34***	3	1.83	4.95**
	Month (Year (Preop-Op))	37	34.93	4.84***	20	10.19	4.14***
	Area	1	0.15	0.79 NS	1	<0.01	0.01 NS
	Preop-Op X Area	1	<0.01	0.02 NS	1	0.02	0.19 NS
	Error	142	27.69		81	37.06	

NS = Not Significant (P> 0.05)
* = Significant (0.05 ≥ P >0.01)
** = Highly Significant (0.01 ≥ P > 0.001)
*** = Very Highly Significant (P ≤ 0.001)

[a]Preop-Op = preoperational period vs. operational period, regardless of area
Year (Preop-Op) = year nested within preoperational and operational periods, regardless of area
Month (Year (Preop-Op)) = month nested within year nested within preoperational and operational periods, regardless of area
Preop-Op X Area = interaction of main effects
Area = nearfield vs. farfield stations

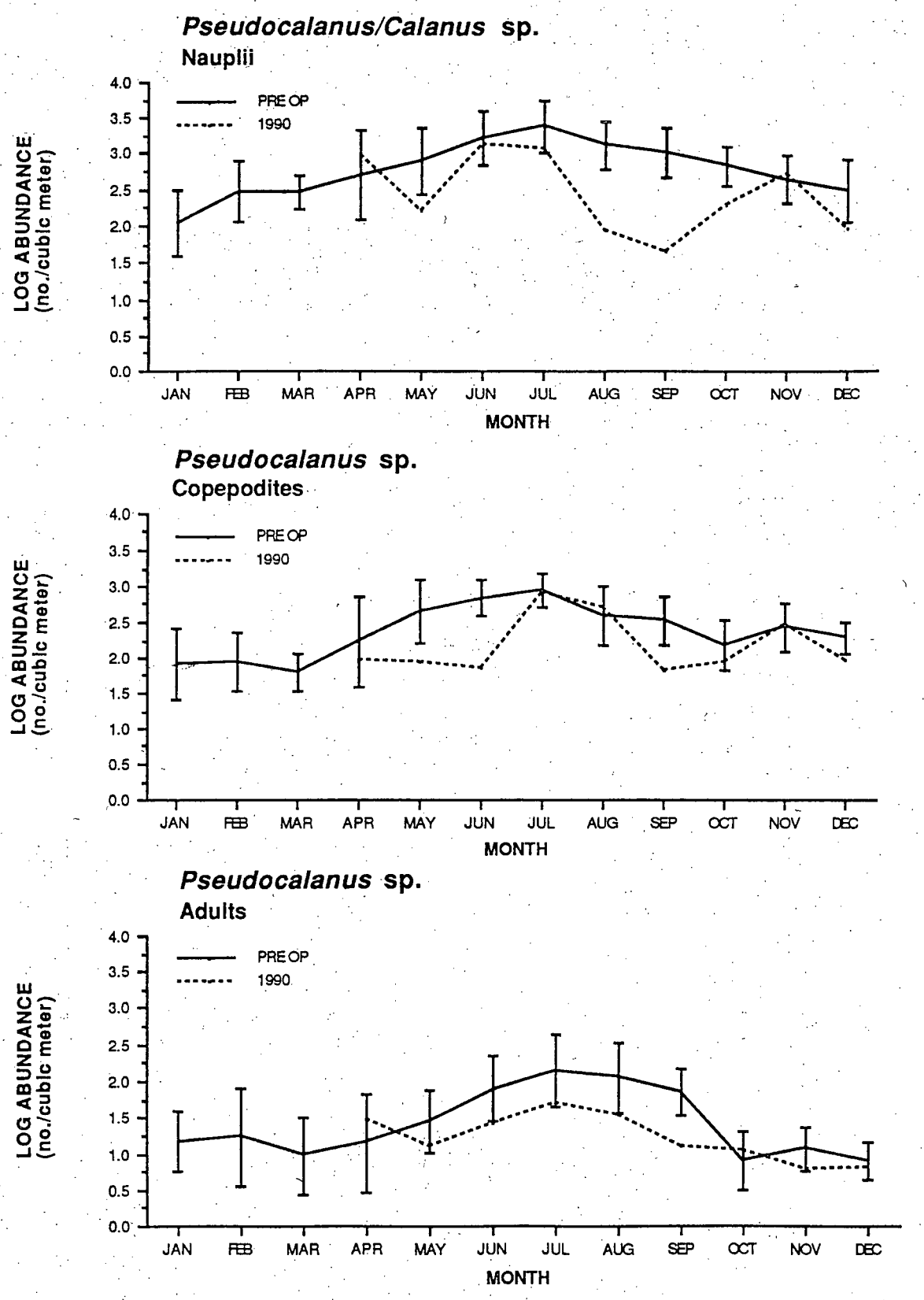


Figure 3.1.3-4. Log (x+1) abundance (no./m^3) of *Pseudocalanus/Calanus* sp. nauplii and *Pseudocalanus* sp. copepodites and adults; monthly means and 95% confidence intervals over all preoperational years (1978-1984 and 1986) and monthly means for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

abundances occurring in mid-summer (Figure 3.1.3-4). Copepodites were generally about one order of magnitude more abundant than the adults. Annual geometric mean abundances of copepodites and adults were also variable during the preoperational years (Table 3.1.3-3). Abundances of both lifestages were at a minimum in 1984 (167 copepods/m^3 and 12 adults/m^3) and at a maximum in 1982 (645 copepodites/m^3 and 73 adults/m^3).

In 1990, the seasonal abundances of *Pseudocalanus/Calanus* sp. nauplii at Station P2 were more variable than during the preoperational years (Figure 3.1.3-4). Values were considerably below average for May, August through October, and December. *Pseudocalanus* sp. copepodite seasonal abundances were also variable during 1990 with values below average in April through, June, September, and December. Adult *Pseudocalanus* sp. followed the same seasonal trend present during the preoperational years. Values were slightly below the mean for May through August, and November, and were much lower than the mean during September. The geometric mean abundances for nauplii and copepodites in 1990 were well below both the means and ranges reported during the preoperational period (Table 3.1.3-3). The 1990 geometric mean for adults was also below the overall mean for the preoperational period but was within the range of individual mean values for that period.

Results of the two-way ANOVA for April through December found temporal differences to be significant for all three lifestages (Table 3.1.3-4, Preop-Op). Although operational densities were lower than preoperational densities, the area and interaction terms were not significant, indicating 1990 densities were generally lower than previous years at all stations. Differences in abundances among years and among months were also significant (Table 3.1.3-4), year (Preop-Op) and month (Year (Preop-Op)), similar to observations made in previous years (NAI 1990b).

During the operational period (August-December), each lifestage of *Pseudocalanus* sp. showed significant differences in the

temporal effects (Table 3.1.3-4, Preop-Op) but no significant difference in the area or among year interaction terms. Month within year densities (month (Year (Preop-Op)) term) were significantly different for *Pseudocalanus/Calanus* nauplii and *Pseudocalanus* copepodite and adult lifestages.

Oithona sp.

All *Oithona* sp. lifestages were present year-round and were the most abundant microzooplankton taxa throughout most of the year during the preoperational period (Table 3.1.3-1). Nauplii and copepodites occurred at similar levels of abundance, while adults were only slightly less abundant (Figure 3.1.3-5). Peak density for nauplii during the preoperational years extended from May through September. Densities were depressed during the winter and early spring, although they varied by only one order of magnitude compared to the peak months. The annual geometric means for nauplii during the preoperational years were highly variable, ranging from 292 nauplii/m^3 in 1984 to 1482 nauplii/m^3 in 1982 (Table 3.1.3-3). During the preoperational period, copepodites maintained high population levels between May and November (Figure 3.1.3-5). Peak abundance was attained in July through September with decreasing values during the winter months. Annual geometric mean abundance at Station P2 ranged from 302 copepodites/m^3 in 1984 to 1798 copepodites/m^3 in 1979, averaging 753 copepodites/m^3 over all preoperational years (Table 3.1.3-3). *Oithona* sp. adults exhibited the same general pattern of seasonality as other lifestages, but maintained a relatively smaller overwintering population than did immature stages. The time of peak abundance for adults during the preoperational period occurred between June and September. The annual geometric means during the preoperational years ranged from 69 adults/m^3 to 330 adults/m^3.

In 1990, *Oithona* sp. nauplii generally exhibited the same seasonal pattern of abundance as during the preoperational period, except abundances were greater than average during June and lower than

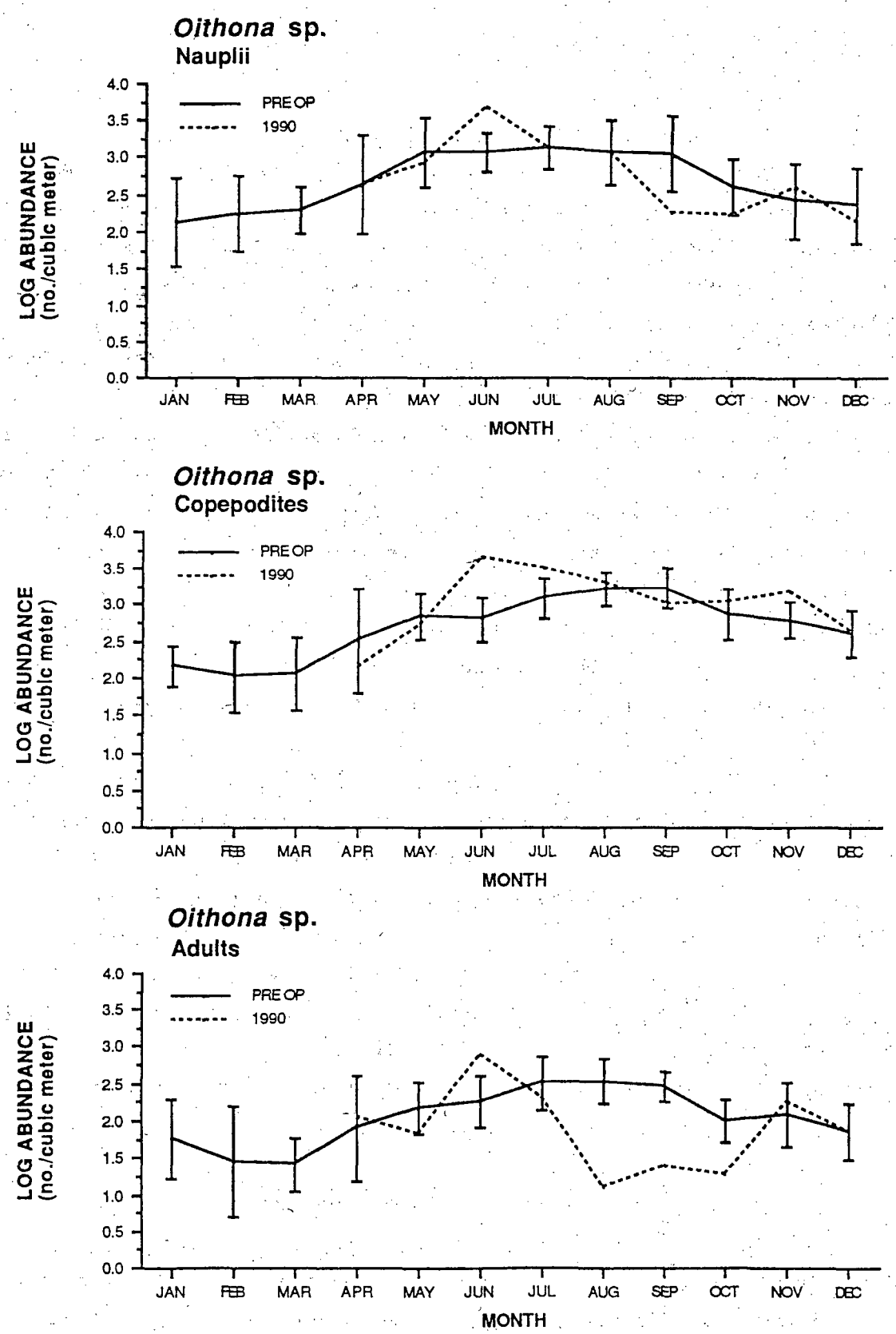


Figure 3.1.3-5. Log (x+1) abundance (no./m^3) of *Oithona* sp. nauplii, copepodites and adults; monthly means and 95% confidence intervals over all preoperational years (1978-1984 and 1986) and monthly means for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

average during September (Figure 3.1.3-5). The annual geometric mean for 1990 at Station P2 was slightly lower than the overall preoperational mean but was within the range of individual mean values recorded during those years (Table 3.1.3-3). *Oithona* sp. copepodites also followed the same pattern of seasonal abundances in 1990 that was evident during the preoperational period. However, abundances for June, July, and November were larger than normal (Figure 3.1.3-5). The geometric mean for copepodites in 1990 was larger than the overall mean for the preoperational period and five of the seven preoperational years (Table 3.1.3-3). Seasonal abundance of *Oithona* sp. adults in 1990 was highly variable, contrasting sharply with preoperational data (Figure 3.1.3-5). Adult abundance was larger than normal for June and much lower than normal for August through October. Geometric mean abundance for 1990 was lower than the mean for all preoperational years but was within the range of individual mean values for those years.

During the April through December period, the results of the two-way ANOVA found temporal differences in the abundances of *Oithona* sp. copepodites and adults to be significant (Table 3.1.3-4, Preop-Op). Area and interaction terms were not significant, indicating that differences in densities in 1990 occurred areawide for these two lifestages. *Oithona* sp. nauplii densities for both temporal and spatial effects and their interactions were not significant. Differences among years and among months were significant for abundances of all three lifestages of *Oithona* sp. during the April through December period. These results indicate highly variable annual and seasonal abundances.

During the period of plant operation (August through December), temporal differences in *Oithona* sp. nauplii and adult densities were significant (Table 3.1.3-4 Preop-Op). Although areawide densities in 1990 were significantly different from the preoperational period, the lack of significance in the area and interaction terms indicate no differences in the nearfield and farfield areas both before and during plant operation. Temporal and spatial effects and their interactions were not significant for *Oithona* sp. copepodites. The seasonal and

annual variability in abundances of all lifestages evident in the April-December period was also apparent in the August-December comparisons (Table 3.1.3-4, year (Preop-Op); month (Year (Preop-Op)).

3.1.4 Bivalve Larvae

3.1.4.1 Community Structure

Temporal Patterns

The bivalve larvae assemblage exhibited strong seasonal patterns that were generally consistent among years and represented seasonal fluctuations in abundance of the dominant taxa. Numerical classification of weekly collections resulted in four distinct seasonal groups (Figures 3.1.4-1, 3.1.4-2). Species composition in all collections from 1990 was similar to that observed in previous years within each time frame (Figure 3.1.4-2).

The spring period (Group 1) encompassed most collections in April and May (Figure 3.1.4-2). Although eight taxa were present at some point in during this period, *Hiatella* sp. dominated (Table 3.1.4-1; Figure 3.1.4-3) contributing 97% of the mean total abundance. Variability in abundance of *Hiatella* sp. coupled with the intermittent occurrence of other taxa resulted in a relatively low within-group similarity (0.44). However, its similarity to other collections was only 0.23, clearly distinct.

The late spring period (Group 2) included most collections from late May through June (Figure 3.1.4-2). The within-group similarity was a moderately high 0.63 (Table 3.1.4-1). The species composition of these collections was most closely related to Groups 3 and 4 (similarity of 0.55). Total abundance of bivalve larvae was higher during these months than at other times during the year, as indicated by the

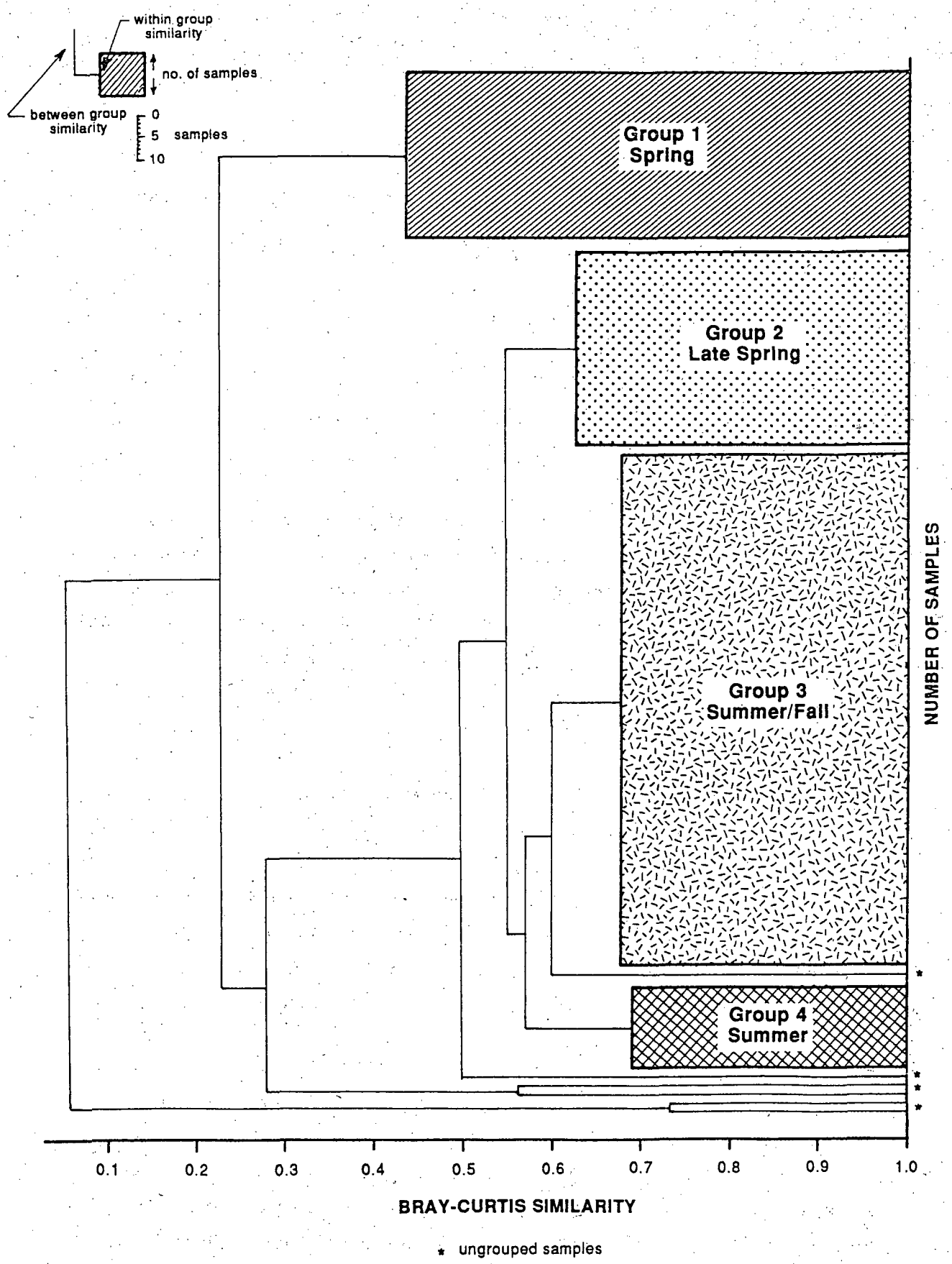
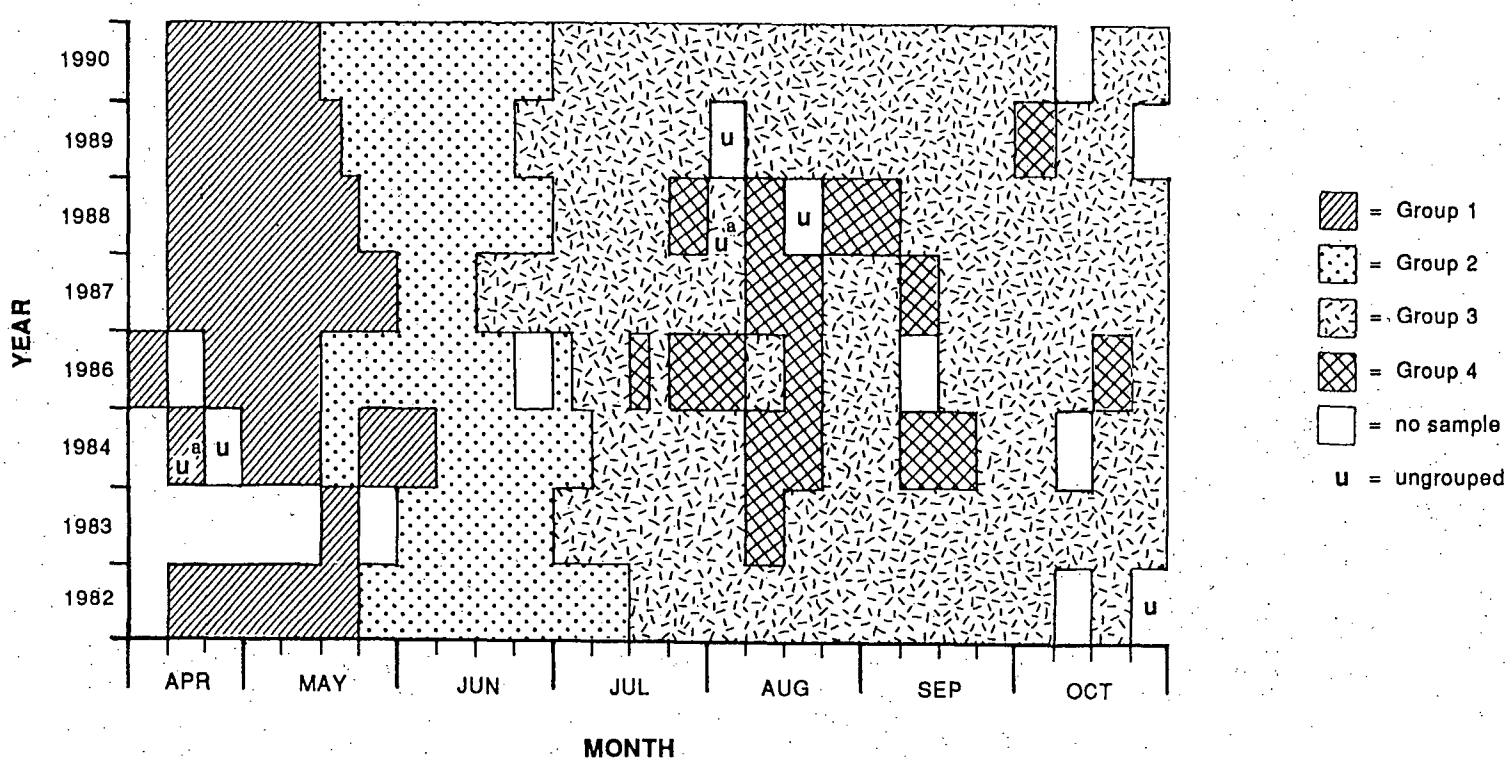


Figure 3.1.4-1. Dendrogram formed by normal classification of weekly (April-October) bivalve larvae log (x+1) transformed abundances (no./m^3) at Seabrook nearfield Station P2, 1982-1984 and 1986-1990. Seabrook Operational Report, 1990.



[a] more than one collection within week

Figure 3.1.4-2. Seasonal groups formed by numerical classification of log (x+1) transformed bivalve collections from nearfield Station P2, 1982-1984 and 1986-1990. Seabrook Operational Report, 1990.

TABLE 3.1.4-1. GEOMETRIC MEAN ABUNDANCE (no./m^3), 95% CONFIDENCE LIMITS OF DOMINANT TAXA, AND NUMBER OF SAMPLES OCCURRING IN SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF BIVALVE LARVAE COLLECTIONS AT NEARFIELD STATION P2, 1982-1984 AND 1986-1989 IN COMPARISON TO 1990. SEABROOK OPERATIONAL REPORT, 1990.

			1982-1984 AND 1986-1989			1990			
GROUP	SPECIES	N	LOWER C.L.	MEAN	UPPER C.L.	N	LOWER C.L.	MEAN	UPPER C.L.
1 Spring (.44/.23)[a]	*Hiatella* sp.	32	39.42	83.7	176.49	5	8.68	54.2	314.48
2 Late Spring (.63/.55)	*Hiatella* sp.	38	1316.26	2021.1	3103.03	6	885.13	2546.7	7323.57
	Mytilus edulis		637.67	1776.2	4944.09		60.30	1130.0	20865.81
	Solenidae		79.89	147.2	270.50		29.13	160.3	862.61
	Heteranomia squamula		14.52	36.5	89.76		2.30	61.7	1189.21
	Mya truncata		14.05	31.2	67.92		143.57	307.0	655.41
	Modiolus modiolus		2.58	7.8	20.54		-0.01	23.2	594.64
3 Summer-Fall (.68/.60)	*Mytilus edulis*	98	463.23	676.1	986.58	17	787.89	2136.4	5790.29
	Heteranomia squamula		440.02	623.5	883.39		857.73	1662.8	3222.54
	Modiolus modiolus		134.68	205.3	312.75		101.56	339.1	1126.88
	Spisula solidissima		33.26	49.2	72.68		56.04	125.5	279.42
	Hiatella sp.		28.55	43.8	67.01		43.11	151.8	528.61
	Solenidae		24.72	35.9	51.84		8.06	25.0	73.60
	Mya arenaria		11.31	17.3	26.13		3.39	11.9	37.12
4 Summer (.69/.57)	*Heteranomia squamula*	18	32.45	53.2	86.69		not represented		
	Mytilus edulis		27.24	45.5	75.71				

[a](within group similarity/between group similarity)

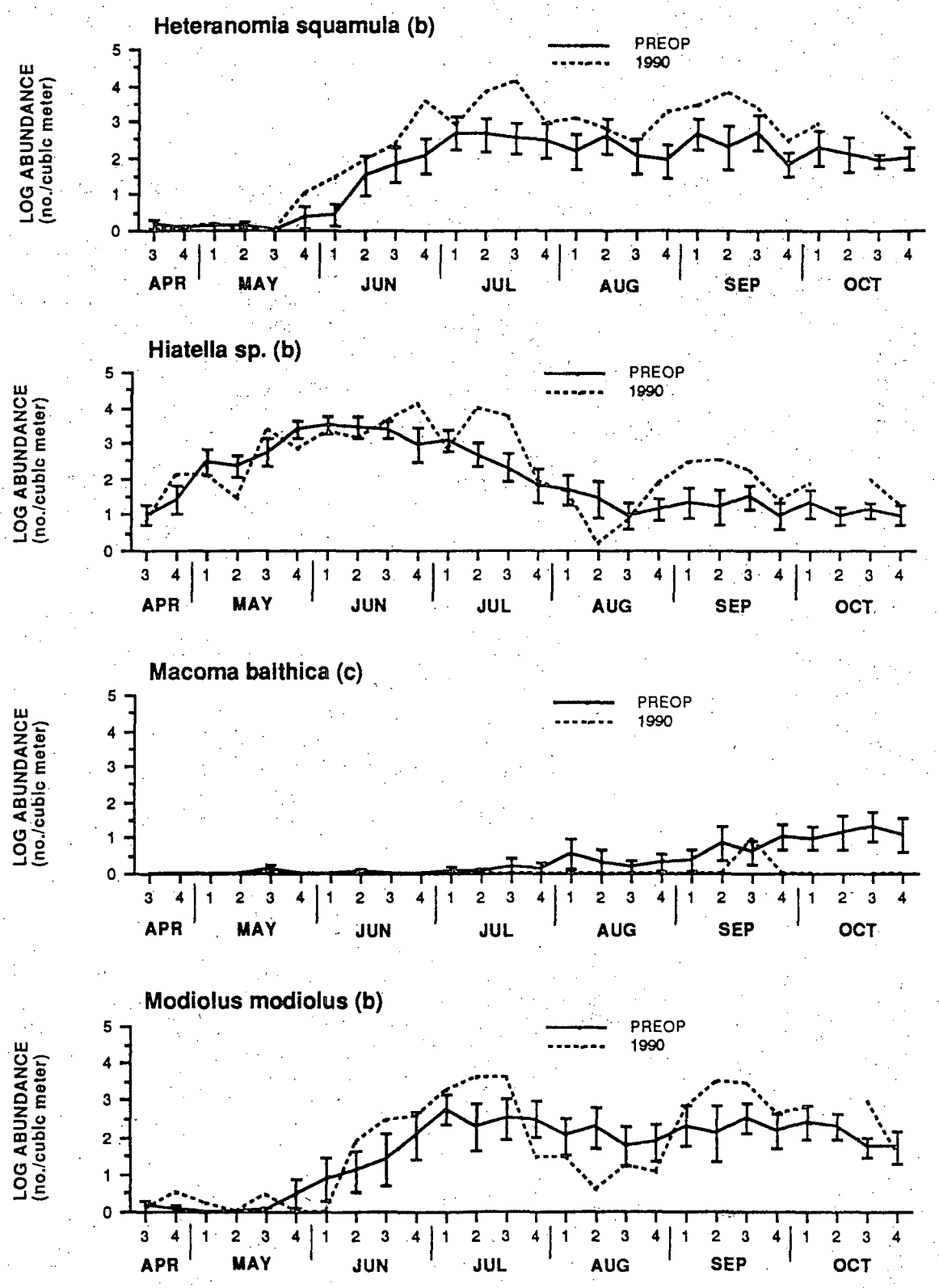


Figure 3.1.4-3. Weekly means log (x+1) abundance (no./m^3) of bivalve larvae; and 95% confidence intervals over all preoperational years 1978-1989 and weekly means for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

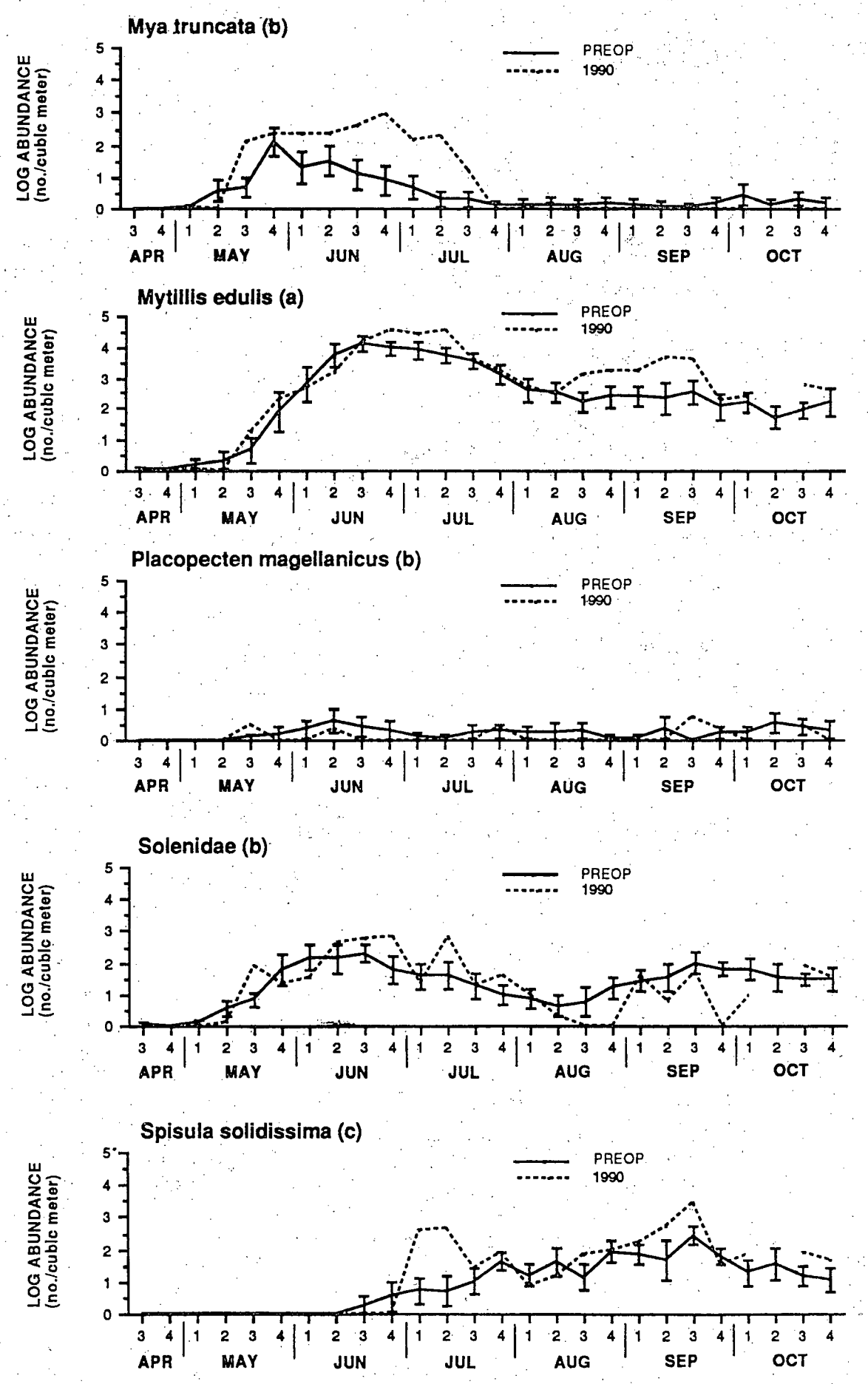


Figure 3.1.4-3. (Continued)

abundance of the dominant taxa. *Hiatella* sp., *Mytilus edulis*, Solenidae and *Mya truncata* abundances all peaked during this period (Figure 3.1.4-3).

Most summer and fall collections were closely linked in Group 3 (within group similarity = 0.68, Table 3.1.4-1). Although mean total abundance was lower than in Group 2, more taxa were numerically dormant. *Heteranomia squamula, Modiolus modiolus* and *Mya arenaria* peaked during this period (Figures 3.1.4-3, and Results Section 3.3.7). All collections after the first week in July 1990 were associated with this group (Figure 3.1.4-2).

A number of summer collections exhibited relatively low abundances of bivalve larvae, particularly during 1984, 1986, 1987 and 1988. These collections were segregated into Group 4 (within group similarity = 0.69; Table 3.1.4-1), and were most closely related to Group 3 (Figure 3.1.4-1). *Heteranomia squamula* and *Mytilus edulis* were the dominant species during this period. No collections from 1990 were included in this group.

Spatial Patterns

In previous years, species composition in the bivalve larvae community has been similar among Stations P1, P2, P5 and P7 (NAI 1990b). Multivariate analysis of variance confirmed there were no significant differences in species composition among stations in 1990 (Table 3.1.4-2). This result was expected due to the combination of hydrographical and biological characteristics present. The magnitude of tidal and longshore currents measured in the area is sufficient to transport a water mass about two nautical miles in one tidal cycle, or 5-15 miles in one day during periods dominated by longshore flow (NAI 1990b). The relatively long planktonic existence (4-6 weeks) of bivalve larvae serves as a dispersal mechanism for these species. Larvae can be transported great distances from the parent population.

TABLE 3.1.4-2. RESULTS OF MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA) COMPARING BIVALVE LARVAE COMMUNITY STRUCTURE AT STATIONS P1, P2, P5 AND P7, APRIL-OCTOBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

NO. OF SPECIES	NO. OF STATIONS	STATISTIC	df	F
11	4	Wilk's Criterion	33,210	1.22 NS
		Pillai's Trace	33,219	1.20 NS
		Hotelling-Lawley Trace	33,209	1.24 NS

The maximum distance between the offshore stations (P2, P5 and P7; Figure 2.1-3) is about five miles; within that distance a water mass could move within a day during periods dominated by longshore flow. Station P1, in Hampton Harbor, would not be directly affected by longshore currents, but it is strongly influenced by tidal currents. Located about 1.5 miles from Stations P2 and P5, P1 is probably subject to essentially the same water masses due to tidal flow in and out of the Harbor except when there is significantly higher freshwater flows from the Blackwater Creek and Taylor River.

Entrainment

Entrainment samples were collected June through October, usually on the same days as the offshore and harbor collections. The entrained community structure was similar to that occurring offshore (Table 3.1.4-3). *Mytilus edulis* and *Heteranomia squamula* were most dominant, together comprising over 55% of the total assemblage at each station. Total abundances were higher in entrainment collections than offshore (Station P2), probably reflecting the tendency of bivalve larvae to concentrate well below the surface.

Entrainment losses were estimated for June through October based on total cooling water system daily flow and the observed bivalve larvae densities in entrained samples (Table 3.1.4-4). Highest entrainment losses were incurred in July, primarily affecting *Mytilus edulis*, *Heteranomia squamula* and *Hiatella* sp. larvae.

3.1.4.2 Selected Species

Mya arenaria

This species is discussed in Section 3.3.7.

TABLE 3.1.4-3. MONTHLY GEOMETRIC MEAN OF DENSITY (NO. PER CUBIC METER) OF BIVALVE LARVAE FROM ENTRAINMENT AND OFFSHORE (P2) COLLECTIONS DURING JUNE-DECEMBER 1990. SEABROOK OPERATIONAL REPORT 1990.

ENTRAINMENT	JUN	JUL	AUG	SEP	OCT
BIVALVIA	306	1006	91	53	39
HETERANOMIA SQUAMULA	934	9312	3063	1784	343
HIATELLA SP.	3950	5093	177	166	48
MACOMA BALTHICA	0	5	0	1	0
MODIOLUS MODIOLUS	976	3657	100	1305	137
MYA ARENARIA	22	12	1	12	39
MYA TRUNCATA	69	845	1	0	6
MYTILUS EDULIS	9241	21632	2044	1130	451
PLACOPECTEN MAGELLANICUS	0	1	0	1	1
SOLENIDAE	410	291	28	3	14
SPISULA SOLIDISSIMA	37	52	41	68	51
TEREDO NAVALIS	0	0	0	0	0

OFFSHORE[a]	JUN	JUL	AUG	SEP	OCT
BIVALVIA	182	373	18	208	101
HETERANOMIA SQUAMULA	452	3753	799	3527	950
HIATELLA SP.	4407	1849	16	263	53
MACOMA BALTHICA	0	0	0	2	0
MODIOLUS MODIOLUS	348	1318	14	1693	227
MYA ARENARIA	32	13	0	114	31
MYA TRUNCATA	480	66	0	0	0
MYTILUS EDULIS	9833	21874	766	3366	587
PLACOPECTEN MAGELLANICUS	1	0	0	1	0
SOLENIDAE	655	181	1	36	79
SPISULA SOLIDISSIMA	0	310	30	668	110
TEREDO NAVALIS	0	0	0	1	0

[a]P2 means based only on dates with a corresponding entrainment collection.

TABLE 3.1.4-4. ESTIMATED NUMBER OF BIVALVE LARVAE (in billions/month) ENTRAINED BY THE COOLING WATER SYSTEM AT SEABROOK STATION DURING JUNE-OCTOBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	JUN	JUL	AUG	SEP	OCT
Mytilus edulis	733.8	2,922.9	178.7	131.3	24.6
Modiolus modiolus	151.8	421.2	19.6	300.1	17.0
Placopecten magellanicus	0	0.4	0	0.2	<0.1
Heteranomia squamula	130.6	915.8	301.0	320.5	23.5
Spisula solidissima	25.0	27.6	4.1	9.9	2.4
Mya arenaria	1.3	2.4	0.1	2.5	1.8
Mya truncata	5.1	243.3	0.2	0.1	0.3
Hiatella sp.	232.4	594.4	24.6	22.5	2.7
Macoma balthica	0	26.4	0	0.1	0
Bivalvia	22.9	114.0	11.0	5.2	2.1
Teredo navalis	0	0	<0.1	0	0
Solenidae	28.7	27.4	3.6	0.8	0.6
TOTAL	1,331.6	5,295.8	543.0	793.2	75.0

Mytilus edulis

Umboned veligers of *Mytilus edulis* were usually present by mid- to late May (Figure 3.1.4-3). Once present, they occurred consistently throughout the sampling program. The protracted presence of larvae was due to recruitment patterns and duration of larval life-stages. Major spawning events in Gulf of Maine mussel populations may be limited to temperatures above 10-12°C (Podniesinski and McAlice 1986). Spawning of *M. edulis* in Long Island Sound was found to be asynchronous both within and among local populations and to occur over a two to three month period (Fell and Balsamo 1985). Spawning of some Long Island Sound mussel populations was also restricted by limited food availability for most of the year, resulting in sporadic spawning events (Newell *et al.* 1982). Therefore it is probable, based on the reproductive behavior of *M. edulis*, that recruitment of larvae to the plankton of New Hampshire coastal waters occurred intermittently throughout much of the sampling program. Recruitment from non-local sources was also probable, as water masses may move large distances over the three to five weeks required for larval development at ambient temperatures (Bayne 1976). Delay of metamorphosis until suitable settlement conditions are encountered can prolong planktonic existence for up to 40 days, depending on temperature (Bayne 1976). These factors suggest that planktonic recruitment to the study area was intermittent and prolonged, and that duration of planktonic life varied over the sampling program as temperature conditions changed.

Highest abundances of *Mytilus edulis* larvae have historically (1976-1989) occurred between early June and early July (Figure 3.1.4-3), although in 1980-1982 and in 1990 abundances in late August, September or October were as high as in early summer (NAI 1981f, 1982a, 1983a, 1990a). Peak abundances ranged from $6 \times 10^3/m^3$ in 1982 to $3.3 \times 10^5/m^3$ in 1979 and 1989 (NAI 1987b, 1990a). The difficulty in assessing the variability in this population is probably compounded by patchiness caused by discontinuous recruitment both spatially and temporally (Bayne 1976; Podniesinski 1986). Collections taken within several days of one

another, even during months of peak abundance, varied by zero to three orders of magnitude (NAI 1981c, 1984a).

Although temporal variability was high, as indicated by significant differences among years (Table 3.1.4-5; Year (Preop-Op)), overall spatial variability was low (Table 3.1.4-5; Area) when tested by ANOVA for both April to October and August to October 1990 collections. The lack of a significant interaction between main effects (Area X Preop-Op) indicated that throughout the 1990 collections, abundance of *Mytilus edulis* larvae in the nearfield during 1990 were not significantly different from those in preoperational years and in the farfield area.

3.1.5 Macrozooplankton

3.1.5.1 Community Structure

Temporal Patterns

The macrozooplankton community is comprised of numerous species that exhibit three basic life history strategies. The holoplankton species, e.g. copepods, are planktonic essentially throughout their entire life cycle. Meroplankton includes species that spend a distinct portion of their lifecycle in the plankton, e.g. larvae of benthic invertebrates. Species that alternate between association with the substrate and rising into the water column on a regular basis are called tychoplankton, e.g. mysids.

Historical analysis (1978-1984 and 1986-1989) of the macrozooplankton assemblage at the nearfield Station P2 showed seasonal changes that were greatly influenced by the population dynamics of the dominant copepods *Centropages typicus* and *Calanus finmarchicus* (NAI 1990b). Other taxa, particularly meroplanktonic species, exerted short-term influences, especially during the spring and summer (NAI 1985b). Because of their lower abundances, seasonal patterns of tychoplanktonic

TABLE 3.1.4-5. RESULTS OF ANALYSIS OF VARIANCE COMPARING NEARFIELD (STATIONS P2 AND P5) AND FARFIELD (STATION P7) WEEKLY *MYTILUS EDULIS* ABUNDANCES[a] DURING PREOPERATIONAL (1978-1989) AND OPERATIONAL[b] (1990) PERIODS. SEABROOK OPERATIONAL REPORT, 1990.

	APRIL-OCTOBER			AUGUST-OCTOBER		
SOURCE OF VARIATION	df	SS	F	df	SS	F
Preop-Op[c]	1	0.14	0.21 NS	1	1.48	2.32 NS
Year (Preop-Op)[d]	6	1.97	0.49 NS	6	10.65	2.79**
Week (Preop-Op X Year)[e]	24	7.09	0.44 NS	24	13.57	0.89 NS
Area[f]	1	0.10	0.14 NS	1	0.04	0.06 NS
Area X Preop-Op[g]	1	0.31	0.47 NS	1	0.08	0.13 NS
Error	492	304.92	--	193	122.86	--

[a]Based on weekly sampling periods
[b]Commercial operation began in August 1990
[c]Preoperational (1978-1989) versus operational period, regardless of area
[d]Year nested within preoperational and operational periods, regardless of area
[e]Week nested within year nested within preoperational and operational periods, regardless of area
[f]Nearfield area = Stations P2 and P5; Farfield area = Station P7, regardless of year or period
[g]Interaction between main effects

NS = Not significant ($p>0.05$)
* = Significant ($0.05 \geq p > 0.01$)
** = Highly significant ($0.01 \geq p \geq 0.001$)
*** = Very highly significant ($0.001 \geq p$)

species, e.g., mysids, amphipods and cumaceans, were not well documented by numerical classification of the entire macrozooplankton assemblage. To more clearly identify seasonal patterns of this valuable finfish food resource, the tychoplankton was analyzed separately from the mero- and holoplankton.

In the holo- and meroplankton assemblage there were four major seasonal groups (Figures 3.1.5-1 and 3.1.5-2) that encompassed the same time frame in most years (Groups 2, 4, 5 and 6). Two smaller groups (Groups 1 and 3) reflected occasional differences from the predominant patterns of species composition. The seasonal groups were distinct; within-group similarities ranged from 0.56 to 0.78 and between-group similarities ranged from 0.43 to 0.68 (Figure 3.1.5-1; Table 3.1.5-1).

Early months in 1978 and 1979 exhibited similar species composition, forming the small winter group, Group 1. Dominated by copepods, abundances in this group were low (Table 3.1.5-1). During most years the holoplanktonic and meroplanktonic constituents were similar in February, March and April, forming winter Group 2 (Figure 3.1.5-2). Cirripedia larvae predominated, coinciding with the onset of vernal warming and initiation of thermocline formation (Figure 3.1.1-2). Copepods, particularly *Calanus finmarchicus*, *Pseudocalanus* sp. and *Centropages typicus* were abundant, as was the chaetognath *Sagitta elegans*. In 1990, March and April collections were associated with Group 2.

April has been shown to be a transitional period in the macrozooplankton, perhaps due to the combined effects of seasonal warming and highly variable freshwater influence (Section 3.1.1). Community structure is not highly predictable as it has varied over the years. In most years, including 1990, it resembled the winter assemblage defining Group 2. In several years, the number of dominant taxa was smaller than in Group 2 although total abundances were higher. Spring Group 3 encompassed only March and April in several years (Figure 3.1.5-2). During these periods *Calanus finmarchicus* and Cirripedia

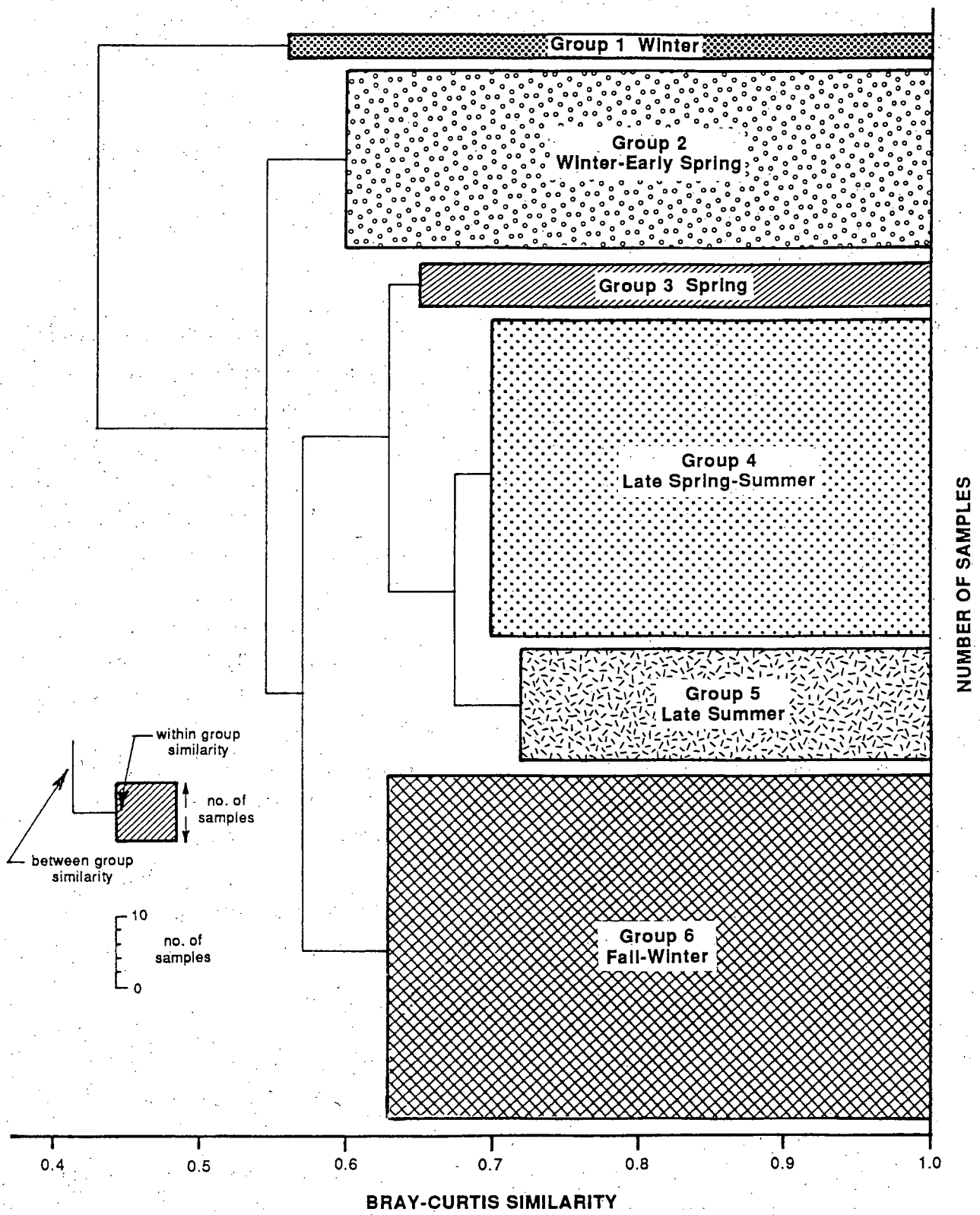


Figure 3.1.5-1. Dendrogram formed by numerical classification of collections of holo- and meroplanktonic species of macrozooplankton monthly mean log (x+1) transformed abundances (no./1000 m^3) at nearfield Station P2, 1978-1984 and 1986-1990. Seabrook Operational Report, 1990.

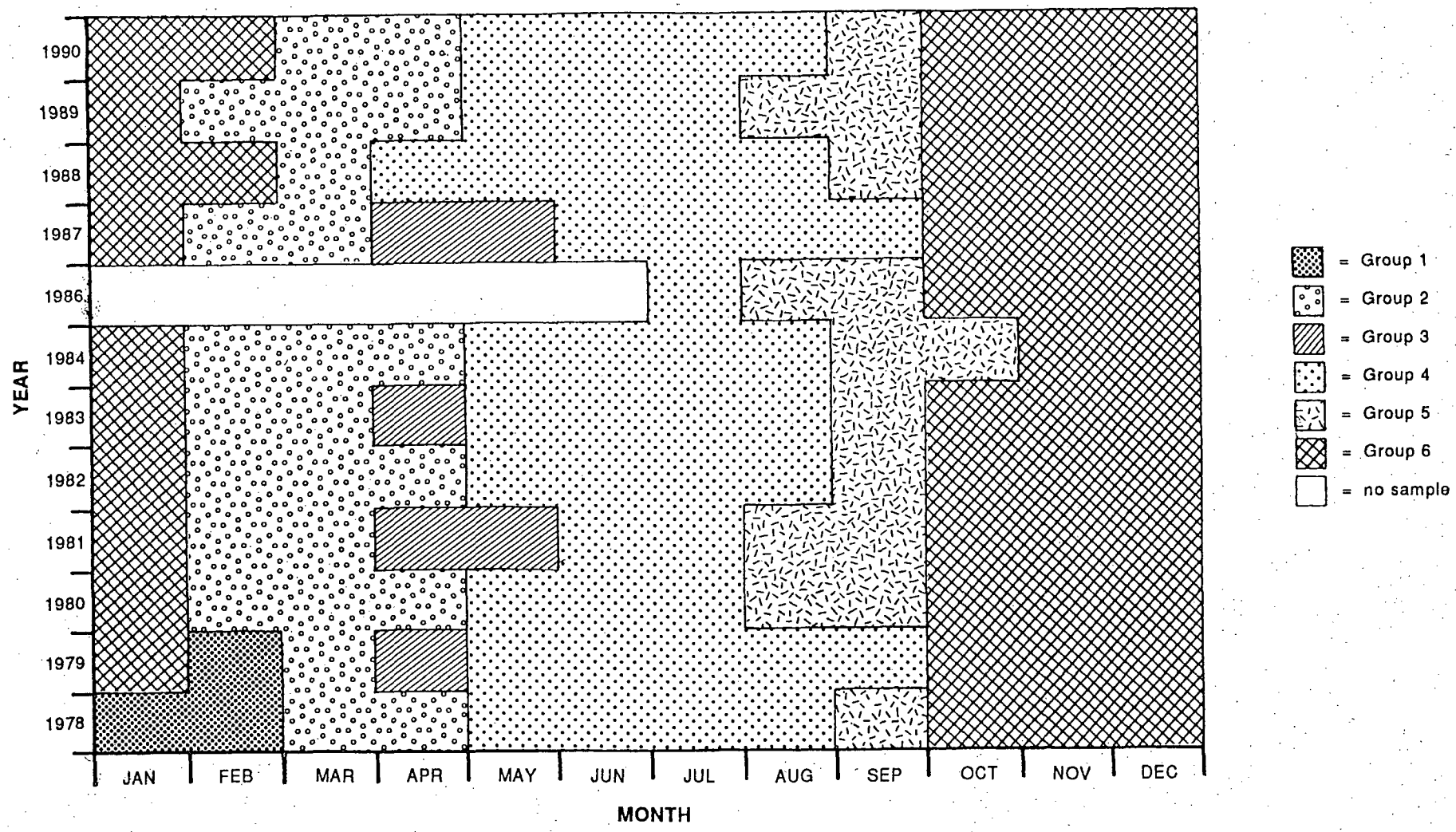


Figure 3.1.5-2. Seasonal groups formed by numerical classification of log (x+1) transformed holo- and meroplankton abundances (monthly mean) from macrozooplankton collections at nearfield Station P2, 1978-1984 and 1986-1990. Seabrook Operational Report, 1990.

TABLE 3.1.5-1. GEOMETRIC MEAN ABUNDANCE (No./1000 m^3) AND 95% CONFIDENCE LIMITS OF DOMINANT[a] HOLO- AND MEROPLANKTONIC TAXA OCCURRING IN SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF MACROZOOPLANKTON COLLECTIONS (MONTHLY MEANS) AT NEARFIELD STATION P2, 1978-1984 AND 1986-1990. SEABROOK OPERATIONAL REPORT, 1990.

		PREOPERATIONAL YEARS (1978-1984;1986-1989)				OPERATIONAL YEARS (1990)	
GROUP	SPECIES	N	LOWER C.L.	$\bar{X}$	UPPER C.L.	N	$\bar{X}$
1 Winter (0.56/0.43)	Calanus finmarchicus	3	11	793	50,601	0	
	Centropages typicus		35	493	6,875		
	Tortanus discaudatus		<1	307	74,182		
	Pseudocalanus sp.		62	295	1,398		
	Sagitta elegans		-1	224	13,078,085		
2 Winter-Early Spring (0.60/0.55)	Cirripedia	22	3,502	11,398	37,090	2	134,378
	Calanus finmarchicus		1,859	3,673	7,257		7,759
	Pseudocalanus sp.		1,757	3,345	6,366		6,084
	Centropages typicus		449	1,049	2,448		396
	Sagitta elegans		345	784	1,780		2,707
	Temora longicornis		126	389	1,201		16,134
	Evadne sp.		10	34	116		13,207
3 Spring (0.65/0.63)	Calanus finmarchicus	6	25,387	69,290	189,114	0	
	Cirripedia		830	25,656	791,768		
	Oikopleura sp.		496	6,079	74,403		
	Evadne sp.		1,485	5,279	18,762		
4 Late Spring-Summer (0.70-0.68)	Calanus finmarchicus	39	68,471	98,477	141,632	4	135,190
	Cancer sp. larvae		10,882	22,329	45,816		7,771
	Eualus pusiolus		7,767	12,080	18,788		6,321
	Temora longicornis		3,862	6,134	9,743		15,745
	Centropages typicus		1,502	4,999	16,633		11,046
	Crangon septemspinosa		3,242	4,694	6,797		1,467
	Pseudocalanus sp.		2,841	4,054	5,785		4,354
	Meganyctiphanes norvegica		813	2,317	6,602		35,130
	Metridia sp.		1,186	2,522	5,363		12,088
5 Late Summer (0.72/0.68)	Centropages typicus	14	77,467	163,246	344,008	1	1,377,271
	Calanus finmarchicus		28,929	62,761	136,155		3,152
	Cancer sp. larvae		6,063	15,199	38,098		18,561
	Crangon septemspinosa		5,907	9,807	16,279		4,152
	Centropages sp. copepodites		720	3,899	21,092		65,081
6 Fall-Winter (0.78/0.64)	Centropages typicus	42	14,079	26,262	48,989	5	2,036
	Centropages sp. copepodites		668	1,503	3,379		161
	Centropages hamatus		456	1,102	2,662		335
	Temora longicornis		478	1,034	2,230		1,929
	Calanus finmarchicus		628	996	1,579		325
	Sagitta elegans		443	751	1,274		1,104
	Pseudocalanus sp.		395	749	1,421		66
	Oikopleura sp.		23	59	148		540
	Tortanus discaudatus		268	561	1,169		276
	Evadne sp.		14	35	86		155

[a]dominant taxa are those whose abundance is 2% of the group geometric mean in either the preoperational or the operational years

larvae were the overwhelming dominants (Table 3.1.5-1). The larvacean *Oikopleura* sp. and the cladoceran *Evadne* sp. were also abundant (Table 3.1.5-1). April 1988 was associated with late spring-summer Group 4.

The holoplankton and meroplankton community structure was similar in most years from May through August (Group 4). Many species achieved high abundances (Table 3.1.5-1). Larvae of crustaceans (e.g. *Cancer* sp., *Eualus pusiolus* and *Crangon septemspinosa*) and euphausiids (*Meganyctiphanes norvegica*) were generally abundant. The copepods *Calanus finmarchicus, Temora longicornis, Pseudocalanus* sp. and *Metridia* sp. typically reached their highest abundances during this part of the year. May through August collections from 1990 were similar to this group.

September was a distinct period (Group 5) in most years (Figure 3.1.5-2). Generally, September marks the period of highest bottom temperature and the beginning of the breakdown in the thermal stratification (Figure 3.1.1-3). *Centropages typicus* reached its annual peak abundance during this period. Copepodite densities of this genus also peaked. Abundances of *Calanus finmarchicus* and *Cancer* sp. larvae were similar to the previous summer months (Table 3.1.5-1). *Crangon septemspinosa*, predominantly immature stages, typically peaked in abundance in September. Species composition in September 1990 was similar to other years comprising Group 5, although abundance of *Calanus finmarchicus* was unusually low.

With the reduction of spawning activity as coastal waters cooled in the fall (Section 3.1.1), meroplanktonic species became less predominant components of the macrozooplankton assemblage (Table 3.1.5-1). Total abundances declined despite the continued presence of most species as dominant taxa. This assemblage (Group 6) characterized the period from October through January of most years (Figures 3.1.5-1 and 3.1.5-2). *Centropages typicus* continued to dominate, exceeding the abundance of other taxa by an order of magnitude. *Centropages* sp. copepodites, *Centropages hamatus, Temora longicornis* and *Calanus*

finmarchicus occurred as secondary dominants. January, February and October through December 1990 collections were similar to the Group 6 assemblage, although *Oikopleura* sp. was unusually abundant in the 1990 collections (Table 3.1.5-1).

In summary, the copepods *Calanus finmarchicus* and *Centropages weretypicus* were consistently among the dominants of the seasonal groups formed by numerical classification, *C. finmarchicus* usually ranking first or second in abundance. Many other species exhibited high abundances seasonally, but were generally limited to dominance during one or two seasonal groups (Table 3.1.5-1). Seasonal patterns of abundance and species composition in 1990 were similar to previous years.

Although seasonality was evident in the assemblage of tychoplanktonic species (Figures 3.1.5-3 and 3.1.5-4), separation of seasonal groups was less distinct than in the holoplankton-meroplankton assemblage. Between group similarities were close to within group similarities and each group was added successively with lower similarities Figure 3.1.5-3). This may result from the fact that twenty of the twenty-two species used in the analysis were present essentially year-round occurring in each of the four major seasonal groups (Groups 1, 2, 7 and 8; Table 3.1.5-2). Total abundances were two or more orders of magnitude lower than holo- and meroplankton abundances. Two species (*Neomysis americana* and *Pontogeneia inermis*) were each ranked among the three most abundant species in eight out of nine groups. Distinctions between groups of tychoplankton assemblages were generally based on moderate changes in abundances rather than dramatic changes in species composition.

Four major seasonal groups encompassed most of the collections (Figures 3.1.5-3 and 3.1.5-4). Winter (January through March) months were generally similar (Group 1). *Neomysis americana*, *Diastylis* sp. and *Pontogeneia inermis* predominated in both preoperational and 1990 collections (Table 3.1.5-2).

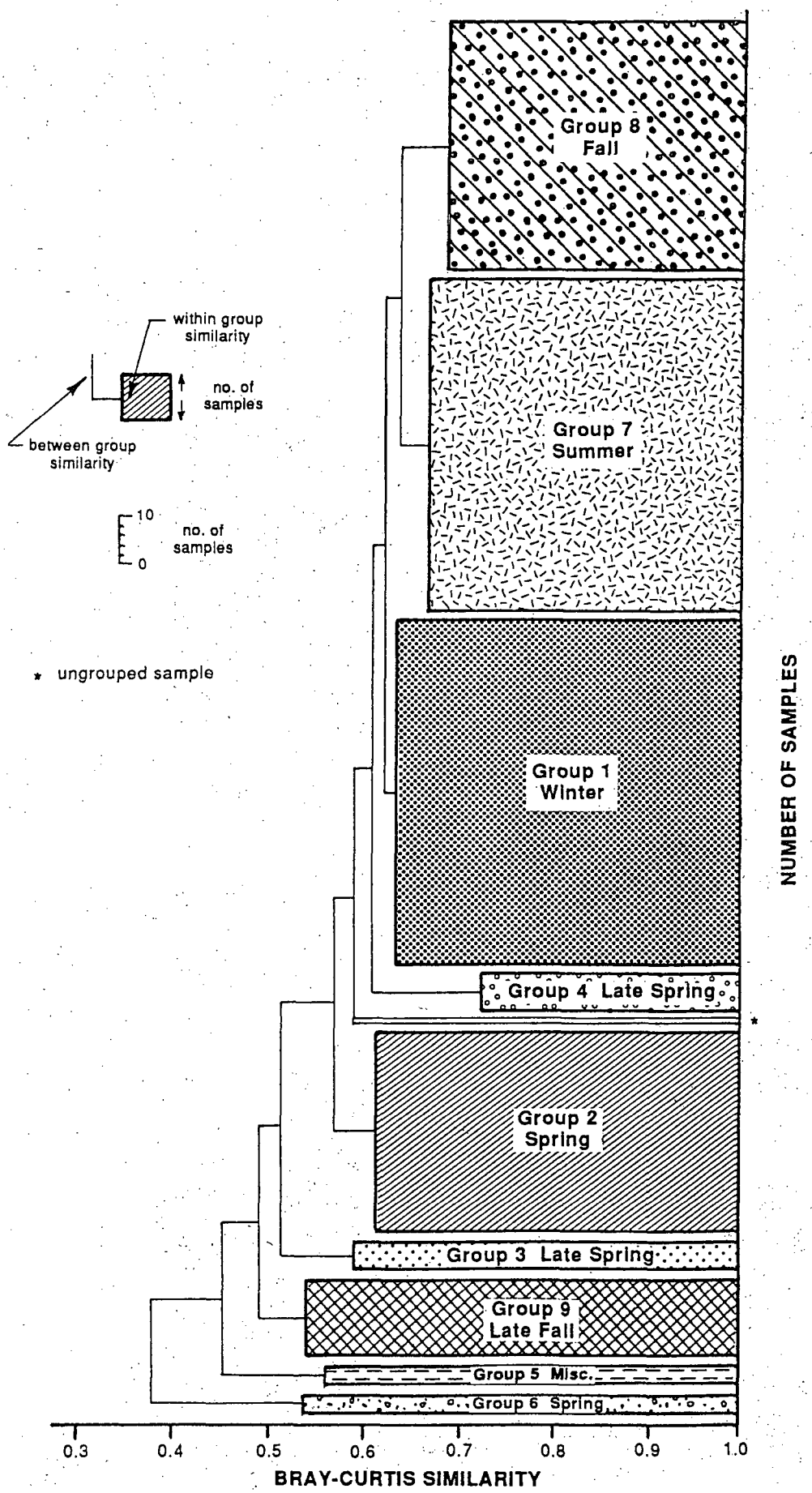


Figure 3.1.5-3. Dendrogram formed by numerical classification of collections of monthly mean log (x+1) transformed tychoplankton abundances (no./1000 m^3) from macrozooplankton collections at nearfield Station P2, 1978-1984 and 1986-1990. Seabrook Operational Report, 1990.

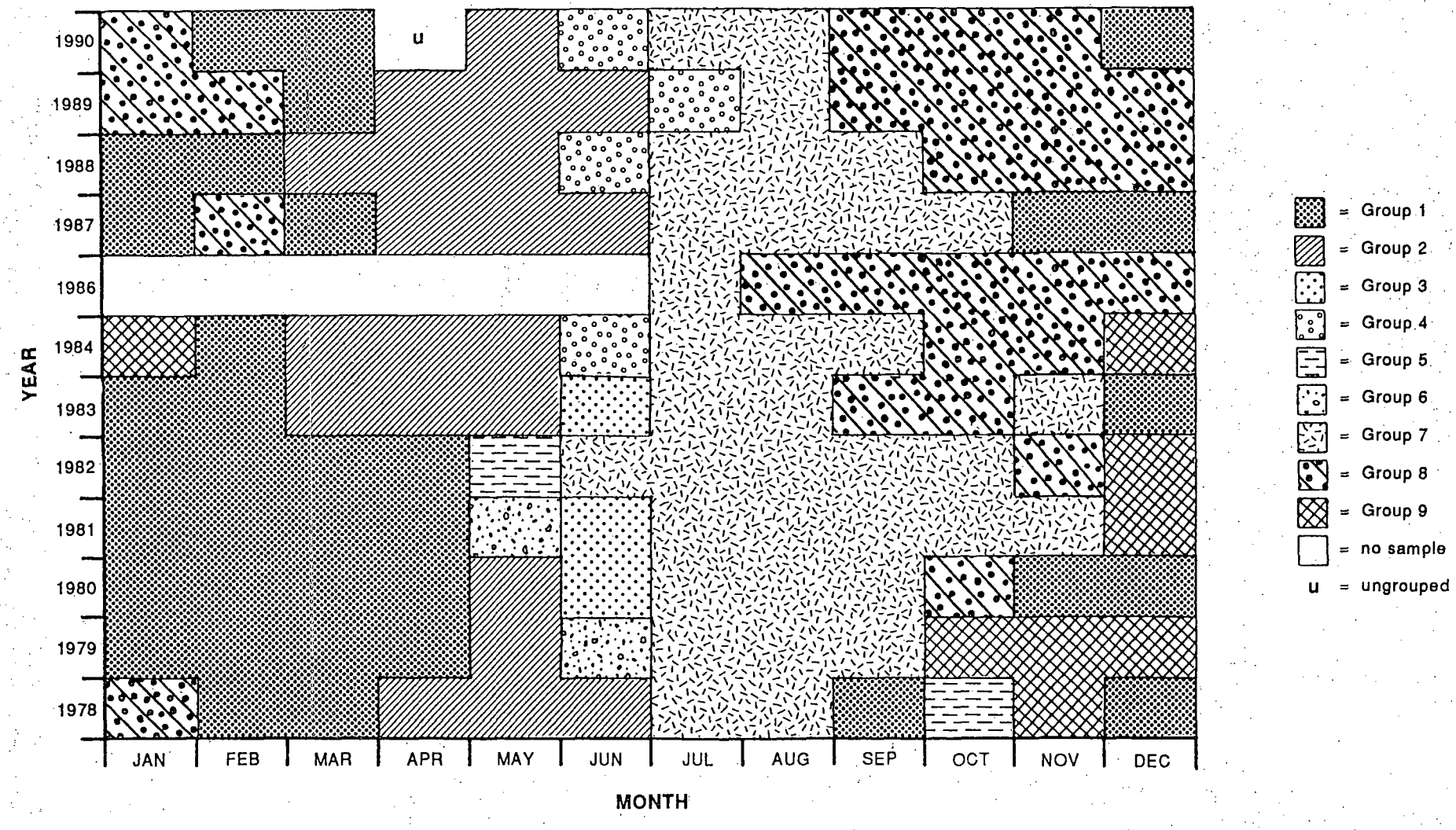


Figure 3.1.5-4. Seasonal groups formed by numerical classification of log (x+1) transformed tychoplankton abundances (monthly mean) from macrozooplankton collections at nearfield Station P2, 1978-1984 and 1986-1990. Seabrook Operational Report, 1990.

TABLE 3.1.5-2. GEOMETRIC MEAN ABUNDANCE (No./1000 m^3) AND 95% CONFIDENCE LIMITS OF DOMINANT[a] TYCHOPLANKTONIC TAXA OCCURRING IN SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF MACROZOOPLANKTON COLLECTIONS (MONTHLY MEANS) AT NEARFIELD STATION P2, 1978-1984 AND 1986-1990. SEABROOK OPERATIONAL REPORT, 1990.

		PREOPERATIONAL YEARS (1978-1984;1986-1989)				OPERATIONAL YEARS (1990)	
GROUP	SPECIES	N	LOWER C.L.	$\bar{X}$	UPPER C.L.	N	$\bar{X}$
1 Winter (0.64/0.61)	Neomysis americana	33	305	655	1,402	3	2,299
	Diastylis sp.		125	197	310		85
	Pontogeneia inermis		75	114	174		65
	Oedicerotidae		28	44	67		52
	Mysis mixta		10	37	133		40
	Pseudoleptocuma minor		23	35	52		22
2 Spring (0.61/0.59)	Mysis mixta	20	205	630	1,936	1	8,204
	Neomysis americana		75	152	308		129
	Pontogeneia inermis		41	71	120		159
	Diastylis sp.		15	27	47		88
	Harpacticoida		9	21	44		9
3 Late Spring (0.59/0.51)	Oedicerotidae	3	1	73	3,082	0	
	Pontogeneia inermis		-1	39	6,262		
	Neomysis americana		2	18	110		
	Diastylis sp.		<1	14	202		
	Ischyrocerus anguipes		1	12	88		
	Gammarus lawrencianus		-1	7	155		
4 Late Spring (0.72-0.61)	Oedicerotidae	3	30	3512	397,640	1	432
	Neomysis americana		27	594	12,561		226
	Pontogeneia inermis		19	471	11,072		837
	Gammarus lawrencianus		-1	<1	4		98
5 Miscellaneous (0.56/0.45)	Hyperiidae	2	-1	216	1,170,067	0	
	Pontogeneia inermis		-1	50	3,242,874		
	Neomysis americana		-1	16	305,023		
	Jassa marmorata		-1	8	6,408		
6 Spring (0.53/0.38)	Pontogeneia inermis	2	8	23	59	0	
	Ishyrocerus anguipes		-1	19	16,392		
	Dulichia sp.		-1	5	31,107		
	Harpacticoida		-1	4	510,993		
	Diastylis sp.		-1	4	5.0×10^9		
	Gammarus lawrencianus		<0	1	4		
7 Summer (0.67/0.64)	Neomysis americana	33	91	168	311	2	114
	Pontogeneia inermis		73	95	123		398
	Diastylis sp.		64	94	137		87
	Oedicerotidae		44	90	182		73
	Harpacticoida		35	58	99		234
	Unciola irrorata		7	12	20		30
8 Fall (0.69/0.64)	Neomysis americana	22	2,651	5,133	9,936	4	3,647
	Diastylis sp.		147	234	373		233
	Pontogeneia inermis		120	204	345		160
	Pseudoleptocuma minor		92	149	239		74
9 Late Fall (0.54/0.51)	Neomysis americana	8	101	362	1,293	0	
	Diastylis sp.		6	13	28		
	Hyperiidae		1	8	52		

[a]dominant taxa are those whose abundance is ≥ 2% of the group geometric mean in either the preoperational or the operational years

The mysid *Mysis mixta* has typically been most abundant in the spring in coastal waters of New Hampshire (Grabe and Hatch 1982) prior to its offshore migration. *M. mixta* dominated in the spring (Group 2) while *Neomysis americana* and *Pontogeneia inermis* continued to occur as subdominants (Table 3.1.5-2). Although the April 1990 collections were not clearly associated with a seasonal group this may be the result of unusually high abundance of *Mysis mixta* ($2.4 \times 10^5/1000m^3$) and *Gammarus lawrencianus* ($4.3 \times 10^4/1000m^3$) (NAI 1991) rather than the absence or reduced abundance of key species.

During the preoperational period, several other assemblages (representing Groups 3, 4, 5 and 6) have characterized the late spring period. *Mysis mixta* was not among the dominants in any of these groups, although *Neomysis americana* or *Pontogeneia inermis* was (Table 3.1.5-2). The amphipod family Oedicerotidae dominated Groups 3 and 4. Subdominants included other amphipod species, generally atypical of the major seasonal groups. The June 1990 assemblage was most similar to Group 4 (Figure 3.1.5-4).

July, August and generally September were similar (Group 7) among years (Figure 3.1.5-4). *Neomysis americana, Pontogeneia inermis* and *Diastylis* sp. were again dominants (Table 3.1.5-2). The occurrence of Oedicerotidae, harpacticoid copepods and the amphipod *Unciola irrorata* as subdominants distinguished this group. The tychoplankton assemblage occurring in July and August 1990 was similar to preoperational collections included in this group.

Neomysis americana generally reached its highest abundances in the fall (Table 3.1.5-2), distinguishing Group 8. Fall months of most years, with the exception of 1978, 1979, 1981 and 1987, were represented in Group 8. Abundances of *N. americana* have been found to be significantly different among years (Section 3.1.3.2), with 1978, 1979 and 1987 exhibiting lower abundances than other years (NAI 1990b). Overall

abundances, as well as *N. americana* abundances, were low in some years, distinguishing a second fall assemblage (Group 9) of tychoplankters (Table 3.1.5-2).

In summary, seasonal groups 1,2, 7 and 8 encompassed more than 85% of the preoperational collections and 83% of 1990 collections. Most tychoplanktonic species were present year-round. *Neomysis americana, Diastylis* sp. and *Pontogeneia inermis* were frequently among the dominants. Moderate changes in abundance of these taxa, rather than dramatic changes in species composition distinguished groups in general, with the exception of spring Group 2 when *Mysis mixta* dominated. Most collections in 1990 were similar to the major seasonal groups. April 1990 was unusual in not showing high similarity to other spring collections but this may have been due to unusually high abundances of *Mysis mixta* and *Gammarus lawrencianus*. June 1990 was similar to a small group that encompassed several historical collections.

Spatial Patterns

The spatial distribution of most holo- and meroplanktonic species in the study area is governed primarily by local currents. Hydrographic studies of temperature and salinity have shown that nearfield Station P2, and farfield Station P7 are exposed to the same water mass (NAI 1985b). Furthermore, bivalve larvae studies suggest that areas at similar depths and distances from shore (such as P2 and P5) have similar species composition (NAI 1977a). Thus no spatial differences in the mero- or holoplanktonic macrozooplankton abundances, percent composition, or rank would be expected among Stations P2, P5 or P7. This has previously been confirmed in examinations of the annual percent composition, percent frequency and rank dominance scores (RDS) of dominant species with nonparametric tests (NAI 1985b, 1989b).

A multivariate analysis of variance (MANOVA) comparing semi-monthly species composition, including mero-, holo- and tychoplankton

taxa indicated that there were some significant species differences among Stations P2, P5 and P7 in 1990 (Table 3.1.5-3). ANOVAs comparing abundances of individual species were utilized to identify where the differences in community structure occurred. The ANOVAs revealed no significant spatial differences in any holoplanktonic or meroplanktonic species. However, of the nine tychoplanktonic species tested, eight exhibited distinct spatial patterns of distribution (Table 3.1.5-3). Generally, abundances were similar at Stations P2 and P5 and were significantly lower at Station P7. These differences were apparently large enough to influence the results of the MANOVA.

Tychoplanktonic species are often strongly associated with particular substrate types. Substrate type and complexity, along with proximity to Hampton-Seabrook estuary, may account for some of the differences observed among tychoplankters. Historically, *Neomysis americana*, *Pontogeneia inermis*, and *Diastylis* sp. have had higher abundances at P2 where substrate is sand and cobble than at P7 where the substrate is mainly sand (NAI 1985b, 1988b, 1989b). At Station P5, where substrate is largely ledge outcrop and cobble, densities of *Diastylis* sp. have been significantly lower than at P2 (NAI 1988b, 1989b). Amphipods in the family Oedicerotidae continued to be more abundant at Stations P2 and P5 than P7 (Table 3.1.5-3; NAI 1988b, 1989b). Of the tychoplanktonic species tested, only *Mysis mixta* did not differ in abundance among stations. This may be attributable to the extreme seasonality (complete absence during much of the year) of this species, overriding the effects of any substrate preference.

MANOVA was not conducted on the August-December operational period in 1990. To properly evaluate community structure it is important to include all dominant taxa. Unfortunately, the constraints of the MANOVA require that the number of samples tested be greater than the number of taxa. Because of the complexity of the macrozooplankton assemblage it was not realistic to reduce the species tested to meet this requirement. However, abundance patterns of the selected species were individually tested using analysis of variance (Section 3.1.5.2).

TABLE 3.1.5-3. RESULTS OF MULTIVARIATE ANALYSIS OF VARIANCE COMPARING MACROZOOPLANKTON COMMUNITY STRUCTURE AT STATIONS P2, P5 AND P7 IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

MULTIVARIATE (MANOVA) TESTS

NUMBER OF TAXA	NUMBER OF STATIONS	STATISTIC	df	F
46	3	Wilks' criterion	92,48	2.30***
		Pillai's trace	92,50	2.22**
		Hotelling-Lawley trace	92,46	2.38***

TAXA SHOWING SPATIAL DIFFERENCES[a]	MULTIPLE COMPARISON[b]
Harpacticoida	P2 P5 P7
Diastylis sp.	P2 P5 P7
Pseudoleptocuma minor	P2 P5 P7
Gammarus lawrencianus	P2 P5 P7
Oedicerotidae	P2 P5 P7
Pontogeneia inermis	P2 P5 P7
Unciola irrorata	P2 P5 P7
Neomysis americana	P2 P5 P7

[a]based on one-way analysis of variance
[b]stations listed in order of decreasing abundance; stations connected by line were not significantly different from each other.

NS = Not significant
* = Significant at 0.05≥p>0.01
** = Highly significant at 0.01≥p>0.001
*** = Very highly significant at 0.001≥p

3.1.5.2 Selected Species

Calanus finmarchicus

Over the length of this study (1978-1984, 1987-1990) *Calanus finmarchicus* has been a dominant species in the macrozooplankton assemblage (Table 3.1.5-1). Historically, although both lifestages usually occurred yearround, copepodites exhibited greater abundances than adults, a trend which continued in 1990 (Table 3.1.5-4). The major peak in copepodite abundance usually occurred April through September. Low abundances of copepodites occurred during winter (Figure 3.1.5-5). Analysis of variance confirmed a strong seasonality in copepodite abundance (Table 3.1.5-5; Month (Year (Preop-Op))). In 1990 copepodites exhibited typical abundances during March through July but midwinter and late summer-fall (August through November) abundances were substantially lower than the historical average, as indicated by a significant Preop-Op term (Figure 3.1.5-5; Table 3.1.5-5). Although this same pattern of relatively low summer and fall abundances was observed in 1989, mean abundance in 1989 was not significantly different than earlier years (NAI 1990b). The annual abundance of copepodites in 1990 was lower than any previously reported value (Table 3.1.5-4), contributing to a significant difference among years (Table 3.1.5-5; Year (Preop-Op)) and between 1990 and the preoperational years (Preop-Op).

Calanus finmarchicus adults tended to peak in the summer months (June through September, Figure 3.1.5-5), declining to lowest abundances in November and December. The general of the seasonal pattern was confirmed with analysis of variance which showed significant differences among months (Table 3.1.5-5). Abundances of adults in 1990 were below the confidence limits of the preoperational mean during April through July as well as September and October (Figure 3.1.5-5), resulting in a significantly lower annual abundance (Tables 3.1.5-4,5). In 1989, monthly abundances of adults had been unusually low in September through November but at typical levels the rest of the year. A more

TABLE 3.1.5-4. ANNUAL GEOMETRIC MEAN ABUNDANCE (No./1000 m^3) AND UPPER AND LOWER 95% CONFIDENCE LIMITS OF SELECTED SPECIES OF MACROZOOPLANKTON AT SEABROOK NEARFIELD STATION P2 DURING PREOPERATIONAL YEARS (1978-1984 AND 1987-1989)[a] AND GEOMETRIC MEAN ABUNDANCE IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

	MEAN VALUES										PREOPERATIONAL YEARS			1990
SPECIES/LIFESTAGES	1978	1979	1980	1981	1982	1983	1984	1987	1988	1989	LCL	$\bar{x}$	UCL	$\bar{x}$
Calanus finmarchicus copepodites	8,999	6,614	19,753	13,159	4,756	12,634	8,819	8,555	6,479	5,396	6,344	8,689	11,900	3,994
Calanus finmarchicus adults	767	129	338	116	186	555	518	160	58	96	115	213	392	35
Carcinus maenas larvae	41	22	42	40	40	93	64	62	56	44	36	47	62	65
Crangon septemspinosa Zoeae and postlarvae	404	342	152	157	425	547	319	360	474	345	241	328	446	203
Neomysis americana all lifestages	154	40	252	400	651	494	758	258	220	1,835	159	332	693	972

[a]1986 sampling took place only from July-December and this is not included in annual $\bar{X}$ computation.

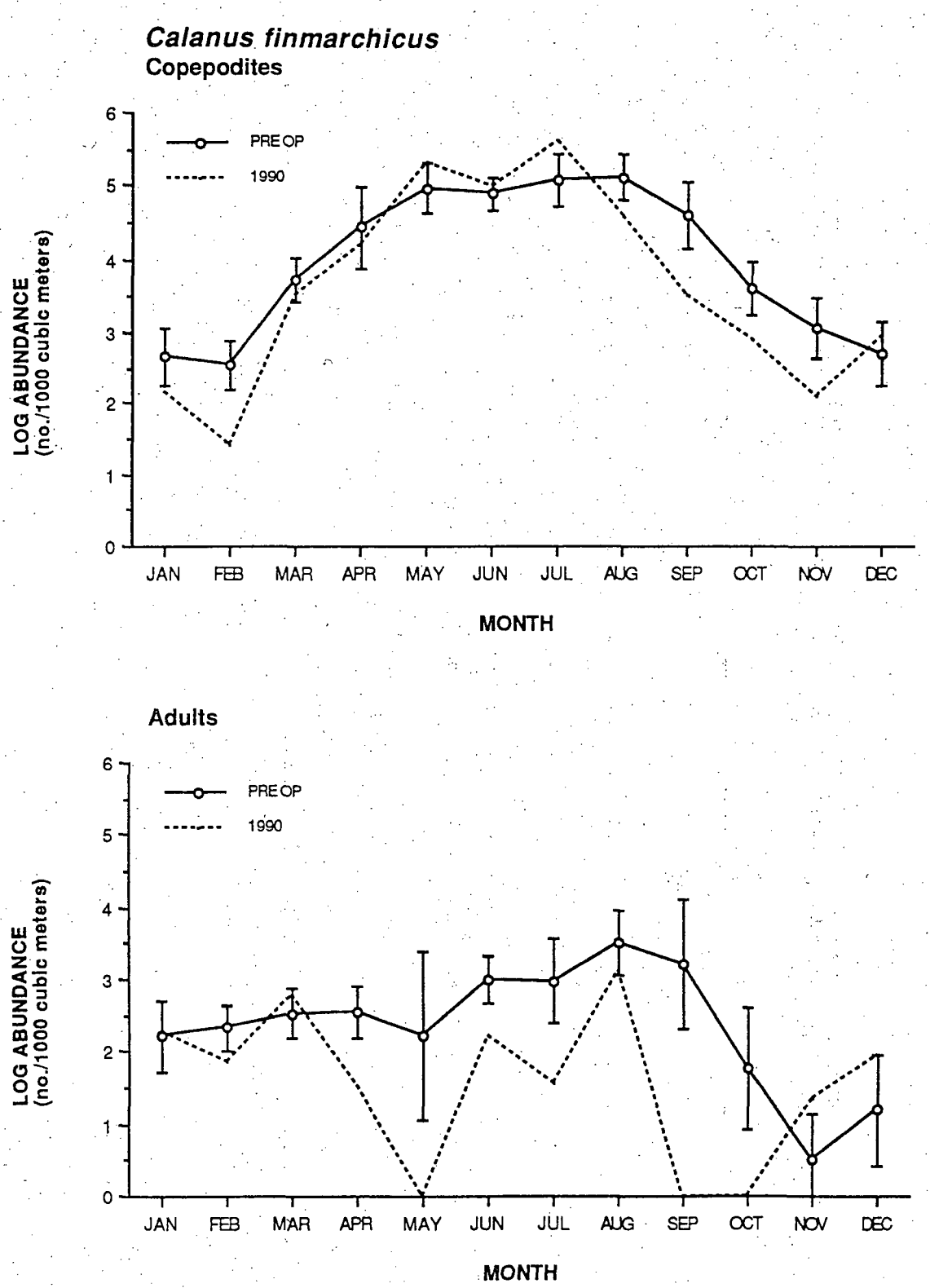


Figure 3.1.5-5. Log (x+1) abundance (no./1000 m^3) of *Calanus finmarchicus* copepodites and adults; monthly means and 95% confidence intervals over all preoperational years (1978-1984, 1986-1989) and monthly means for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

TABLE 3.1.5-5. RESULTS OF ANALYSIS OF VARIANCE[a] COMPARING NEARFIELD (STATIONS P2 AND P5) AND FARFIELD (STATION P7) ABUNDANCES OF SELECTED SPECIES OF MACROZOOPLANKTON DURING PREOPERATIONAL(1978-1989) AND OPERATIONAL (1990) PERIODS. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	SOURCE OF VARIATION	JANUARY-DECEMBER df	SS	F	AUGUST[b]- DECEMBER df	SS	F
Calanus finmarchicus copepodites	Preop-Op[c]	1	11.46	22.05***	1	17.58	25.39***
	Year (Preop-Op)[d]	6	18.13	5.81***	6	24.52	5.90***
	Month (Year (Preop-Op))[e]	82	647.95	15.21***	32	237.78	10.73***
	Area[f]	1	0.96	1.85 NS	1	0.54	0.78 NS
	Preop-Op X Area[g]	1	0.08	0.15 NS	1	0.33	0.48 NS
	Error	376	195.38		168	116.37	
Calanus finmarchicus adults	Preop-Op	1	39.86	39.93***	1	21.81	24.39***
	Year (Preop-Op)	6	58.82	9.82***	6	33.67	6.28***
	Month (Year (Preop-Op))	82	525.41	6.42***	32	369.01	12.90***
	Area	1	3.33	3.33 NS	1	0.76	0.85 NS
	Preop-Op X Area	1	0.40	0.40 NS	1	0.09	0.10 NS
	Error	376	375.33		168	150.20	
Carcinus maenas larvae	Preop-Op	1	3.37	11.26***	1	0.08	0.27 NS
	Year (Preop-Op)	6	59.89	33.32***	6	9.90	5.62***
	Month (Year (Preop-Op))	82	1173.71	47.78***	32	346.98	36.97***
	Area	1	0.15	0.52 NS	1	0.23	0.77 NS
	Preop-Op X Area	1	0.01	0.03 NS	1	0.20	0.69 NS
	Error	376	112.63		168	49.28	
Crangon septemspinosa zoeae and post larvae	Preop-Op	1	15.02	54.37***	1	3.67	15.03***
	Year (Preop-Op)	6	23.48	14.17***	6	4.86	3.31**
	Month (Year (Preop-Op))	82	538.70	23.79***	32	164.80	21.07***
	Area	1	1.68	6.08*	1	0.47	1.93 NS
	Preop-Op X Area	1	0.03	0.10 NS	1	0.20	0.80 NS
	Error	376	103.84		168	41.07	
Neomysis americana all lifestages	Preop-Op	1	6.53	10.45**	1	0.62	1.03 NS
	Year (Preop-Op)	6	83.41	22.24***	6	71.72	19.80***
	Month (Year (Preop-Op))	82	242.68	4.73***	32	94.01	4.87***
	Area	1	26.27	42.05***	1	8.21	13.60***
	Preop-Op X Area	1	1.90	3.03 NS	1	<0.01	0.00 NS
	Error	376	235.04		168	101.41	

[a]based on twice monthly sampling periods
[b]commercial operation began in August 1990
[c]preoperational (1978-1989) versus operational period, regardless of area
[d]year nested within preoperational and operational periods, regardless of area
[e]month nested within year nested within preoperational and operational periods, regardless of area
[f]nearfield area = Stations P2 and P5; Farfield area = Station P7, regardless of year or period
[g]interaction between main effects

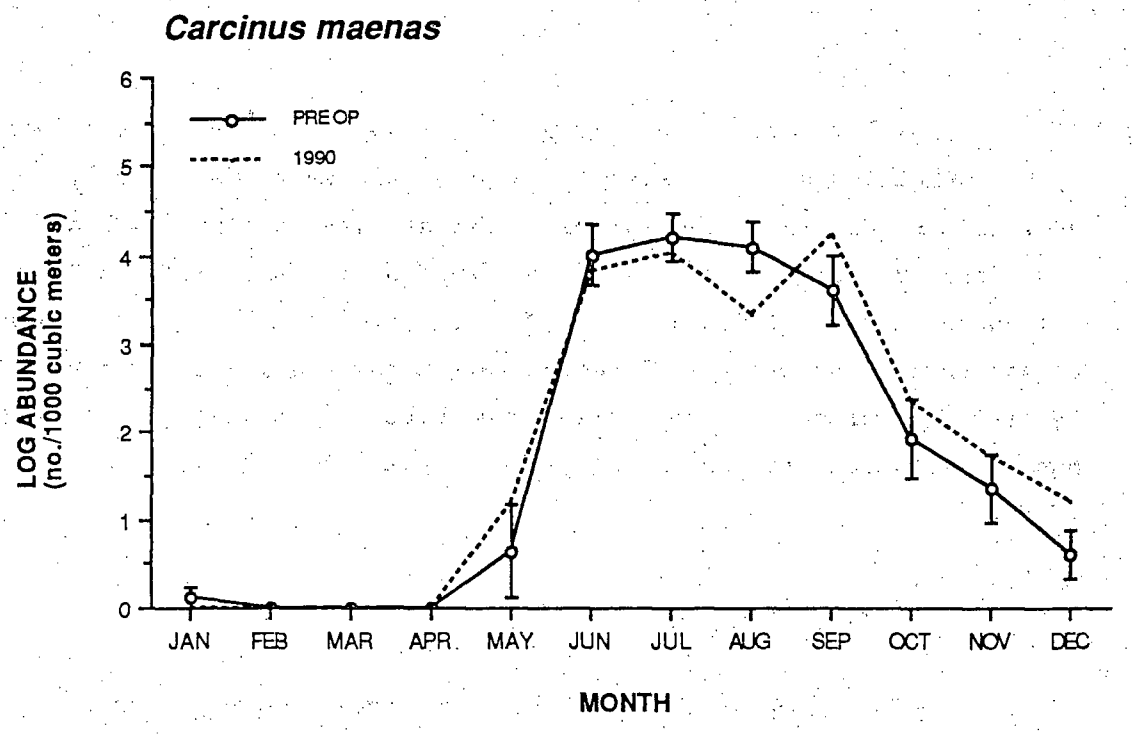
NS = not significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p \geq 0.001$)
*** = very highly significant ($0.001 \geq p$)

detailed description of the life history of *Calanus finmarchicus* and other selected species is available in the 1984 baseline report (NAI 1985b).

Previously, the lifestages were combined to assess spatial distribution. In both 1989 and 1990, abundances were similar at Stations P2, P5 and P7 (NAI 1990b). Analysis of variance was performed on both copepodites and adults to ascertain whether the relationship of their abundances in the nearfield area (Stations P2 and P5) to those in the farfield varied between preoperational and operational periods (Preop-Op X Area). Despite differences among years for both copepodites and adults, the spatial relationship did not change between the operational and preoperational periods for either the January through December time frame or the August through December time frame (Table 3.1.5-5).

Carcinus maenas

In 1990, *Carcinus maenas* larvae exhibited the same seasonal pattern of abundance observed historically, first occurring in May and persisting through December (Figure 3.1.5-6). Larvae were most abundant between June and September and declined sharply in abundance during October in 1990 as in previous years. Seasonal aspects of larval development are detailed in annual data reports (e.g., NAI 1990a) and are summarized here. Stage I zoeae were abundant in June and July. In 1990, zoeae Stages II, III and IV were most abundant in September. Megalopa were most abundant in August. The extended period of abundance for zoea I, II and III suggests that spawning and recruitment from local and regional adult populations is asynchronous. Annual abundances of these larval stages at Station P2 in 1990 were lower than preoperationally (Tables 3.1.5-4, -5; Preop-Op). Abundances during the August through December period of commercial operation in 1990 were similar to the preoperational mean from the same period.



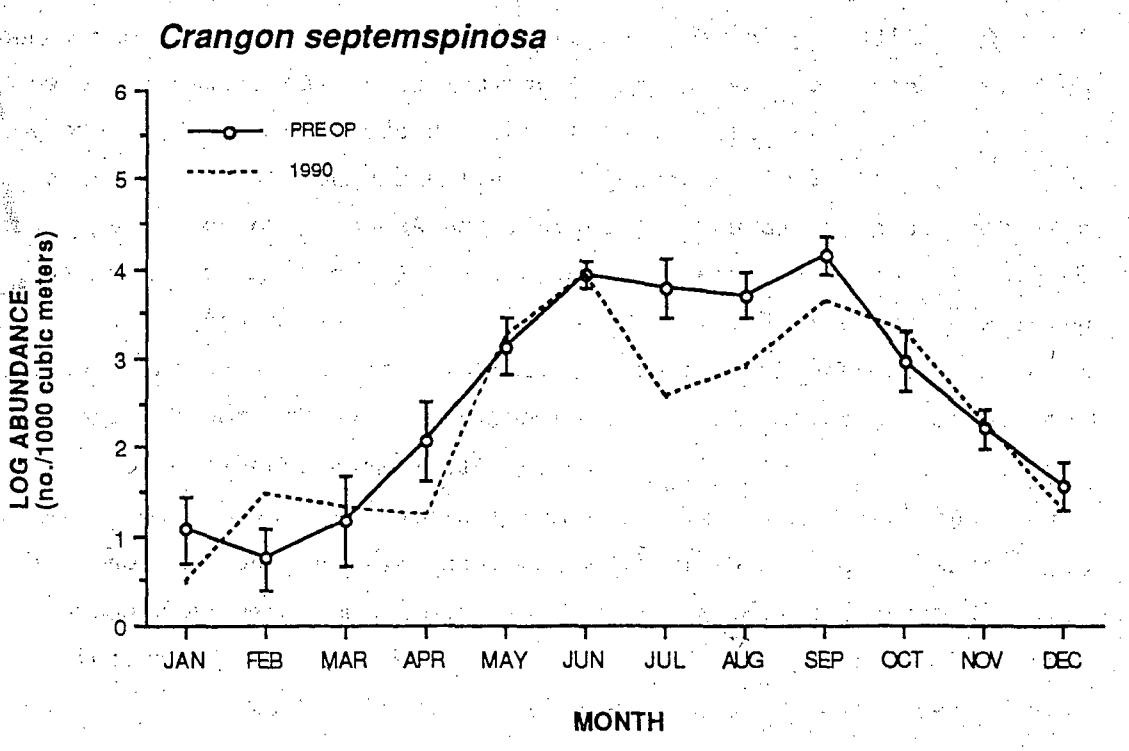


Figure 3.1.5-6. Log (x+1) abundance (no./1000 m^3) of *Carcinus maenas* larvae and *Crangon septemspinosa* zoeae and post larvae; monthly means and 95% confidence intervals over all preoperational years (1978-1984, 1986-1989) and monthly means for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

Neither spatial nor temporal differences of *Carcinus maenas* larval abundances had been evident in previous years (NAI 1990b), since adults are common in-shore near all three stations and hydrographic conditions typically do not separate plankton stations (NAI 1985b). Abundances in the nearfield during the period of commercial operation (August through December 1990) were statistically similar to those in the farfield during the same period and to both nearfield and farfield abundances in the preoperational years (Table 3.1.5-5).

Crangon septemspinosa

Spawning in *Crangon septemspinosa* typically commenced in April, with zoeae and post-larvae abundant through November (Figure 3.1.5-6). Although larvae, including zoea I, were present year round, peak abundances in June through September were usually two to three orders of magnitude higher than abundances observed November through April. In 1990, winter, spring and fall abundances were typical of previous years but abundances in July and August were about an order of magnitude lower than occurred previously. Although annual mean abundance at Station P2 for 1990 was within the range of this study (Table 3.1.5-4), abundance was significantly lower in 1990 than the preoperational mean across the whole year (January through December; Table 3.1.5-5, Preop-Op). A comparison of semi-monthly mean abundances of *Crangon* larvae and post-larvae indicated no significant change in the relationship of nearfield and farfield abundances between preoperational years and 1990 throughout the year or during the August through December period (Table 3.1.5-5; Preop-Op X Area). No spatial or temporal differences have been observed in the past (NAI 1990b).

Neomysis americana

Neomysis americana has been present year round in the macrozooplankton but was usually most abundant from September through April (Figure 3.1.5-7). Generally, the annual cycle was slightly bimodal,

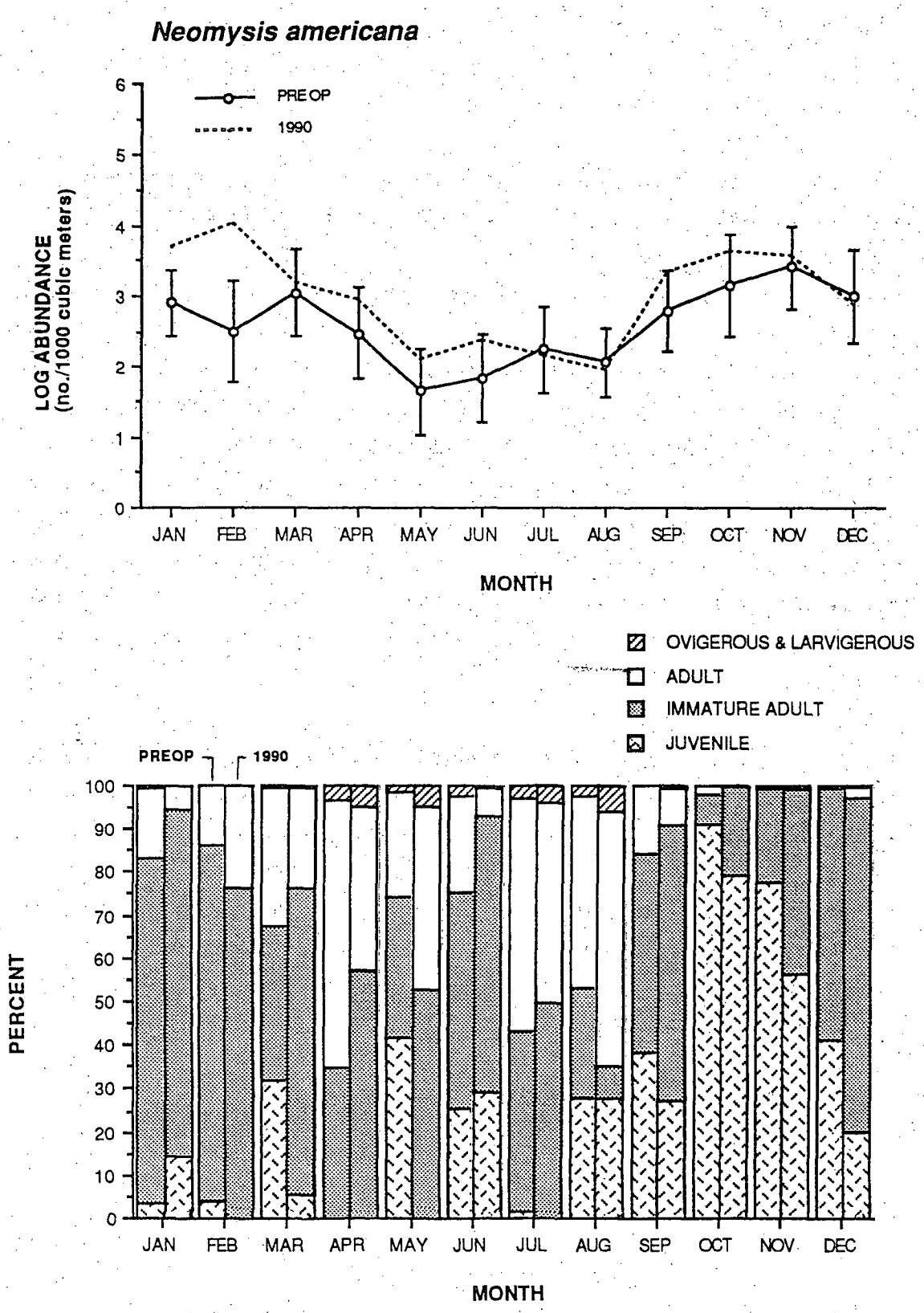


Figure 3.1.5-7. Log (x+1) abundance (no./1000 m^3) of *Neomysis americana;* monthly means and 95% confidence interval over all preoperational years (1978-1984, 1986-1989) and monthly means for 1990 and mean percent composition of *Neomysis americana* lifestages over all preoperational years (1978-1984, 1986-1989) and for 1990 at nearfield Station P2. Seabrook Operational Report, 1990.

with lowest abundances May through August. The elevated abundances observed in 1989 (NAI 1990b) continued into the early part of 1990, contributing to the significantly higher annual mean in 1990 than in preoperational years (Tables 3.1.5-4,5; Preop-Op). From March through the end of 1990, abundances were similar to the mean of the preoperational period. Abundances in August-December 1990 were similar to the same months in preoperational years (Table 3.1.5-5). Lifestages of *N. americana* have historically exhibited distinct seasonal patterns (NAI 1985b). Juveniles were most numerous in late spring and fall (Figure 3.1.5-7). Immature mysids were most prevalent from late fall through winter. Mature individuals were most abundant in winter with a secondary peak in the summer, while ovigerous and larvigerous females were most abundant in April and July. All lifestages generally followed these patterns in 1990.

Spatial differences in abundance of *Neomysis americana* have been detected in the past and occurred again in 1990 (NAI 1990b; Tables 3.1.5-3,5). Spatial differences were attributed both to substrate conditions and distance to Hampton Harbor. However, when abundances in the nearfield area as a whole (i.e. Stations P2 and P5) were compared to those in the farfield (Station P7) between operational and preoperational periods, no significant changes in the spatial distribution of *N. americana* were observed (Table 3.1.5-5, Preop-Op X Area).

3.2 FINFISH

Common names recognized by the American Fisheries Society (Robins *et al.* 1991) are used for fish taxa. The common and scientific names for every taxon collected from 1975 through 1990 in the Seabrook ichthyoplankton and adult finfish programs are listed with their relative abundances by gear type in Appendix Table 3.2.1-1. No species new to the Seabrook program were encountered during the 1990 surveys.

3.2.1 Ichthyoplankton

3.2.1.1 Community

The nearfield ichthyoplankton community has been examined in annual baseline reports using numerical classification (NAI 1982c, 1983b, 1984b, 1985b) and discriminant analysis (NAI 1987b, 1988b, 1989b, 1990b). Species composition of both eggs and larvae exhibited distinct seasonal changes, which were consistent among years. For this first operational report, numerical classification (cluster analysis) was used to examine how well the 1990 community fit the patterns observed in previous years.

Temporal Patterns of Nearfield Fish Egg Assemblages

Numerical classification of monthly fish egg abundances showed the species composition to be highly seasonal in nature, with different taxa occurring at different times of the year and the same seasonal succession repeating year after year. The basic pattern over the period 1976 through 1990 can be summarized by nine seasonal groups of samples, each characterized by a particular assemblage of taxa (Figure 3.2.1-1 and Table 3.2.1-1).

Group 1 occurred in the fall of most years, primarily during November (Figure 3.2.1-2), and was dominated by Atlantic cod eggs, with

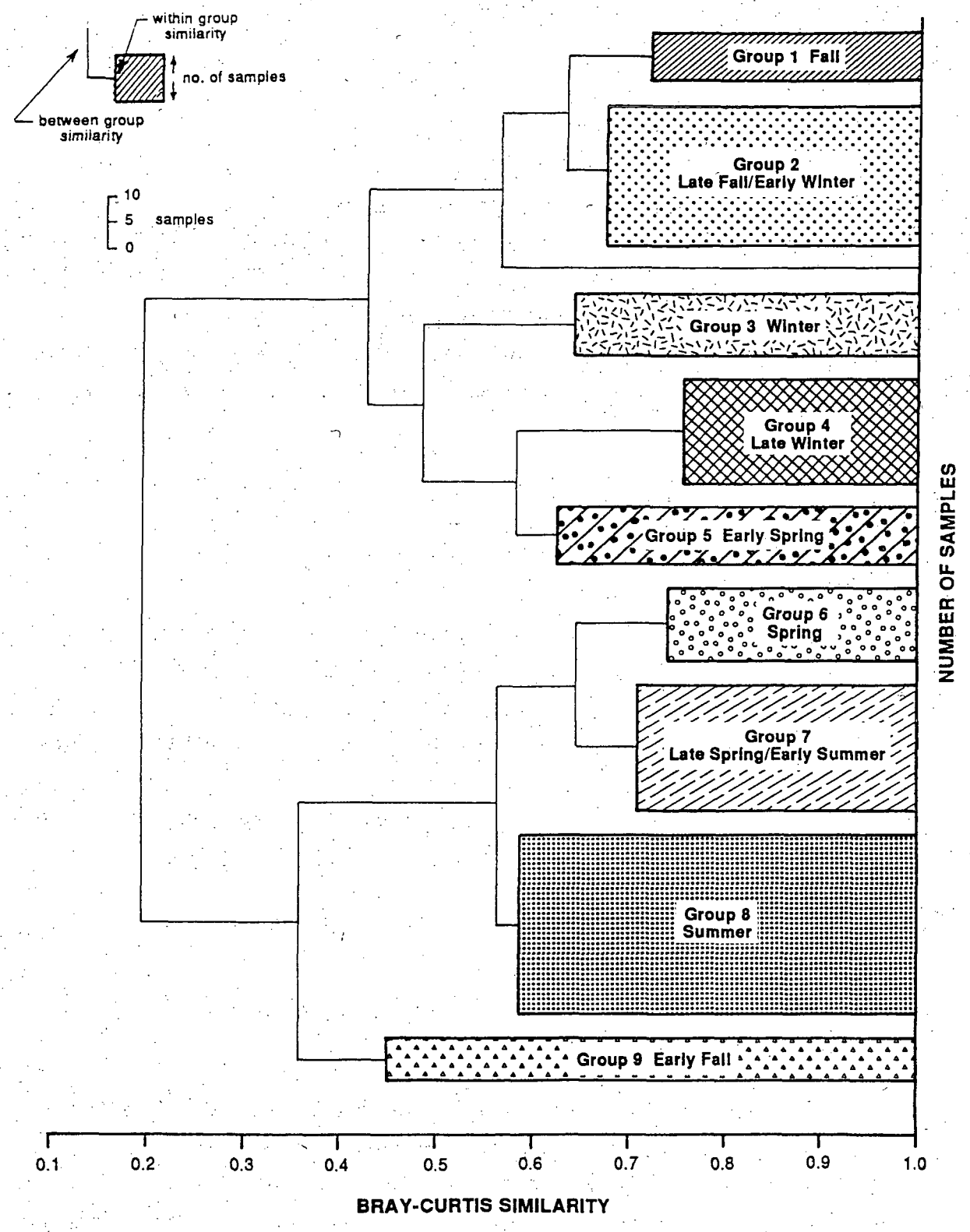


Figure 3.2.1-1. Dendrogram formed by normal classification of monthly abundances (log (x+1) transformed number per 1000 m^3) of fish eggs at Seabrook nearfield Stations P2 and P3, January 1976-December 1990. Seabrook Operational Report, 1990.

TABLE 3.2.1-1. FAUNAL CHARACTERIZATION OF SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF SAMPLES OF FISH EGGS COLLECTED AT SEABROOK NEARFIELD STATIONS P2 AND P3 DURING JANUARY 1976 THROUGH DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

	NO. OF SAMPLES[b]			DENSITY (NO./1000m³)[d]			
				PREOP. YEARS			1990
SAMPLE GROUP[a]	PREOP. YEARS	1990	DOMINANT FISH EGGS[c]	MEAN	LCL	UCL	MEAN
Group 1 Fall 0.72/0.64	9	1	Atlantic cod/haddock	154	90	263	166
Group 2 Late fall-early winter 0.68/0.64	27	2	Atlantic cod/haddock	63	42	95	63
			Pollock	46	27	78	8
Group 3 Winter 0.64/0.49	11	2	Atlantic cod/haddock	8	6	13	10
			American plaice	4	1	8	1
Group 4 Late winter 0.76/0.58	22	0	Atlantic cod/haddock	61	42	88	-
			American plaice	57	36	89	-
Group 5 Early spring 0.63/0.58	11	1	American plaice	302	122	745	62
			Atlantic cod/haddock	51	17	153	14
			Fourbeard rockling	48	21	107	85
Group 6 Spring 0.74/0.65	14	1	Cunner/yellowtail flounder	782	529	1160	507
			Atlantic mackerel	643	172	2390	2440
			Fourbeard rockling	331	103	1060	470
			American plaice	283	119	672	105
Group 7 Late spring-early summer 0.71/0.65	25	2	Cunner/yellowtail flounder	21200	14000	32000	51100
			Atlantic mackerel	3500	1700	7230	20600
Group 8 Summer 0.59/0.57	35	2	Hake	1570	972	2530	1530
			Cunner/yellowtail flounder	316	118	845	213
			Windowpane	94	51	171	290
Group 9 Early fall 0.45/0.36	8	1	Hake	15	7	32	7
			Atlantic cod	12	2	49	38
			Atlantic whiting	10	2	41	43
			Fourbeard rockling	5	1	17	1
			Fourbeard rockling/hake	3	<1	12	14

[a] The predominant season of occurrence is listed for each group, along with the within-group and the among-group similarities.
[b] Each monthly "sample" included in the analysis consists of the average of tows within date and dates within month.
[c] Taxa listed as dominants are those whose geometric mean densities together account for ≥90% of the sum of the geometric mean densities of all taxa within the group.
[d] Densities shown are geometric mean and corresponding lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) among the samples within the group.Table 3.2.1-1.

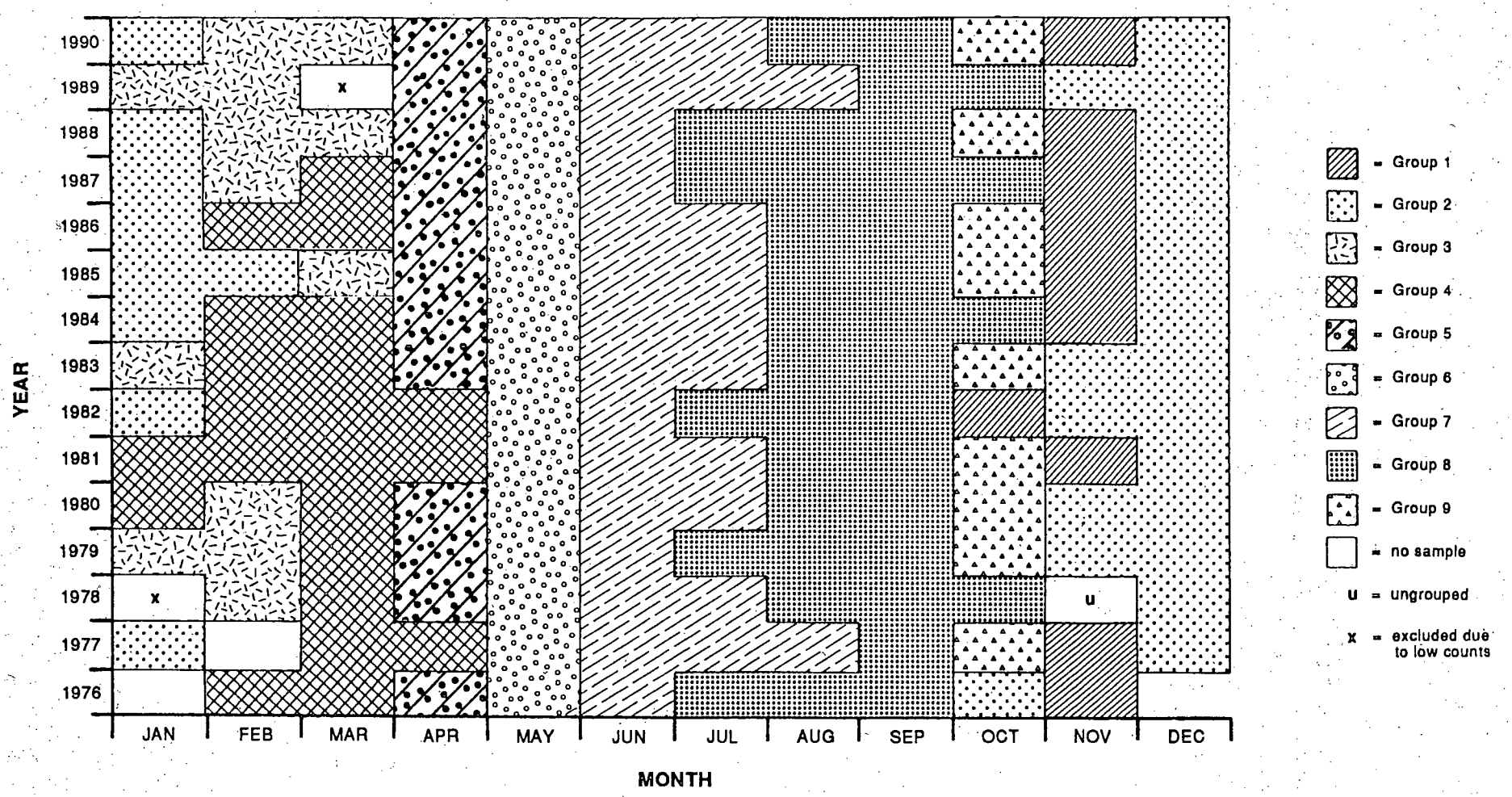


Figure 3.2.1-2. Temporal occurrence pattern of seasonal assemblages of fish eggs collected at Seabrook nearfield Stations P2 and P3 during January 1976 through December 1990. Seabrook Operational Report, 1990.

no other taxon making an important contribution. Late fall-early winter collections (Group 2) were characterized by the co-dominance of Atlantic cod eggs and pollock eggs. This assemblage was always present in December, sometimes appearing as early as November, and often persisting through January.

The next seasonal assemblage to appear was Atlantic cod/haddock and American plaice, characterizing both Groups 3 and 4. These two groups had similar dominant taxa, but different abundances. In Group 4 collections, egg densities were roughly an order of magnitude greater than in Group 3. Nearfield fish egg samples were classified as either Group 3 or Group 4 from January or February through March or occasionally April.

Most April collections were classified as Group 5 (except for three years in which Group 4 persisted through April). In addition to the continued importance of Atlantic cod/haddock, these samples featured an increase in the abundance of American plaice eggs and also the first appearance of substantial numbers of fourbeard rockling eggs.

The next group, Group 6, was seasonally the most consistent of all groups. It included only the month of May in every year (Figure 3.2.1-2). Group 6 was characterized by a fish egg assemblage of increased abundance and increased diversity. Four taxa shared the dominance: cunner/yellowtail flounder, Atlantic mackerel, fourbeard rockling, and American plaice.

A late spring-early summer assemblage (Group 7) appeared each year in June, often continued through July, and twice extended into August. Abundances of the two dominant taxa were much higher than in May (Group 6): Atlantic mackerel and particularly cunner/yellowtail flounder.

Group 8 consisted of mid-summer to late summer collections, occasionally including samples as late as October. These were

characterized by hake eggs, cunner/yellowtail flounder (much less abundant than in Group 7, but still important), and windowpane.

October was a transitional month. The majority of October samples were classified in a separate group, Group 9, but in some years they were classified into Groups 1, 2, or 8. The Group 9 samples exhibited relatively low densities compared to the other eight groups, reflecting the low level of spawning activity typical for the early fall. This assemblage included hake, Atlantic whiting, and fourbeard rockling eggs, as well as some early Atlantic cod eggs.

Species assemblages occurring in 1990 were consistent with those observed in previous years (Figure 3.2.1-2). Collections of fish eggs during the first half-year of commercial operation of Seabrook Station were classified in a similar pattern to those from 1976-1989. The only exception was the absence of Group 4 samples in 1990, an indication that the abundances of the winter Atlantic cod/haddock and American plaice assemblage were lower than in most previous years. No group 4 samples were observed in 1985, 1988, and 1989.

Temporal Patterns of Nearfield Fish Larvae Assemblages

Numerical classification of monthly fish larvae abundances revealed a degree of seasonality similar to that observed in the analysis of the fish egg community. Seasonal assemblages of fish larvae were identified on the basis of sample groups that consistently included only collections from a particular time of year regardless of which year they were from. Nine sample groups were identified as representative of the seasonal progression of species assemblages (Figure 3.2.1-3 and Table 3.2.1-2).

Group 1 consisted of fall samples, primarily during October and November (Figure 3.2.1-4). The dominant fish larvae during this period were Atlantic herring. In the late fall and early winter, the

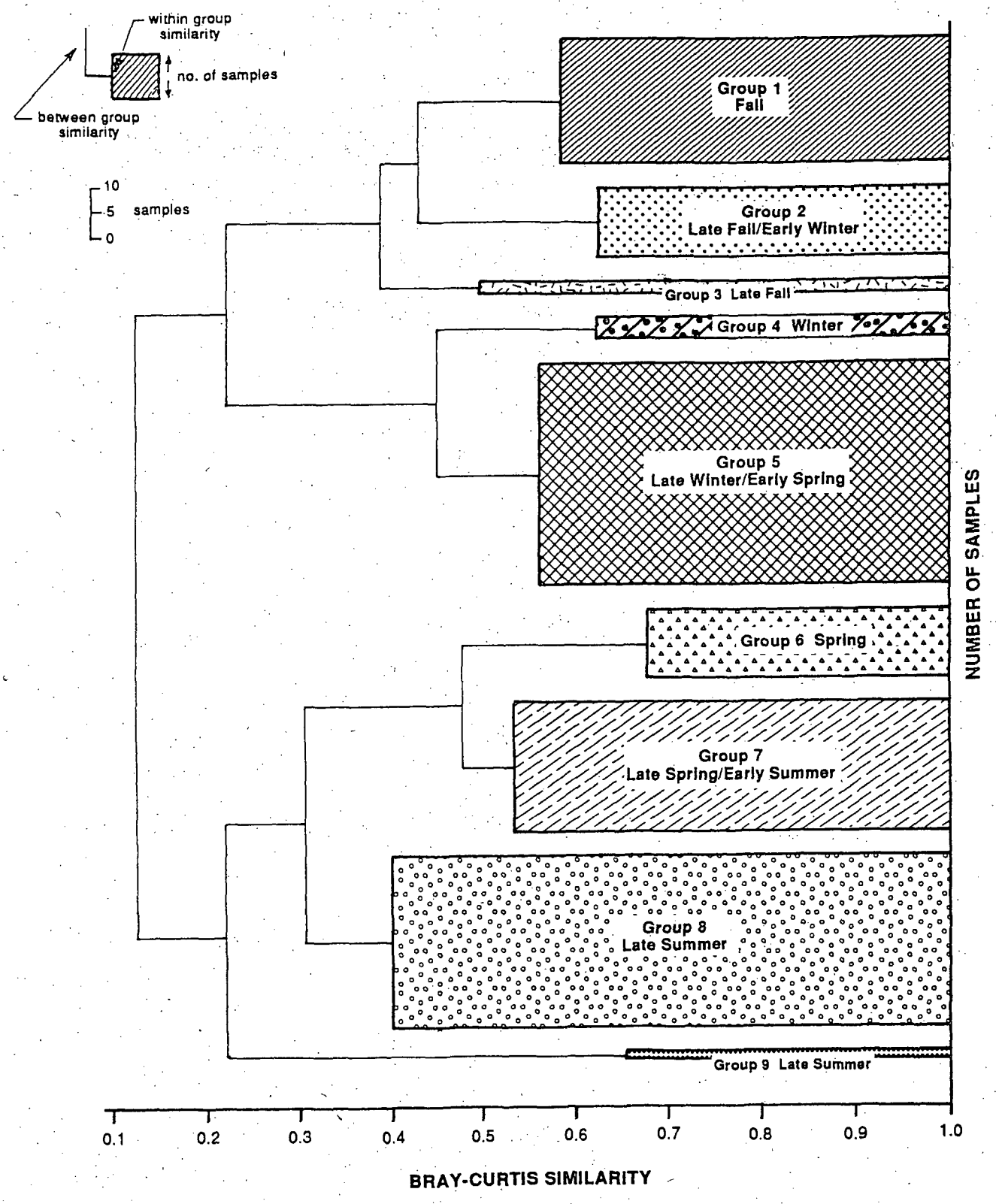


Figure 3.2.1-3. Dendrogram formed by normal classification of monthly abundances (log (x+1) transformed number per 1000 m^3) of fish larvae at Seabrook nearfield Stations P2 and P3, July 1975-December 1990. Seabrook Operational Report, 1990.

TABLE 3.2.1-2. FAUNAL CHARACTERIZATION OF SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF SAMPLES OF FISH LARVAE COLLECTED AT SEABROOK NEARFIELD STATIONS P2 AND P3 DURING JULY 1975 THROUGH DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

	NO. OF SAMPLES[b]			DENSITY (NO./1000m^3)[d]			
				PREOP. YEARS			1990
SAMPLE GROUP[a]	PREOP. YEARS	1990	DOMINANT FISH LARVAE[c]	MEAN	LCL	UCL	MEAN
Group 1 Fall 0.58/0.43	27	0	Atlantic herring	156	94	257	-
Group 2 Late fall-early winter 0.63/0.43	15	0	Pollock	55	28	108	-
			American sand lance	15	4	49	-
			Atlantic herring	12	6	22	-
Group 3 Late fall 0.50/0.39	1	2	Atlantic herring	13	-	-	3
Group 4 Winter 0.62/0.45	4	1	American sand lance	28	10	75	7
			Snailfishes	3	0	30	11
Group 5 Late winter-early spring 0.56/0.45	44	4	American sand lance	412	277	611	425
			Rock gunnel	38	22	67	72
Group 6 Spring 0.67/0.47	15	0	Snailfishes	149	87	254	-
			Winter flounder	85	52	140	-
			Radiated shanny	55	32	94	-
			American plaice	42	16	107	-
			American sand lance	35	17	72	-
Group 7 Late spring-early summer 0.53/0.47	26	2	Atlantic mackerel	147	55	393	1150
			Cunner	121	40	359	437
			Fourbeard rockling	107	58	197	51
			Radiated shanny	77	50	120	45
			Witch flounder	29	15	57	<1
			Winter flounder	26	11	63	71
			American plaice	18	10	32	23
Group 8 Late summer 0.40/0.30	34	3	Cunner	79	33	186	183
			Fourbeard rockling	30	16	55	54
			Hake	15	7	31	68
			Atlantic whiting	11	5	24	49
			Windowpane	8	5	12	16
Group 9 Late summer 0.65/0.22	2	0	Cunner	4	0	1530	-
			Radiated shanny	3	0	40	-
			Windowpane	1	0	10	-
			Fourbeard rockling	<1	0	2	-

Footnotes:

[a] For each group is listed the predominant season of its occurrence, the within-group similarity, and the among-group similarity.

[b] Each monthly "sample" included in the analysis consists of the average of tows within date and dates within month.

[c] Taxa listed as dominants are those whose geometric mean densities together account for ≥90% of the sum of the geometric mean densities of all taxa within the group.

[d] Densities shown are geometric mean and corresponding lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) among the samples within the group.

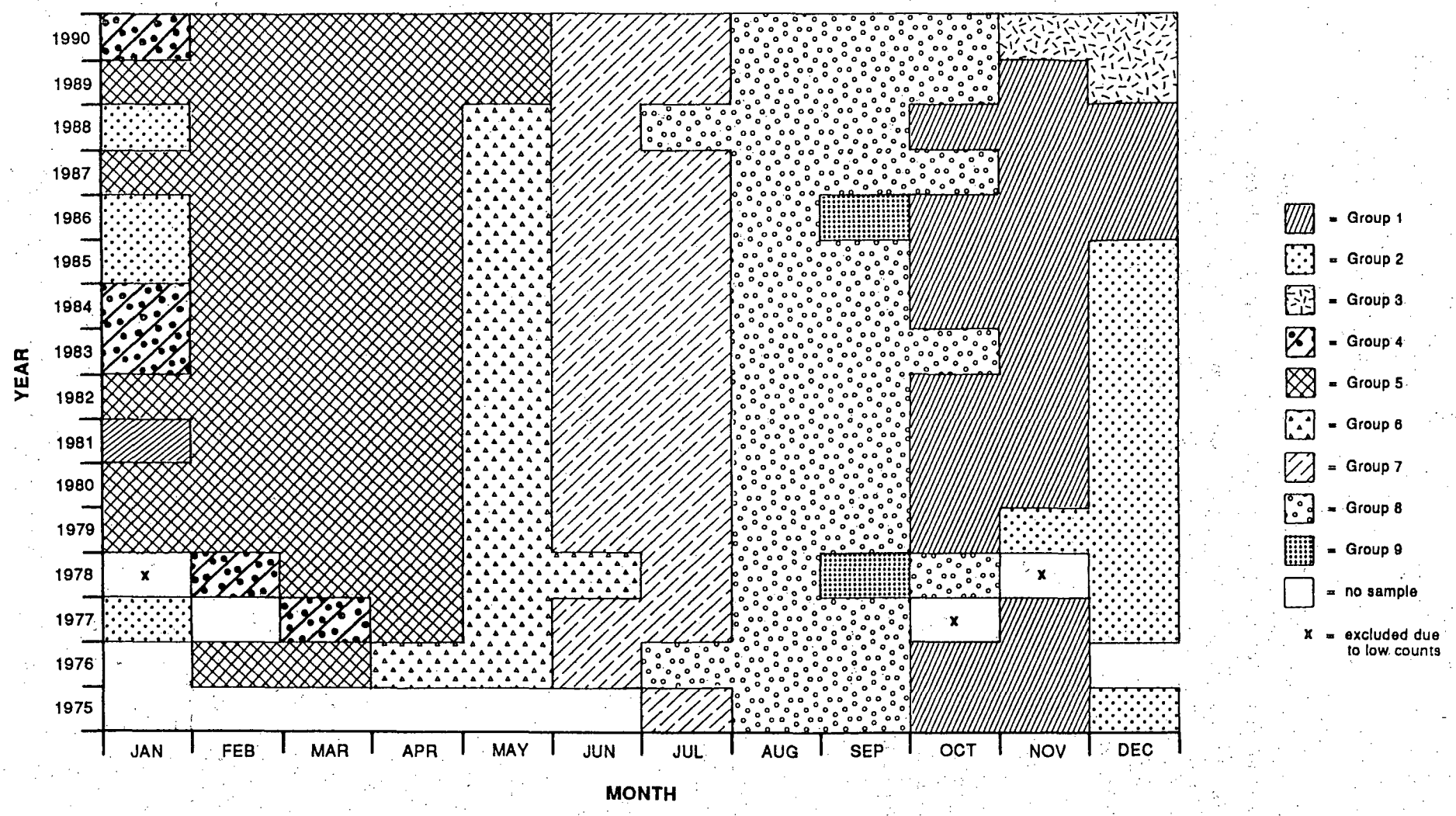


Figure 3.2.1-4. Temporal occurrence pattern of seasonal assemblages of fish larvae collected at Seabrook nearfield Stations P2 and P3 during July 1975 through December 1990. Seabrook Operational Report, 1990.

abundance of Atlantic herring larvae was generally lower, and pollock and American sand lance larvae became prevalent (Group 2). Three monthly collections at this time of year segregated into a separate group, Group 3, characterized by similarly reduced Atlantic herring densities as in Group 2, but lacking the pollock and American sand lance (December 1989 and November and December 1990).

Another small group, Group 4, consisted of a few winter collections dominated by American sand lance and snail fishes. Most of the winter samples, as well as some early spring collections, were classified as Group 5. American sand lance larvae also dominated this group, although their abundances were substantially higher than in Group 4. Group 5 was also characterized by increased abundances of rock gunnel larvae.

This group contained the May samples from every year but 1989 and 1990. The June and July samples from almost every year were classified together as a group (Group 7). This late spring-early summer group was characterized by even greater diversity than was Group 6, with seven species occurring in substantial abundance (Table 3.2.1-2). The three most abundant species were Atlantic mackerel, cunner, and four-beard rockling.

Group 8 was primarily a late summer feature, extending into October in some years. Cunner and fourbeard rockling continued their importance into this period, and were joined as dominant species by hake, Atlantic whiting, and windowpane. Two additional later summer samples (September 1978 and September 1986) were classified as a distinct group, Group 9. These were characterized primarily by low abundances (Table 3.2.1-2).

The 1990 collections generally agreed with the pattern of seasonal progression of larval assemblages observed in previous years. In 1990, however, none of the samples from the fall and early winter were classified with Group 1 or Group 2 as they had been in most

previous years. Instead, November and December 1990 were grouped with the December 1989 collection (Group 3), an indication of lower-than-normal abundances of Atlantic herring, American sand lance, and pollock larvae at this time of the year in 1989 and 1990. No 1990 sample was classified into Group 6. The grouping of the May 1990 sample with Group 5 indicated that the late winter-early spring American sand lance assemblage persisted into May just before the appearance of the late-spring and early summer Atlantic mackerel and cunner assemblage. This pattern also occurred in 1989.

Spatial Patterns of Fish Eggs and Larvae

Spatial comparison of abundance and species composition from the nearfield and farfield stations was previously done using numerical classification of the 1982 and 1983 collections for both fish eggs and larvae (NAI 1983b, 1984b). Spatial (station) differences were found to be less important than short-term temporal differences. Samples collected on the same date at different stations (nearfield and farfield) more likely resembled each other than if collected one to two weeks apart at the same station.

This similarity in species composition and abundance between nearfield and farfield sites was consistent with the known extent of water mass movements in the study area. Tidal currents and longshore (northward and southward) currents in the study area are typically in the range of 0.2 to 0.6 knots about 75% of the time (NAI 1980d). Currents of this magnitude would transport a water mass about two nautical miles during a single tidal excursion, or about 5-15 miles in 24 hours during periods dominated by longshore flow. The distance from Station P2 to P5 (1-1/2 miles) or to P7 (3-1/2 miles) is relatively short. Considering that, for example, a water mass sampled at Station P2 could very possibly have been located at Station P7 a few hours before sampling, the assumption (for the purpose of statistical analysis

of spatial effects) that these locations are distinct from each other in terms of plankton is not always met.

Despite this possibility of exchange of plankton-bearing water masses among the stations, the 1990 ichthyoplankton data were analyzed in an attempt to test for differences in communities of fish eggs and larvae among intake, discharge, and farfield stations. These analyses were conducted for two different time frames: the entire year (January-December) and just the period of commercial operation (August-December).

The taxonomic composition of fish eggs based on relative abundance appeared to be similar among stations both for the whole year (Table 3.2.1-3) and for the period after commercial operation commenced at Seabrook Station (Table 3.2.1-4). Multivariate analysis of variance results indicated, however, that fish egg abundances did differ significantly among stations during the year as a whole (Table 3.2.1-5). For individual taxa, there were some significant differences among the three stations in the log(x+1) transformed densities for 1990 (Table 3.2.1-5). Station P2 had fewer fourbeard rockling eggs than P5, while P5 had more cunner/ yellowtail flounder eggs than both P2 and P7. In the farfield area (P7) there were fewer rockling/hake and windowpane eggs than at either nearfield station, and fewer cod/haddock eggs than at P5. The analysis did not indicate any station differences in fish egg composition during operational months.

The percent composition of species for fish larvae was also similar among stations for all of 1990 (Table 3.2.1-6) and for the operational months (Table 3.2.1-7). Multivariate analysis of dominant taxa did not indicate any difference among stations either during plant operation or for the January-December period (Table 3.2.1-5).

TABLE 3.2.1-3. COMPARISON OF PERCENT ABUNDANCE AND PERCENT FREQUENCY OF FISH EGG COLLECTIONS AT INTAKE (P2), FARFIELD (P7) AND DISCHARGE (P5) STATIONS DURING JANUARY - DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

	P2		P7		P5	
	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY
FOURBEARD ROCKLING	0.61	37.50	0.65	43.75	1.19	50.00
ROCKLING/HAKE	2.94	43.75	4.36	35.42	3.73	39.58
COD/WITCH FLOUNDER	0.35	41.67	0.35	35.42	0.56	45.83
ATLANTIC COD	0.19	39.58	0.21	33.33	0.21	37.50
ATLANTIC COD/HADDOCK	0.01	14.58	0.01	14.58	0.05	16.67
WITCH FLOUNDER	<0.01	4.17	<0.01	4.17	0.02	8.33
AMERICAN PLAICE	0.12	29.17	0.16	33.33	0.25	27.08
CUNNER/YELLOWTAIL FLOUNDER	59.85	39.58	48.63	43.75	59.70	41.67
YELLOWTAIL FLOUNDER	0.03	4.17	0.03	6.25	0.02	8.33
HADDOCK	0.00	0.00	<0.01	6.25	<0.01	10.42
ATLANTIC WHITING	0.62	27.08	1.25	22.92	1.00	27.08
POLLOCK	0.01	12.50	0.01	12.50	0.02	16.67
NORTHERN SEA ROBIN	<0.01	2.08	0.00	0.00	0.00	0.00
ATLANTIC MACKEREL	23.21	20.83	37.33	22.92	25.56	22.92
WINDOWPANE	1.34	43.75	0.69	39.58	1.55	41.67
HAKE	10.72	35.42	6.33	35.42	6.13	35.42

TABLE 3.2.1-4. COMPARISON OF PERCENT ABUNDANCE AND PERCENT FREQUENCY OF FISH EGG COLLECTIONS AT INTAKE (P2), FARFIELD (P7) AND DISCHARGE (P5) STATIONS DURING THE FIRST FIVE MONTHS OF COMMERCIAL OPERATION (AUGUST-DECEMBER 1990). SEABROOK OPERATIONAL REPORT, 1990.

	P2		P7		P5	
	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY
FOURBEARD ROCKLING	0.43	30.00	0.50	35.00	0.52	50.00
ROCKLING/HAKE	17.47	60.00	9.57	50.00	18.91	55.00
COD/WITCH FLOUNDER	0.46	40.00	0.44	40.00	1.00	45.00
ATLANTIC COD	2.42	40.00	4.09	40.00	2.04	40.00
WITCH FLOUNDER	0.01	5.00	0.02	5.00	<0.01	5.00
CUNNER/YELLOWTAIL FLOUNDER	30.38	35.00	38.31	45.00	27.47	40.00
ATLANTIC WHITING	7.89	40.00	19.69	25.00	6.61	40.00
POLLOCK	0.10	10.00	0.06	10.00	0.08	10.00
SEAROBIN	<0.01	5.00	0.00	0.00	0.00	0.00
ATLANTIC MACKEREL	0.00	0.00	0.00	0.00	0.14	5.00
WINDOWPANE	5.25	50.00	2.89	40.00	7.03	45.00
HAKE	35.59	50.00	24.44	45.00	36.20	55.00

TABLE 3.2.1-5. RESULTS OF MULTIVARIATE ANALYSIS OF VARIANCE TESTS FOR DIFFERENCE AMONG STATIONS IN COMMUNITIES OF FISH EGGS AND LARVAE DURING PREOPERATIONAL AND OPERATIONAL PERIODS IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

LIFE STAGE	PERIOD	NUMBER OF TAXA (DEPENDENT VARIABLES)	INDEPENDENT VARIABLES (NUMBER OF LEVELS)[a]	TOTAL NO. OF OBS.	CRITERION[b]	df	F-VALUE[c]	UNIVARIATE ANOVAs[d] TAXON	UNIVARIATE ANOVAs[d] COMPARISONS
Eggs	Jan-Dec	11	Station (3) Date (38)	114	Wilks Pillai Hotelling	22,128 22,130 22,126	2.63*** 2.64*** 2.62***	Fourbeard rockling Rockling/hake Cod/haddock Cunner/yellow tail flounder Windowpane Six other taxa	P5>P2 P2=P5>P7 P5>P7 P5>P7=P2 P2=P5>P7 no differences
Eggs	Aug-Dec	10	Station (3) Date (19)	57	Wilks Pillai Hotelling	20,54 20,56 20,52	1.46 NS 1.50 NS 1.42 NS		
Larvae	Jan-Dec	19	Station (3) Date (36)	108	Wilks Pillai Hotelling	38,104 38,106 38,102	1.46 NS 1.41 NS 1.51 NS		
Larvae	Aug-Dec	11	Station (3) Date (10)	30	Wilks Pillai Hotelling	22,16 22,18 22,14	0.69 NS 0.73 NS 0.64 NS		

[a] Analyses excluded those dates on which the average density for all three stations was <20/100m^3.
[b] Criteria: Wilks' criterion, Pillai's trace, and Hotelling-Lawley trace.
[c] Significance levels: NS $p>0.05$, * $0.05 \geq p>0.01$, ** $0.01 \geq p>0.001$, *** $p \leq 0.001$.
[d] If the MANOVA was significant, univariate ANOVAs were performed on individual taxa. ANOVAs with significant station effects were followed by Waller-Duncan K-ratio multiple comparisons test at $\alpha=0.05$.

TABLE 3.2.1-6. COMPARISON OF PERCENT ABUNDANCE AND PERCENT FREQUENCY OF FISH LARVAE COLLECTIONS AT INTAKE (P2), FARFIELD (P7) AND DISCHARGE (P5) STATIONS DURING JANUARY-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

TAXA[a]	P2		P7		P5	
	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY
AMERICAN SAND LANCE	15.82	52.08	17.79	43.75	21.83	47.92
AMERICAN EEL	0.03	8.33	0.01	6.25	0.01	4.17
ALLIGATOR FISH	0.17	18.75	1.34	25.00	0.11	20.83
ATLANTIC HERRING	0.08	33.33	0.24	37.50	0.23	37.50
LUMPFISH	0.01	8.33	0.01	10.42	0.01	8.33
FOURBEARD ROCKLING	1.39	41.67	2.39	37.50	2.70	43.75
ATLANTIC COD	0.05	18.75	0.02	14.58	0.05	20.83
WITCH FLOUNDER	0.16	10.42	0.16	10.42	0.06	12.50
AMERICAN PLAICE	0.30	18.75	0.24	20.83	0.58	25.00
YELLOWTAIL FLOUNDER	0.04	14.58	0.05	14.58	0.07	14.58
ATLANTIC SEASNAIL	0.94	29.17	0.30	29.17	0.38	27.08
GULF SNAILFISH	0.88	43.75	2.01	41.67	0.59	39.58
ATLANTIC WHITING	2.60	22.92	6.26	18.75	2.36	22.92
GRUBBY	0.47	25.00	1.19	27.08	0.28	16.67
LONGHORN SCULPIN	0.08	22.92	0.18	22.92	0.06	18.75
SHORTHORN SCULPIN	0.09	12.50	0.14	16.67	0.03	8.33
RAINBOW SMELT	0.01	4.17	0.01	8.33	<0.01	4.17
FOURSPOT FLOUNDER	0.09	8.33	0.08	10.42	0.09	10.42
ROCK GUNNEL	2.78	37.50	5.01	29.17	1.60	27.08
POLLOCK	0.04	20.83	0.03	14.58	0.04	25.00
WINTER FLOUNDER	1.07	18.75	0.23	14.58	0.62	22.92
ATLANTIC MACKEREL	32.36	14.58	22.68	16.67	21.35	16.67
WINDOWPANE	0.63	22.92	0.37	20.83	0.63	25.00
TAUTOG	0.09	8.33	0.10	6.25	0.09	8.33
CUNNER	36.62	31.25	34.49	31.25	43.53	29.17
RADIATED SHANNY	0.48	20.83	0.33	25.00	0.36	18.75
HAKE	2.40	22.92	4.17	25.00	2.02	22.92

[a]Only common taxa are listed (percent frequency at least 5% at one or more stations).Table 3.2.1-6.

TABLE 3.2.1-7. COMPARISON OF PERCENT ABUNDANCE AND PERCENT FREQUENCY OF FISH LARVAE COLLECTIONS AT INTAKE (P2), FARFIELD (P7) AND DISCHARGE (P5) STATIONS DURING THE FIRST FIVE MONTHS OF COMMERCIAL OPERATION (AUGUST-DECEMBER, 1990). SEABROOK OPERATIONAL REPORT, 1990.

	P2		P7		P5	
	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY	PERCENT ABUNDANCE	PERCENT FREQUENCY
AMERICAN SAND LANCE	<0.01	5.00	0.02	10.00	0.02	10.00
ALLIGATORFISH	0.13	10.00	0.00	0.00	0.00	0.00
ATLANTIC HERRING	0.17	50.00	0.37	45.00	0.23	55.00
LUMPFISH	0.00	0.00	0.02	10.00	0.00	0.00
FOURBEARD ROCKLING	2.47	55.00	4.33	50.00	4.41	60.00
ATLANTIC COD	0.01	10.00	0.00	0.00	<0.01	10.00
WITCH FLOUNDER	0.40	20.00	0.37	15.00	0.05	20.00
GOOSEFISH	0.00	0.00	0.05	10.00	0.03	10.00
ATLANTIC WHITING	6.80	50.00	14.97	35.00	4.84	30.00
FOURSPOT FLOUNDER	0.23	20.00	0.19	25.00	0.18	20.00
BUTTERFISH	0.04	5.00	0.09	10.00	0.02	5.00
POLLOCK	0.03	25.00	0.01	5.00	0.04	25.00
ATLANTIC MACKEREL	0.26	5.00	0.40	10.00	0.36	10.00
WINDOWPANE	1.46	40.00	0.69	40.00	1.12	45.00
TAUTOG	0.25	20.00	0.24	15.00	0.19	20.00
CUNNER	81.58	40.00	68.36	40.00	83.91	40.00
HAKE	5.86	45.00	9.71	45.00	4.15	45.00

3.2.1.2 Entrainment

Seabrook Station's Circulating Water System was in operation throughout 1990, with average daily flows of 531 million gallons per day (MGD) during the preoperational period (January-July) and 589 MGD during the commercial operational period (August-December)(Table 2.1-1). Entrainment samples were collected June-December, usually on the same days that the nearfield and farfield ichthyoplankton samples were collected at stations P2, P5, and P7.

Fish egg taxa in entrainment samples had similar species composition to those in offshore nearfield collections collected during the same week (Table 3.2.1-8). Atlantic mackerel, hake, cod/witch flounder, rockling/hake, cunner/yellowtail flounder, and windowpane were the six most abundant taxa in the in-plant and offshore samples. In general, mean abundances at nearfield Station P2 exceeded those observed in entrainment samples, often by as much as an order of magnitude. Species such as Atlantic mackerel, windowpane, hake, and fourbeard rockling, which have large oil globules, exhibit characteristics similar to other buoyant species in the middle Atlantic bight (Kendall and Naplin 1981) in that they tend to be found more often at surface depths. Because of this tendency to concentrate near the surface, eggs of these species were less abundant in the entrainment samples than in the oblique offshore tows, because the plant intake draws water from well below the surface. Cunner/yellowtail flounder eggs were approximately 20 times higher in abundance in offshore samples than in entrainment samples. Although this species lacks an oil globule, previous studies (NAI 1981b, 1981f) have shown that this species is present in much greater abundances in middle and surface depths. Species such as Atlantic cod/witch flounder, which lack oil, may be less buoyant and therefore more abundant in the bottom portions of the water column, thus accounting for the occasionally higher abundances observed in in-plant samples compared with offshore samples.

TABLE 3.2.1-8. MONTHLY GEOMETRIC MEAN OF DENSITY (PER 1000 CUBIC METERS) OF ENTRAINED FISH EGGS FROM ENTRAINMENT AND OFFSHORE (P2) COLLECTIONS DURING JUNE-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

ENTRAINMENT	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CUSK		<1					
FOURBEARD ROCKLING	19	3	24	10			
ROCKLING/HAKE	130	85	169	23	9		
COD/WITCH FLOUNDER	239	60	29	10	15		
ATLANTIC COD		2	1			23	14
WITCH FLOUNDER			<1	3			
AMERICAN PLAICE	22	3					
CUNNER/YELLOWTAIL FLOUNDER	1121	1036	45	2			
ATLANTIC WHITING	12	51	5	6	3		
ATLANTIC MACKEREL	1457	107	1				
WINDOWPANE	142	123	112	42			
HAKE	50	88	195	29			

OFFSHORE[a]	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN
FOURBEARD ROCKLING	510	5	1	18	3		
ROCKLING/HAKE	1159	660	1429	271	1		
COD/WITCH FLOUNDER	42	209	4	5	106		
ATLANTIC COD		1				314	438
WITCH FLOUNDER		1		1			
AMERICAN PLAICE	2						
CUNNER/YELLOWTAIL FLOUNDER	19620	20071	1225	6			
ATLANTIC WHITING	3	37	2	433			
ATLANTIC MACKEREL	14097	993					
WINDOW PANE	1001	799	425	187			
HAKE	210	11267	3471	507	1		

[a]Includes only collections corresponding to dates when entrainment samples were collected.

Entrained fish larvae also followed trends in species composition similar to those observed in the offshore nearfield station collections (Table 3.2.1-9). Abundances of entrained and offshore larvae were comparable for several species, but Atlantic whiting, Atlantic mackerel, cunner, and hake larvae had higher abundances at the offshore nearfield station than at the entrainment station. The variety of depths sampled might explain the larger abundances for the offshore oblique tows at Station P2 (the cooling water intake is 5 m above the bottom in 17 m of water). In a few cases, abundances of entrained larvae were an order of magnitude higher than in offshore samples, such as Atlantic seasnail in June and July.

Total entrainment was estimated for both eggs and larvae for June-December on the basis of observed densities in entrainment samples and the total cooling water flow, (Table 3.2.1-10 and 3.2.1-11). Atlantic mackerel and cunner/yellowtail flounder were the egg taxa entrained in the greatest quantities. The greatest entrainment losses among larvae were those for fourbeard rockling and cunner.

The high degree of similarity of the 1990 fish eggs and larvae communities to those observed in previous years and the similar species composition at nearfield and farfield stations both indicate that ichthyoplankton losses due to entrainment have had a negligible effect on the ichthyoplankton in the nearfield area.

3.2.1.3 Selected Species

Larvae of nine fish species were selected for a detailed analysis of their within-year and among-year patterns of abundance because of their numerical dominance or importance as a recreational or commercial species. Each of the nine species displayed distinct seasonal patterns of abundance. While fish larvae were present in every month, the larvae of each species exhibited a sharply defined period of peak abundance of only a few months' duration. Fish larvae in other

TABLE 3.2.1-9. MONTHLY GEOMETRIC MEAN OF DENSITY (PER 1000 CUBIC METERS) OF ENTRAINED FISH LARVAE FROM ENTRAINMENT AND OFFSHORE (P2) COLLECTIONS DURING JUNE-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

ENTRAINMENT	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ATLANTIC HERRING						3	10
LUMPFISH	2						
FOURBEARD ROCKLING	3		83	37			
ATLANTIC COD	5			1			
WITCH FLOUNDER			2				
AMERICAN PLAICE	3	1					
YELLOWTAIL FLOUNDER	1						
ATLANTIC SEASNAIL	124	35	1				
GULF SNAILFISH	1						
SNAILFISH	1						
ATLANTIC WHITING			3	4			
RAINBOW SMELT	1						
UNIDENTIFIED			2	2			
FOURSPOT FLOUNDER				1			
POLLOCK							3
WINTER FLOUNDER	46	3					
ATLANTIC MACKEREL	2						
WINDOWPANE		1	6	23			
TAUTOG				1			
CUNNER		1	383	63			
RADIATED SHANNY	50	1	1				
HAKE		1	10	5			

OFFSHORE[a]	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN
ATLANTIC SILVERSIDE	3						
ALLIGATOR FISH			4				
ATLANTIC HERRING				1	24	1	2
LUMPFISH	1						
FOURBEARD ROCKLING	38	56	25	130	1		
ATLANTIC COD	4					1	
WITCH FLOUNDER		1		32			
AMERICAN PLAICE	3	3					
YELLOWTAIL FLOUNDER	3	1		2			
ATLANTIC SEASNAIL	13	2					
SILVER HAKE			84	337			
UNIDENTIFIED	2	6	5	4			
FOURSPOT FLOUNDER			1	16			
BUTTERFISH				2			
POLLOCK							2
NORTHERN SEAROBIN				1			
WINTER FLOUNDER	25	5					
ATLANTIC MACKEREL	37	47	2				
WINDOWPANE		8	1	112			
NORTHERN PIPEFISH		1					
TAUTOG			5	3			
CUNNER	13	622	5602	763			
RADIATED SHANNY	53	14					
HAKE		6	417	89			

[a]Includes only collections corresponding to dates when entrainment samples were collected.

TABLE 3.2.1-10. MONTHLY ESTIMATED NUMBERS OF FISH EGGS (IN MILLIONS) ENTRAINED BY THE COOLING WATER SYSTEM AT SEABROOK STATION DURING JUNE-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

TAXON	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Atlantic mackerel	499.1	19.1	0.6	0	0	0	0
Cunner/yellowtail flounder	380.4	105.0	4.7	0.2	0.1	0	0
Rockling/hake	86.1	10.2	15.4	1.6	0.7	0.2	0
Hake	6.2	10.9	17.6	2.2	0.4	0	0
Windowpane	13.5	10.0	8.8	4.0	0.1	0	0
Cod/witch flounder	16.3	5.3	2.2	1.3	0.7	0.4	0
Atlantic whiting	1.5	3.6	1.5	2.7	2.0	0.1	0
Fourbeard rockling	4.2	0.7	1.7	0.7	0.1	0	0
American plaice	2.3	0.3	0	0	0	0	0
Atlantic cod	0	0.2	0.4	0	0	0.9	1.0
Witch flounder	0	0	0.1	0.3	0	0	0
Cusk	0	0.1	0	0	0	0	0

TABLE 3.2.1-11. MONTHLY ESTIMATED NUMBERS OF FISH LARVAE (IN MILLIONS) ENTRAINED BY THE COOLING WATER SYSTEM AT SEABROOK STATION DURING JUNE-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

TAXON	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Cunner	0	0.1	31.7	10.2	0.7	0	0
Fourbeard rockling	1.9	0.1	16.5	11.7	7.7	0	0
Atlantic seasnail	8.6	2.9	0.1	0	0	0	0
Atlantic whiting	0	0	0.3	4.4	3.0	0	0
Radiated shanny	4.6	0.1	0.1	0	0	0	0
Hake	0	0.1	1.4	2.0	1.3	0	0
Windowpane	0	0.1	0.7	2.0	1.0	0	0
Winter flounder	2.9	0.3	0	0	0	0	0
Atlantic herring	0	0	0	0	0	0.1	0.6
Unidentified	0	0	0.3	0.3	0.1	0	0
Lumpfish	0.6	0	0	0	0	0	0
Atlantic cod	0.5	0	0	0.1	0.1	0	0
American plaice	0.3	0.1	0	0	0	0	0
Witch flounder	0	0	0.3	0	0	0	0
Tautog	0	0	0.1	0.1	0.1	0	0
Atlantic mackerel	0.2	0	0	0	0	0	0
Pollock	0	0	0	0	0	0	0.2
Fourspot flounder	0	0	0	0.1	0.1	0	0
Rainbow smelt	0.2	0	0	0	0	0	0
Gulf snailfish	0.1	0	0	0	0	0	0
Goosefish	0	0	0.1	0	0	0	0
Atlantic menhaden	0	0	0.1	0	0	0	0
Yellowtail flounder	0.1	0	0	0	0	0	0
Snailfish	0.1	0	0	0	0	0	0

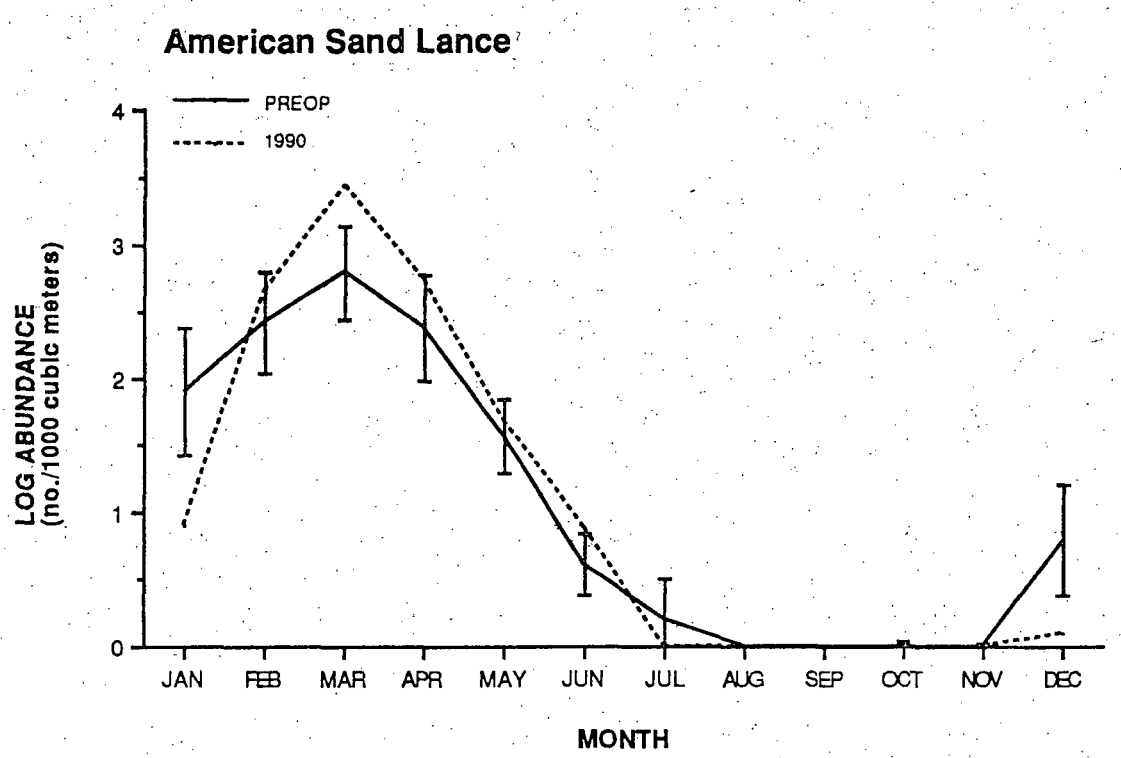
months were typically much less abundant or absent from samples. These seasonal fluctuations were the primary reason for the high within-year variability (NAI 1983b).

Two-way analyses of variance (ANOVAs) were used to test the statistical significance of temporal (preoperational vs. 1990) and spatial (nearfield vs. farfield areas) differences in log (x+1) transformed densities. Because sampling at both the nearfield and farfield areas was initiated in January of 1982, only data collected since that time were included in the two-way ANOVAs. ANOVAs focussed on the period of peak abundance for each species identified in the historical data. Of the selected species, only Atlantic herring abundance typically peaks between August and December, the period of commercial operation in 1990.

Pollock peak abundances occur in winter, from November or December through February. This report presents annual abundances from November 1989 through February 1990. Information on pollock during the operational period will be presented in the 1991 Operational Report.

American Sand Lance

Historically, American sand lance larvae were present in collections at Station P2 from October through July with peak abundances occurring from January through April (Figure 3.2.1-5). In 1990, abundances were slightly higher than normal in March, and lower than normal in January and December with no larvae caught during July through November. This broad peak was due primarily to two factors: an extended hatching period (Richards 1982) and a long planktonic stage for larvae (Bigelow and Schroeder 1953). American sand lance was the most abundant species over all years at Station P2, ranging from 35.0/1000 m^3 in 1977 to 447.7/1000 m^3 in 1982 (Table 3.2.1-12). Abundance for 1990 (163.3 larvae/1000 m^3) was slightly higher than the overall mean for the preoperational period (147.9 larvae/1000 m^3). Combining nearfield and



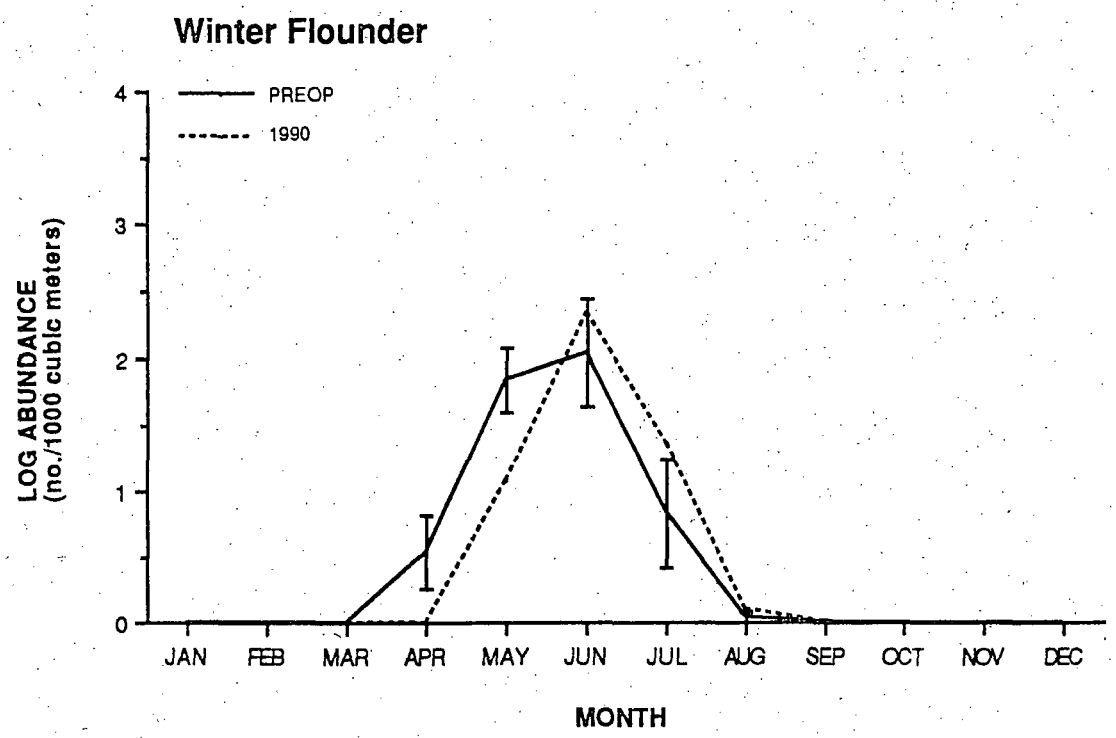


Figure 3.2.1-5. Log (x+1) abundance (no./1000 m^3) of American sand lance and winter flounder larvae; monthly means and 95% confidence intervals over all preoperational years (1975-1989) and monthly means for 1990 at nearfield Stations P2 and P3. Seabrook Operational Report, 1990.

TABLE 3.2.1-12. GEOMETRIC MEAN OF SEASON OF PEAK ABUNDANCE (NUMBER PER 1000 M^3) BY YEAR, PREOPERATIONAL MEAN (PREOP.), AND OPERATIONAL YEAR (1990) OF SELECTED FISH SPECIES LARVAE AT STATION P2, JULY 1975 THROUGH DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES (and months included)	YEAR 1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	PREOP. MEAN	CONFIDENCE LIMIT LOWER	CONFIDENCE LIMIT UPPER	OPERATIONAL YEAR 1990
American sand lance (Jan-Apr)	-[a]	352.9	35.0	384.0	203.2	219.7	213.7	447.7	95.0	73.8	71.5	314.8	87.9	139.7	168.0	147.9	106.5	205.3	163.9
Winter flounder (Apr-Jul)	-	12.5	10.4	17.5	7.9	9.5	2.9	12.4	14.4	19.7	22.4	19.1	15.4	17.2	12.4	14.0	9.7	19.9	5.7
Yellowtail flounder (May-Aug)	-	3.7	20.1	4.1	12.4	6.5	1.3	0.3	4.3	2.9	2.2	5.3	1.7	2.8	0.7	3.1	2.2	4.3	0.7
Atlantic cod (Apr-Jul)	-	4.7	9.4	16.1	1.2	3.4	9.9	2.8	1.8	2.1	1.3	1.6	0.6	1.1	0.1	2.0	1.4	2.8	0.7
Atlantic mackerel (May-Aug)	-	2.6	5.4	2.3	8.0	24.2	12.4	4.3	12.0	8.4	11.7	12.5	8.5	4.0	2.0	7.3	4.6	11.3	5.9
Cunner (June-Sep)	-	21.1	224.5	30.3	46.1	97.7	29.1	22.6	97.9	22.7	40.7	12.4	255.2	49.4	59.9	49.6	32.3	75.8	274.0
Hake (Jul-Sep)	6.5	0.5	4.2	2.7	8.2	5.4	5.9	2.4	10.4	7.8	10.0	0.1	3.2	3.9	2.3	4.1	2.5	6.3	60.9
Atlantic herring (Oct-Dec)	197.0	144.7	16.1	2.1	7.4	34.0	50.0	62.7	9.3	40.3	21.5	126.7	28.8	26.6	8.7	26.9	18.1	39.6	2.1
Pollock (Nov-Feb)	12.2	27.7	5.1	1.9	49.2	7.3	4.0	2.1	3.4	22.7	13.8	1.2	5.8	4.4	0.6	6.6	4.7	9.1	-[b]

[a] Sampling at P2 began in July 1975, excluding part of annual peak.
[b] Yearly mean not computed for pollock in 1990 because January and February 1991 data were not available.

farfield collections, the two-way ANOVA showed that abundances of larvae of this species were not significantly different in 1990 than the mean of historical abundances (Table 3.2.1-13; Preop-Op). As discussed in regard to the ichthyoplankton community, the nearfield and farfield areas are linked hydrographically. Abundances of American sand lance larvae were similar in these areas (Table 3.2.1-13; Area). The interaction between temporal (Preop-Op) and spatial (Area) factors indicated that mean abundance of American sand lance larvae in 1990 in the nearfield was similar to mean abundance in both the nearfield and farfield in preoperational years and in the farfield in 1990 (Table 3.2.1-13). Annual differences in American sand lance densities were highly significant (Table 3.2.1-13; year (Preop-Op)), indicating a high variability from year to year.

Winter Flounder

Winter flounder larvae, the fourth most abundant (over all preoperational years) of the nine selected species, were usually present from April through August, with the highest concentrations occurring in May and June (Figure 3.2.1-5). Few or no specimens were encountered in January through March and September through December. In 1990, abundances followed the same general pattern as in previous years, but the concentration of winter flounder larvae was lower than average in April and May, and greater than average in July. Abundances of winter flounder larvae, relatively consistent in earlier years (1976-1978), decreased from 17.5 larvae/1000 m^3 (1978) to an all-time low of 2.9 larvae/1000 m^3 in 1981 (Table 3.2.1-12). Abundance increased during the next four years to the highest value recorded, 22.4 larvae/1000 m^3 (1985). Since that time, a general trend of decreasing abundance was observed. Despite the annual variability in the abundance of winter flounder larvae, there were no statistically significant differences among years (Table 3.2.1-13, year (Preop-Op)). However, the reduced number of winter flounder larvae occurring in 1990 (5.7 larvae/1000m^3 was statistically significant at both nearfield and farfield areas.

TABLE 3.2.1-13. RESULTS OF ANALYSIS OF VARIANCE OF LOG (x+1) TRANSFORMED ABUNDANCES (no/1000 m^3) OF SELECTED SPECIES OF ICHTHYOPLANKTON LARVAE DURING MONTHS OF PEAK ABUNDANCE FOR THE YEARS 1982-1984, 1986-1990. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES (PEAK PERIOD)	SOURCE OF VARIATION[a]	df	SS	F	MULTIPLE COMPARISONS
American sand lance (Jan-Apr)	Preop-Op	1	<0.01	0.00 NS	
	Area	1	2.71	3.40 NS	
	Preop-Op X Area	1	0.86	1.09 NS	
	Year (Preop-Op)	6	13.44	2.94**	
	Error	266	202.90		
Winter flounder (Apr-Jul)	Preop-Op	1	8.60	11.34***	
	Area	1	2.70	3.57 NS	
	Preop-Op X Area	1	0.71	0.94 NS	
	Year (Preop-Op)	6	1.04	0.23 NS	
	Error	286	220.29		
Yellowtail flounder (May-Aug)	Preop-Op	1	3.03	6.42*	
	Area	1	<0.01	0.00 NS	
	Preop-Op X Area	1	0.47	1.00 NS	
	Year (Preop-Op)	6	7.84	2.87**	
	Error	302	137.75		
Atlantic cod (Apr-Jul)	Preop-Op	1	0.81	3.48 NS	
	Area	1	0.17	0.73 NS	
	Preop-Op X Area	1	0.32	1.39 NS	
	Year (Preop-Op)	6	7.71	6.13***	
	Error	286	59.96		
Atlantic mackerel (May-Aug)	Preop-Op	1	0.01	0.01 NS	
	Area	1	0.03	0.31 NS	
	Preop-Op X Area	1	0.01	0.01 NS	
	Year (Preop-Op)	6	10.47	1.32 NS	
	Error	302	400.28		
Cunner (Jun-Sep)	Preop-Op	1	12.51	8.38**	
	Area	1	0.01	0.01 NS	
	Preop-Op X Area	1	0.01	0.01 NS	
	Year (Preop-Op)	6	42.21	5.08***	
	Error	306	423.77		
Hake (Jul-Sep)	Preop-Op	1	23.91	29.05***	
	Area	1	0.05	0.05 NS	
	Preop-Op X Area	1	0.21	0.25 NS	
	Year (Preop-Op)	6	14.02	2.98**	
	Error	230	180.20		
Atlantic herring (Oct-Dec)	Preop-Op	1	22.55	29.14***	
	Area	1	<0.01	0.00 NS	
	Preop-Op X Area	1	<0.01	0.00 NS	
	Year (Preop-Op)	6	21.00	4.99***	
	Error	225	157.77		
Pollock (Nov-Feb)	Year	14	56.53	10.50***	79 75 85 76 84 80 87 77 81 88 83 78 82 86 89
	Error	330	126.88		

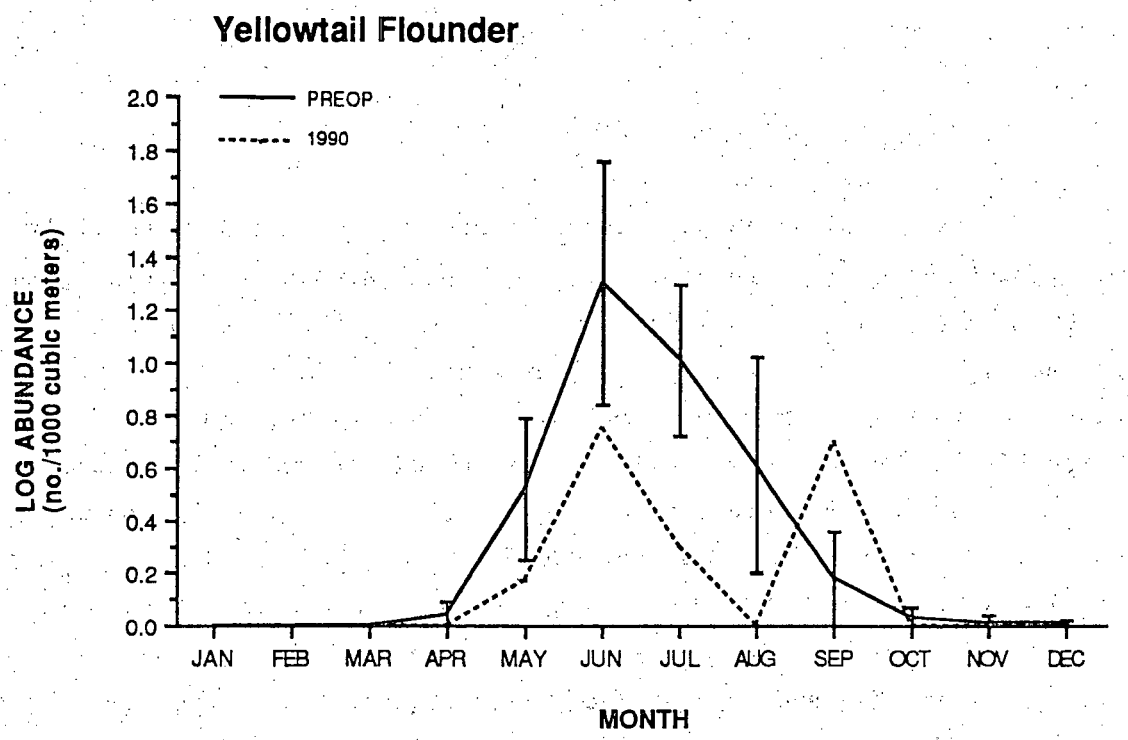
[a]Preop-Op = temporal variation (preoperational years vs. operational year)
Area = nearfield vs. farfield
Preop-Op X Area = interaction between main effects
Year (Preop-Op) = year nested within preoperational and operational periods, regardless of area
NS = not significant (p>0.05)
* = significant (0.05≥p>0.01)
** = highly significant ((0.01≥p>0.001)
*** = very highly significant (p≤0.001)

Yellowtail Flounder

Yellowtail flounder larvae at nearfield Station P2 normally occurred from May through September, with peak abundances occurring in June and July (Figure 3.2.1-6). In recent years there has been an increasing number of larvae present in April, but in 1990 there was no evidence of this. Larvae were present only during the months of May through July and September in 1990. Yellowtail flounder abundances have shown significant differences among years (Table 3.2.1-12). Abundance was highest in 1977 (20.1 larvae/1000 m^3) then generally decreased to the lowest value in 1982 (0.3 larvae/1000 m^3). Since that time abundances have remained relatively consistent and moderate through 1988. Abundances in 1989 and 1990 at Station P2 reached the second lowest value recorded during the years of study (0.7 larvae/1000 m^3). This contributed to significantly lower abundances in 1990 in comparison to previous years at both nearfield and farfield stations (Table 3.2.1-13). Abundances were statistically similar at both stations throughout the study period.

Atlantic Cod

Atlantic cod larvae typically exhibited a bimodal distribution with one peak lasting from November through January (late fall-winter) and the other (usually stronger) peak in April through July (spring-early summer, Figure 3.2.1-6). Very few cod larvae were caught in 1990 with abundances below normal for May and no larvae present in February through April, July through October, and December. Geometric mean peak-season abundance for Atlantic cod includes only the spring-early summer peak, which represents the higher abundances and longer period of occurrence in comparison to the late fall-winter peak. Abundance increased in early years, reaching a peak in 1978 of 16.1 larvae/1000 m^3 (Table 3.2.1-12). Abundances were low during the next two years and then rose again in 1981. A trend of decreasing and below-average abundances began in 1982 and has continued through 1990. The geometric mean for 1990 (0.7 larvae/1000 m^3) rose slightly from 1989 (0.1



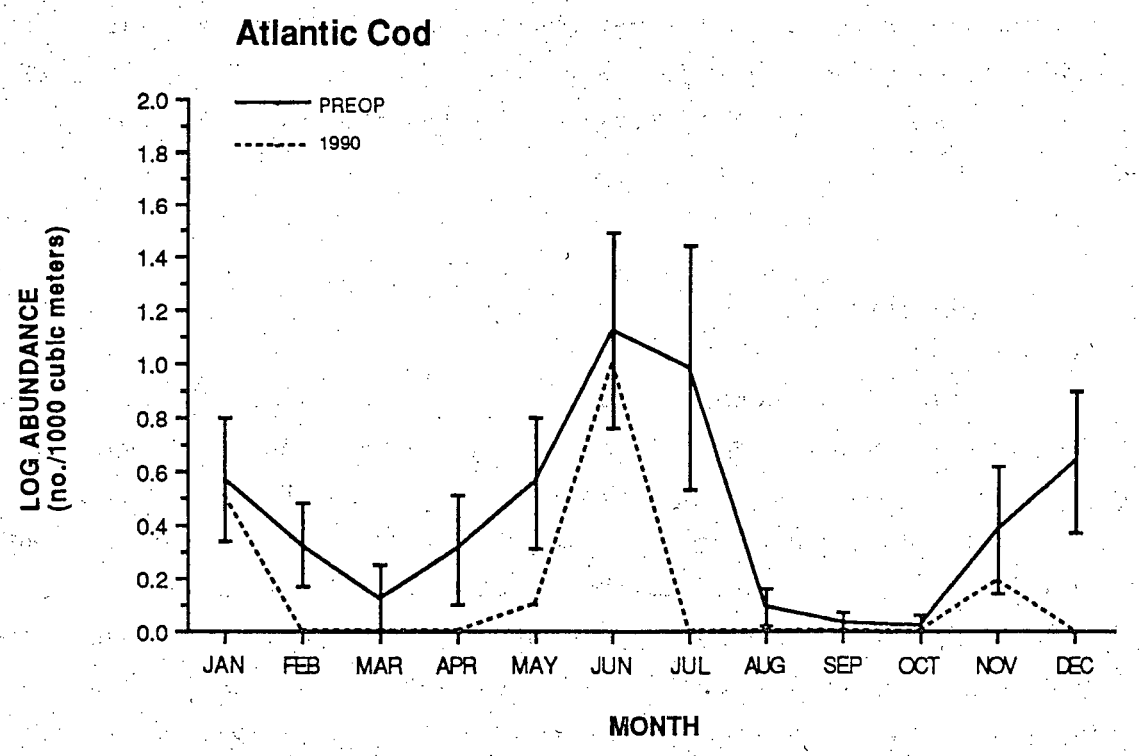


Figure 3.2.1-6. Log (x+1) abundance (no./1000 m^3) of yellowtail flounder and Atlantic cod larvae; monthly means and 95% confidence intervals over all preoperational years (1975-1989) and monthly means for 1990 at nearfield Stations P2 and P3. Seabrook Operational Report, 1990.

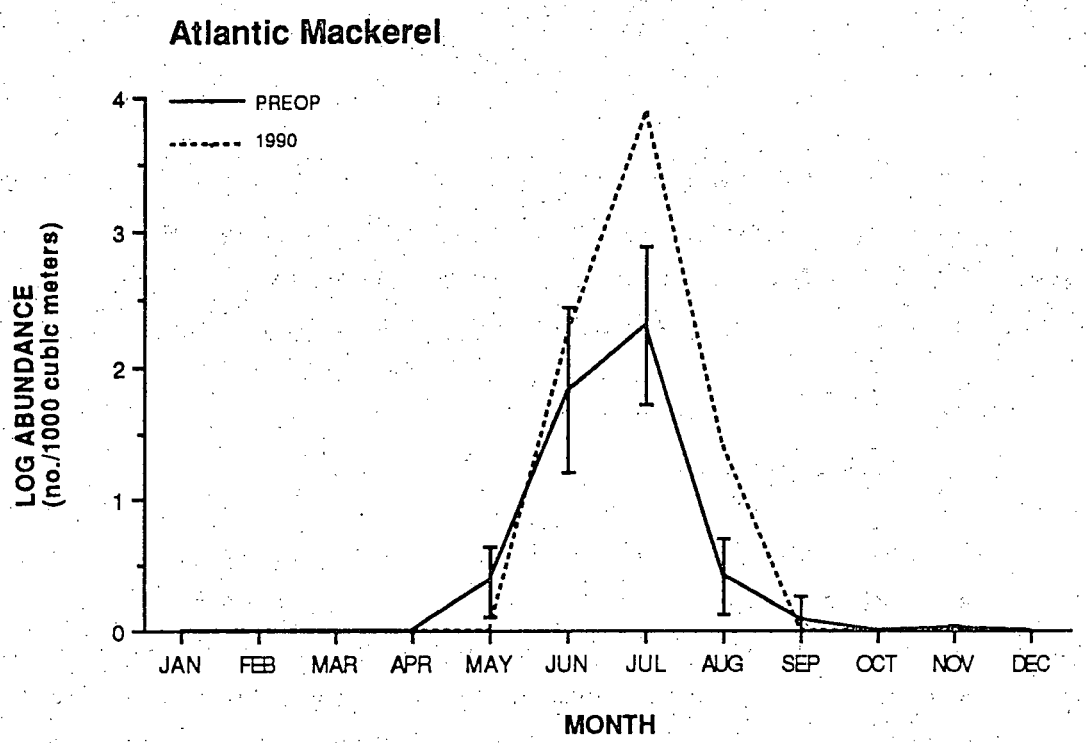
larvae/1000 m^3), the lowest abundance during the preoperational period, but was still well below the mean abundance for that period (2.0 larvae/1000 m^3). Abundances in 1990 were statistically similar to previous years at both nearfield and farfield stations (Table 3.2.1-13).

Atlantic Mackerel

Atlantic mackerel larvae have historically exhibited a May through September pattern of occurrence , with the highest monthly average occurring in July. No larvae were found in January through April, October and December (Figure 3.2.1-7). In 1990, mackerel larvae followed the historical seasonal pattern of occurrence, except that July and August had above normal abundances and no larvae were caught in May or September. Mean abundances for mackerel larvae during the peak season of May-August have been variable throughout the study period and had been decreasing from 1986 through 1989(from 12.5 to 2.0 larvae/1000 m^3)(Table 3.2.1-12). Abundance for 1990 (5.9 larvae/1000 m^3 at Station P2) increased slightly over 1989 abundance; however 1990 abundances at P2 and P7 were statistically similar to previous years (Table 3.2.1-13).

Cunner

Cunner larvae were present throughout June through October, showing a pattern of occurrence similar to mackerel larvae but generally a little later. Cunner larvae have historically peaked during July and August and usually disappeared by October (Figure 3.2.1-7). Larval abundance in 1990 continued to follow the seasonal pattern observed in previous years, but values for June, August, and September were much larger than the preoperational mean. Mean peak season abundances for cunner larvae have shown significant differences among the preoperational years (Table 3.2.1-12) with 1987 exhibiting the highest abundance (255.2 larvae/1000 m^3) during that time. Cunner larvae have ranked among the top three in abundance throughout all years of the study period except 1986. In 1990 cunner larvae ranked first in abundance



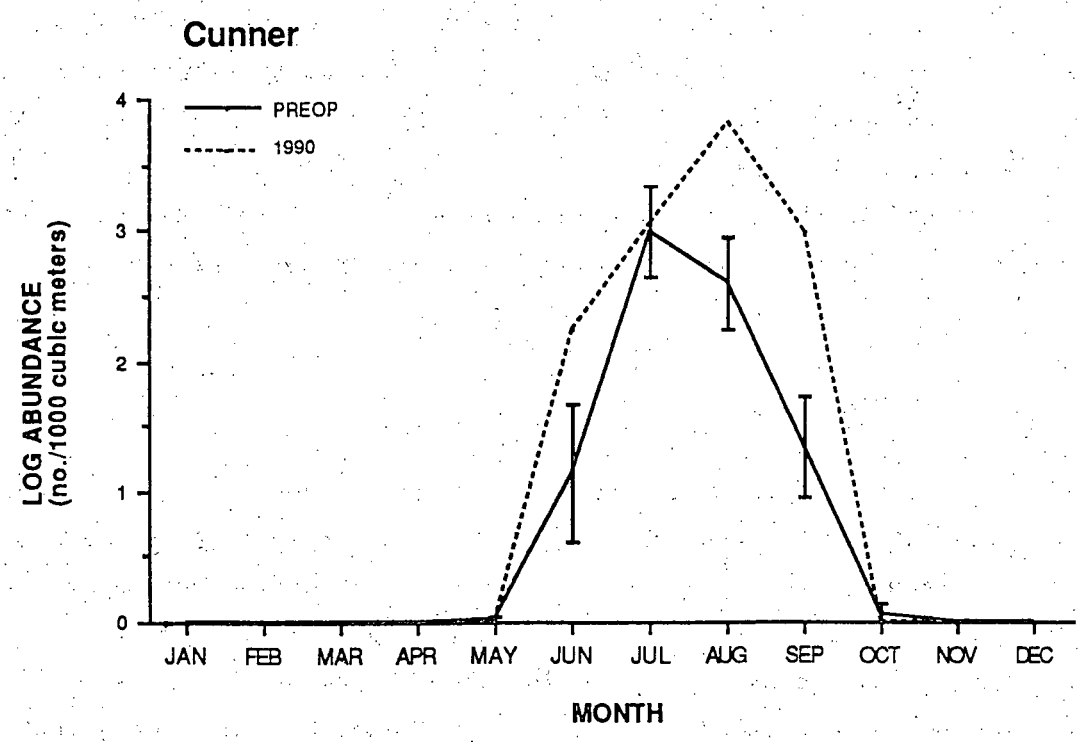


Figure 3.2.1-7. Log (x+1) abundance (no./1000 m^3) of Atlantic mackerel and cunner larvae; monthly means and 95% confidence intervals over all preoperational years (1975-1989) and monthly means for 1990 at nearfield Stations P2 and P3. Seabrook Operational Report, 1990.

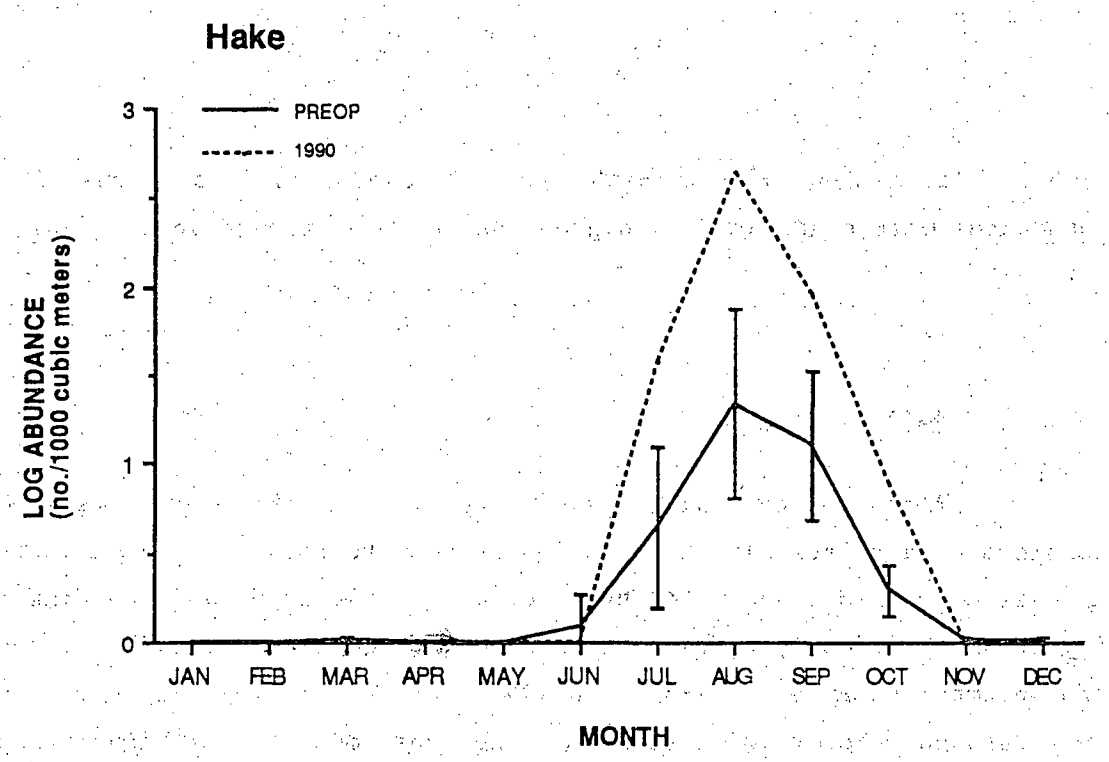
with 274 larvae/1000 m^3. At both nearfield and farfield stations, 1990 abundances were significantly higher than preoperational years (Table 3.2.1-13).

Hake

Historically, hake larvae, like mackerel and cunner, were confined to a relatively short period of occurrence. Abundances were at or near zero from January to May, increased in June and July peaking in August and September, decreasing in October, and negligible in November and December (Figure 3.2.1-8). In 1990, larvae were only present from July through October, with values during these months much higher than average. Yearly peak season abundance at Station P2 during the preoperational years did not rise above 10.4 larvae/1000 m^3 (Table 3.2.1-12). During the operational year, the abundance of hake larvae (60.9/1000 m^3) was significantly higher than in any of the preoperational years which averaged (4.1/1000 m^3).

Atlantic Herring

Atlantic herring larvae typically occurred from October through May and were rare for the remainder of the year (Figure 3.2.1-8). Abundances were usually highest from October through December with peak values occurring in November. In 1990, herring followed the same seasonal pattern; however, abundances for most of the season were much lower than the mean for the preoperational period. As is the case with most of the other selected species, herring larvae have had a highly variable yearly peak-season abundance at Station P2 during the preoperational years (Table 3.2.1-12). Abundances ranged from 145 larvae/1000 m^3 in 1976 to 2.1 larvae/1000 m^3 in 1978. In 1990, mean abundance (2.1 larvae/1000 m^3) was substantially lower than the overall mean (26.9 larvae/1000 m^3) and all preoperational years except 1978.



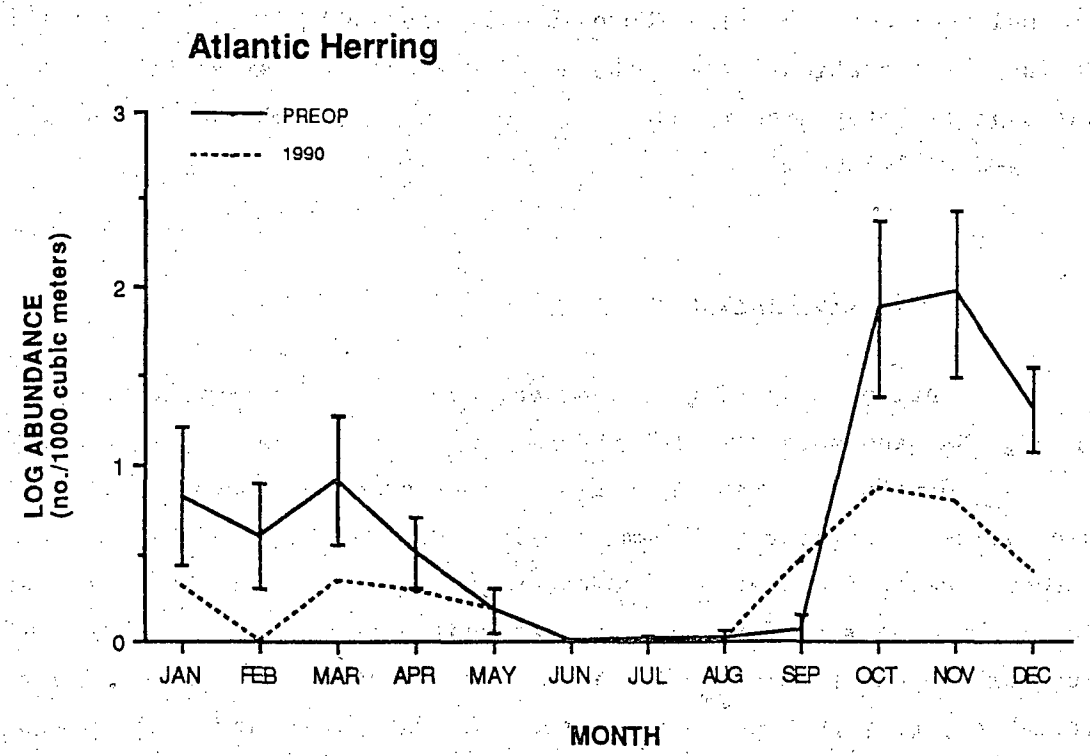


Figure 3.2.1-8. Log (x+1) abundance (no./1000 m^3) of hake and Atlantic herring larvae; monthly means and 95% confidence intervals over all preoperational years (1975-1989) and monthly means for 1990 at nearfield Stations P2 and P3. Seabrook Operational Report, 1990.

Atlantic herring was the only larvae species with its peak period of abundance during the period of 100% plant operation (August-December). 1990 abundances were significantly lower than previous years at both nearfield and farfield stations (Preop-Op term; Table 3.2.1-13). However, there has been a general decline in abundance of Atlantic herring larvae since 1986 in the nearfield area (Table 3.2.1-12). Adult Atlantic herring catches in both the study area (NAI 1990b) and the Gulf of Maine (NOAA 1991a) have been low in recent years indicating a possible reduction in the number of spawning individuals and the resulting number of larvae.

Pollock

Pollock larvae also exhibited a fall-winter pattern of occurrence, but briefer than that of herring larvae. Large abundances occurred in November through February and few or no larvae were caught from March through October (Figure 3.2.1-9). Pollock larvae were absent in February, March and July through October 1990. They were also less abundant than normal in November and December. Peak seasonal abundances for pollock were highly variable during the preoperational years (Table 3.2.1-12) with the highest abundance occurring in 1979 (49.2 larvae/1000 m^3). In 1990, the seasonal mean was not computed for pollock because its period of peak abundance extends into 1991. For this reason, an ANOVA design testing among-years differences was used to be consistent with the previous year's results (NAI 1990b). However, mean abundance in 1989 (which includes samples collected in early 1990) was the lowest recorded for any of the preoperational years (0.6 larvae/1000 m^3) and was well below the overall mean of 6.9 larvae per 1000 cubic meters. Annual abundances were significantly different among years (Table 3.2.1-13). The multiple comparison test showed eight overlapping groups of years, making interpretation of among-year patterns very complicated. Although the late 1989-early 1990 abundances were the lowest among all years, they were not significantly lower than those in 1978, 1982, 1983 or 1986.

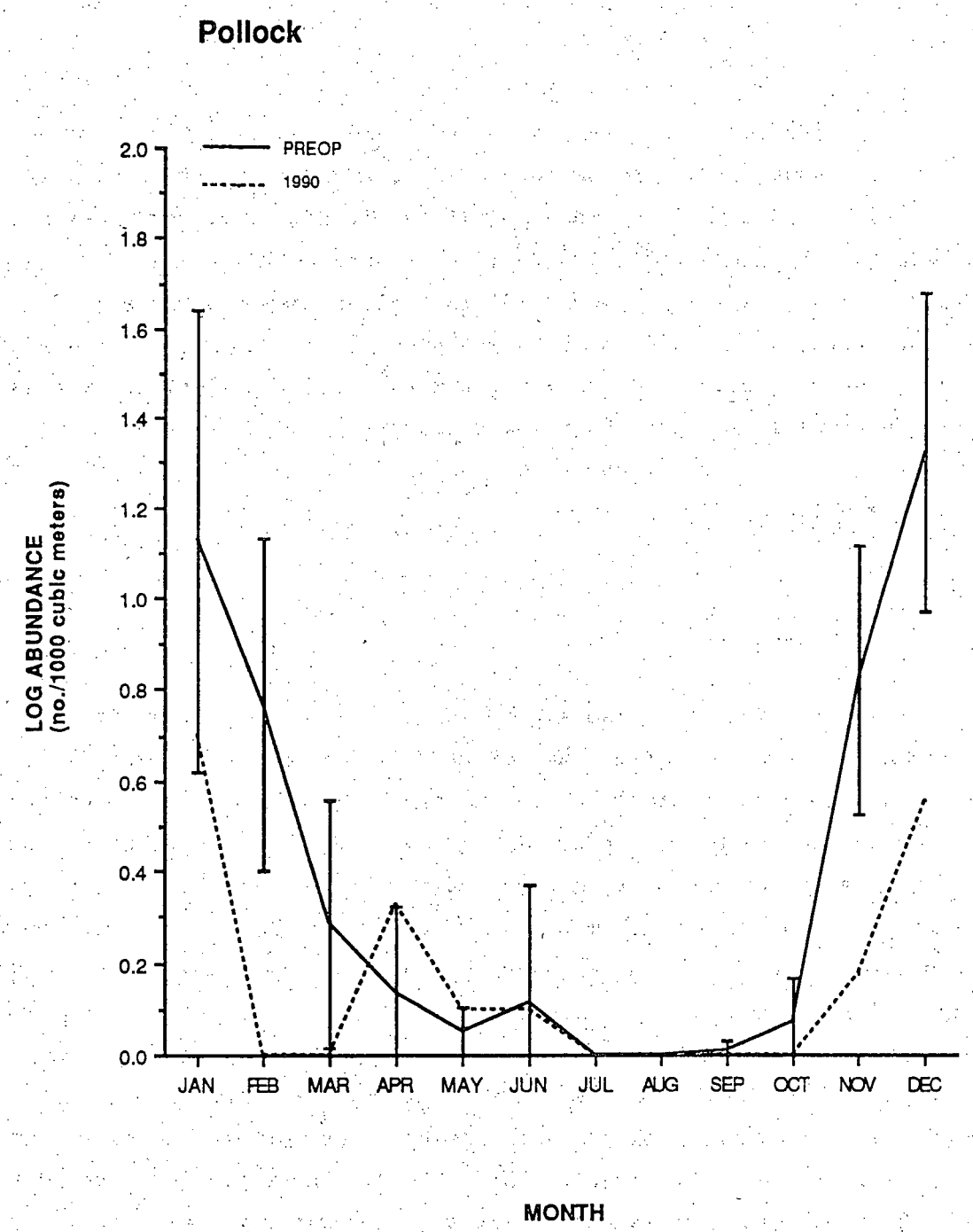


Figure 3.2.1-9. Log (x+1) abundance (no./1000 m^3) of pollock larvae; monthly means and 95% confidence intervals over all preoperational years (1975-1989) and monthly means for 1990 at nearfield Stations P2 and P3. Seabrook Operational Report, 1990.

3.2.2 Adult Finfish

3.2.2.1 Community

Inter-Annual Patterns in the Pelagic Fish Community

Mean catch per unit of effort (CPUE: catch/24-hour set) for gill nets (all stations combined) rose to a peak of 29 fish/net in 1980 then declined to 6 fish/net in 1981, remaining at low levels through 1989 (Figure 3.2.2-1). CPUE remained low in 1990 (3 fish/net) and was virtually identical to levels encountered in 1984 through 1989. The high CPUE in 1980 was due to unusually high catches of Atlantic herring and pollock (NAI 1981e). Commercial landings for Atlantic herring in the western Gulf of Maine also reached a maximum in 1980 (NOAA 1989) indicating a large, widespread population.

The low CPUE in 1990 reflects a continuation of the low and generally decreasing trend in CPUE that started in 1981 and appears to be due to the regional decline in herring abundance (NOAA 1991a).

Atlantic herring were the most abundant species in gill net collections during every preoperational year sampled, comprising from 26 to 82 percent of the total annual catch and averaging 63 percent for all preoperational years combined (Table 3.2.2-1). The percent contribution of Atlantic herring to the annual gill net catch was highest in 1978, 1979 and 1980 (74, 80, and 82%) and lowest in 1984, 1985, 1986, and 1988 (26, 26, 34, and 33%). During all other years, Atlantic herring ranged from 45 to 63% of the total annual catch. In 1990, Atlantic herring formed only 3% of the total catch, a substantial decrease from previous years. This low percentage is a result of abnormally low catches of Atlantic herring and higher than average catches of Atlantic mackerel (see Section 3.2.2-3).

Atlantic whiting, blueback herring, pollock, and Atlantic mackerel collectively composed 27 percent of the gill net catch for all preoperational years combined. In the years when Atlantic herring

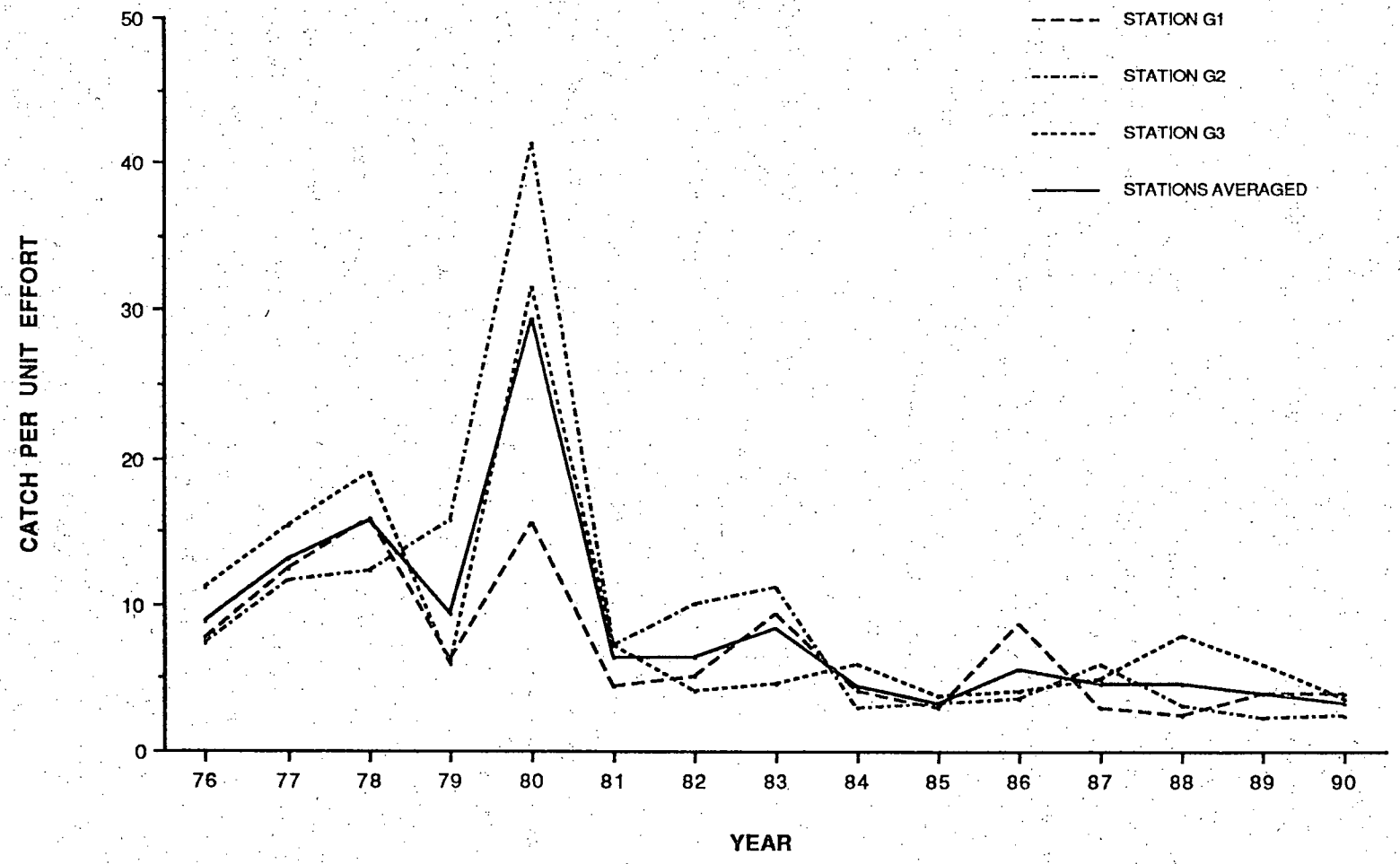


Figure 3.2.2-1. Annual total catch per unit effort (number per 24-hour set of one net, surface or bottom) in gill nets by station and mean of stations, 1976-1990. Seabrook Operational Report, 1990.

TABLE 3.2.2-1. PERCENT COMPOSITION BY YEAR, ALL PREOPERATIONAL YEARS COMBINED, AND 1990 FOR THE TEN MOST ABUNDANT SPECIES IN GILL NET SAMPLES FROM 1976 THROUGH 1990 AT STATIONS G1, G2, AND G3 COMBINED. SEABROOK OPERATIONAL REPORT, 1990.

	YEAR														ALL PREOP. YEARS COMBINED	1990
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989		
Atlantic herring	53	48	74	80	82	45	63	48	26	26	34	52	33	61	63	3
Atlantic whiting	17	21	2	4	6	5	7	1	5	1	1	5	1	1	8	5
Blueback herring	5	11	14	2	2	2	10	11	9	10	15	16	11	7	8	5
Pollock	6	3	1	2	5	18	3	13	10	22	18	6	13	10	6	23
Atlantic mackerel	12	7	2	2	2	14	5	5	6	10	3	7	22	6	5	37
Alewife	1	2	2	<1	<1	2	2	5	5	6	4	2	6	1	2	1
Atlantic menhaden	<1	3	<1	2	1	<1	1	6	5	4	4	2	1	2	2	2
Hake species[a]	2	2	1	1	<1	4	1	1	7	2	2	<1	5	<1	1	1
Rainbow smelt	1	1	1	1	<1	<1	<1	1	6	2	4	3	1	1	1	1
Atlantic cod	1	1	<1	1	<1	<1	2	2	3	1	2	2	2	1	1	<1
Other species	2	<1	2	4	<1	8	6	7	18	16	13	4	5	10	4	22
Total number of species	19	26	23	22	21	29	29	24	30	23	23	19	20	24	24	20

[a]includes red, white and spotted hake

accounted for less than 50 percent of the total annual catch, these four species comprised from 30 to 47 percent of the total catch. These taxa have consistently ranked among the five most abundant taxa during the 14-year preoperational sampling period. In 1990, these four taxa combined accounted for 70% of the total catch. Atlantic mackerel, the most abundant of these, comprised 37% of the total catch. This percentage was much higher than any of the preoperational years and the mean of all years. Catches of Atlantic mackerel were atypically high in June and July in 1990 (NAI 1991), accounting for the higher-than-normal percent composition. Atlantic mackerel stocks have been increasing in recent years throughout the Gulf of Maine and the Northwest Atlantic (NOAA 1991a).

Pollock ranked second in relative abundance in 1990, comprising 23 percent of the total catch, which is considerably larger than the mean of 6% for all preoperational years (Table 3.2.2-1). This change was due to a decrease in the relative abundance of Atlantic herring. Atlantic whiting and blueback herring both ranked third in abundance, each contributing 5% to the total catch. Values for these taxa in 1990 were similar to values during the preoperational years.

Less abundant taxa (e.g., alewife, Atlantic menhaden, hakes, rainbow smelt and Atlantic cod) composed a larger portion of the total annual catch during 1984, 1985, 1986 and 1988, when catches were below normal and Atlantic herring were relatively less abundant. In 1990, these taxa formed a smaller percentage of the catch despite the low abundance of Atlantic herring. However, "other" species accounted for a greater proportion of the catch in 1990 (22%) than during the preoperational years, primarily due to large numbers of spiny dogfish *Squalus acanthus* (12% of the 1990 catch) and butterfish *Peprilus triacanthus* (7% of the catch). During the preoperational period, spiny dogfish and butterfish accounted for no more than 7% and 5% of the catch in any given year.

Average species richness for the preoperational period was 24, ranging from 19 to 30 species annually. Forty-five species were collected during all preoperational years combined. Species richness in 1990 (20 species) was within the range for previous years but slightly below the average for the preoperational period. No long-term trend of increasing or decreasing species richness was evident.

Seasonality of the pelagic species assemblage has been analyzed in previous reports (NAI 1982c, 1983b). Two distinct sample groups were observed based on abundances of the dominant species: "summer" (June-August) and "winter" (September-May). Atlantic mackerel and Atlantic whiting were more abundant in summer samples, while Atlantic herring were more numerous in winter catches. In recent years, Atlantic mackerel have been caught in increasing numbers in October and November. In 1990, Atlantic mackerel continued this trend but were much more numerous during the summer months. Catches for Atlantic herring were so low that no seasonality could be detected. The other dominant species continued to exhibit their historical seasonal differences. Blueback herring and pollock showed inconsistent seasonal differences in abundance from 1976 through 1990.

Spatial Patterns in the Pelagic Fish Community

Mean annual catch per unit of effort at the three gill net Stations G1, G2, and G3 showed similar fluctuations among years (Figure 3.2.2-1). Mean annual CPUE peaked in 1980 for all stations combined. This peak was more evident at Stations G2 and G3, where Atlantic herring comprised a greater portion of the catch, than at Station G1 (NAI 1981a). Since 1980, CPUE at each gill net station has fluctuated within a narrow range.

Percent composition for the dominant species in gill net collections was similar among stations during the preoperational years (Table 3.2.2-2). Atlantic herring was the dominant species at each gill net station, accounting for 58 to 68 percent of the total catch for all

TABLE 3.2.2-2. PERCENT COMPOSITION BY STATION OF ABUNDANT SPECIES COLLECTED IN GILL NETS, ALL PREOPERATIONAL YEARS (1976-1989) AND 1990, DEPTHS COMBINED. SEABROOK OPERATIONAL REPORT, 1990.

	STATION					
	G1		G2		G3	
SPECIES	PREOP. YEARS	1990	PREOP. YEARS	1990	PREOP. YEARS	1990
Atlantic herring	61	2	68	2	58	4
Atlantic whiting	8	3	6	9	9	3
Blueback herring	6	3	6	6	10	6
Atlantic mackerel	6	41	4	45	6	26
Pollock	6	6	6	20	6	44
Hake species[a]	2	1	1	2	1	0
Atlantic menhaden	2	4	1	1	2	0
Alewife	2	2	2	2	2	1
Rainbow smelt	1	0	1	2	1	0
Longhorn sculpin	1	1	1	0	<1	1
Atlantic cod	1	1	1	1	1	0
Bluefish	1	1	1	0	<1	4
All other species	3	35	2	10	3	11
Total number of species	17	14	18	14	18	14

[a]includes red, white, and spotted hakes

preoperational years combined. Blueback herring comprised a slightly larger percentage of the total catch at Station G3 (10%) than at Station G1 or Station G2 (6% at each station). Atlantic whiting, Atlantic mackerel, and pollock were also numerically important at each station, each comprising from 4 to 9 percent of the catch at the three stations for all years combined. Percent composition for Atlantic herring, although similar among stations, was very low in 1990. These results are coincidental with low commercial landings in the Gulf of Maine fishery in recent years, suggesting a regional decline in herring abundance (NOAA 1991a). In 1990, Atlantic mackerel was the most abundant species at Stations G1 and G2 and ranked second at G3, while pollock was the most abundant species at G3 and ranked second at G2. At Station G1, pollock comprised similar percentages during 1990 and the preoperational years. Percent composition for the remaining species was similar among stations with one exception. "Other" species accounted for 35 percent of the catch at G1. Spiny dogfish and butterfish comprised 25 percent and 10 percent respectively of the catch and were the only two "other" species.

Depth differences in species composition were examined by comparing percent composition in surface nets to that in off-bottom nets (3 m above the bottom) for all years combined (Table 3.2.2-3). Historically, Atlantic herring was the dominant species in collections at both depths, with a slightly higher percent composition in surface nets compared to off-bottom nets. The proportions of blueback herring and Atlantic mackerel were also higher in surface nets during the preoperational years. Atlantic whiting, pollock, and hakes composed a larger percentage of the catch in the off-bottom nets. Atlantic menhaden and alewives accounted for a similar percentage in both surface and off-bottom nets. During 1990, Atlantic herring formed similar percentages in surface and off-bottom nets. However, percent composition was much lower than during the preoperational years. Atlantic mackerel were dominant and most abundant in the surface nets while pollock were dominant and most abundant in the off-bottom nets. These species

TABLE 3.2.2-3. PERCENT COMPOSITION OF DOMINANT GILL NET SPECIES ACCORDING TO DEPTH (SURFACE AND OFF-BOTTOM), ALL PREOPERATIONAL YEARS COMBINED (1976-1989) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

	DEPTH			
	SURFACE		OFF-BOTTOM	
SPECIES	PREOP. YEARS	1990	PREOP. YEARS	1990
Atlantic herring	69	1	55	4
Blueback herring	10	9	5	1
Atlantic mackerel	7	59	3	16
Atlantic whiting	5	5	11	5
Atlantic menhaden	2	4	1	0
Alewife	2	1	1	2
Pollock	1	0	12	45
Rainbow smelt	1	0	1	1
Hake species[a]	<1	0	3	2
Other species	3	21	8	24

[a]includes red, white, and spotted hakes

accounted for much higher percentages in 1990 than during the preoperational years as discussed above. Blueback herring and Atlantic menhaden accounted for higher percentages in the surface nets. Atlantic whitings, alewives, rainbow smelts and hakes all had similar percentages in surface and off-bottom nets.

Since 1980, mid-water nets have been set in addition to the surface and off-bottom nets during February, June, and October. Comparison of CPUE among surface, mid-water, and off-bottom nets on dates when all three nets were fished revealed that Atlantic menhaden was the only species that was slightly more abundant in mid-water catches than in surface and off-bottom catches during the preoperational period and 1990 (Table 3.2.2-4). As observed with the regular surface and off-bottom gill net collections (Table 3.2.2-3), Atlantic herring and Atlantic mackerel were more abundant in surface nets and least abundant in off-bottom nets. Blueback herring were most abundant in surface nets and least abundant in mid-water nets. Atlantic whiting, pollock, alewife and rainbow smelt were most abundant in bottom nets. In 1990, for those dates when all three nets were fished, Atlantic menhaden was more abundant in the surface and mid-water nets. Atlantic mackerel were more abundant in the surface nets and pollock were more abundant in the off-bottom nets. Atlantic herring, Atlantic whiting, alewives, and blueback herring were similarly abundant in surface, mid and off-bottom nets. Rainbow smelt were only caught in off-bottom nets.

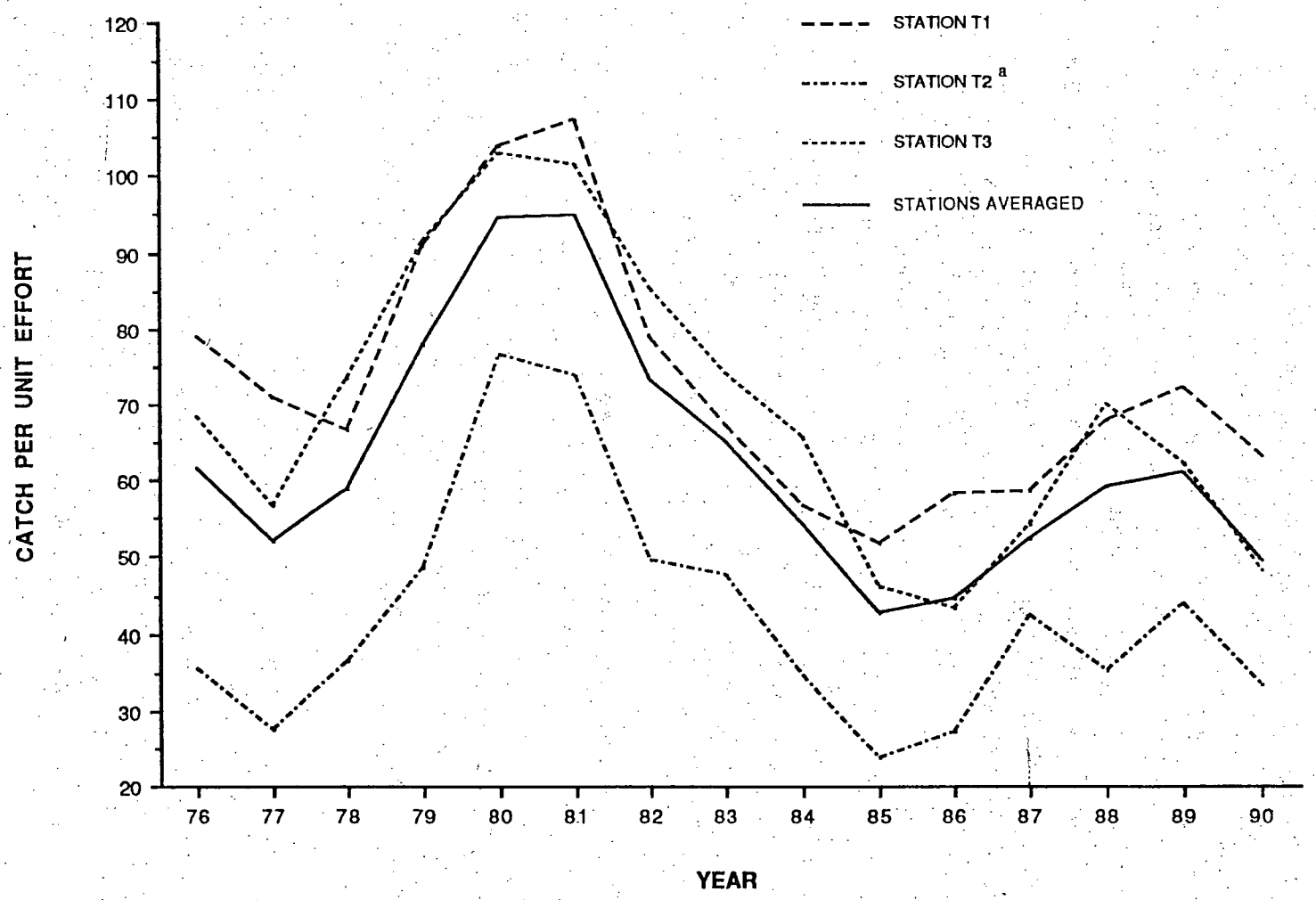
Inter-Annual Patterns in the Demersal Fish Community

Otter trawl catch per unit of effort for all stations and species combined during the 1976 through 1989 period rose from 50 fish/ten minute tow (fish/tow) in 1977 to a peak of 95 fish/tow in 1980 and 1981 (Figure 3.2.2-2). CPUE subsequently declined to a second low point in 1985 when an average of 43 fish/tow were collected. CPUE gradually increased to 61 fish/tow in 1989 but declined to 49 fish/tow in 1990.

TABLE 3.2.2-4. CATCH PER UNIT EFFORT[a] BY DEPTH FOR THE DOMINANT GILL NET SPECIES OVER ALL STATIONS AND DATES WHEN SURFACE MID-DEPTH AND BOTTOM NETS WERE SAMPLED, PREOPERATIONAL YEARS (1980 THROUGH 1989) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

	DEPTH					
	SURFACE		MID-DEPTH		BOTTOM	
SPECIES	PREOP. YEARS	1990	PREOP. YEARS	1990	PREOP. YEARS	1990
Atlantic herring	5.3	0.1	2.9	0.1	1.9	0.1
Atlantic whiting	0.2	0.6	0.5	0.4	0.7	0.5
Atlantic mackerel	1.0	4.3	0.9	2.2	0.5	1.7
Pollock	0.2	0.0	0.2	0.0	1.2	4.4
Alewife	0.1	0.1	0.1	0.2	0.2	0.2
Blueback herring	0.8	0.3	0.3	0.2	0.5	0.1
Atlantic menhaden	0.6	0.5	0.7	0.6	0.2	0.0
Rainbow smelt	<0.1	0.0	<0.1	0.0	0.1	0.1

[a]number per one 24-hour set of one net (surface, mid-depth, or bottom)



[a] In most years sampling was curtailed at station T2 during September and October due to presence of lobster gear.

Figure 3.2.2-2. Annual total catch per unit effort (mean number per 10-minute tow) in otter trawls by station and mean of stations, 1976-1990. Seabrook Operational Report, 1990.

The number of fish species (species richness) collected annually in otter trawls ranged from 32 in 1985 to 40 in 1982 and totaled 56 for all preoperational years combined (Table 3.2.2-5). Changes in the annual composition of the demersal fish community were examined by comparing percent composition of the dominant trawl species. Six taxa accounted for nearly 80 percent of the trawl catch abundance for all preoperational years combined (Table 3.2.2-5). Yellowtail flounder composed the largest percentage of the annual catch (19-36%) in all years except 1983 and 1984, when it ranked second to longhorn sculpin. The percentage of yellowtail flounder in trawl collections consistently declined from 1980 until 1984 when that species represented only 18 percent of the total annual catch. The percent contribution of yellowtail flounder increased to 27 percent in 1985 ending a five-year decline in relative contribution, but was less than 20 percent for the next three years (1986-1988). The percent composition of yellowtail flounder increased to 30% in 1989 and was 27% in 1990, values slightly larger than the average for the preoperational (1976-1989) period.

Longhorn sculpin was the second most abundant demersal species in trawl collections, composing 14% of the catch for all years combined (Table 3.2.2-5). Longhorn sculpins accounted for an increasingly larger portion of the catch from 1976 (5%) through 1984 (27%) but their contribution to the total catch fell back to pre-1979 levels, ranging from 9 to 11%, from 1986 through 1989. Relative abundance in 1990 was 15%.

Hake species (red, white and spotted hake) were the third most abundant group of demersal fishes in the trawl catches. The annual relative contribution of hake species was variable, ranging from 8 to 30% during the preoperational period (Table 3.2.2-5). Hakes composed 8% of the total catch in 1988 and 1989 and 5% in 1990, which is below the average percent composition (13%) in preoperational years.

Historically, winter flounder ranked fourth in relative abundance averaging (10%), contributing from 5 to 15% of the total

TABLE 3.2.2-5. PERCENT COMPOSITION BY YEAR, ALL PREOPERATIONAL YEARS COMBINED, AND 1990 FOR THE TWELVE MOST ABUNDANT TAXA IN OTTER TRAWLS, 1976 THROUGH 1990 AT STATIONS T1, T2[a] AND T3 COMBINED. SEABROOK OPERATIONAL REPORT, 1990.

	YEAR														ALL PREOP YEARS COMBINED	
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989		1990
Yellowtail flounder	36	29	21	34	33	28	22	19	18	27	20	19	20	30	26	27
Longhorn sculpin	5	8	9	12	15	17	16	24	27	22	9	9	11	10	14	15
Hake species[b]	18	30	21	8	8	14	19	10	13	15	14	10	8	8	13	5
Winter flounder	5	8	10	7	12	15	9	8	7	9	10	11	9	11	10	11
Rainbow smelt	13	3	10	7	4	6	5	9	6	1	3	15	18	19	8	11
Atlantic cod	4	3	13	14	9	6	7	8	5	3	3	6	9	1	7	1
Skate species[c]	3	5	2	2	2	2	3	7	8	11	14	11	9	9	5	11
Atlantic whiting	5	3	4	2	1	3	4	1	1	1	8	1	1	1	3	1
Ocean pout	2	4	4	2	1	2	2	3	5	3	3	3	2	2	3	3
Pollock	<1	<1	<1	4	7	2	1	2	<1	<1	2	<1	<1	1	2	4
Windowpane	2	2	1	<1	3	2	2	5	6	5	7	8	8	5	4	7
Haddock	3	2	<1	3	4	<1	2	1	<1	<1	<1	<1	<1	0	1	0
Other species	4	4	5	2	1	3	8	3	3	4	8	5	5	3	4	3
Total number of species	37	34	38	37	34	39	40	38	38	32	37	39	38	56	39	39

[a]In most years sampling was curtailed at Station T2 during September and October due to presence of lobster gear.
[b]includes red, white, and spotted hakes
[c]includes big, little, and thorny skates

annual catch (Table 3.2.2-5). Winter flounder formed 11% of the total catch in 1989 and 1990 and have consistently formed 9 to 11% of the total annual catch since 1985.

Rainbow smelt formed 11% of the total annual catch in 1990, slightly more than the 8% contribution for all years combined (Table 3.2.2-5). The relative contribution of rainbow smelt to the total catch has been highly variable, ranging from 1 to 19% and has increased by as much as 12% in one year. The percent composition in 1990 (11%) was higher than the average for the preoperational period but represented a decline from 1987-1989 values.

Atlantic cod was the sixth most common species based on all preoperational years (7%) but formed a minor portion (1%) of the 1989 and 1990 catches (Table 3.2.2-5). The relative abundance of Atlantic cod has been highly variable as evidenced by increases from 3% in 1977 to 13% in 1978 and decreases from 9% in 1988 to 1% in 1989. Lower abundance of juvenile/adults was coincidental with lower abundance of Atlantic cod larvae in recent years (see previous section).

Skates (big, little, and thorny skates) were relatively uncommon in trawl catches from 1976 through 1982, but have formed from 7 to 14% of the total demersal catch since 1983 (Table 3.2.2-5). Since 1985, skates have composed, on average, 11% of the total annual catch, including 9% in 1988 and 1989 and 11% in 1990.

Spatial Patterns in the Demersal Fish Community

Mean annual catch per unit of effort was similar at the offshore stations (T1 and T3), while CPUE at the shallower nearshore station (T2) was much lower (Figure 3.2.2-2). Trawls are generally not fished at Station T2 during September and October due to the high density of lobster gear in the station area. These two months are typically a period of high abundance for demersal species and the lack

of data could be biasing the results to a lower mean CPUE at Station T2. In addition, the accumulation of drift algae decreased gear effectiveness. Otter trawl catches at the offshore stations (T1 and T3) were dominated by yellowtail flounder, hakes, and longhorn sculpin (Table 3.2.2-6). Collectively, these species comprised 64% of the catch at Station T1 and 57% at T3 for all years combined during the preoperational period. Atlantic cod, Atlantic whiting, and skates were less common at these stations. The most notable difference in species composition between Stations T1 and T3 was that Atlantic cod, skates, and ocean pout comprised a larger percentage of the total catch at Station T3. This, and other small differences in species composition between Stations T1 and T3, may be related to differences in bottom substrates. Station T1 has a sandy bottom, while the bottom substrate at Station T3 is sand, littered with small cobble and shell debris. Yellowtail flounder prefer any sandy bottom, but cod prefer a cobble and shell debris habitat (Bigelow and Schroeder 1953).

Otter trawl catches at the nearshore station (T2) were dominated by winter flounder, rainbow smelt, yellowtail flounder, and hakes, contributing 68% of the catch for all years combined. Relative abundances of hakes, yellowtail flounder, and longhorn sculpin were lower at Station T2 than at Stations T1 and T3, while the opposite was true of winter flounder, rainbow smelt, and pollock.

Percent composition results for 1990 were somewhat different than previous years at all stations. Hakes and Atlantic cod formed a smaller portion of the 1990 catches. White skates and windowpane were proportionally more common in 1990 (Table 3.2.2-6).

Inter-annual Patterns in the Estuarine Fish Community

Catch per unit of effort for all seine stations within the Hampton/Seabrook estuary ranged from 41 to 362 fish/haul (Figure 3.2.2-3). Seine CPUE values were lower from 1982 through 1989 (41 to 114

TABLE 3.2.2-6. PERCENT COMPOSITION BY STATION OF ABUNDANT SPECIES COLLECTED IN OTTER TRAWLS, ALL PREOPERATIONAL YEARS COMBINED (1976-1989) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

	STATION					
	T1		T2[a]		T3	
SPECIES	PREOP. YEARS	1990	PREOP. YEARS	1990	PREOP. YEARS	1990
Yellowtail flounder	38	35	14	14	21	23
Hake species[b]	15	7	9	4	15	3
Longhorn sculpin	11	11	5	5	21	27
Atlantic cod	5	1	5	1	10	1
Rainbow smelt	6	7	19	21	6	11
Winter flounder	6	8	26	24	5	8
Atlantic whiting	3	1	1	<1	3	1
Windowpane	4	11	4	5	3	4
Skate species[c]	4	12	2	4	8	13
Pollock	1	5	7	9	1	1
Ocean pout	1	<1	3	5	4	5
Haddock	1	0	<1	0	2	0
Other species	5	2	5	8	3	3
Total number of species	30	29	23	21	28	28

[a] In most years sampling was curtailed at Station T2 during September and October due to presence of lobster gear.
[b] includes red, white, and spotted hakes
[c] includes big, little, and thorny skates

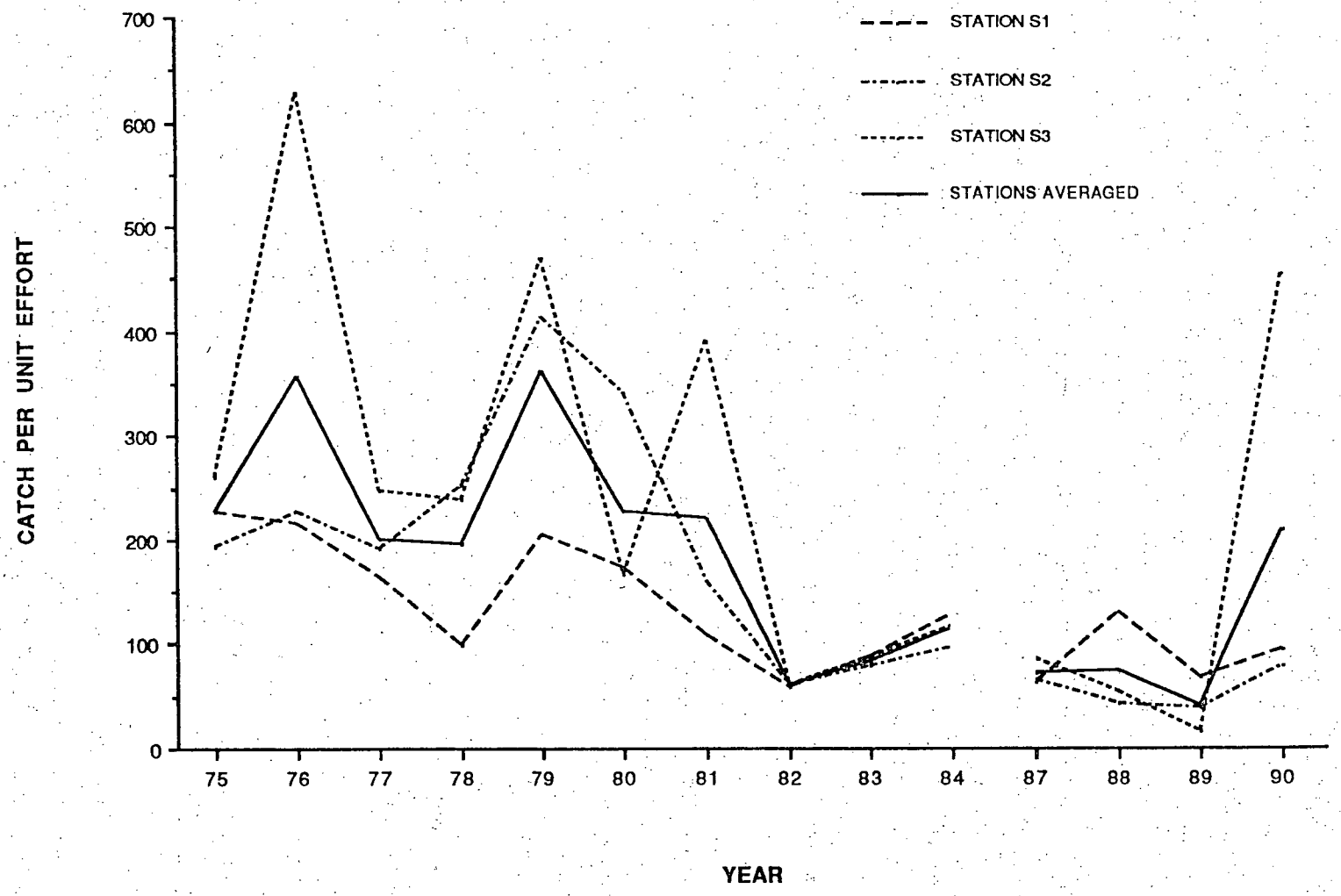


Figure 3.2.2-3. Annual total catch per unit effort (mean number per seine haul) in beach seines by station and mean of stations 1976-1984, 1987, 1988, 1989, and 1990. Seabrook Operational Report, 1990.

fish/haul) than during the period 1976 through 1981 (200 to 362 fish/haul). Annual variations in beach seine CPUE were influenced primarily by annual catches of the Atlantic silverside, which was the most abundant species in seine collections each year (Table 3.2.2-7). In 1990, CPUE for all stations combined increased to 208 fish per haul and was primarily influenced by the large catches of rainbow smelt.

The relative contribution of silversides to the total annual seine catch ranged from 47 to 88% during the preoperational period and remained relatively steady from 1982 to 1989. Atlantic silverside contributed only 41 percent of the total annual catch in 1990, lower than any of the previous years and the average over preoperational years (66%). Rainbow smelt ranked second in relative abundance in 1990, accounting for 35% of the total catch. During the preoperational period, percent composition for this species ranged from one to nine percent of the total catch. *Fundulus* spp. (primarily mummichog) ranked third in relative abundance in 1990 (9%), slightly higher than the overall mean for the previous years but within the range for those years. Abundance for ninespine stickleback, highly variable during preoperational years, ranked fourth in 1990. Many of the other species fluctuated from year to year in their ranking, often comprising less than 1% of the total annual seine catch during the previous period. In 1990, means for these other species were similar to means for the previous years except that no alewife were caught in beach seines in 1990.

The total number of species collected ranged from 16 in 1988 and 1989 to 27 in 1977 and averaged 21. In 1990, a total of 21 species was caught in the beach seines.

Seasonality of the estuarine fish community was analyzed previously using numerical classification (NAI 1983b, 1984b). The estuarine community was highly seasonal in all years, and all three seine stations exhibited similar seasonal changes in their fish assemblages. Catches in the spring were usually characterized by low

TABLE 3.2.2-7. PERCENT COMPOSITION BY YEAR, ALL PREOPERATIONAL YEARS COMBINED, AND 1990 FOR THE TEN MOST ABUNDANT SPECIES COLLECTED IN BEACH SEINES (EXCLUDING 1985 AND 1986) AT STATIONS S1, S2 AND S3 COMBINED. SEABROOK OPERATIONAL REPORT, 1990.

	YEAR													
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1987	1988	1989	ALL PREOP. YEARS COMBINED	1990
Atlantic silverside	73	55	75	60	68	88	57	47	48	56	52	55	66	41
Fundulus species[a]	15	23	5	3	4	2	10	8	7	3	4	24	8	9
Pollock	1	<1	1	8	21	<1	7	5	1	2	<1	0	5	<1
Alewife	<1	1	<1	18	<1	<1	1	<1	1	<1	0	0	4	0
Rainbow smelt	4	5	<1	5	<1	2	5	4	9	8	<1	2	3	35
American sand lance	2	9	8	<1	<1	<1	8	2	<1	0	2	<1	3	4
Atlantic herring	<1	<1	5	1	4	4	<1	7	8	2	<1	2	3	<1
Ninespine stickleback	1	4	1	<1	<1	1	2	7	16	22	37	4	3	8
Winter flounder	1	2	2	2	3	1	6	3	3	2	1	5	2	1
Blueback herring	<1	<1	1	1	<1	<1	<1	14	<1	0	1	0	1	<1
Other species	2	<1	1	1	<1	1	4	3	6	4	2	8	2	1
Total number of species	11	17	14	22	9	12	12	13	14	12	7	9	13	12

[a]includes mummichogs and striped killifish

abundance, and species composition in early summer was highly variable among years. The most distinct group was the late summer-fall assemblage, which occurred yearly from August-November, and in which Atlantic silverside was the dominant taxon (NAI 1984b). With the exception of the unusually high catches of rainbow smelt at Station S3, species composition and relative abundance were similar in 1990 to the previous years.

Spatial Patterns in the Estuarine Fish Community

Mean annual catch per unit of effort during the period 1976 through 1981 was usually highest at Station S3 and lowest at Station S1 (Figure 3.2.2-3). From 1982 through 1984 and 1987, when catches were small relative to earlier years, mean annual CPUE was similar among the three stations. In 1988 and 1989, Station S1 had the highest CPUE among the three stations but total CPUE remained low. In 1990, CPUE was highest at Station S3 and was a result of unusually high catches of rainbow smelt (Table 3.2.2-8).

Stations S1 and S2 were similar during the 1976-1989 period in their overall species composition, with Atlantic silversides composing 53 and 66 percent and *Fundulus* spp. composing 14 and 15 percent of the total catch for all years combined (Table 3.2.2-8). These stations were distinguished at that time from each other and from Station S3 by a higher proportion of blueback herring at Station S1 (3%) and alewife at Station S2 (10%). Atlantic silverside comprised a larger percentage of the catch at Station S3 (76%) than at Stations S1 and S2, and *Fundulus* spp. accounted for a much smaller percentage (<1%). Because of its proximity to the harbor mouth, salinity was higher at Station S3 than at S1 and S2 (NAI 1981b). *Fundulus* spp. prefer a more brackish environment, explaining the larger numbers caught at S1 and S2 than at S3. Rainbow smelt, a species which prefers a more saline environment, accounted for a larger percentage of the catch at Station S3 (6%) than

TABLE 3.2.2-8. MEAN PERCENT COMPOSITION BY STATION OF ABUNDANT SPECIES COLLECTED IN BEACH SEINES OVER ALL PREOPERATIONAL YEARS COMBINED (1976-1984, 1987-1989) AND IN 1990, APRIL THROUGH NOVEMBER. SEABROOK OPERATIONAL REPORT, 1990.

	STATION					
	S1		S2		S3	
SPECIES	PREOP. YEARS	1990	PREOP. YEARS	1990	PREOP. YEARS	1990
Atlantic silverside	66	66	53	26	76	39
Fundulus species[a]	14	5	15	69	<1	<1
American sand lance	4	25	3	<1	2	<1
Blueback herring	3	1	<1	<1	1	<1
Ninespine stickleback	5	2	2	1	4	11
Atlantic herring	2	<1	6	0	1	<1
Winter flounder	1	<1	1	2	3	<1
Pollock	1	0	7	0	5	0
Gasterosteus species[b]	1	1	1	1	1	<1
Alewife	1	0	10	0	<1	0
Rainbow smelt	1	<1	1	<1	6	49
Smooth flounder	<1	0	<1	0	<1	0
All other species	<1	<1	<1	<1	<1	<1
Total number of species	13	10	14	12	17	19

[a] includes mummichog and striped killifish
[b] includes threespine and blackspotted sticklebacks

at either Station S1 or S2 (1% for each station). Station S3 was also distinguished by greater species richness (36) than Stations S2 (32) and S1 (29).

In 1990, Atlantic silverside was the most abundant species at Station S1. *Fundulus* species were the most abundant taxa and comprised a much greater percentage of the total catch at Station S2, while rainbow smelt was the most abundant species and comprised a greater percentage of the total catch at Station S3. Additional station differences were reflected in the higher relative abundances of American sand lance at Station S1 and of ninespine sticklebacks at Station S3. Pollock and alewife, normally present at Station S2, were not caught at any station during 1990. Percentages for the remainder of the species caught in 1990 were similar to those during the preoperational years.

Spatial differences in the estuarine fish community in 1990 were caused by extremely large catches of American sand lance in July at Station S1, and *Fundulus* species at Station S2 and rainbow smelt at Station S3 in August (NAI 1991).

3.2.2.2 Impingement

A total of 499 fishes were impinged at the Seabrook Station during 1990 (Table 3.2.2-9). Impingement was greatest during May, June, November, and December. Lumpfish, pollock, longhorn sculpin, windowpane, herrings (Clupeidae), and sea raven each formed more than 5% of the total number of fish that were impinged. With the exception of herrings and pollock, each of these are demersal species. Lumpfish, windowpane, and sea raven were the most common fishes impinged during May and June. Pollock, longhorn sculpin, windowpane, and herrings were the most common species impinged in November and December. Fish between 15 and 45 cm were the most commonly impinged among most species although

TABLE 3.2.2-9. NUMBER OF FISH IMPINGED AT THE SEABROOK STATION BY MONTH AND SPECIES DURING 1990. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	PERCENT
Lumpfish		1	4	8	10	38	5	1		2			69	13.8
Pollock						6			23	11	24	5	69	13.8
Longhorn sculpin		1	2	2	4	1	2	3		2	21	29	67	13.4
Windowpane		3			11	11	2		3	3	9	10	52	10.4
Herring spp.			1	4	6	2		6	1	9	12	3	44	8.8
Sea raven		1			17	12	2	1			5		38	7.6
Cunner		1		1	6	6		4	1	1	1		21	4.2
Winter flounder		8	1	1		1					2	5	18	3.6
Cod						3	5	2	3		2	3	18	3.6
Hake spp.		1						1	4	3	2	5	16	3.2
Rock gunnel				4	1	1		3	4	1			14	2.8
Grubby		4		2	1	1		1	1		1		11	2.2
Sea robin			2	1				3		3		1	10	2.0
Clearnose skate		4									1	1	6	1.2
Little skate				1							3	2	6	1.2
Wrymouth					1							4	5	1.0
Shorthorn sculpin				2		1						1	4	0.8
Unknown								1	3				4	0.8
Radiated shanny		1			3								4	0.8
Mackerel						4							4	0.8
Smooth flounder				3									3	0.6
Tautog							1	1	1				3	0.6
Sand lance				3									3	0.6
Fourspot flounder				1	1								2	0.4
Goosefish					1								1	0.2
White perch						1							1	0.2
Lamprey eel				1									1	0.2
Ocean pout												1	1	0.2
American eel												1	1	0.2
Toadfish												1	1	0.2
Striped anchovy									1				1	0.2
Spiny dogfish									1				1	0.2
All species	0	25	10	34	62	88	17	27	36	35	83	72	499	100.0

pollock, windowpane, herrings, cunner, winter flounder, hakes, rock gunnel, and grubby less than 15 cm were also relatively common (Figure 3.2.2-4).

Each of the most common species impinged (except lumpfish) was also relatively abundant in otter trawl, gill net, or beach seine samples during 1990 and most are demersal species. Adult lumpfish are not particularly vulnerable to otter trawls, gill nets, or seines and this probably explains their absence from the fisheries surveys. However, it appears that lumpfish are relatively abundant near the intake structure as evidenced by the impingement data. Most of the impinged lumpfish were found in May or June and most were adults (Table 3.2.2-9; Figure 3.2.2-4). This seasonal periodicity could be related to post-spawning movements by adults such that they are more vulnerable to impingement than during the spawning period (April-May; Bigelow and Schroeder 1953).

3.2.2.3 Selected Species

General

Seasonal, inter-annual, and spatial variations in abundance were analyzed for nine selected species. Selection of species was based on two criteria: 1) high abundance in at least one life stage and gear type; and 2) importance in local commercial or sport fisheries. The nine species selected and their primary collection methods were:

Species	Gear Type
Atlantic herring	gill nets
Atlantic mackerel	gill nets
Pollock	gill nets
Atlantic cod	otter trawl
Hakes (red, white and spotted)	otter trawl
Yellowtail flounder	otter trawl
Winter flounder	otter trawl and beach seine
Rainbow smelt	otter trawl and beach seine
Atlantic silverside	beach seine

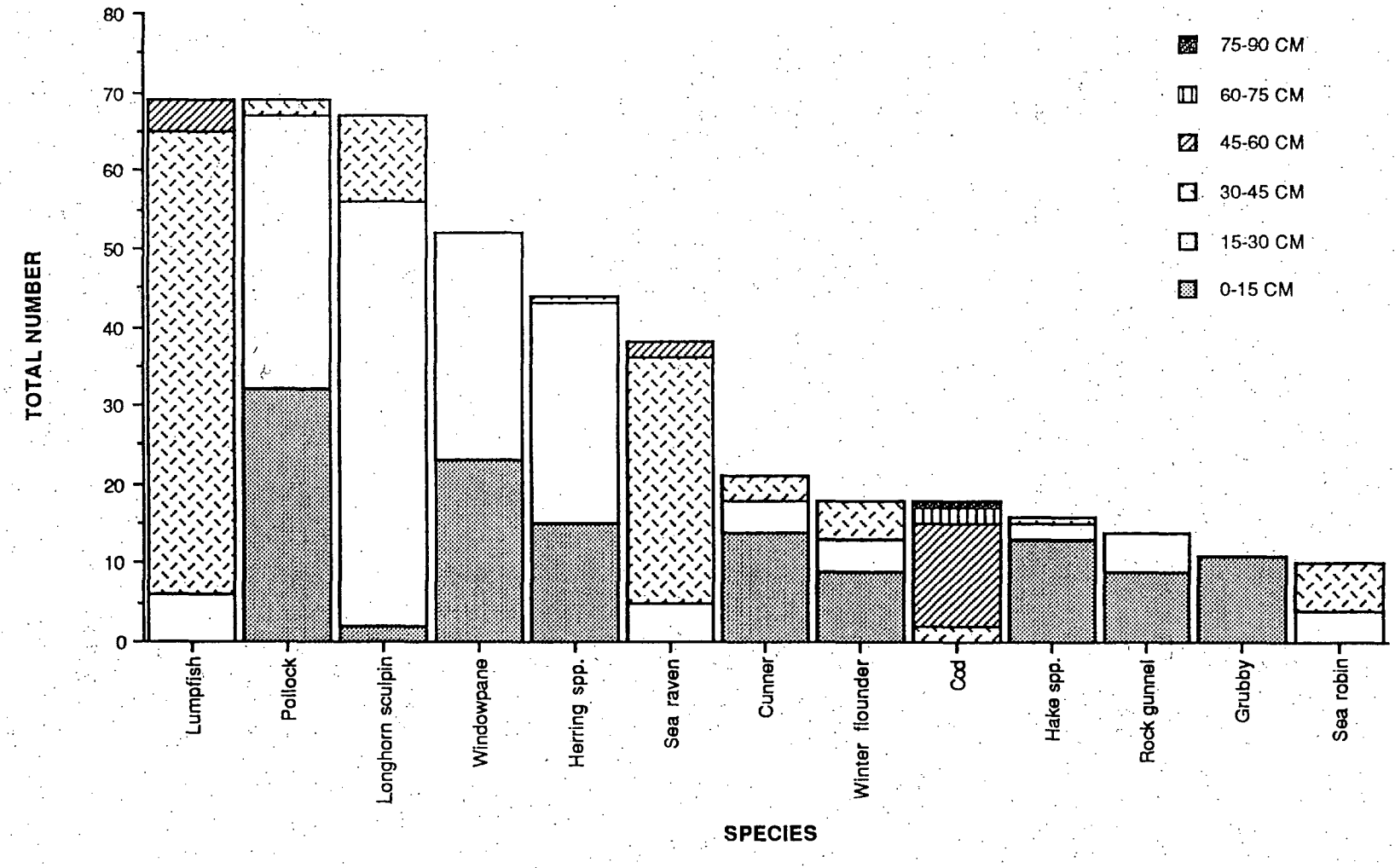


Figure 3.2.2-4. Number of fish impinged at Seabrook Station during 1990 for various size classes of most abundant species. Seabrook Operational Report, 1990.

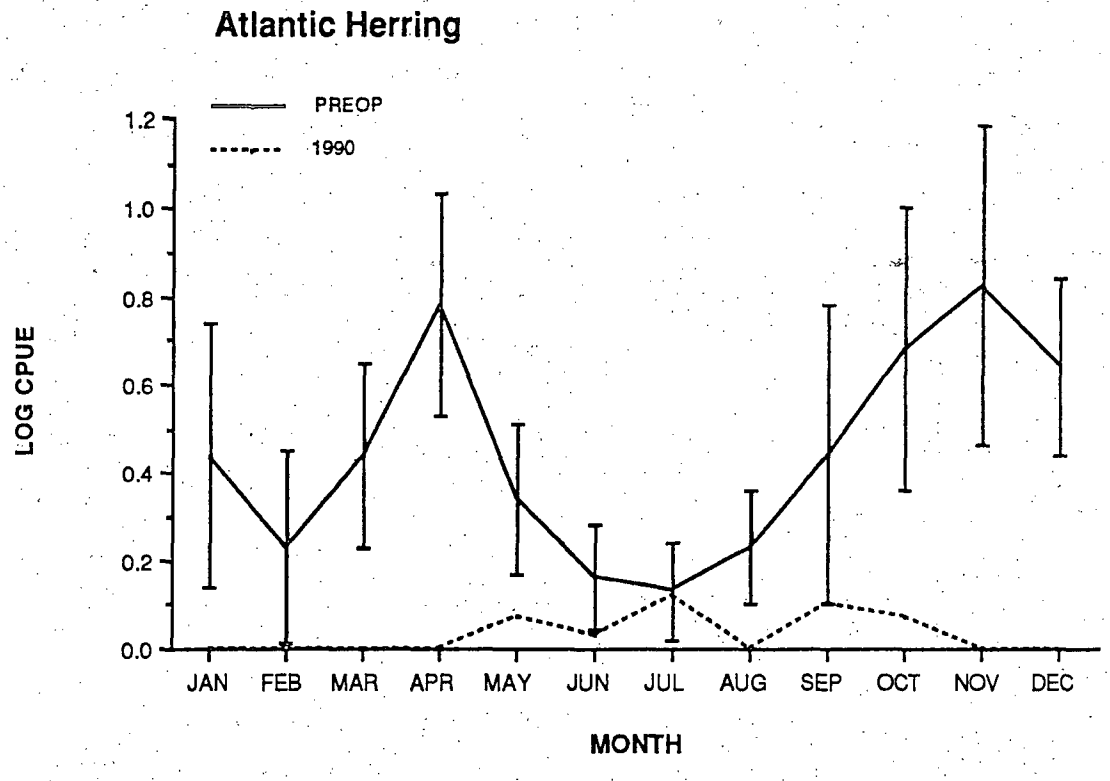
Analysis of variance was used to statistically test the differences in catch per unit of effort (CPUE) for selected gill net, otter trawl, and beach seine species. Data were log (x+1) transformed prior to analysis. For all species, a nested ANOVA was run with month nested within year and operational status, and year nested within operational status. For species collected in gill nets or beach seines, the mean CPUE for the preoperational period and 1990 were also compared. Otter trawl species were subjected to a factorial design with interaction comparing the effect of operational status and station on mean CPUE.

Comparison of yearly mean catch per unit of effort revealed general patterns in population size, while comparison of monthly mean catch per unit of effort provided information on seasonal cycles. Statistical analysis of the seasonal and annual differences showed they were highly variable for almost all of the selected species. Size-structure of fish populations also yields important information on age classes that use the area and supplies information on recruitment patterns; this information was examined thoroughly in the 1984 Baseline Report (NAI 1985b).

Pelagic Species

Atlantic Herring

Atlantic herring were typically most abundant during the spring and fall (Figure 3.2.2-5), with gill net CPUE values greatest during March through May and October through December. In 1990, catches were zero or much lower than the overall mean for all months except July. The annual geometric mean CPUE of Atlantic herring rose from 3.1 fish/net in 1976 to 4.5 fish/net in 1978 and then generally declined to the lowest levels observed during the program (0.5 in 1984 and 1985; Table 3.2.2-10). Annual mean CPUE increased slightly in 1986 and 1987 (0.6 and 1.0) but then decreased slightly in 1988 (0.7) and again in



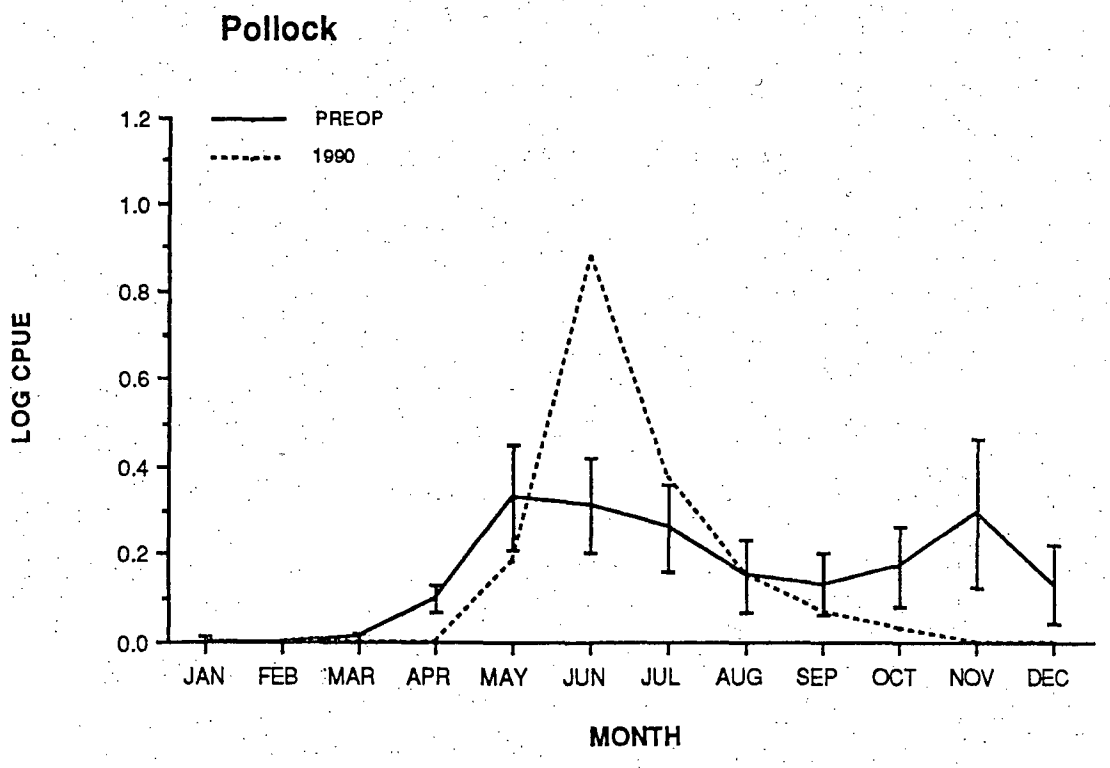


Figure 3.2.2-5. Log (x+1) catch per unit effort (one 24-hr. set) for Atlantic herring and pollock; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 averaged over gill net Stations G1, G2 and G3. Seabrook Operational Report, 1990.

TABLE 3.2.2-10. ANNUAL GEOMETRIC MEAN[a] CPUE FOR SELECTED FINFISH SPECIES FOR THE PREOPERATIONAL PERIOD (1976-1989), THEIR CONFIDENCE LIMITS, AND 1990 DATA. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	STATION	YEAR 1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	MEAN[b] OVER ALL PREOP. YEARS	CONFIDENCE LIMITS LOWER	UPPER	1990
Atlantic herring	G1-G3	3.07	3.32	4.51	2.22	3.54	1.40	1.41	1.51	0.53	0.47	0.62	1.05	0.69	0.52	1.51	1.15	1.92	0.07
Pollock	G1-G3	0.32	0.34	0.13	0.17	0.82	0.74	0.17	0.54	0.34	0.43	0.57	0.20	0.42	0.27	0.38	0.30	0.4	0.29
Atlantic mackerel	G1-G3	0.56	0.48	0.20	0.12	0.33	0.47	0.24	0.32	0.17	0.24	0.13	0.22	0.53	0.16	0.29	0.21	0.37	0.64
Atlantic cod	T1	1.83	1.26	3.77	4.04	4.42	4.30	3.96	3.98	2.11	0.94	1.03	2.16	1.92	0.67	2.33	1.94	2.77	0.28
	T2	0.33	0.30	1.30	2.00	1.47	1.50	1.75	0.81	0.60	0.14	0.55	0.71	0.41	0.21	0.79	0.60	1.01	0.20
	T3	3.07	1.47	9.74	6.29	8.63	5.98	4.67	6.29	3.33	0.90	1.55	3.59	8.98	0.73	3.82	3.14	4.61	0.43
	T1-T3	1.48	0.93	3.91	3.80	4.05	3.52	3.26	3.22	1.78	0.61	0.99	1.94	2.61	0.56	2.08	1.77	2.43	0.31
Hake species	T1	6.77	7.57	6.63	3.82	4.49	7.27	6.43	3.48	3.61	3.20	4.19	3.22	4.20	3.47	4.68	3.65	5.95	2.55
	T2	1.91	3.08	3.17	1.07	2.11	3.68	2.32	1.39	2.40	1.01	2.36	1.38	1.57	1.41	1.99	1.55	2.51	1.05
	T3	4.32	6.48	5.50	3.49	3.81	8.85	5.93	3.41	3.57	3.43	3.24	3.69	2.85	2.14	4.11	3.19	5.23	1.03
	T1-T3	3.94	5.39	4.92	2.55	3.35	6.25	4.55	2.95	3.15	2.54	3.42	2.80	3.05	2.54	3.55	2.83	4.40	1.54
Yellowtail flounder	T1	33.50	26.34	18.88	33.54	44.88	40.47	22.13	18.03	15.73	14.82	14.51	13.36	16.49	24.52	22.34	20.13	24.80	18.13
	T2	4.21	2.58	1.78	4.73	7.05	4.67	5.28	2.62	1.03	2.91	1.83	2.62	2.23	7.82	3.30	2.70	4.00	2.92
	T3	20.57	12.50	13.12	21.82	27.68	17.98	10.31	8.27	7.66	8.40	4.83	7.53	8.65	10.92	11.58	10.42	12.86	9.55
	T1-T3	14.71	9.98	8.21	15.53	20.97	15.46	10.79	8.25	5.65	7.64	5.72	6.84	7.99	13.43	10.05	9.18	11.00	9.07
Winter flounder	T1	1.27	3.11	2.82	2.53	5.32	6.43	4.39	3.39	2.71	3.24	4.60	4.99	4.61	6.31	3.76	3.34	4.21	4.49
	T2	3.79	4.87	7.18	8.90	17.49	17.10	9.55	7.72	5.50	5.65	3.71	4.32	4.36	6.34	6.89	5.87	8.06	6.60
	T3	1.32	1.72	3.20	2.08	5.13	4.11	2.75	2.52	2.26	1.08	2.56	4.47	2.89	2.52	2.60	2.25	2.98	2.75
	T1-T3	1.94	3.04	4.08	3.76	7.95	7.82	4.97	3.96	3.28	2.86	3.64	4.75	3.96	4.68	4.11	3.71	4.55	4.29
	S1-S3	1.54	2.98	2.36	3.83	4.41	2.38	2.47	1.44	2.16	NS[c]	ID[d]	0.89	0.75	1.23	2.03	1.71	2.39	0.72

(continued)

TABLE 3.2.2-10. (Continued)

SPECIES	STATION	YEAR 1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	MEAN[b] OVER ALL PREOP. YEARS	CONFIDENCE LIMITS LOWER	UPPER	1990
Rainbow smelt	T1	1.88	0.71	1.67	1.23	1.00	1.10	0.92	1.41	0.89	0.30	0.63	2.30	2.20	2.61	1.25	0.88	1.70	1.37
	T2	2.26	0.94	4.63	1.73	1.60	2.48	1.21	2.89	1.69	0.64	1.34	3.28	4.70	4.55	2.14	1.56	2.85	3.18
	T3	1.59	0.74	1.15	1.07	0.80	0.44	0.72	0.37	0.48	0.37	0.38	1.03	1.64	2.94	0.89	0.60	1.23	1.12
	T1-T3	1.90	0.79	2.19	1.33	1.11	1.20	0.94	1.17	0.96	0.43	0.66	1.97	2.33	2.90	1.33	0.97	1.74	1.57
	S1-S3	1.06	0.67	0.09	1.05	0.05	0.72	0.70	0.59	1.06	NS	ID	0.30	0.08	0.21	0.50	0.31	0.72	1.29
Atlantic silverside	S1-S3	24.37	13.47	23.58	22.36	16.05	19.97	5.80	9.78	8.32	NS	ID	7.30	5.31	4.08	11.44	6.91	18.54	5.94

a) OTTER TRAWL (T) mean catch per tow per month at each station and mean of all stations.
GILL NET (G) mean catch per 24 hour set of either level (surface or bottom) per month, a mean for all stations.
SEINES (S) mean catch per haul per month, a mean for all stations.
b) Otter Trawl (T) mean of 168 months except T2 mean of 158 months; Gill Net (G) mean of 167 months; Seines (S) mean of 96 months.
c) NS = not sampled
d) ID = Insufficient data for comparison with previous years (April - June not sampled)

1989 (0.5). Mean CPUE for 1990 was much lower than any of the preoperational years. Analysis of variance showed that the difference between preoperational and 1990 means was highly significant (Table 3.2.2-11) and that the preoperational mean was greater than the 1990 mean (Table 3.2.2-10).

Atlantic herring monthly CPUE in 1990 (Figure 3.2.2-5) for most of the year was much lower than the preoperational mean or was zero. A similar pattern was observed in each of the past four years and lower than normal annual geometric means have also been recorded for the past six years (1984-1989; Table 3.2.2-10). These results suggest a trend of decreasing monthly and yearly means that has continued into 1990 and is coincidental with decreasing Atlantic herring catches from the commercial fishery along the Maine coast and the western Gulf of Maine (NOAA 1991a).

Pollock

Pollock gill net catches were highest during late spring and late fall, and lowest during winter (Figure 3.2.2-5). The high catches in the spring and late fall reflected annual onshore and offshore movements. CPUE for April, May, and September through December in 1990 were lower than the overall mean CPUE for the preoperational period. No pollock were caught during the months of January through April, November and December. Annual mean CPUE (all stations combined) for pollock varied from 0.1 to 0.8 fish/net and averaged 0.4 fish/net over all preoperational years (Table 3.2.2-10). The 1990 mean CPUE of 0.3 fish/net was similar to the mean in 1989 and slightly lower than the preoperational mean. Results of the analysis of variance on differences between preoperational and operational years were not significant (Table 3.2.2-11).

TABLE 3.2.2-11. RESULTS OF ANALYSIS OF VARIANCE BETWEEN PREOPERATIONAL YEARS (1976-1989) AND 1990 FOR SELECTED FINFISH SPECIES AT ALL GILL NET STATIONS COMBINED. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	SOURCE OF VARIATION[a]	df	SS	F[b]
Atlantic herring	Preop-Op	1	2.06	49.75***
	Year (Preop-Op)	11	12.98	28.53***
	Month (Year (Preop-Op))	142	43.63	7.43***
	Error	487	20.15	
Pollock	Preop-Op	1	0.01	0.70 NS
	Year (Preop-Op)	11	0.75	4.21***
	Month (Year (Preop-Op))	142	5.65	2.46***
	Error	487	7.88	
Atlantic mackerel	Preop-Op	1	0.28	24.08***
	Year (Preop-Op)	11	0.62	4.86***
	Month (Year (Preop-Op))	142	10.08	6.15***
	Error	487	5.62	

[a]Pre-Op = Preoperational period vs. 1990.
Year (Preop-Op) = Year nested within preoperational and operational periods.
Month (Year (Preop-Op)) = Month nested within year nested within preoperational and operational periods.
[b]NS = not significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

Atlantic Mackerel

Historically, Atlantic mackerel were present in gill net collections primarily from June to November with low or zero CPUE from December through May (Figure 3.2.2-6). Following a gradual increase in abundance in June, monthly mean CPUE leveled off and remained at stable levels through November. In 1990, CPUE was above the preoperational mean during June, July and October and was zero in August. Catches for mackerel were variable over the years, with mean CPUE ranging from 0.1 to 0.6 fish/net, and averaging 0.3 fish/net (Table 3.2.2-10). In 1990, CPUE was 0.6 fish/net, significantly larger than both the overall preoperational mean and any of the preoperational years (Table 3.2.2-11). Analysis of variance showed a highly significant difference between preoperational and 1990 means (Table 3.2.2-11) with the 1990 mean exceeding that of the preoperational period.

Demersal Species

Atlantic Cod

During 1990, Atlantic cod were present in otter trawl catches from March through July and September through December (Figure 3.2.2-7). Monthly mean CPUE in 1990 were generally lower than the overall mean for the preoperational period (1976-1989) at Stations T1 and T3. Monthly mean CPUE at Station T2 in 1990 were also typically lower than the preoperational mean except during May, June, and July.

The annual mean CPUE (geometric mean averaged over the three stations) rose from 0.9 fish/tow in 1977 to greater than 3.8 fish/tow from 1978 through 1980 (Table 3.2.2-10). Annual mean CPUE declined gradually from 1981 to 0.6 fish/tow in 1985. The annual mean CPUE rebounded from 1986 through 1988 but declined to 0.6 fish/tow in 1989. The 1990 annual mean CPUE of 0.3 fish/tow is the lowest value observed during the study period. The annual mean CPUE at each station in 1990

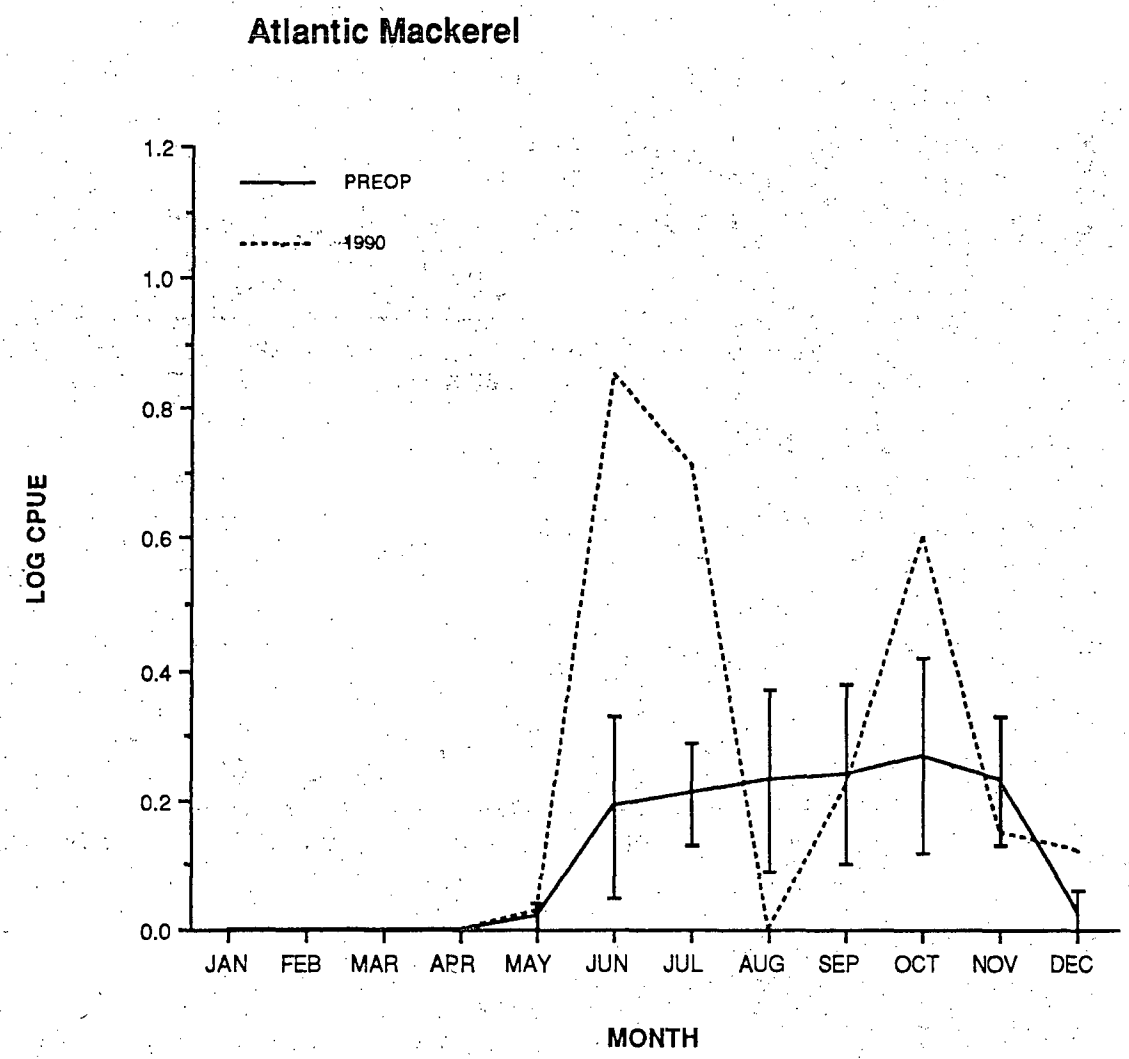


Figure 3.2.2-6. Log (x+1) catch per unit effort (one 24-hr. set) for Atlantic mackerel; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 averaged over gill net Stations G1, G2 and G3. Seabrook Operational Report, 1990.

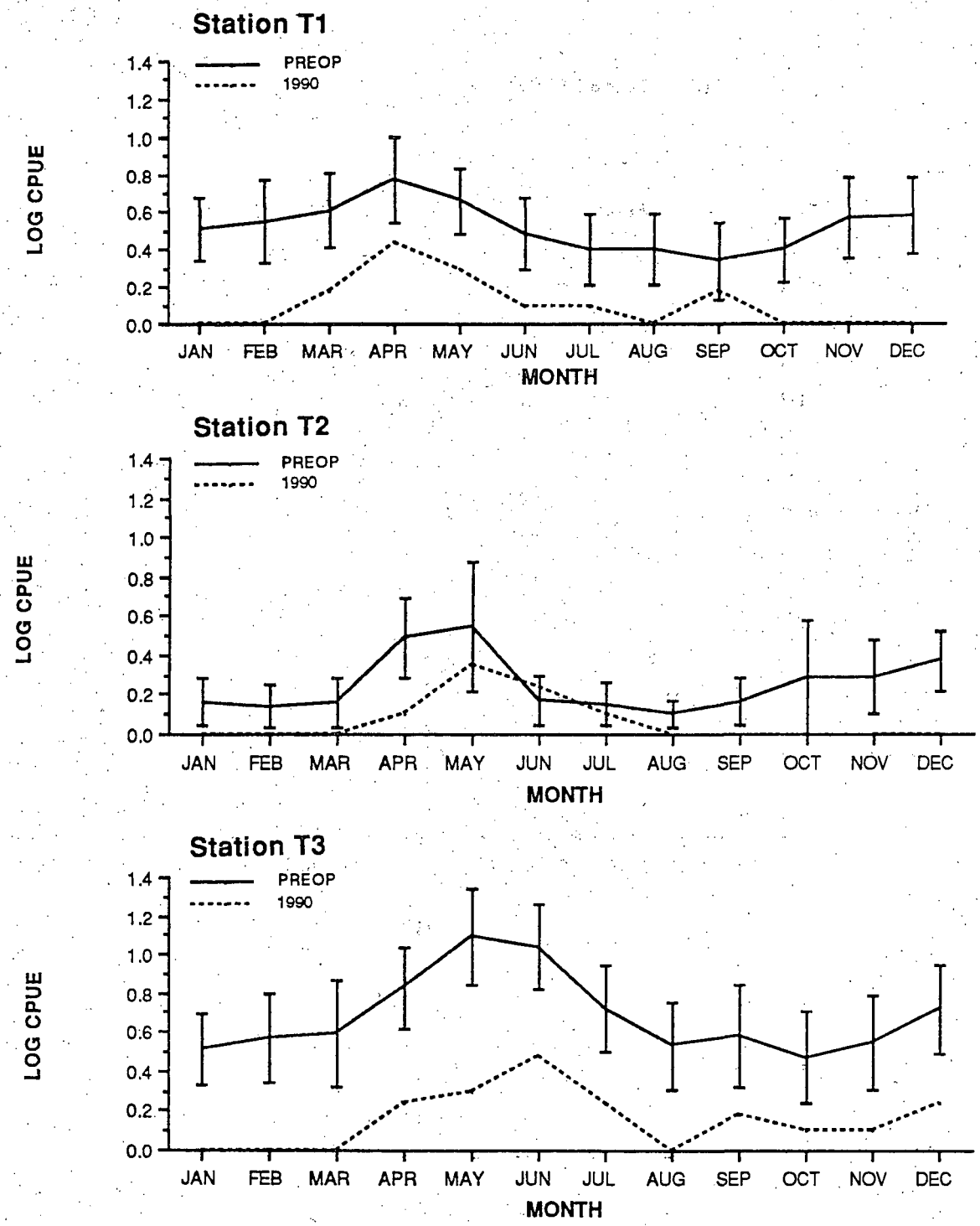


Figure 3.2.2-7. Log (x+1) catch per unit effort (one tow) for Atlantic cod; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 from otter trawl Stations T1, T2 and T3. Seabrook Operational Report, 1990.

was considerably lower than the overall mean for the preoperational period and was most pronounced at Stations T1 and T3, indicated by a significant interaction between station and Preop-Op variables in the ANOVA (Table 3.2.2-10). Annual mean CPUE was greater during preoperational years at all stations; however, the difference between preoperational and 1990 CPUE was less at Station T2 than at Stations T1 and T3 (Table 3.2.2-12).

Hakes

Hakes were generally present in otter trawl catches throughout the year during 1990 (Figure 3.2.2-8). Peak abundance generally occurred during May, June, and July but each station showed a secondary peak during autumn. Monthly mean CPUE during 1990 were generally lower than the overall mean for the preoperational period at Station T3. Monthly mean CPUE at Stations T1 and T2 in 1990 were also typically lower than the preoperational mean; however, during February and December, 1990 values exceeded the preoperational mean at Station T2.

The annual geometric mean CPUE (averaged over all stations) fluctuated within a narrow range between 1976 and 1989, with the maximum of 6.3 fish/tow recorded in 1981 and the minimum of 2.5 fish/tow recorded in 1985 and again in 1989 (Table 3.2.2-10). Annual mean CPUE in 1990 was lower than the preoperational mean at all stations, with the largest differences at Stations T1 and T3. These results indicate that abundance of hakes was low at all stations during 1990. Analysis of variance indicated that a significant interaction between station and operational status affected the annual mean CPUE for hakes. Mean CPUE was greater during preoperational years at all stations, but the difference between preoperational and 1990 CPUE was smaller at Station T1 and T2 than at Station T3 (Table 3.2.2-12).

TABLE 3.2.2-12. RESULTS OF TWO-WAY ANALYSIS OF VARIANCE AMONG STATIONS (T1, T2, AND T3), PREOPERATIONAL (1976-1989) AND OPERATIONAL (1990) YEAR AND THEIR INTERACTIONS OF LOG (x+1) TRANSFORMED CATCH PER UNIT EFFORT FOR SELECTED FINFISH FROM OTTER TRAWLS. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	SOURCE OF VARIATION[a]	df	SS	F[b]	INTERACTION TERMS STATION	PERIOD	N	MEAN
Atlantic cod	Station	2	2.06	16.47***	T1	Op.	20	0.081
	Preop-Op	1	7.20	108.33***	T1	Preop.	177	0.475
	Year (Preop-Op)	13	15.81	19.43***	T2	Op.	19	0.069
	Month (Year (Preop-Op))	135	26.72	3.16***	T2	Preop.	172	0.214
	Preop-Op X Station	2	1.16	9.42***	T3	Op.	20	0.125
	Error	419	26.23		T3	Preop.	177	0.633
Hake	Station	2	2.15	15.41***	T1	Op.	20	0.494
	Preop-Op	1	2.39	34.16***	T1	Preop.	177	0.607
	Year (Preop-Op)	13	4.72	5.18***	T2	Op.	19	0.254
	Month (Year (Preop-Op))	135	96.10	10.15**	T2	Preop.	172	0.369
	Preop-Op X Station	2	0.49	3.52*	T3	Op.	20	0.209
	Error	419	29.39		T3	Preop.	177	0.525
Rainbow smelt	Station	2	1.28	7.09***				
	Preop-Op	1	0.06	0.14 NS				
	Year (Preop-Op)	13	8.92	7.60**				
	Month (Year (Preop-Op))	135	115.54	9.48***				
	Preop-Op X Station	2	0.01	0.06 NS				
	Error	419	37.83					
Yellowtail flounder	Station	2	17.46	91.83***				
	Preop-Op	1	0.54	5.57*				
	Year (Preop-Op)	13	11.43	9.35***				
	Month (Year (Preop-Op))	135	15.33	1.21 NS				
	Preop-Op X Station	2	0.05	0.25 NS				
	Error	419	39.42					
Winter flounder	Station	2	3.12	23.18***				
	Preop-Op	1	0.12	0.04 NS				
	Year (Preop-Op)	13	7.46	8.34***				
	Month (Year (Preop-Op))	135	24.16	2.60***				
	Preop-Op X Station	2	0.05	0.40 NS				
	Error	419	28.82					

[a]Station: T1 vs. T2 vs. T3 regardless of year or month; Preop-Op = preoperational period vs. 1990; Year (Preop-Op) = year nested within preoperational and operational periods, regardless of area; Month (Year (Preop-Op)) = month nested within year nested within Preop-Op reagardless of station; Preop-Op X Station = interaction of main effects

[b]NS = not significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

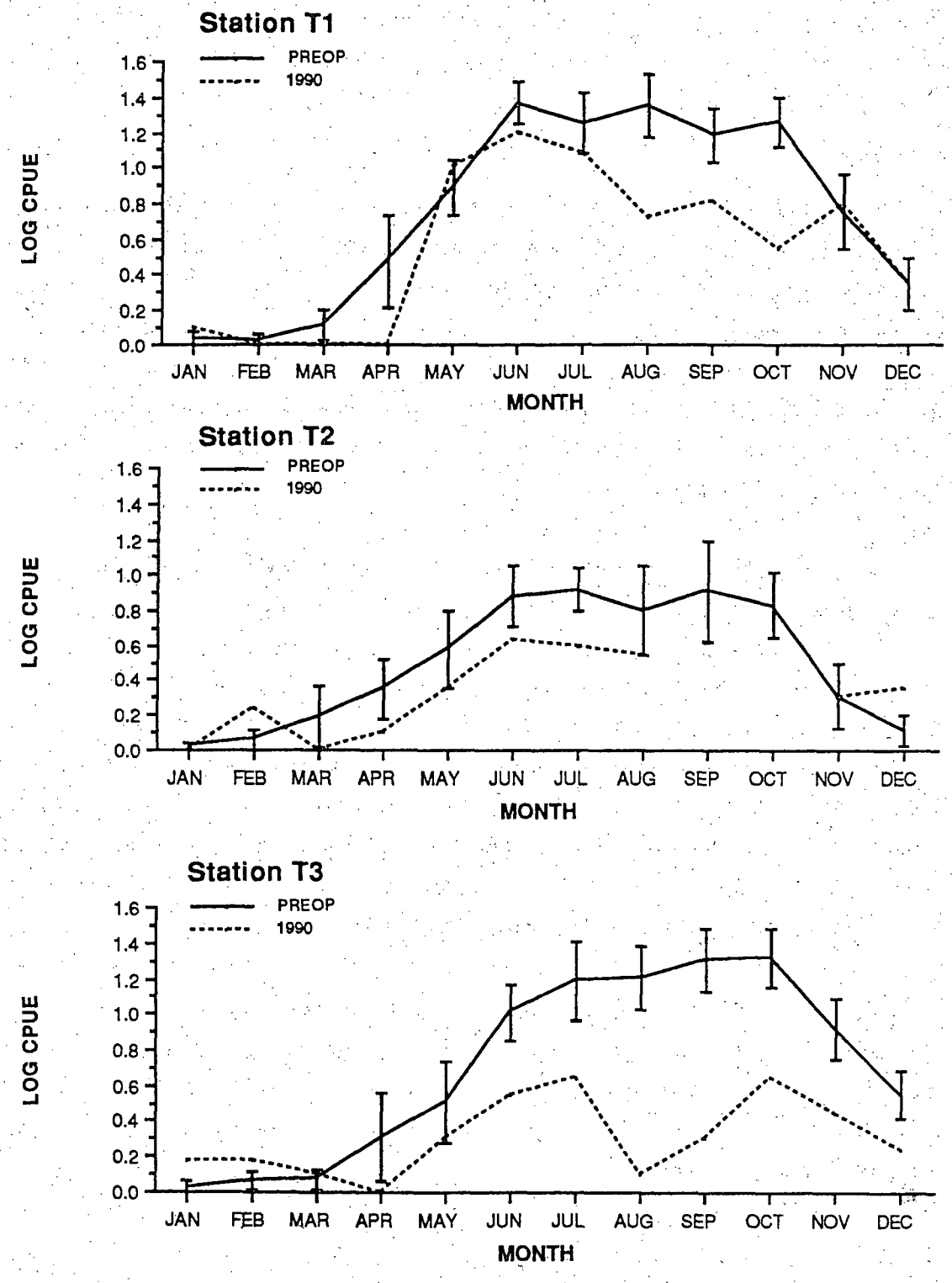


Figure 3.2.2-8. Log (x+1) catch per unit effort (one tow) for hakes; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 from otter trawl Stations T1, T2 and T3. Seabrook Operational Report, 1990.

Yellowtail Flounder

Yellowtail flounder were collected throughout 1990 in otter trawls and there was limited variation among the months at each of the stations (Figure 3.2.2-9). Monthly mean CPUE during 1990 at Stations T1 and T2 were generally similar to the overall mean for the preoperational period except during April, November, and December. Monthly mean CPUE at Station T3 in 1990 were generally lower than the preoperational mean from January through May but similar to the preoperational mean during the remaining months.

The annual geometric mean CPUE for yellowtail flounder (averaged over all stations) ranged from 5.7 fish/tow in 1984 and 1986 to 21.0 fish/tow in 1980. Annual mean CPUE in 1990 (9.1 fish/tow) was slightly lower than the overall mean of 10.1 fish/tow (Table 3.2.2-10). The 1990 annual mean CPUE at Stations T1 and T3 were less than the lower limit of the 95% confidence interval for the overall mean; however, the annual mean at Station T2 (2.9 fish/tow) was within the 95% confidence interval for the overall mean. Analysis of variance indicated that annual mean CPUE for yellowtail flounder were significantly greater at Stations T1 and T3 than at Station T2 (Table 3.2.2-12). Also, annual mean CPUE was significantly larger during the preoperational period at all stations. These results indicate that abundance of yellowtail flounder is typically lower at Station T2 regardless of plant operational status and that during 1990 (the first year of plant operation), abundance of yellowtail flounder was lower than the mean of the preoperational period at each station.

Demersal and Estuarine Species

Winter Flounder

Winter flounder were collected in otter trawls throughout 1990 (Figure 3.2.2-10). Monthly mean CPUE during 1990 were generally similar to or greater than the overall mean for the preoperational period at

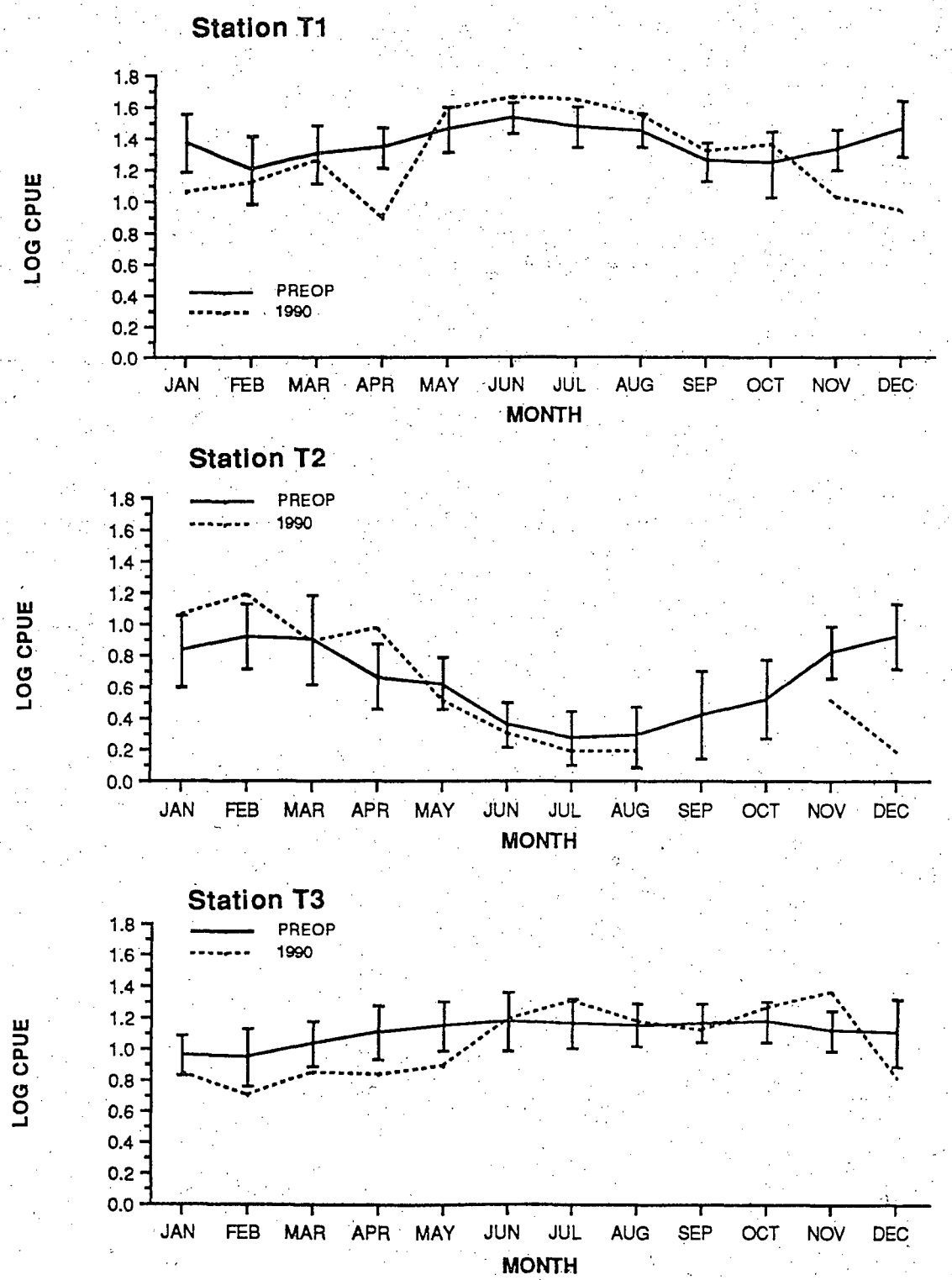


Figure 3.2.2-9. Log (x+1) catch per unit effort (one tow) for yellowtail flounder; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 from otter trawl Stations T1, T2 and T3. Seabrook Operational Report, 1990.

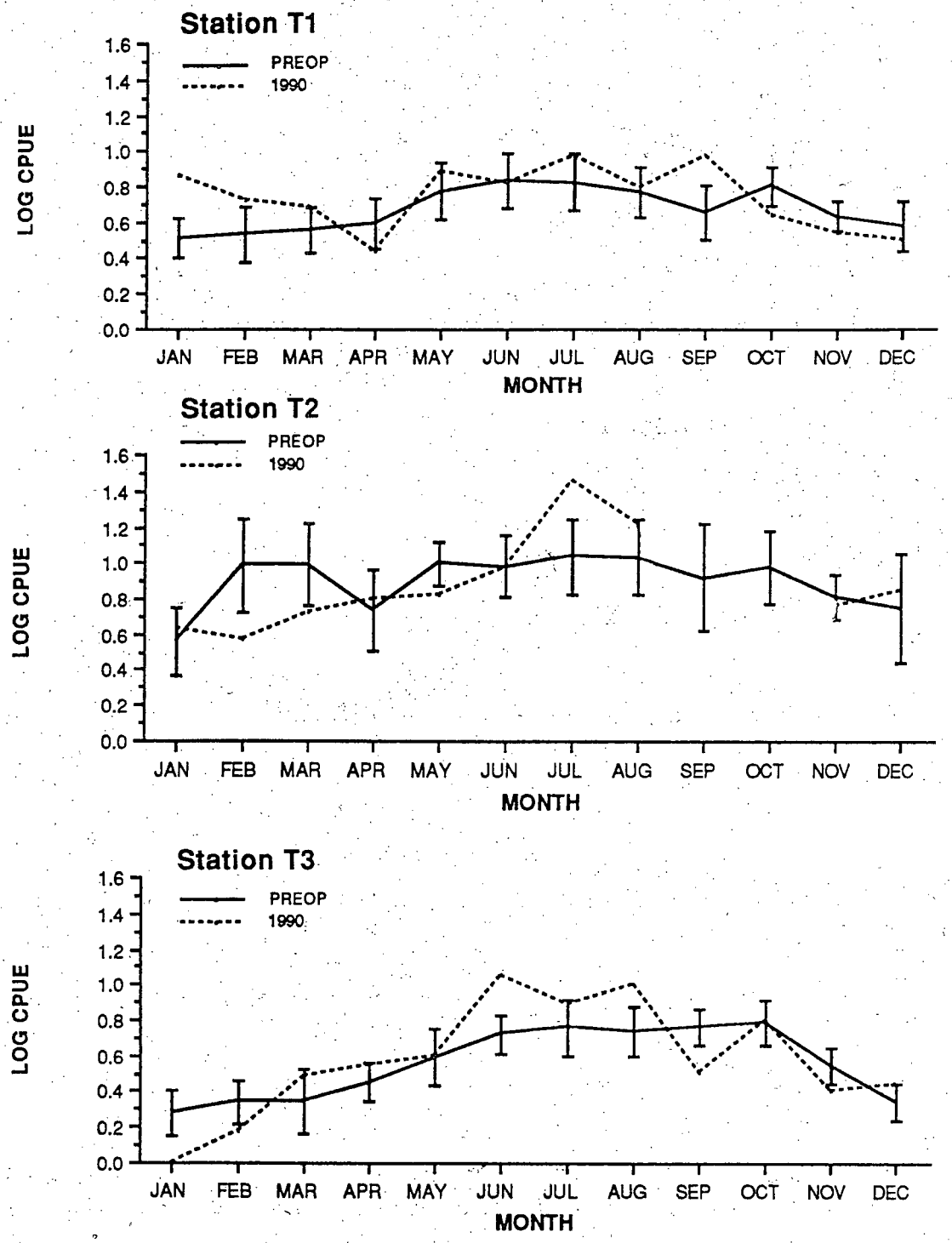


Figure 3.2.2-10. Log (x+1) catch per unit effort (one tow) for winter flounder; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 from otter trawl Stations T1, T2 and T3. Seabrook Operational Report, 1990.

each station. However the 1990 mean CPUE was less than the lower limit of the 95% confidence interval for the overall mean during at least one month at each station. The highest monthly mean CPUE occurred during June or July at each station.

Annual geometric mean CPUE (averaged over all stations) ranged from 1.9 fish/tow in 1976 to 8.0 fish/tow in 1980 and has been relatively stable since 1986 (Table 3.2.2-10). Annual mean CPUE for 1990 at each station was slightly higher than the overall mean for the preoperational period. However, there were significant differences in annual mean CPUE among the three stations (Table 3.2.2-12).

Winter flounder were also collected in beach seines during 1990 from May through November (Figure 3.2.2-11). Monthly mean CPUE during 1990 were less than the lower limit of the 95% confidence interval for the overall mean except during July, October, and November. Analysis of variance indicated a significant difference between mean CPUE for the preoperational period and 1990 (Table 3.2.2-13), with the mean for 1990 (0.7 fish/haul) less than the preoperational mean (2.0 fish/haul; Table 3.2.2-10).

Rainbow Smelt

Rainbow smelt were typically most abundant in otter trawls from January through March (through April at Station T2) and in December (Figure 3.2.2-12). During these months, mean CPUE in 1990 were generally equal to or greater than the overall mean for the preoperational period.

The annual geometric mean CPUE for rainbow smelt (averaged over all stations) ranged from 0.4 fish/tow in 1985 to 2.9 fish/tow in 1989 (Table 3.2.2-10). The 1990 value (1.6 fish/tow) was slightly greater than the mean for the preoperational period. During 1990 the annual mean CPUE also exceeded the overall mean CPUE at each station and at Station T2 was greater than the upper limit of the 95% confidence

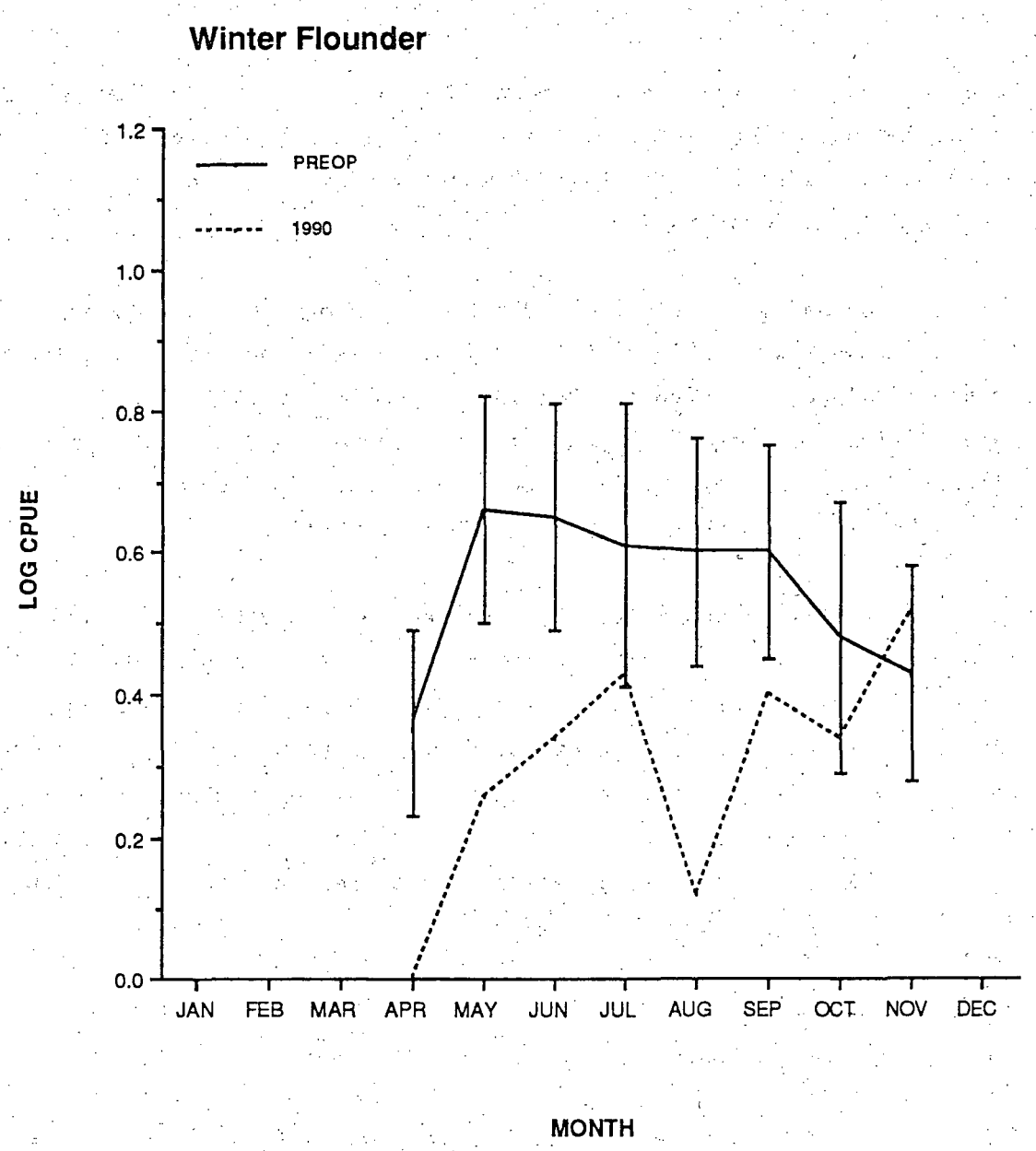


Figure 3.2.2-11. Log (x+1) catch per unit effort (one haul) for winter flounder; monthly means and 95% confidence intervals over all preoperational years (1976-1984, 1987-1989) and monthly means for 1990 averaged over beach seine Stations S1, S2 and S3. Seabrook Operational Report, 1990.

TABLE 3.2.2-13. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE BETWEEN PREOPERATIONAL YEARS (1976-1989) AND THE OPERATIONAL YEAR (1990) FOR SELECTED FINFISH SPECIES FOR ALL BEACH SEINE STATIONS COMBINED. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	SOURCE OF VARIATION[a]	df	SS	F[b]
Winter flounder	Preop-Op	1	0.33	7.02*
	Year (Preop-Op)	11	2.01	3.85***
	Month (Year (Preop-Op))	91	5.55	1.29 NS
	Error	61	2.89	
Rainbow smelt	Preop-Op	1	0.36	6.68*
	Year (Preop-Op)	11	1.10	1.86 NS
	Month (Year (Preop-Op))	91	8.08	1.65*
	Error	61	3.28	
Atlantic silverside	Preop-Op	1	0.24	1.40 NS
	Year (Preop-Op)	11	6.32	3.41***
	Month (Year (Preop-Op))	91	131.64	8.58***
	Error	61	10.28	

[a]Preop-Op = Preoperational period vs. 1990.
Year (Preop-Op) = Year nested within preoperational and operational periods.
Month (Year (Preop-Op)) = Month nested within year nested within pereoperational and operational periods.
[b]NS = not significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

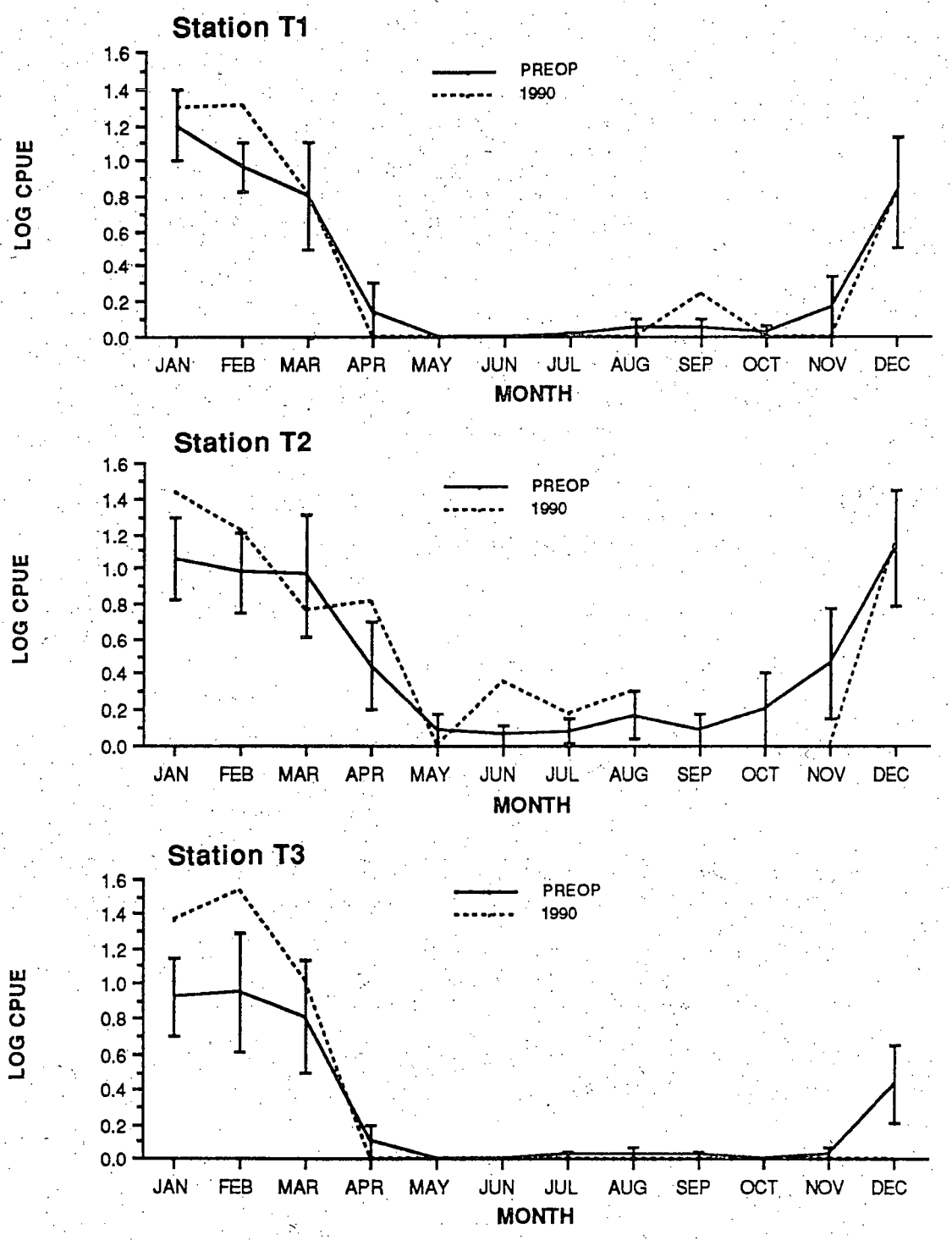


Figure 3.2.2-12. Log (x+1) catch per unit effort (one tow) for rainbow smelt; monthly means and 95% confidence intervals over all preoperational years (1976-1989) and monthly means for 1990 from otter trawl Stations T1, T2 and T3. Seabrook Operational Report, 1990.

interval for the overall mean. Analysis of variance indicated that annual mean CPUE for rainbow smelt was significantly greater at Station T2 that at Stations T1 or T3 (Table 3.2.2-12). However, there was no difference between preoperational and 1990 CPUE at any of the stations.

Rainbow smelt were present in beach seine collections from April through November (excluding June) during 1990 (Figure 3.2.2-13). Annual mean CPUE averaged over all stations for the preoperational period was 0.5 fish/haul with a low of 0.1 fish/haul recorded in 1980 and 1988. The 1990 mean CPUE of 1.3 fish/haul was substantially higher than the overall mean for the preoperational period and therefore is in general agreement with the otter trawl results.

Atlantic Silverside

Throughout the preoperational period, Atlantic silversides were most abundant in beach seine collections from August through November and this pattern was repeated in 1990 (Figure 3.2.2-14). The annual geometric mean CPUE ranged from 4.1 fish per haul in 1989 to 24.4 fish/haul in 1976, averaging 11.4 fish/haul throughout the preoperational period (Table 3.2.2-10). The 1990 CPUE of 5.9 fish/haul was not significantly different from the preoperational mean (Table 3.2.2-13). Atlantic silverside CPUE have remained relatively low since a sharp decline in 1982.

The catches were highly variable over the years with annual mean CPUE ranging from 4.1 to 24.4 fish/haul and averaging 11.4 fish/haul over all years (Table 3.2.2-9). The high variability is most likely due to the fact that this species tends to move in large schools, and samples are collected only once a month. As a result, the chances of encountering this species can vary greatly. The annual geometric mean for 1989 was 4.1 fish per haul, slightly lower than the mean for 1988 (5.3 fish/haul) and the lowest value for the fourteen years of this study. Results of the one-way analysis of variance were not significant (Table 3.2.2-12).

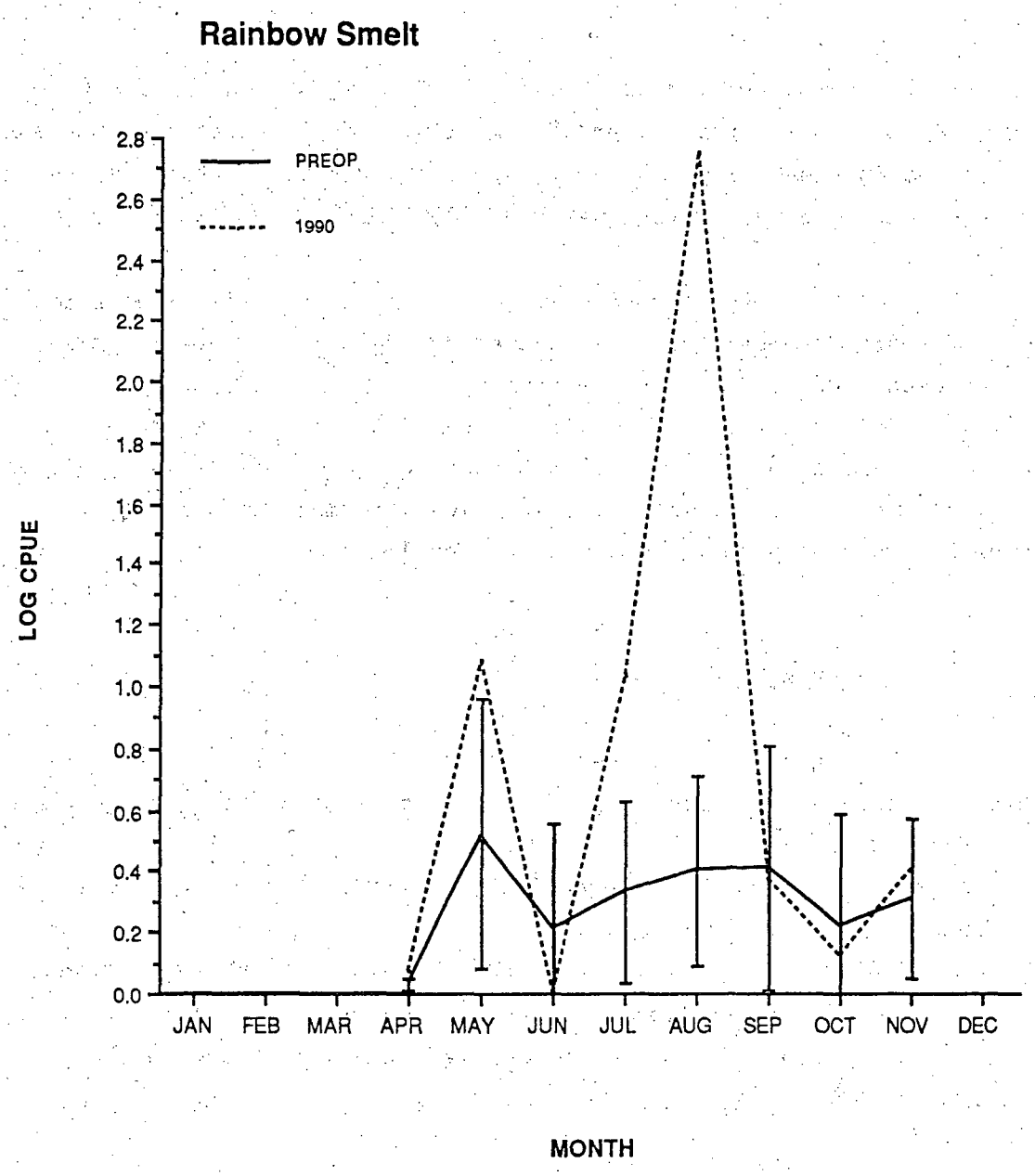


Figure 3.2.2-13. Log (x+1) catch per unit effort (one haul) for rainbow smelt; monthly means and 95% confidence intervals over all preoperational years (1976-1984, 1987-1989) and monthly means for 1990 averaged over beach seine Stations S1, S2 and S3. Seabrook Operational Report, 1990.

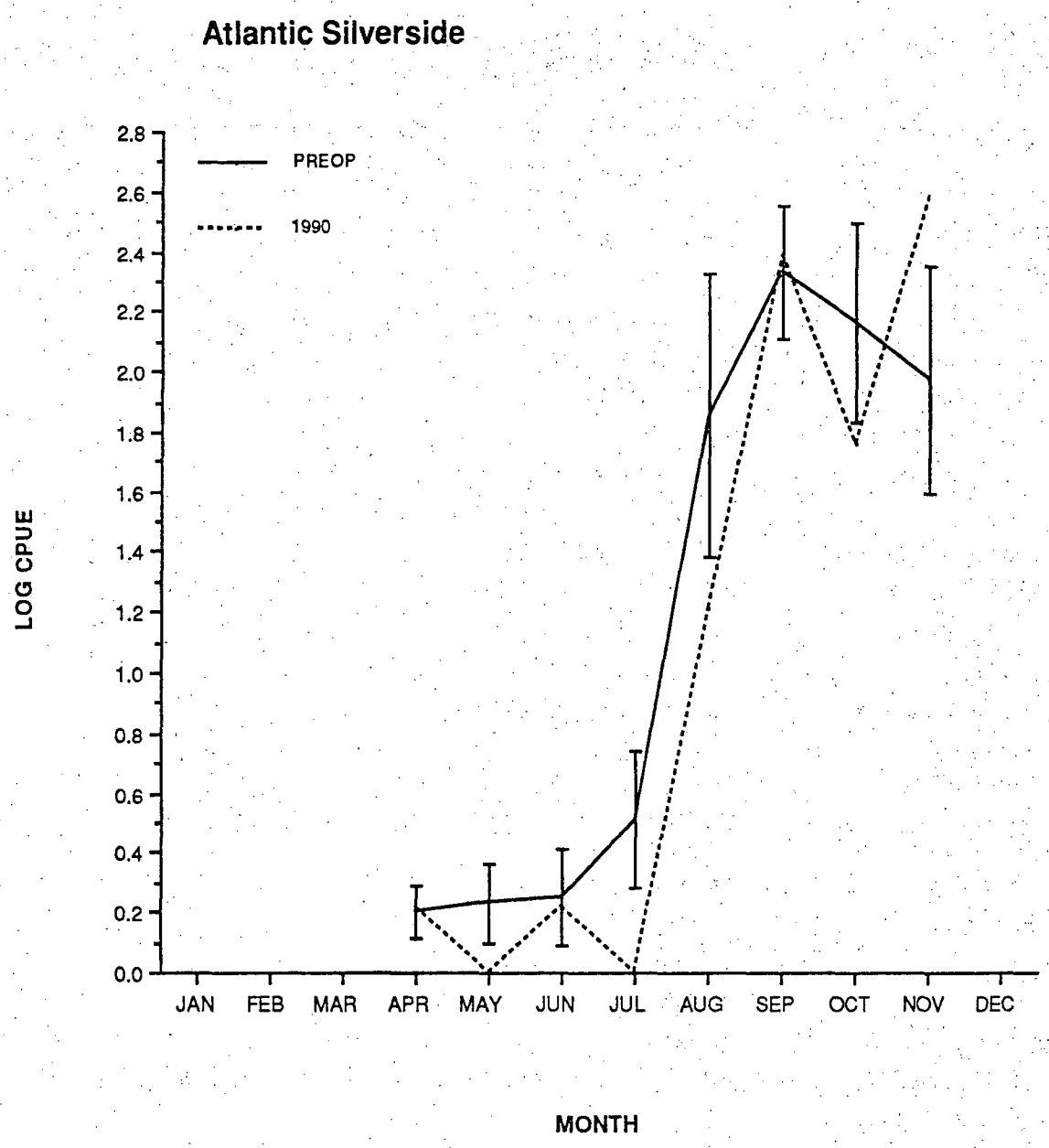


Figure 3.2.2-14. Log (x+1) catch per unit effort (one haul) for Atlantic silverside; monthly means and 95% confidence intervals over all preoperational years (1976-1984, 1987-1989) and monthly means for 1990 averaged over beach seine Stations S1, S2 and S3. Seabrook Operational Report, 1990.

APPENDIX TABLE 3.2.1-1. FINFISH SPECIES COMPOSITION BY LIFE STAGE AND GEAR, JULY 1975-DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

		ICHTHYO-PLANKTON TOWS		ADULT AND JUVENILE FINFISH		
SCIENTIFIC NAME[a]	COMMON NAME[a]	EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Acipenser oxyrhynchus	Atlantic sturgeon				R[b]	
Alosa aestivalis	blueback herring		-	R	C	C
Alosa mediocris	hickory shad		-		R	
Alosa pseudoharengus	alewife		-	O	O	O
Alosa sapidissima	American shad		-	R	O	O
Alosa sp.			R	-	-	-
Ammodytes americanus	American sand lance		A	O	R	O
Anarhichas lupus	Atlantic wolffish			R		
Anchoa hepsetus	striped anchovy					R
Anguilla rostrata	American eel		C	R		
Apeltes quadracus	fourspine stickleback					R
Archosargus probatocephalus	sheepshead			R		
Aspidophoroides monopterygius	alligatorfish		C	O		
Brevoortia tyrannus	Atlantic menhaden	O	O		O	R
Brosme brosme	cusk	O	O			
Caranx hippos	crevalle jack					R
Centropristis striata	black sea bass			R	R	
Conger oceanicus	conger eel		R			
Clupea harengus	Atlantic herring		C	O	A	O
Cryptacanthodes maculatus	wrymouth		O	R		
Cyclopterus lumpus	lumpfish		C	R	R	R
Enchelyopus cimbrius	fourbeard rockling	C	C	O		
Fundulus sp.[c]	mummichog[c]					C
Gadus morhua	Atlantic cod	-	C	C	O	R
Gadus/Melanogrammus	Atlantic cod/haddock	C	-	-	-	-
Gasterosteus sp.[d]	stickleback[d]		R	R		C
Glyptocephalus cynoglossus	witch flounder	C	C	O		
Hemitripterus americanus	sea raven		O	C	O	R

(Continued)

APPENDIX TABLE 3.2.1-1. (Continued)

SCIENTIFIC NAME[a]	COMMON NAME[a]	ICHTHYOPLANKTON TOWS		ADULT AND JUVENILE FINFISH		
		EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Hippoglossoides platessoides	American plaice	C	C	O		
Hippoglossus hippoglossus	Atlantic halibut			R		
Labridae/*Pleuronectes*	cunner/yellowtail flounder[e]	A	-	-	-	-
Liparis atlanticus	Atlantic seasnail	R	C	-	-	-
Liparis coheni	gulf snailfish		C	-	-	-
Liparis sp.[f]	snailfish[f]	R	-	O		
Lophius americanus	goosefish	R	O	O	R	
Lumpenus lampretaeformis[g]	snakeblenny		O	R		
Lumpenus maculatus	daubed shanny		R	R		
Macrozoarces americanus	ocean pout		O	C	R	
Melanogrammus aeglefinus	haddock	-	O	C	R	
Menidia menidia	Atlantic silverside			O	R	A
Menticirrhus saxatilis	northern kingfish				R	
Merluccius bilinearis	Atlantic whiting[h]	C	C	C	C	R
Microgadus tomcod	Atlantic tomcod		R	R		O
Morone americana	white perch					R
Morone saxatilis	striped bass				R	R
Mugil cephalus	striped mullet					R
Mustelus canis	smooth dogfish				R	
Myoxocephalus aenaeus	grubby		C	O	R	O
Myoxocephalus octodecemspinosus	longhorn sculpin		C	A	O	R
Myoxocephalus scorpius	shorthorn sculpin		C	O	R	R
Odontaspis taurus	sand tiger				R	
Oncorhynchus kisutch	coho salmon				R	R
Oncorhynchus mykiss	rainbow trout					R
Osmerus mordax	rainbow smelt		C	C	O	C
Paralichthys dentatus	summer flounder			R		

(Continued)

APPENDIX TABLE 3.2.1-1. (Continued)

SCIENTIFIC NAME[a]	COMMON NAME[a]	ICHTHYO-PLANKTON TOWS		ADULT AND JUVENILE FINFISH		
		EGGS	LARVAE	TRAWLS	GILL NETS	SEINES
Paralichthys oblongus	fourspot flounder	R	O	C	R	
Peprilus triacanthus	butterfish	O	O	R	O	R
Petromyzon marinus	sea lamprey				R	
Pholis gunnellus	rock gunnel		C	O	R	R
Pleuronectes americanus[i]	winter flounder		C	C	O	C
Pleuronectes ferrugineus[j]	yellowtail flounder	-	C	A	R	R
Pleuronectes putnami[k]	smooth flounder		R	R		C
Pollachius virens	pollock	C	C	C	C	O
Pomatomus saltatrix	bluefish				O	O
Prionotus carolinus	northern searobin	-	-	O	R	
Prionotus evolans	striped searobin	-	-	R		
Prionotus sp.	searobin	O	R	-	-	-
Pungitius pungitius	ninespine stickleback					C
Raja sp.[l]	skate[l]			C	R	
Salmo trutta	brown trout					O
Salvelinus fontinalis	brook trout					R
Scomber japonicus	chub mackerel				R	
Scomber scombrus	Atlantic mackerel	A	A	R	C	R
Scophthalmus aquosus	windowpane	C	C	C	R	O
Sebastes sp.[m]	redfish		O			
Sphoeroides maculatus	northern puffer			R		R
Squalus acanthias	spiny dogfish			R	O	
Stenotomus chrysops	scup		R	O	R	
Stichaeus punctatus	Arctic shanny		O			
Syngnathus fuscus	northern pipefish		C	O	R	O
Tautoga onitis	tautog	-	C		R	
Tautogolabrus adspersus	cunner	-	A	O	O	R
Torpedo nobiliana	Atlantic torpedo			R		
Triglops murrayi	moustache sculpin		O	R		
Ulvaria subbifurcata	radiated shanny		C	O		
Urophycis sp.[n]	hake[n]	A	C	A	O	C

Footnotes: See next page.

APPENDIX TABLE 3.2.1-1. (Continued)

Footnotes:

[a]Names are according to Robins et al. (1991) unless otherwise noted. Taxa usually identified to a different level are not included in this list to avoid duplication (e.g., Gadidae, *Enchelyopus/Urophycis*, *Myoxocephalus* sp., *Urophycis chuss*, etc.)

[b]Occurrence of each species is indicated by its relative abundance or frequency of occurrence for each lifestage or gear type:

A = abundant (≥ 10% of total catch over all years)
C = common (occurring in ≥ 10% of samples but < 10% of total catch)
O = occasional (occurring in < 10 and ≥ 1% of samples)
R = rare (occurring in < 1% of samples)
- = not usually identified to this taxonomic level at this lifestage

[c]Predominantly *Fundulus heteroclitis*, mummichog, but may include a small number of *Fundulus majalis*, striped killifish.

[d]Two species of *Gasterosteus* have been identified from seine samples: *G. aculeatus*, threespine stickleback; and *G. wheatlandi*, blackspotted stickleback (both occurring commonly).

[e]May also include a small number of tautog.

[f]Three species of *Liparis* have been identified from trawl samples: *L. atlanticus*, *L. coheni*, and *L. inquilinus* (inquiline snailfish).

[g]Spelling after Faber (1976).

[h]Previously called silver hake; Atlantic whiting was recommended by Kendall and Naplin (1981:707).

[i]formerly *Pseudopleuronectes americanus*

[j]formerly *Limanda ferruginea*

[k]formerly *Liopsetta putnami*

[l]Four species of *Raja* have been identified from trawl samples: *R. radiata*, thorny skate (common); *R. erinacea*, little skate (common); *R. ocellata*, winter skate (occasional); and *R. eglanteria*, clearnose skate (rare).

[m]Previously called *S. marinus*. Recently *S. mentella* and *S. fasciatus* have also been reported to occur in the northwest Atlantic (Ni 1981a; 1981b). *Sebastes* in coastal New Hampshire waters are probably *S. fasciatus* (Dr. Bruce B. Collette, U.S. National Museum, pers. comm. April 1982), but larval descriptions are insufficient to allow distinction among the three species.

[n]Three species of *Urophycis* have been identified from trawl samples: *U. chuss*, red hake (common); *U. tenuis*, white hake (common); and *U. regia*, spotted hake (rare).

3.3 BENTHOS

3.3.1 Estuarine Benthos

3.3.1.1 Physical Environment

Salinity and Temperature

Weekly measurements of surface water salinity and temperature at high and low slack tides in Browns River and Hampton Harbor and daily rainfall data from Logan Airport, Boston, MA (National Climatic Data Center, 1990) were used to investigate annual and monthly patterns. The Browns River salinity station is a nearfield station just downstream from the benthic transect, and about 0.5 km downstream from the settling basin outfall; the Hampton Harbor station is a farfield station away from the influence of that outfall (Figure 2.1-6). The most extreme environmental conditions at the stations sampled occur at low tide in Browns River, because the water is less influenced by the tidal influx of sea water. Those conditions are most likely to influence the structure of the estuarine benthic communities.

Precipitation (rain and melted snow and ice) is measured daily by the National Climatic Data Center at Logan Airport, Boston, Massachusetts (Table 3.3.1-1), and has a relatively high annual variation. The thirteen-year average and 95% confidence interval for the study period from 1978-1990 was 41.96 ± 4.09 inches per year. Precipitation that was below the lower 95% confidence limit occurred in 1978, 1980, 1981, 1985, and 1988. Rainfall that was above the 95% confidence limit occurred in 1983, 1984, and 1990. Rainfall in 1990 was especially high in October (when 3.34 inches fell on October 14), followed by August, April, and May (National Climatic Data Center 1990, Figure 3.3.1-1).

Mean monthly salinity and 95% confidence interval, 1979-1990, at low tide in Browns River ranged from 17.0 ± 3.4 ppt in April to 25.1 ± 1.3 ppt in August (Appendix Table 3.3.1-1, Figure 3.3.1-1). In 1990, monthly salinities were below the 95% confidence limits of the mean for

TABLE 3.3.1-1. TOTAL PRECIPITATION (WATER EQUIVALENT IN INCHES) BY MONTH AND YEAR TAKEN AT LOGAN INTERNATIONAL AIRPORT, BOSTON, MA[a] FROM JANUARY 1978 - DECEMBER 1990 AND 30-YEAR NORMALS[b]. SEABROOK OPERATIONAL REPORT, 1990.

	TIME PERIOD														
	30-YR. NORMAL	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	13 YR. MEAN
JAN	3.99	8.12	10.55	0.74	0.95	4.69	5.03	2.31	1.12	3.42	7.28	2.50	0.61	3.78	3.93
FEB	3.70	2.87	3.46	0.88	6.65	2.66	5.00	7.81	1.83	2.83	0.72	3.93	2.51	3.60	3.44
MAR	4.13	2.46	3.03	5.37	0.62	2.17	9.72	6.82	2.29	3.42	4.27	3.52	3.07	1.71	3.73
APR	3.73	1.79	3.19	4.36	3.14	3.42	6.86	4.43	1.62	1.59	9.46	1.47	3.58	5.94	3.91
MAY	3.52	4.50	4.24	2.30	1.17	2.58	2.94	8.77	3.36	1.31	1.75	2.86	3.54	6.53	3.53
JUN	2.92	1.53	0.86	3.05	1.65	13.20	1.07	3.06	3.94	7.74	2.62	1.29	2.84	0.69	3.35
JUL	2.68	1.48	2.36	2.20	3.47	4.22	1.07	4.43	3.51	3.96	0.82	7.62	5.09	4.08	3.41
AUG	3.68	4.62	5.02	1.55	1.04	2.22	3.28	1.60	6.67	3.32	2.93	1.11	5.92	6.57	3.53
SEP	3.41	1.30	3.61	0.82	2.54	1.57	1.06	1.22	3.00	1.08	7.29	1.29	4.61	1.67	2.39
OCT	3.36	3.13	3.14	4.14	3.43	3.19	3.74	5.18	1.65	3.27	2.73	1.60	5.71	7.36	3.71
NOV	4.21	2.21	3.29	3.01	4.78	3.42	8.89	1.68	6.39	6.01	3.49	6.57	4.13	1.39	4.25
DEC	4.48	3.63	1.42	0.97	6.27	1.27	4.94	2.93	1.21	6.38	2.12	1.02	0.81	3.18	2.78
ANNUAL	43.81	37.64	44.17	29.39	35.71	44.61	53.60	50.24	36.59	44.33	45.48	34.78	42.42	46.50	41.96

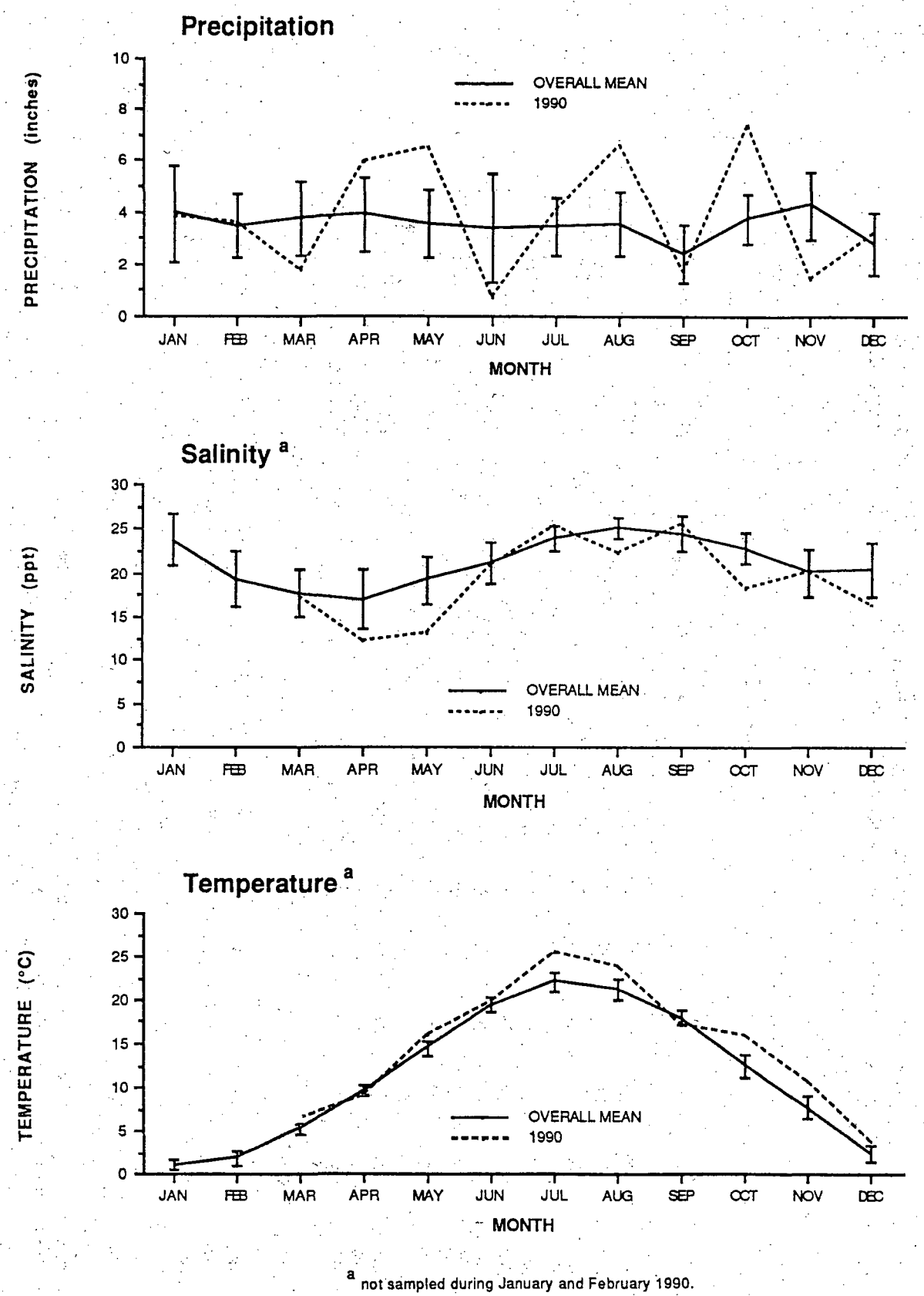
YEARS RANKED IN ASCENDING ORDER

YEAR	80	88	81	85	78	89	79	86	82	87	90	84	83
PRECIPITATION	29	35	36	37	38	42	44	44	45	45	47	50	54

[a]Source: National Climatic Data Center, 1990. Local climatological data, monthly summary. January-December, Federal Building, Ashville, NC.

[b]Normals are based on the 1951-1980 record period. Source: National Climatic Data Center, 1989. Local climatological data, annual summary with comparative data, Boston, MA. Federal Building, Ashville, NC.

[c]Monthly maximum since 1951. Source: National Climatic Data Center, 1989.



[a] not sampled during January and February 1990.

Figure 3.3.1-1. Monthly means and 95% confidence limits for precipitation measured in Boston, MA, from 1978-1990 and surface salinity and temperature taken at low tide in Browns River over the entire study period (May 1979-December 1990) and in 1990. Seabrook Operational Report, 1990.

five out of ten months (Figure 3.3.1-1). Low tide salinity in Browns River tended to have an inverse relationship with monthly precipitation (Figure 3.3.1-1).

The mean monthly salinity and 95% confidence interval at high tide in Browns River ranged from 27.1 ± 2.3 ppt in April to 31.5 ± 0.8 ppt in January during the study period (Appendix Table 3.3.1-1). High tide salinity was always higher and less variable than low tide salinity due to the influx of more saline water from Hampton Harbor into Browns River.

At the Hampton Harbor station, the mean monthly low tide salinity and 95% confidence interval during the study period ranged from 24.5 ± 2.7 ppt in April to 29.6 ± 0.7 ppt in September (Appendix Table 3.3.1-1). The mean monthly high tide salinity and 95% confidence interval ranged from 30.0 ± 0.8 ppt in May to 32.2 ± 0.5 ppt in January; very similar to offshore, coastal salinities. The salinity in Hampton Harbor was always higher and less variable than in Browns River due to its proximity to the harbor inlet. The low tide eleven-year average and 95% confidence interval was 27.7 ± 0.5 ppt (Appendix Table 3.3.1-2). Mean salinity fell below the 95% confidence limit of the overall mean in 1983, 1984, and 1990, and coincided with years of above average precipitation. Years of high salinity (above 28.2 ppt, the upper confidence limit of the overall mean) included 1980, 1981, and 1985, and coincided with years of low precipitation, except for 1988 which had salinity within the 95% confidence interval and below average precipitation.

The overall mean monthly temperature and 95% confidence interval at low tide in Browns River ranged from 1.0 ± 0.6°C in January to 22.1 ± 1.1°C in July during the study period (Appendix Table 3.3.1-1, Figure 3.3.1-1). In 1990, average monthly temperatures were above the 95% confidence limits of the averages for seven out of the 10 months sampled (Figure 3.3.1-1).

In Hampton Harbor, the overall average monthly temperatures and 95% confidence intervals at low tide ranged from 1.0 ± 0.5°C in January to 18.8 ± 0.7°C in August during the study period (Appendix Table 3.3.1-1). The temperature range in Hampton Harbor was not as great as Browns River, due to its proximity to the inlet. The low tide eleven-year average temperature and 95% confidence interval from 1980 to 1990 was 10.1 ± 1.1°C, which includes all the annual means (Appendix Table 3.3.1-2). Low tide temperatures in 1990 were average, with a yearly mean of 10.3 ± 4.3°C.

In summary, total annual low tide salinity in Browns River and Hampton Harbor (Appendix Table 3.3.1-2) generally had an inverse relationship to mean annual precipitation (Table 3.3.1-1), as would be expected. In 1983 and 1984, when precipitation was over 50 inches a year, annual low tide salinity in both Browns River and Hampton Harbor were at or near all time lows. Likewise in 1980 and 1981, when precipitation was very low, annual low tide salinities at both nearfield and farfield stations were at or near all time highs. The years 1983 and 1984 were warm at both stations; however, the coldest years varied from station to station.

The outfall from the Seabrook Station settling basin runs into Browns River, and usually contains the fresh water discharge from the station's sewage treatment plant and runoff from rainfall. During the years of intake and discharge tunnel construction from November 1979 through November 1983, the outfall became saline and volume of the discharge increased (Figure 3.3.1-2). Coincident with the first two full years of saline discharge (1980, 1981) was a period of low rainfall (Table 3.3.1-1), and above average salinities occurred in both Browns River and Hampton Harbor (Appendix Table 3.3.1-2), indicating that the salinity increase was area-wide. Once tunnel construction was completed in 1983, the discharge from the settling basin diminished to low levels. In 1990, the total annual volume of discharge (150 x 10^6 gallons) was greater than the discharge in the preceding year (86 x 10^6 gallons), but remained low, relative to the entire study period.

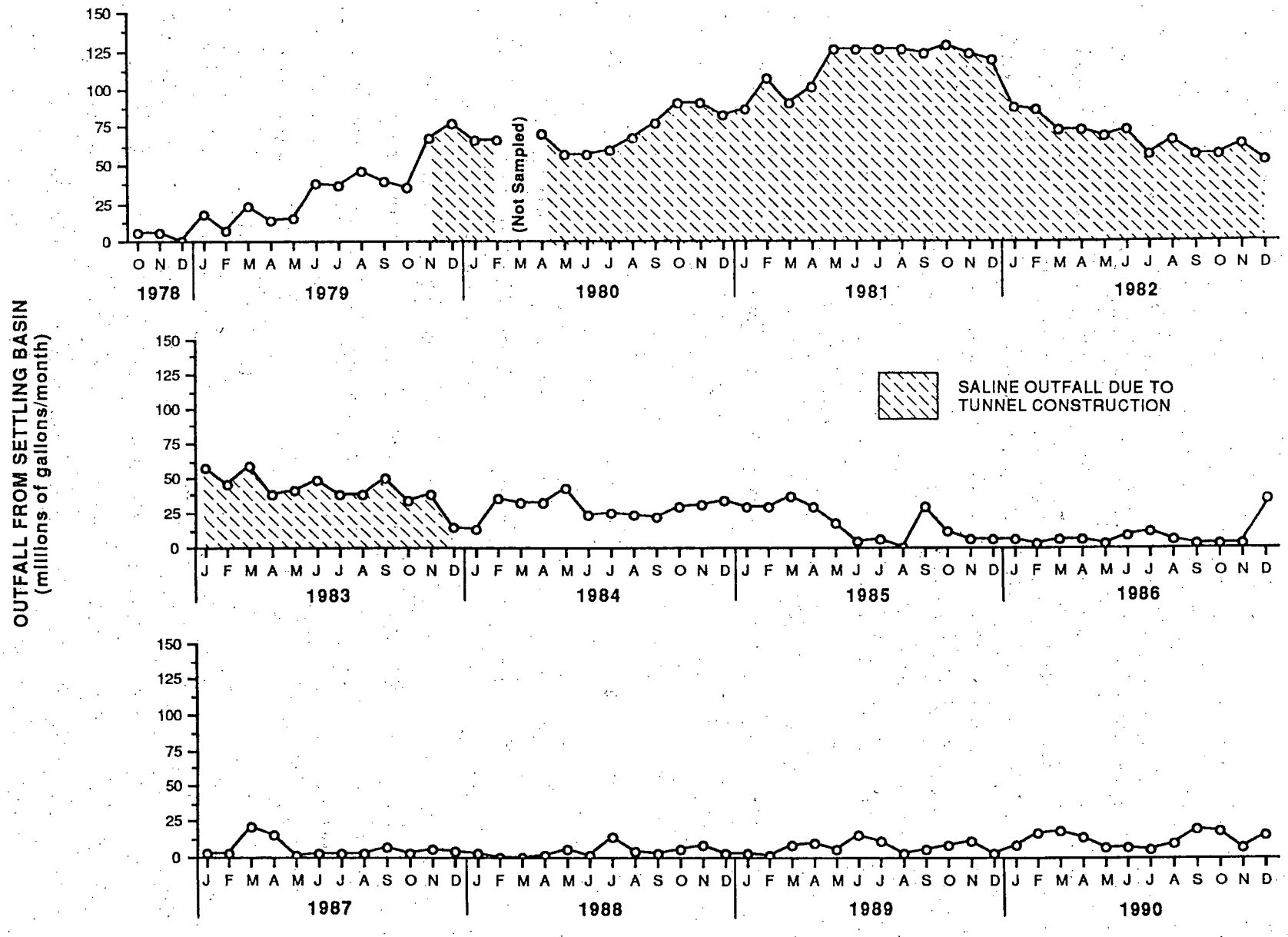


Figure 3.3.1-2. Total monthly outfall (millions of gallons per month) from the Seabrook Settling Basin into Browns River from October 1978 through December 1990. Seabrook Operational Report, 1990.

Sediment

Yearly and seasonal differences in sediment collected from 1978-1984 indicated grain size was highly variable among stations, with little year-to-year stability (NAI 1985b). Yearly averages at subtidal stations (3 and 9) showed the median grain size was in the fine sand range, which was usually poorly sorted with organic carbon ranging from 0.97 to 2.08% (NAI 1985b). The yearly averages for intertidal stations (3MLW and 9MLW) showed the median grain size varied from fine sand to silt, which was often very poorly sorted. The percentage of organic carbon was higher than at subtidal stations and ranged from 1.56 to 5.86% (NAI 1985b). Sediment parameters during the 1980-1982 period were within the range of natural variation, and did not noticeably change during the period of maximum discharge (due to tunnel dewatering) from the settling pond.

3.3.1.2 Macrofauna

Subtidal and intertidal estuarine benthic communities in Browns River (Stations 3 and 3MLW) and Mill Creek (Stations 9 and 9MLW) were typical for quiet, tidal creeks with fine-grained sediments, where average monthly salinity ranged from about 17 ppt at low tide to 31.5 ppt at high tide (Appendix Table 3.3.1-1). Spatial distribution of organisms was very patchy, and large population fluctuations occurred seasonally, as is typical in estuarine habitats. The polychaete *Streblospio benedicti* was the most abundant species in the estuary, and comprised 6 to 8% of the total density at both intertidal stations, and 14 to 20% of the total density at both subtidal stations (Table 3.3.1-2). Oligochaeta and *Capitella capitata* were also present in very high numbers. The clam worm *Nediste diversicolor* (formerly *Nereis diversicolor*) was very abundant intertidally in Browns River. The soft-shelled clam, *Mya arenaria*, was also present in substantial numbers at all sampling locations, especially Mill Creek (Table 3.3.1-2).

TABLE 3.3.1-2. MEAN NUMBER OF TAXA[a] AND THE GEOMETRIC MEAN DENSITY[b] (No./m^2) FOR EACH YEAR AND OVERALL YEARS WITH 95% CONFIDENCE LIMITS FROM ESTUARINE STATIONS AT BROWNS RIVER (3) AND MILL CREEK (9) SAMPLED FROM 1978 THROUGH 1990 (EXCLUDING 1985).[c] SEABROOK OPERATIONAL REPORT, 1990.

	STATION	1978	1979	1980	1981	1982	1983	1984	1986	1987	1988	1989	1990	ALL YEARS MEAN	ALL YEARS UPPER	ALL YEARS LOWER
Mean No. of Taxa	3	35	41	38	42	47	32	27	38	33	38	38	35	37	39	35
	9	26	34	47	44	34	36	21	36	21	27	25	31	32	35	28
	3MLW	28	37	31	38	35	28	18	32	23	31	31	28	30	32	28
	9MLW	28	35	35	41	36	33	21	36	16	29	29	36	31	34	28
	MEAN	29	37	38	41	38	32	22	35	23	31	31	33	32	34	31
Total Density	3	3170	4616	4978	5360	9331	2635	1244	1182	1198	3472	2583	1707	2826	3713	2150
	9	3619	2209	14,767	11,277	4335	4533	620	2819	726	4764	1878	2488	3084	4599	2068
	3MLW	4260	6136	5695	6833	8022	2723	2187	5632	1727	3936	6940	1778	4106	5260	3205
	9MLW	3120	4512	6947	12,189	11,383	11,151	5131	4203	653	6115	7525	3845	5185	7420	3622
	MEAN	3514	4099	7344	8424	7796	4364	1715	2980	995	4467	3990	2321	3691	4339	3139
Capitella capitata	3	11	63	123	473	889	216	66	73	57	105	72	16	90	161	50
	9	238	29	2453	277	291	376	28	808	113	1530	262	259	269	468	155
	3MLW	17	29	138	244	540	208	124	197	26	46	27	24	76	122	48
	9MLW	279	45	125	320	276	800	303	234	19	1068	173	466	221	350	140
	MEAN	60	40	269	318	443	341	91	228	42	299	98	84	142	186	109
Caulleriella sp. B	3	330	221	835	1	2	3	12	9	1	101	7	6	18	41	8
	9	10	40	46	292	136	35	7	10	3	16	4	4	19	41	9
	3MLW	106	174	607	3	23	52	44	255	87	244	80	28	74	134	41
	9MLW	8	298	48	43	1634	278	325	307	1	21	3	8	51	123	21
	MEAN	42	147	183	17	64	37	34	53	5	54	10	9	34	50	23
Hediste diversicolor	3	83	172	158	352	452	45	50	52	43	128	52	38	94	137	64
	9	21	29	41	205	41	7	7	43	2	33	29	8	22	36	13
	3MLW	800	1343	1169	1613	975	220	296	987	150	523	1235	199	606	941	391
	9MLW	170	164	101	241	135	57	513	184	6	29	93	18	86	144	51
	MEAN	125	183	167	410	223	45	89	143	18	90	115	33	102	137	76

(continued)

TABLE 3.3.1-2. (Continued)

	STATION	1978	1979	1980	1981	1982	1983	1984	1986	1987	1988	1989	1990	ALL YEARS MEAN	ALL YEARS UPPER	ALL YEARS LOWER
Mya arenaria	3	69	158	92	181	132	75	31	21	30	12	35	64	56	82	38
	9	265	427	299	246	148	168	157	34	53	83	69	208	143	213	95
	3MLW	106	224	26	179	117	103	22	13	27	12	73	25	50	83	30
	9MLW	100	328	62	400	141	70	86	13	73	39	425	266	110	172	70
	MEAN	118	265	82	237	134	98	55	19	42	26	93	98	82	102	65
Oligochaeta	3	242	270	204	651	2189	556	225	95	133	768	301	156	319	485	209
	9	16	100	2910	969	1058	1603	162	528	131	272	233	260	327	576	186
	3MLW	87	186	318	320	350	292	382	968	215	322	409	48	258	399	167
	9MLW	574	810	1067	861	565	2877	572	742	161	351	2888	362	714	1172	435
	MEAN	119	253	671	646	823	931	298	437	157	392	537	163	372	474	292
Spio setosa	3	38	39	65	155	159	120	113	151	171	244	447	334	133	190	93
	9	50	59	287	346	170	16	3	75	6	315	236	110	69	137	35
	3MLW	7	9	8	6	4	8	2	46	25	46	24	26	12	21	7
	9MLW	54	59	43	78	48	30	8	65	2	32	41	117	35	61	20
	MEAN	30	33	51	72	51	26	10	76	16	104	102	103	45	61	33
Streblospio benedicti	3	367	123	193	525	1064	552	239	99	66	550	181	56	231	359	149
	9	106	26	2396	525	81	538	16	161	49	744	167	400	178	368	86
	3MLW	439	505	1010	928	3584	525	535	1421	316	1306	3227	259	827	1256	545
	9MLW	566	434	466	2700	2354	3215	1560	1299	11	744	399	1023	710	1309	385
	MEAN	314	163	684	912	925	842	242	415	58	794	445	278	395	529	295

[a]Yearly mean number of taxa = mean of three seasonal totals (where seasonal total = total number in all five 1/16 m^2 replicates combined)
[b]Yearly mean density = mean of three seasonal means (where seasonal mean = mean of five replicates)
[c]All years mean = mean of 36 seasonal means (3 seasons x 12 years)

Total density of all macrofaunal organisms (number/m^2) showed year-to-year variations during the thirteen-year study period. These variations appear to be related to area-wide environmental trends, since major changes often occurred simultaneously in both Browns River and Mill Creek (Figures 3.3.1-3, 4). Subtidal stations in Browns River (Station 3) and the reference station in Mill Creek (Station 9) had highly significant differences in densities among years; 1980-1981 ranked with years of highest density, and 1984 and 1987 ranked with years of lowest abundance at both stations according to multiple comparison tests (Table 3.3.1-3). Differences among years were less pronounced at intertidal stations; however, densities were at or near the all time high in 1981 and at the all time low in 1987 at both stations, (Table 3.3.1-2,3). In 1990, total densities at all stations were lower than average, but within the range of previous years. This trend was more evident at the intertidal stations, as indicated by the multiple comparison test.

Precipitation and its effect on salinity in the tidal creeks seems to be an important environmental factor causing area-wide changes in total macrofaunal density. In 1980 and 1981, when annual precipitation was lowest (Table 3.3.1-1), salinity was very high (Appendix Table 3.3.1-2), and total densities at both subtidal stations (Stations 3 and 9) were very high (Table 3.3.1-3). In 1984, when annual rainfall was very high and salinities at both stations were very low, total densities at both stations were also very low. Low densities in 1987 could be accounted for by heavy rainfall in April and September, normally periods of high recruitment. Density variations at intertidal stations appeared to be less associated with fluctuations in precipitation than at subtidal stations.

The mean number of taxa collected annually at all four stations ranged from 16 to 47 during the thirteen-year study period (Table 3.3.1-2). Annual variations in the number of taxa were highly significant at all stations except Station 3 (Table 3.3.1-3). Annual changes in the number of taxa were generally similar at all four

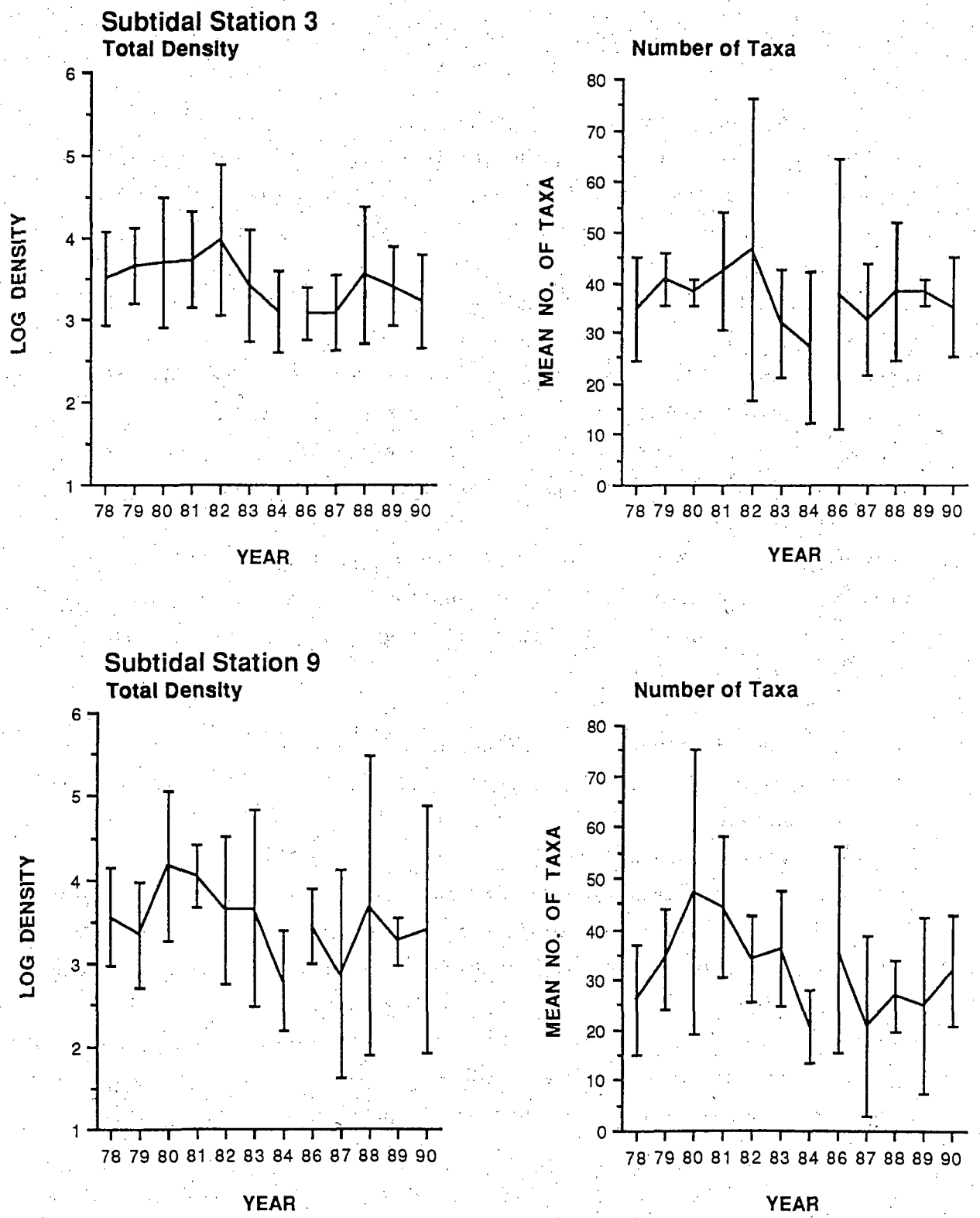


Figure 3.3.1-3. Yearly means and 95% confidence limits for the log (x+1) density (no./m^2) of macrofauna and mean number of taxa per 5/16m^2 collected at subtidal estuarine stations sampled three times per year from 1978 through 1990 (excluding 1985). Seabrook Operational Report, 1990.

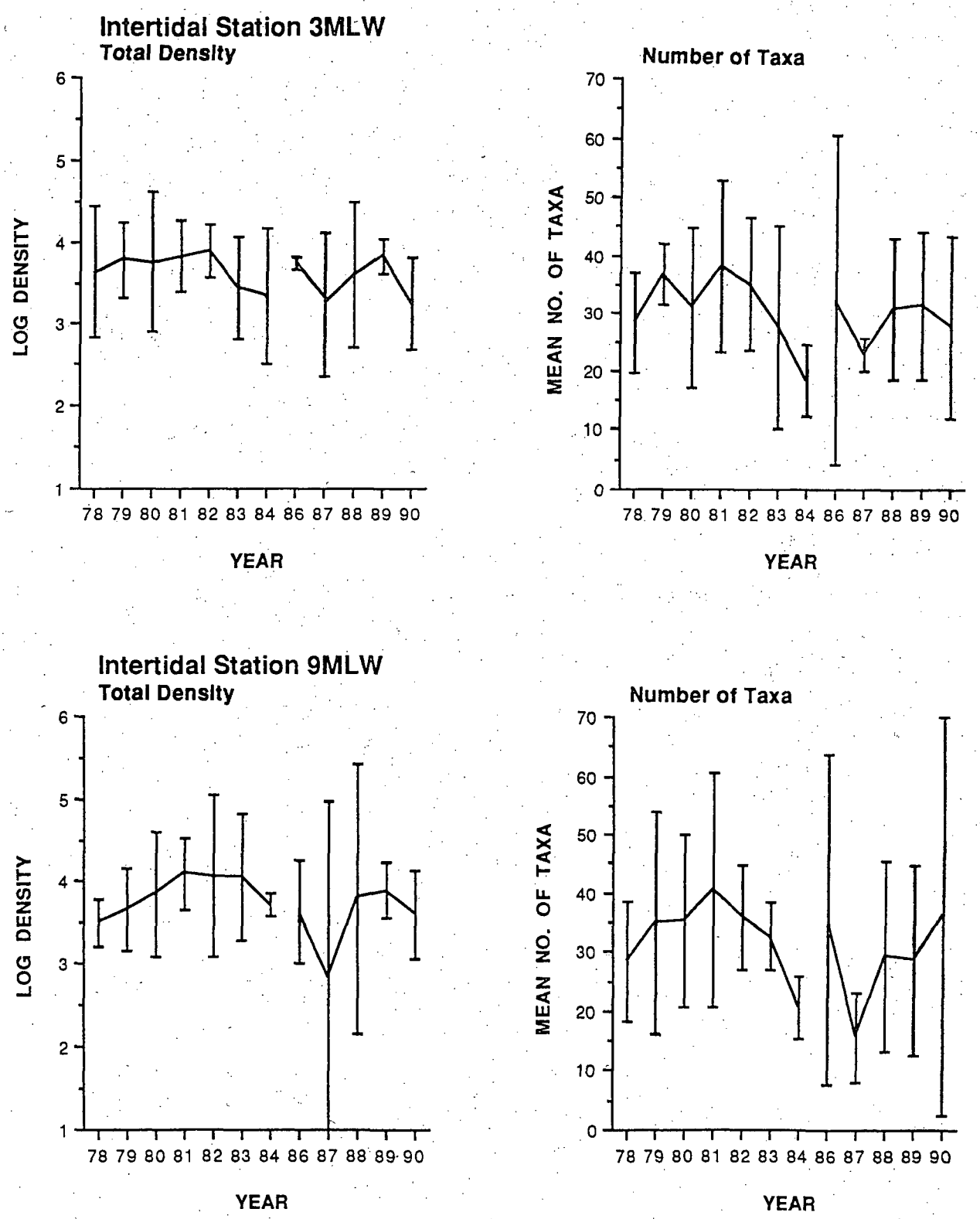


Figure 3.3.1-4. Yearly means and 95% confidence limits for the log (x+1) density (no./m^2) of macrofauna and mean number of taxa per 5/16m^2 collected at intertidal estuarine stations sampled three times per year from 1978 through 1990 (excluding 1985). Seabrook Operational Report, 1990.

TABLE 3.3.1-3. RESULTS OF ONE-WAY ANALYSIS OF VARIANCE[a] AMONG YEARS FOR THE MEAN NUMBER OF TAXA (per 5/16 m^2) AND LOG (x+1) TRANSFORMED DENSITY (No./m^2) OF THE MOST ABUNDANT ESTUARINE SPECIES AND THE TOTAL DENSITY OF MACROFAUNA COLLECTED AT ESTUARINE STATIONS FROM 1978 THROUGH 1990 (EXCLUDING 1985). SEABROOK OPERATIONAL REPORT, 1990.

	STATION	F[b]	MULTIPLE COMPARISONS[c] - SUBTIDAL STATIONS	STATION	F[b]	MULTIPLE COMPARISONS[c] - INTERTIDAL STATIONS
Number of Taxa	3	2.18 NS[d]	82 81 79 80 88 89 86 90 78 87 83 84	3MLW	2.95**	81 79 82 86 89 80 88 78 83 90 87 84
	9	6.02***	80 81 83 86 79 82 90 88 78 89 87 84	9MLW	3.07**	81 90 82 86 80 79 83 88 89 78 84 87
Total Density	3	3.92**	82 81 80 79 88 78 83 89 90 84 87 86	3MLW	2.55*	82 89 81 79 80 86 78 88 83 84 90 87
	9	3.21**	80 81 88 83 82 78 86 90 79 89 87 84	9MLW	2.42*	81 82 83 89 80 88 84 79 86 90 78 87
Streblospio benedicti	3	2.04 NS	82 83 88 81 78 84 80 89 79 86 87 90	3MLW	1.73 NS	82 89 86 88 80 81 84 83 79 78 87 90
	9	1.72 NS	80 88 83 81 90 89 86 78 82 87 79 84	9MLW	3.93**	83 81 82 84 86 90 88 78 80 79 89 87
Oligochaeta	3	1.94 NS	82 88 81 83 89 79 78 84 80 90 87 86	3MLW	1.09 NS	86 89 84 82 88 81 80 83 87 79 78 90
	9	4.46***	80 83 82 81 86 88 90 89 84 87 79 78	9MLW	0.92 NS	89 83 80 81 79 86 78 84 82 90 88 87
Capitella capitata	3	2.02 NS	82 81 83 80 88 86 89 84 79 87 90 78	3MLW	3.98**	82 81 83 86 80 84 88 79 89 87 90 78
	9	3.83***	80 88 86 83 82 81 89 90 78 87 79 84	9MLW	3.88**	88 83 90 81 84 78 82 86 89 80 79 87

(continued)

TABLE 3.3.1-3. (Continued)

	STATION	F[b]	MULTIPLE COMPARISONS[c] - SUBTIDAL STATIONS	STATION	F[b]	MULTIPLE COMPARISONS[c] - INTERTIDAL STATIONS
Hediste diversicolor	3	2.68*	82 81 79 80 88 78 86 89 84 83 87 90	3MLW	1.43 NS	81 79 89 80 86 82 78 88 84 83 90 87
	9	2.75**	81 86 82 80 88 79 89 78 90 84 83 87	9MLW	3.30**	84 81 86 78 79 82 80 89 83 88 90 87
Mya arenaria	3	2.47*	81 79 82 80 83 78 90 89 84 87 86 88	3MLW	1.81 NS	79 81 82 78 93 89 87 80 90 84 86 88
	9	1.41 NS	79 80 78 81 90 83 84 82 88 89 87 86	9MLW	2.85*	89 81 79 90 82 78 84 87 83 80 88 86
Caulleriella sp. B	3	7.20***	80 78 79 88 84 86 89 90 83 82 87 81	3MLW	2.67*	80 86 88 79 78 87 89 83 84 90 82 81
	9	1.32 NS	81 82 80 79 83 88 86 78 84 89 90 87	9MLW	3.71**	82 84 86 79 83 80 81 88 90 78 89 87
Spio setosa	3	2.17 NS	89 90 88 87 82 81 86 83 84 80 79 78	3MLW	0.96 NS	86 88 90 87 89 79 80 83 78 81 82 84
	9	2.65*	81 88 80 89 82 90 86 79 78 83 87 84	9MLW	1.32 NS	90 81 86 79 78 82 80 89 88 83 84 87

[a]Degrees of freedom for the model (years) = 11
Degrees of freedon for the error = 24

[b] NS = not significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)

[c]Multiple comparison test is Waller-Duncan K-ratio T test
Horizontal lines connect statistically similar years.
[d]Since the F value is NS, years are reported in order of decreasing abundance

stations for most of the study period. Like total density, the number of taxa collected in 1984 and 1987 ranked among the lowest two or three years of the study period at every station sampled. Number of taxa in 1981 ranked in the highest group at every station with the multiple comparison test (Table 3.3.1-3). The seasonal cycle at each of the four stations showed that the highest number of taxa usually occurred in August or May, and the lowest number occurred in November (NAI 1987b).

The annual trend in the number of taxa seems to show an inverse relationship with the annual precipitation. This was evident at all four stations, but was more prominent at subtidal stations. In 1984, the mean number of taxa was at or near the all time low at every station, and 1984 was the second consecutive year of extremely high precipitation (Table 3.3.1-1). A substantial decline in the number of taxa was also observed in 1987 when rainfall in April reached a 30-year high for that month, and salinity in the second week of April was <2 ppt (NAI 1988a). In 1990, mean number of taxa was similar to past years (within the overall 95% confidence interval) at three out of four stations; at Station 9MLW the mean was higher than average, but had very wide confidence limits (Figure 3.3.1-3,4; Table 3.3.1-2).

Streblospio benedicti is a cosmopolitan opportunistic polychaete (Grassle and Grassle 1974), and one of the first to colonize after a perturbation of the environment (Rhoads et al. 1978). It is the most abundant species in the estuary, and extremely high densities occurred during any season at both intertidal and subtidal stations. Such high densities were rarely sustained into the next sampling period, causing tremendous population fluctuations (NAI 1987b). With such high natural variation, no significant differences among years were found except at the intertidal station (9 MLW) in Mill Creek (Table 3.3.1-3). The most consistent trend among stations was that in general, the densities were well below average in 1987. Extremely high monthly rainfall occurred in April 1987 and also in September (Table 3.3.1-1). The dramatic overall population decrease in 1987 was followed by an increase of an order of magnitude in 1988 at three out of four stations.

In 1983, the inverse relationship between precipitation and population density did not hold true. Even though annual rainfall was very high, annual densities were also very high at two out of four stations (Table 3.3.1-2). In 1990, the annual density of *S. benedicti* was at an all-time low in Browns River (Stations 3 and 3 MLW), but was intermediate in Mill Creek (Stations 9 and 9MLW). Average densities for the study period were similar for each intertidal and subtidal station pair; the highest densities occurred intertidally (Table 3.3.1-2).

The class Oligochaeta is a species complex that is abundant in the estuary. The seasonal cycle of oligochaetes indicated that peak densities occurred during any season (NAI 1987b), but were not sustained. No consistent differences in densities were found between Browns River and Mill Creek stations (Table 3.3.1-2). No significant differences occurred among years, except at the subtidal station in Mill Creek (Table 3.3.1-3). When examining the yearly densities, population fluctuations were not consistent, probably because they were represented by more than one species. Oligochaete densities in 1990 were similar to previous years, except in the Browns River, where they were the lowest recorded to date.

The opportunistic polychaete *Capitella capitata* was common at both intertidal and subtidal stations and typically showed large annual population fluctuations. Browns River densities were consistently lower than densities at Mill Creek (Table 3.3.1-2). Highly significant differences were found among years at all stations except the subtidal station in Browns River (Table 3.3.1-3). Following the very low population levels in 1987 at all stations, populations increased greatly in 1988, particularly in Mill Creek (Figures 3.3.1-5,6). Densities declined at every station in 1989, and averaged less than $100/m^2$ at both stations in Browns River (Table 3.3.1-2). In 1990, densities in Browns River were very near the all time low (which occurred in 1978), but in Mill Creek, they were near or above average (Tables 3.3.1-2,3).

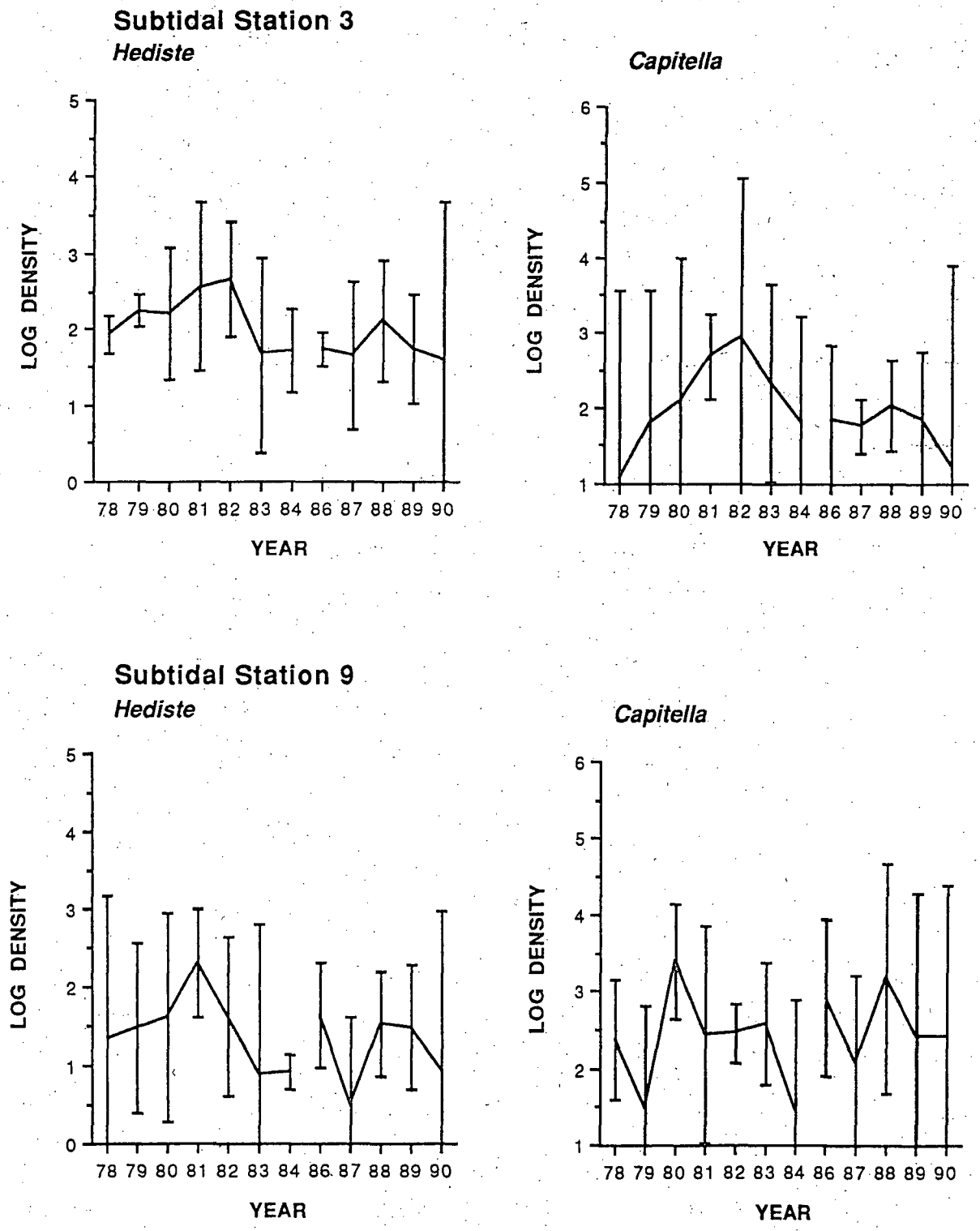


Figure 3.3.1-5. Yearly means and 95% confidence limits for the log (x+1) density (no./m^2) of *Hediste diversicolor* and *Capitella capitata* collected at subtidal estuarine stations sampled three times per year from 1978 through 1990 (excluding 1985). Seabrook Operational Report, 1990.

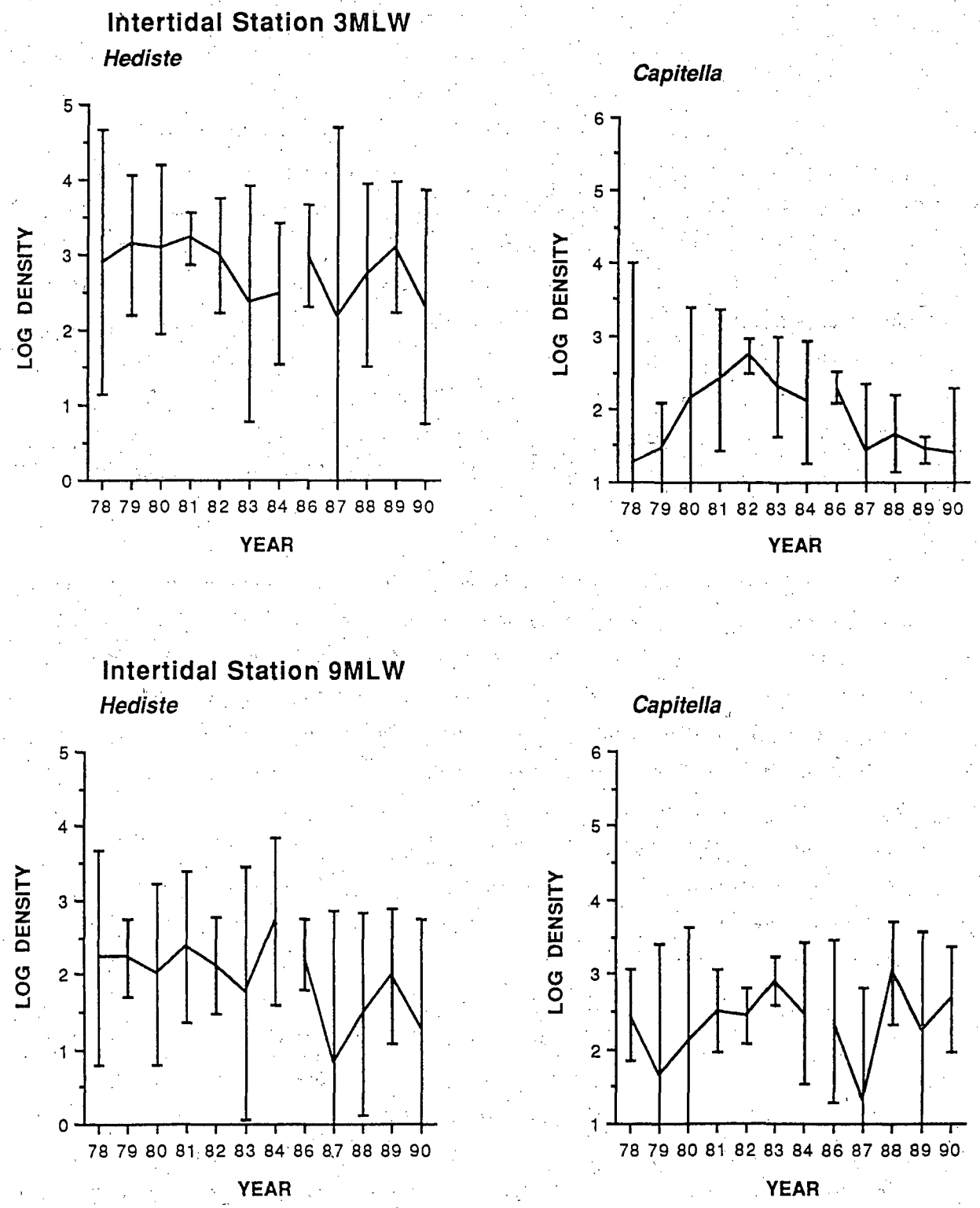


Figure 3.3.1-6. Yearly means and 95% confidence limits for the log (x+1) density (no./m^2) of *Hediste diversicolor* and *Capitella capitata* collected at intertidal estuarine stations sampled three times per year from 1978 through 1990 (excluding 1985). Seabrook Operational Report, 1990.

Caulleriella sp. B is a polychete that was occasionally abundant in the estuary. It rarely sustained densities of over 100/m^2 for more than three consecutive years, and in 1987 it had annual densities of less than 10 at three of the four estuarine stations (Table 3.3.1-2). Significant differences among years occurred at all stations except the subtidal station in Mill Creek (Table 3.3.1-3). Relatively low population densities occurred at three out of four stations in 1987, while 1980 ranked among the top three years at three out of four stations. In 1989, densities declined substantially from the previous year at all four stations, and remained low at all four stations in 1990 (Table 3.3.1-2).

The clam worm, *Hediste diversicolor*, is a euryhaline species that is most common intertidally where there is a mixture of fresh and salt water (Pettibone 1963). It is an omnivore, frequently abundant in nutrient rich areas, and has been considered an opportunist and an indicator of pollution (Hull 1987). Both intertidal and subtidal stations at Browns River had substantially higher densities than stations of comparable depth at Mill Creek (Table 3.3.1-2). Intertidal stations had higher densities than subtidal stations (Table 3.3.1-2), particularly Station 3MLW in Browns River. Highly significant differences among years occurred at all stations except Station 3MLW, where *H. diversicolor* was most abundant (Table 3.3.1-3).

H. diversicolor abundances at all four stations followed the trend of numbers of taxa, total density, and *S. benedicti* and *C. capitata* abundances; the extremes of population density appeared inversely related to precipitation, with one exception. Density was high in 1981 at all four stations, and low in 1987, and was grouped accordingly with multiple comparison tests (Table 3.3.1-3). Low abundances occurred at three out of four stations in 1984; however, at Station 9MLW, it reached its highest annual abundance. In 1990, the year with the third highest rainfall, *Hediste* populations declined substantially at all stations (Figures 3.3.1-5, 6).

Mya arenaria, the soft-shelled clam, has important commercial and recreational value within the estuary. *Mya* spat (<5 mm) and a few yearling clams (≤12 mm) predominate in estuarine samples. Densities of *Mya* spat were statistically similar among years at two of the four stations (Table 3.3.1-3); however, densities were usually higher in Mill Creek than in Browns River (Table 3.3.1-2). *Mya* densities in 1990 in Mill Creek were well above average.

In summary, substantial variability has occurred throughout the estuary in total density, number of taxa, and density of the most dominant species. As these changes were not site-specific, and tended to occur simultaneously at Browns River and Mill Creek (except in 1983), they were probably related to area-wide environmental variables such as precipitation and corresponding salinity changes, temperature, and abundance of predators and competitors. The largest population increases for most of the estuarine polychaetes, total density, and number of taxa in both Browns River and Mill Creek occurred during the period of low precipitation and highest salinity (1980-1983). By 1986, physical and biological parameters had returned to the pre-1980 conditions. In 1984 and 1987 the most pronounced drops in density and number of taxa which occurred during the study period seemed to be related to high precipitation and low salinity. These biological parameters recovered, and approached the average range within one or two years. In 1990, a year of intermediate salinity (although in some months, lower than average) and slightly above average precipitation, densities were typically within normal range, although lower than average.

3.3.2 Marine Macroalgae

3.3.2.1 Macroalgal Community

Number of Taxa

The effect of depth on light quality and quantity is reflected in the diversity (number of taxa), total biomass and species composition of the macroalgae community from hard substrate rock and ledge. The number of taxa is an important measure of community diversity. Macroalgae taxa richness is measured two ways. Although a qualitative measure, the number of taxa from "general collections" represents the maximum number occurring at a station during a given season, depending on the visibility and other factors affecting collection efficiency. The number of taxa collected from destructive samples represents a quantitative measure in a 1/16 m^2 area, and thus can be statistically tested.

A total of 128 taxa has been collected during the preoperational study from 1978 through 1989 in general collections (NAI 1990b). No new taxa were collected in 1990. This number includes plants not identifiable to the species level that were placed in genera or higher classifications. Historically, over half (51%) of these taxa were red algae (Rhodophyta), with the remainder divided almost evenly between brown algae (Phaeophyta, 27%) and green algae (Chlorophyta, 22%)(NAI 1990b). This proportion is typical for the New Hampshire coast (Mathieson and Hehre 1986). In 1990, the proportions were slightly different. More than half of the species were red algae (57%), more than one quarter brown algae (29%), and the remainder (14%) were green algae (NAI 1991).

Spatially, the highest number of taxa collected from general collections throughout the historical period was in the mean low water (MLW) zone (a median of 49 at Station B5MLW); numbers decreased with increasing depth, with the fewest taxa collected at the deepest stations (Figure 3.3.2-1). The lower numbers at the deep stations were due to

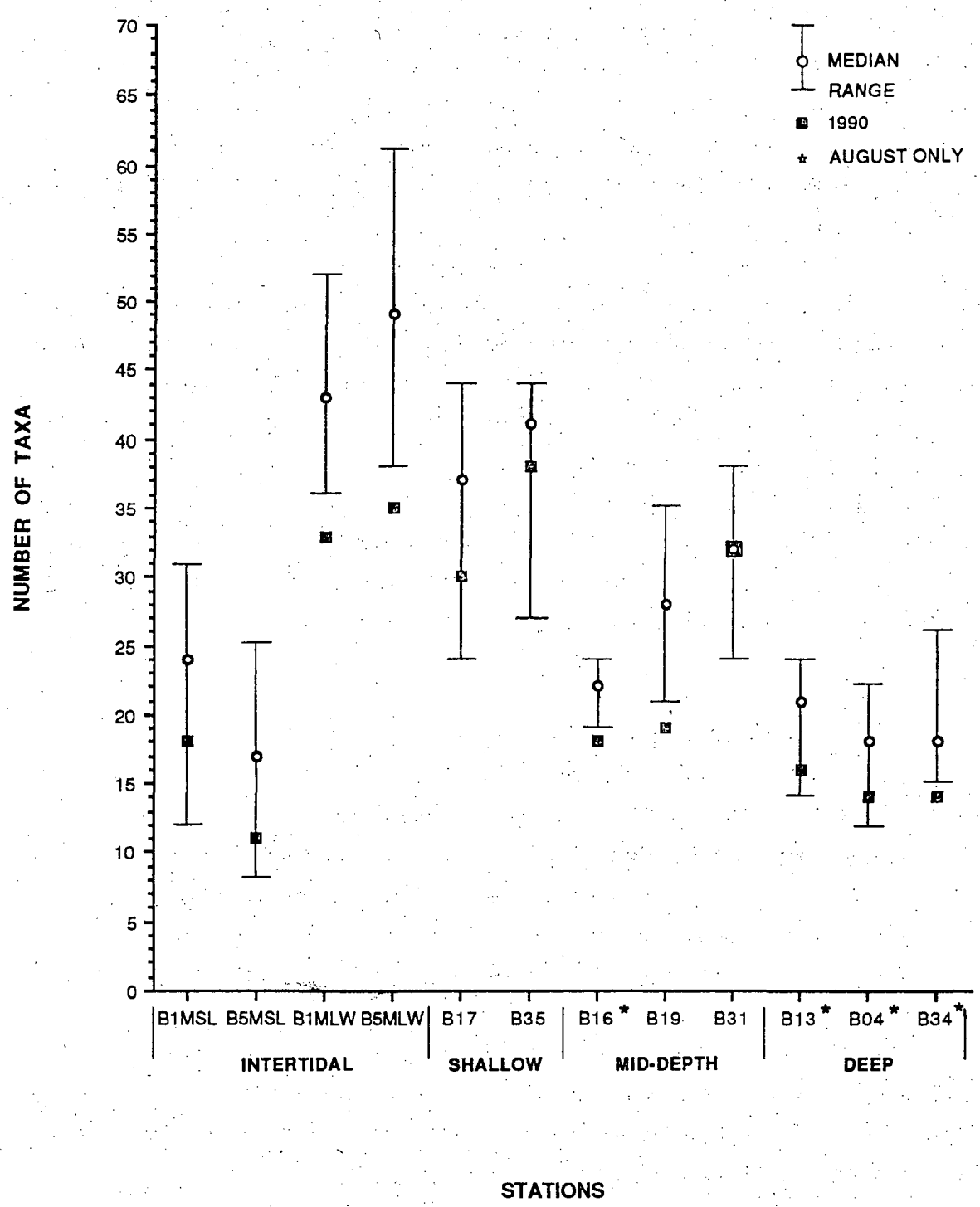


Figure 3.3.2-1. Preoperational (through 1989) median and range and 1990 value of number of taxa collected in triannual general collections at Stations B1MSL, B1MLW, B17 B19, B31 (1978-1990), B5MSL, B5MLW, B35 (1982-1990), and annual collections at B16 (1980-1984; 1986-1990), B13, B04 (1978-1984; 1986-1990) and B34 (1979-1984; 1986-1990). Seabrook Operational Report, 1990.

several factors: lower light, lower temperatures, fewer annual taxa and a less-intensive sampling effort (once per year). Number of taxa collected also decreased with increasing elevation from MLW (e.g., at the MSL stations). This is consistent with other New Hampshire studies (Mathieson *et al.* 1981).

In 1990, numbers of taxa from general collections were below the median value for the preoperational period at all stations, although more than half were within the range of previous years. Numbers of taxa in 1990 were the lowest ever recorded at both intertidal MLW stations, nearfield mid-depth, and farfield deep stations. The 1990 values were within the range of previous years at both of the high intertidal and shallow subtidal stations, and farfield mid-depth and nearfield deep stations. A decrease in the annual number of taxa was first noted in 1989, when the number of taxa at half of the stations was lower than the lowest recorded annual value (NAI 1990b).

For the most part, the numbers of taxa collected at corresponding nearfield and farfield stations from 1978 to 1989 were similar. In the intertidal zone, the nearfield station (B1MLW) had fewer taxa at the approximate mean low water mark and a greater number of taxa at mean sea level than its farfield counterpart at Rye Ledge (B5MLW), a trend that continued in 1990 (Figure 3.3.2-1). In the mid-depth zone, fewer taxa have been recorded throughout the study at the station near the intake (Station B16) than at the discharge and farfield stations (B19 and B31). This may be due in part to fewer annual collections at B16 (once per year) than at B19 and B31 (three times per year). In 1990, the number of taxa was lower at the nearfield mid-depth station (B19) than at the farfield (B31).

Numbers of taxa collected quantitatively from destructive sampling paralleled the trends noted in general collections. Historically, the average number of taxa during the preoperational period was highest at the farfield intertidal and shallow subtidal stations (Figure 3.3.2-2). Nearfield intertidal and shallow subtidal areas had moderate

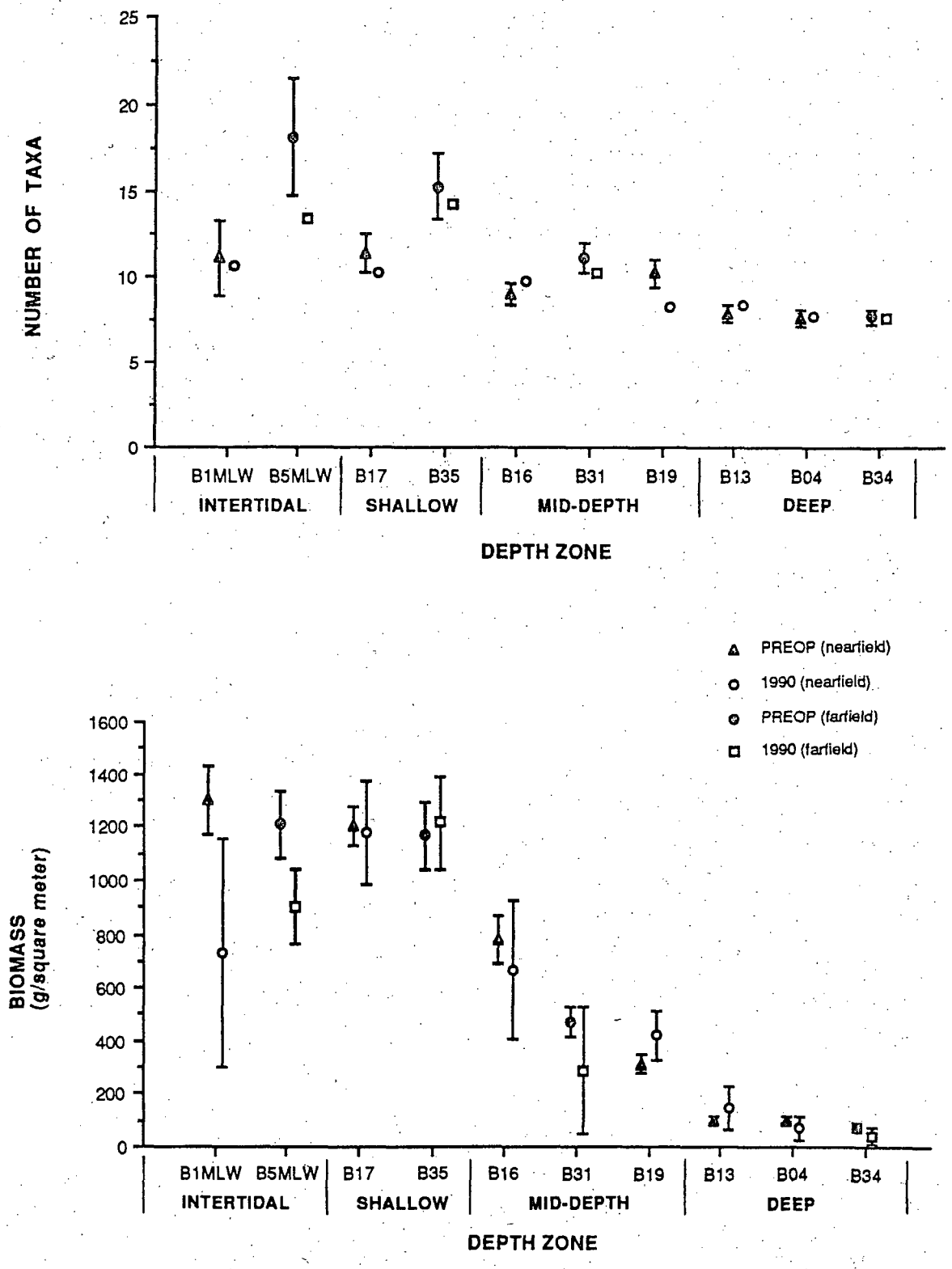


Figure 3.3.2-2. Mean number of taxa (per 1/16 m^2), total biomass (g/m^2) and 95% confidence limits of macroalgae collected at intertidal and subtidal stations during the preoperational period (see Figure 3.2.2-1 for years sampled) and in 1990. Seabrook Operational Report, 1990.

numbers of taxa and deep stations had the lowest numbers of taxa. Numbers of taxa in 1990 showed similar spatial relationships. However, numbers of taxa were significantly lower in the intertidal area in 1990 at both nearfield and farfield stations, although the difference was more pronounced at the farfield station (Table 3.3.2-1; Figure 3.3.2-2). Significant differences in numbers of taxa were also noted in 1990 at mid-depth stations. However, trends in 1990 were not similar at all three stations, as indicated by the significance of the Station X Preop-op interaction term (Table 3.3.2-1). At the intake station (B16), numbers of taxa were higher than average, while numbers of taxa were lower at both the discharge and farfield stations (B19 and B31). Numbers of taxa in 1990 were similar to previous years at the shallow subtidal and deep stations.

Total Biomass

The effect of light on the quantity of macroalgae was evident from the changes in total biomass with depth. Historically (1978-1989), August total biomass values have been highest in the intertidal areas (Figure 3.3.2-2). In 1990, total biomass values were significantly lower than those observed historically at both nearfield and farfield intertidal stations. This difference was pronounced at the nearfield area, as indicated by the significant Station-Preop-Op interaction term in the ANOVA (Figures 3.3.2-2,3; Table 3.3.2-1).

Shallow subtidal areas also historically had high biomass values. Levels in 1990 were similar to the historical averages at both stations (Figures 3.3.2-2,3; Table 3.3.2-1). The intake Station B16 historically has had total biomass levels that were intermediate between shallow subtidal and mid-depth discharge and farfield stations, a trend that continued in 1990. At the discharge mid-depth station, total biomass in 1990 was signigicantly higher than previous years, whereas biomass was lower than previous years at the intake and farfield stations. The deepest stations (B04, B13, B34) have historically had

TABLE 3.3.2-1. RESULTS OF ANALYSIS OF VARIANCE OF NUMBER OF TAXA (per 1/16 m^2) AND TOTAL BIOMASS (g per m^2) OF MACROALGAE COLLECTED IN AUGUST AT INTERTIDAL, SHALLOW SUBTIDAL, AND DEEP STATION PAIRS, 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

PARAMETER	DEPTH ZONE	SOURCE OF VARIATION	df	SS	F[e]
Number of Taxa	Intertidal	Preop-Op[a]	1	33.1	4.48*
		Station[b]	1	161.0	21.78***
		Year (Preop-Op)[c]	11	1072.7	13.19***
		Station X Preop-Op[d]	1	19.1	2.58 NS
		Error	91	672.6	
	Shallow Subtidal	Preop-Op	1	6.5	1.46 NS
		Station	1	117.4	26.46***
		Year (Preop-Op)	11	270.4	5.54***
		Station X Preop-Op	1	1.11	0.25 NS
		Error	91	403.7	
	Mid-depth	Preop-Op	1	6.0	3.23 NS
		Station	2	22.8	6.14**
		Year (Preop-Op)	11	134.2	6.56***
		Station X Preop-Op	2	18.5	4.98**
		Error	158	294.1	
	Deep	Preop-Op	1	0.6	0.58 NS
		Station	2	3.4	1.57 NS
		Year (Preop-Op)	10	47.5	4.37***
		Station X Preop-Op	2	0.5	0.20 NS
		Error	159	172.8	

(continued)

TABLE 3.3.2-1. (Continued)

PARAMETER	DEPTH ZONE	SOURCE OF VARIATION	df	SS	F[e]
Total Biomass	Intertidal	Preop	1	977,400.4	12.00***
		Station	1	37,676.4	0.46 NS
		Year (Preop)	11	12,685,235.8	14.16***
		Station X Preop	1	494,681.3	6.07*
		Error	91	7,412,357.0	
	Shallow Subtidal	Preop	1	7.3	0.00 NS
		Station	1	802.8	0.01 NS
		Year (Preop)	11	2,381,208.8	2.66**
		Station X Preop	1	7,546.9	0.09 NS
		Error	91	7,413,102.6	
	Mid-depth	Preop	1	53,650.0	1.35 NS
		Station	2	1,486,648.3	18.75***
		Year (Preop)	11	1,647,974.4	3.78***
		Station X Preop	2	214,368.6	2.70 NS
		Error	158	6,263,875.5	
	Deep	Preop	1	185.4	0.08 NS
		Station	2	36,710.1	7.86***
		Year (Preop)	10	59,345.0	2.54**
		Station X Preop	2	17,370.2	3.72*
		Error	159	371,397.4	

[a]Preop-Op = 1990 vs. preoperational (1978-1989) period (Stations B1MLW, B17, B19, B31: 1978-1989; Stations B5MLW, B35: 1982-1989; Station B16: 1980-1984, 1986-1989; Stations B13, B04: 1978-1984, 1986-1989; B34: 1979-1984, 1986-1989)
[b]Stations within depth zone Intertidal: B1I, B5I; shallow subtidal: B17, B35; mid-depth: B16, B19, B31; deep: B04, B34, B13
[c]Year nested within preoperational and operational periods regardless of area
[d]interaction between main effects
[e]NS = Not significant ($p>0.05$)
* = Significant ($0.05 \geq p > 0.01$)
** = Highly significant ($0.01 \geq p > .001$)
*** = Very highly significant ($p \leq .001$)

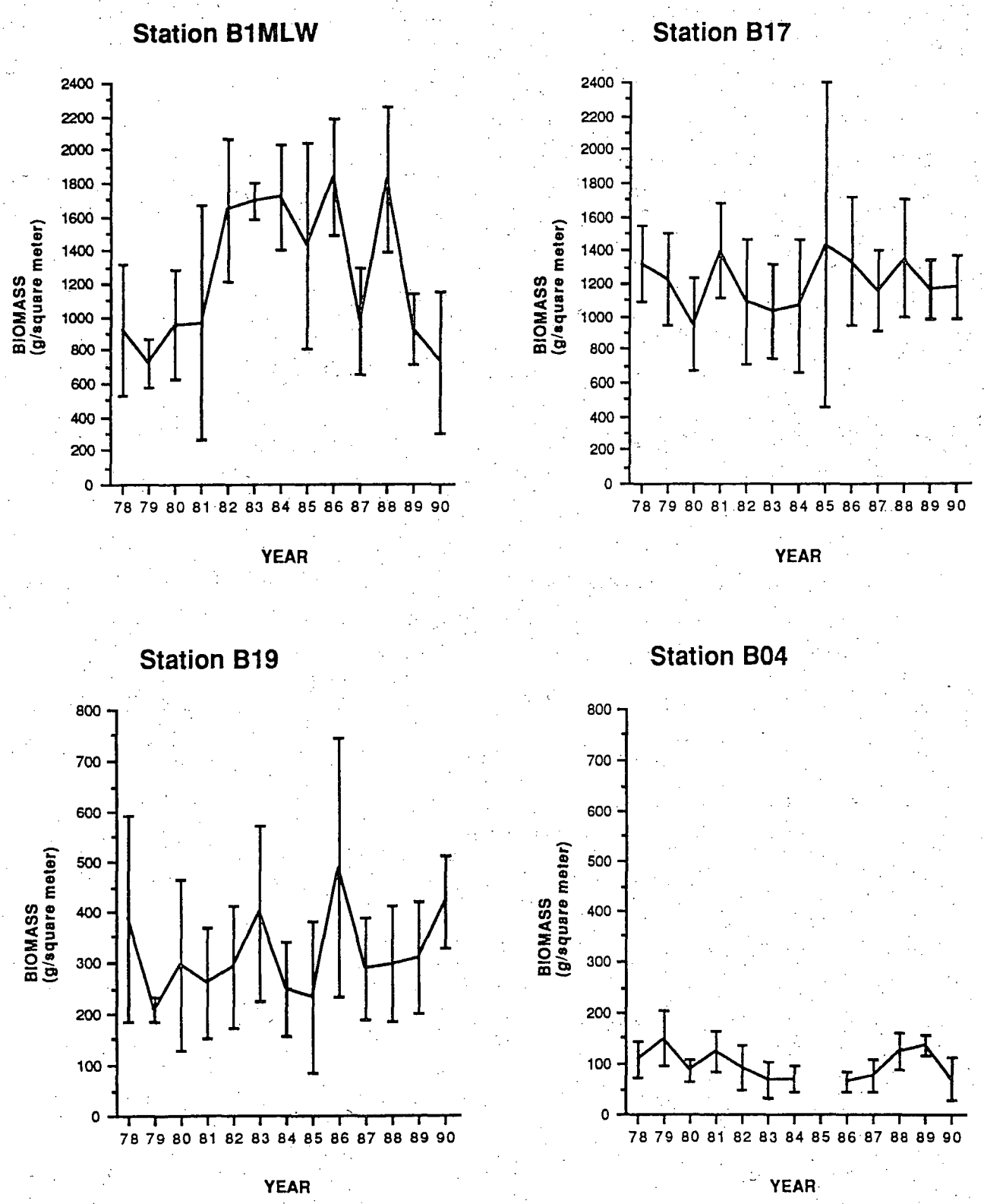


Figure 3.3.2-3. Annual mean biomass (g/m 2) and 95% confidence limits for macroalgae collected in August at selected nearfield benthic stations. Seabrook Operational Report, 1990.

lowest biomass levels. This trend continued in 1990. However, total biomass in 1990 was significantly lower than average at both nearfield discharge and farfield deep stations and higher than average at the deep intake station.

Community Analysis

Depth-related differences in species distribution have led to the development of distinct communities at the different depth zones. These communities were evaluated through the use of two techniques: examination of the relative abundance (percent of total biomass) of the seven most abundant taxa, and utilization of numerical classification. Changes in relative abundance give an indication of general changes in the dominant taxa. Numerical classification quantitatively evaluates similarities in community structure among years using all but the rarest taxa.

Depth differences among benthic stations were reflected in changes in the relative abundance of the seven dominant taxa (Figure 3.3.2-4). During the preoperational period, *Chondrus crispus* was dominant in the shallow subtidal and intertidal. *Mastocarpus stellatus* was restricted to the intertidal zone. *Phyllophora* spp. (*P. truncata* and *P. pseudoceranoides*) were most abundant at mid-depth Stations B19, and to a lesser extent B31 and B16, as well as deep Station B13. *Ptilota serrata* was dominant at the deepest (18.9, 21.0 m) Stations B04 and B34.

Trends in community composition in 1990 were similar to previous years, with a few exceptions. In the intertidal zone, the relative importance of *Chondus crispus* diminished, with a corresponding increase in *Mastocarpus stellatus* (Figure 3.3.2-4). Percentages of *M. stellatus* in 1990 at B1MLW (73%) were six-fold higher than the preoperational average (11%). The increase in *M. stellatus* in the farfield intertidal was approximately double the average of previous years.

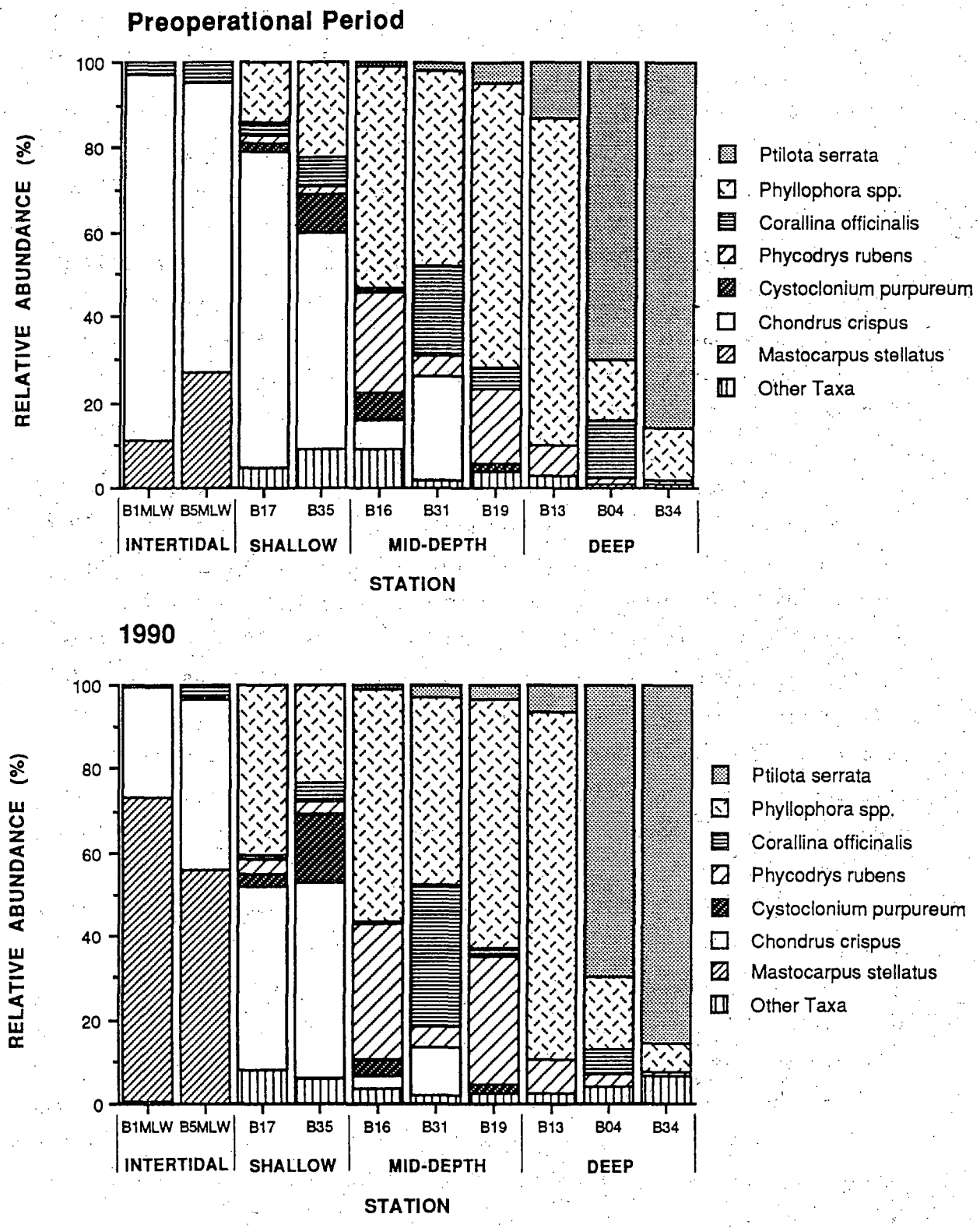


Figure 3.3.2-4. Relative abundance (% biomass) of dominant macroalgae at marine benthic stations in August for the preoperational period (see Figure 3.3.2-1 for dates) and 1990. Seabrook Operational Report, 1990.

Proportions of *C. crispus* also decreased in the shallow subtidal zone at the nearfield station only, coinciding with a corresponding increase in *Phyllophora* spp. The proportion of *C. crispus* also decreased at the farfield mid-depth station (B31), with a corresponding increase in *Corallina officinalis*. Changes in *C. crispus* biomass in 1990 will be further discussed in Section 3.3.2.2. At the discharge station (B19), relative abundance of *Phycodrys rubens* was higher than average, replacing *Phyllophora* spp. Species composition at the remaining stations in 1990 was similar to previous years.

Community composition differed in some cases between nearfield stations and their farfield counterparts. Historically, Station B5MLW had a larger proportion of *M. stellatus* and correspondingly smaller proportions of *Chondrus crispus* in comparison to Station B1MLW. Increases in *M. stellatus* at the nearfield area in 1990 reduced this discrepancy (Figure 3.3.2-4). At shallow subtidal stations, farfield Station B35 historically had higher percentages of *Phyllophora* spp., *Corallina officinalis*, and *Cystoclonium purpureum* when compared to Station B17, where the overwhelming dominant was *Chondrus crispus*. Reductions in the proportion of *C. crispus* in 1990 at the nearfield station increased the similarity of these two stations. Farfield Station B31 was typified by three dominants, *Phyllophora* spp., *Corallina officinalis*, and *Chondrus crispus*; whereas at nearfield Station B19, *Phyllophora* spp. predominated and *Phycodrys rubens* occurred as a subdominant. In 1990, relative abundance of *C. crispus* at B31 was lower than previous years, and abundance of *P. rubens* was correspondingly higher. Deep stations differed mainly in the presence of *C. officinalis* as a subdominant at the nearfield Station (B04). In 1990, *C. officinalis* was relatively less abundant at Station B04 than during the historical period.

The focus of the multivariate community analysis was to determine if plant operation had caused changes in the species assemblages typically found in each depth zone. The algae community in 1990

was judged to be similar to previous years if 1990 collections at a given station grouped with the majority of collections from the pre-operational period. This was true in all cases in 1990.

Numerical classification of samples collected from 1978 through 1990 produced results consistent with previous analyses (NAI 1985b, 1990b). Community structure was stable from year-to-year, but changed markedly with depth (Figure 3.3.2-5). Intertidal, shallow subtidal, mid-depth discharge and farfield (B19, B31), mid-depth intake (B16), deep intake (B13) and deep discharge and farfield stations had distinct species assemblages. Nearfield stations were more similar to their farfield counterparts than to other areas.

Differences in community structure at the different station groups were typified by differences in the biomass of dominant species in each group. Intertidal and shallow subtidal areas (Groups 5 and 6) historically had been characterized by large amounts of *Chondrus crispus* (Table 3.3.2-2). Although *C. crispus* biomass was lower in 1990 than in previous years, it remained a dominant in these areas. Increased biomass of secondary dominants, *Phyllophora* spp. in the shallow subtidal area and *Mastocarpus stellatus* in the intertidal area, coincided with reduced biomass of *Chondrus*. *Phyllophora* spp. was predominant at mid-depth areas (Groups 3 and 4) and deep intake Station B13 (Group 1). Large amounts of *Phycodrys rubens* and presence of two typically shallow subtidal species as subdominants (*Cystoclonium purpureum*, *Ceramium rubrum*) distinguished Station B16 (Group 4 except in 1984) from the other mid-depth stations. With the exception of the decreased importance of *C. crispus*, 1990 community dominants were similar to previous years. The community at Station B13 (Group 1) has consistently been a transition zone between mid-depth areas, as indicated by the predominance of *Phyllophora* spp., and deep areas, suggested by the presence of *Ptilota serrata*. At this depth (18.3 m), the shallow subtidal and intertidal species were not part of the community. This trend continued in 1990, although biomass of *Phyllophora* in 1990 was lower than the

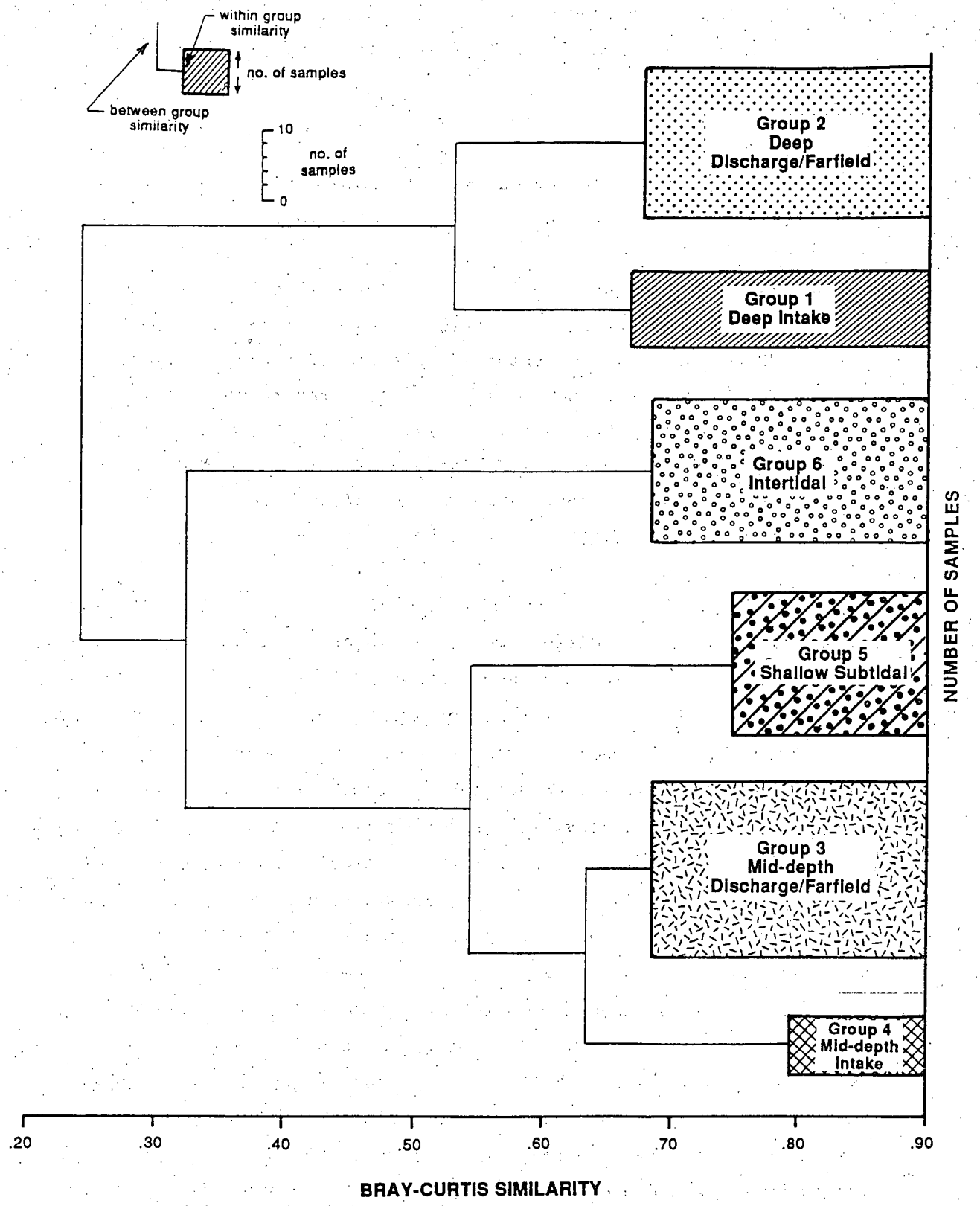


Figure 3.3.2-5. Dendrogram formed by numerical classification of August collections of marine benthic algae, 1978-1990. Seabrook Operational Report, 1990.

TABLE 3.3.2-2. SUMMARY OF SPATIAL ASSOCIATIONS IDENTIFIED FROM NUMERICAL CLASSIFICATION (1978-1990) OF BENTHIC MACROALGAE SAMPLES COLLECTED IN AUGUST. SEABROOK OPERATIONAL REPORT, 1990.

GROUP	STA-TIONS	MEAN DEPTH (m)	YEARS INCLUDED	WITHIN/ BETWEEN GROUP SIMILARITY	DOMINANT TAXA	GROUP BIOMASS (g/m^2) PREOP[a] MEAN[b]	PREOP[a] CI[b]	1990 MEAN
Deep Intake								
(1)	B13	18.3	1978-1984; 1986-1990	.67/.53	*Phyllophora* spp.	68.85	23.77	118.82
					Ptilota serrata	11.54	3.96	9.09
					Phycodrys rubens	5.82	2.95	11.04
					Polysiphonia urceolata	2.87	3.35	0.06
					Scagelia corallina	2.86	2.83	0.70
Deep Discharge/ Farfield								
(2)	B04	18.9-21.0	1978-1984; 1986-1990	.68/.53	*Ptilota serrata*	64.00	18.27	42.39
					Phyllophora spp.	10.97	5.04	7.49
	B34		1979-1984; 1986-1990		*Corallina officinalis*	6.86	3.59	2.13
					Scagelia corallina	1.32	1.18	1.01
					Phycodrys rubens	1.01	0.40	1.27
Mid-depth Discharge/ Farfield								
(3)	B19	9.4-12.2	1978-1990	.69/.64	*Phyllophora* spp.	207.25	33.13	188.56
	B31		1978-1990		*Chondrus crispus*	56.81	30.00	16.13
	B16		1984		*Corallina officinalis*	54.48	21.19	52.80
					Phycodrys rubens	37.86	10.81	72.05
					Callophyllis cristata	11.42	3.49	5.04
					Ptilota serrata	11.09	3.82	11.28

(continued)

TABLE 3.3.2-2. (Continued)

GROUP	STA-TIONS	MEAN DEPTH (m)	YEARS INCLUDED	WITHIN/ BETWEEN GROUP SIMILARITY	DOMINANT TAXA	GROUP BIOMASS (g/m^2) PREOP[a] MEAN[b]	PREOP[a] CI[b]	1990 MEAN
Mid-depth Intake (4)	B16	9.4	1980-1983; 1986-1990	.80/.64	*Phyllophora* spp.	429.87	93.92	369.02
					Phycodrys rubens	203.80	72.19	215.46
					Chondrus crispus	61.16	33.55	17.60
					Cystoclonium purpureum	49.39	27.86	28.90
					Ceramium rubrum	37.08	23.41	2.21
					Callophyllis			
Shallow *cristata*	32.73	10.02	19.30					
Subtidal (5)	B17	4.6	1978-1990	.75/.55	*Chondrus crispus*	774.22	111.65	544.96
	B35		1982-1990		*Phyllophora* spp.	204.73	61.90	378.61
					Ceramium rubrum	69.29	20.72	51.79
					Cystoclonium purpureum	56.59	41.12	115.82
					Corallina officinalis	51.58	23.24	35.39
Intertidal (6)	B1MLW	MLW	1978-1990	.68/.33	*Chondrus crispus*	986.18	189.73	278.13
	B5MLW	MLW	1982-1990		*Mastocarpus stellatus*	215.23	108.66	517.71
					Corallina officinalis	51.25	31.30	14.13
					Ceramium rubrum	2.43	2.24	0.94

[a]Preop = preoperational, 1978-1989 period (Stations B1MLW, B17, B19, B31: 1978-1989; Stations B5MLW, B35: 1982-1989; Station B16: 1980-1984, 1986-1989; Stations B13, B04: 1978-1984, 1986-1989; B34: 1979-1984, 1986-1989)
[b]Geometric mean and 95% confidence interval

historical average. Areas sampled at 18.9-21 m depth, the deepest areas sampled in the study (Group 2), were characterized by a community where *Ptilota serrata* predominated, and *Phyllophora* spp. was less important than in shallower areas. Deep areas in 1990 had the same dominants as found historically, although average biomass was lower than previous years.

In order to monitor the algal community for new or infrequently occurring species that might bloom to "nuisance" levels, the occurrence of rare taxa was also examined. Thirty taxa out of a total of 128 occurred sparsely (less than 1.7% frequency) in the biomass collections from 1978 to 1989 (Appendix Table 3.3.2-1). Five of these taxa occurred in 1990 in low frequencies. Only one taxon appeared more frequently in 1990 than in previous years. *Bonnemaisonia hamifera*, a relatively uncommon taxon that was new to biomass collections in 1986, occurred in small amounts eight times in 1990 at three farfield stations (B5MLW, B35, B31). This species, typical of southern Massachusetts and Long Island (Taylor 1952), has been recorded in coastal New Hampshire and Great Bay (Mathieson and Hehre 1986). Its occurrence at offshore sites in this study beginning in 1986 may have been related to the naturally-increased water temperatures in the nearshore area (NAI 1987a; 1988a; 1989a, 1990a). As *B. hamifera*, which is not considered a nuisance organism, has occurred only at low levels, it does not pose a threat to the established algae community.

Kelps and Understory Species

To monitor larger macroinvertebrates and macroalgae that are not adequately represented in destructive samples, transect surveys were performed at shallow and mid-depth stations. Invertebrate results are discussed in Sections 3.3.3.4 and 3.3.5.7. Kelps are important habitat formers that are not collected in destructive samples. Spatial differences in adult kelp (>15cm) species abundance appear primarily attributable to depth differences. Historically, *Laminaria saccharina* was most

abundant at the shallow subtidal stations (Figure 3.3.2-6). *Laminaria digitata* and *Alaria esculenta* reached maximum abundance in the study area at farfield Station B31 (9.4 m below MLW), whereas *Agarum cribrosum*'s greatest abundance was at Station B19 (discharge, 12.2 m below MLW). Substantial spatial differences between mid-depth stations (B19 and B31), were found for some species; *L. digitata* and *Alaria esculenta* were more abundant (and outside the 95% confidence limits) at farfield Station B31, whereas *A. cribosum* was more abundant at the nearfield Station B19 (Figure 3.3.2-6).

Spatial trends observed in 1990 were similar to previous years (Figure 3.3.2-6). Mean numbers of *A. esculenta* and *A. cribrosum* in 1990 did not differ significantly from previous years at mid-depth stations (Table 3.3.2-3). Abundances of the two *Laminaria* species in 1990 showed differences from previous years. *L. digitata* had significantly lower abundances in 1990 (including May, August and November samples) at the nearfield shallow subtidal station (B17) and at the farfield mid-depth station (B31) when compared to previous years (Table 3.3.2-3). However, when the operational period (October) was compared to the same period in previous years, no significant differences were detected. Abundances were not significantly different at the other stations. *L. saccharina* abundances in all months of 1990 were significantly lower than the historical average at the shallow subtidal nearfield station (B17), although October abundances were similar to previous years. Remaining stations showed no change from previous years.

No consistent seasonal variation in abundance was observed for any species of kelp, probably because "juvenile" (<15 cm) plants were not enumerated; these plants are difficult to count accurately *in situ* because of their small size and high density (NAI 1984a, 1985b). Seasonal variation in biomass was reflected in growth studies conducted prior to 1985; growth closely followed the solar irradiance and nutrient cycles (NAI 1985b). Stand density, which is controlled by substrate availability, recruitment and environmental conditions (e.g. storm disruption), showed some variability among years. Kelps, particularly

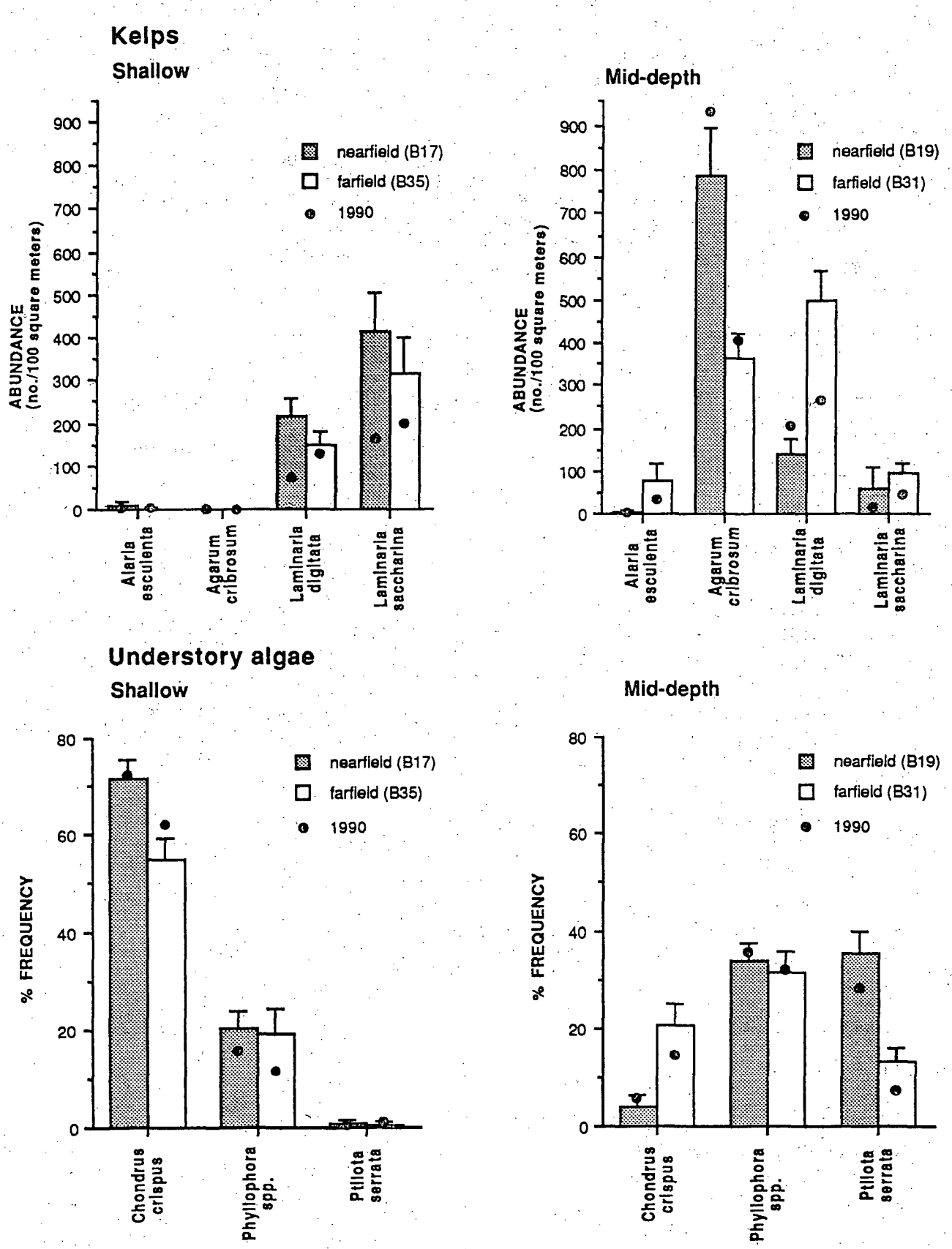


Figure 3.3.2-6. Preoperational means and 95% confidence limits of abundance of kelps (no./100 m^2), (B17: 1978-1989; B35: 1982-1989) and percent frequencies and 95% confidence limits of dominant understory algae (B17: 1981-1989; B35: 1982-1989) and 1990 means, collected triannually in the shallow and mid-depth subtidal zones. Seabrook Operational Report, 1990.

TABLE 3.3.2-3. RESULTS OF NONPARAMETRIC ONE-WAY ANOVA COMPARING NUMBERS OF FOUR KELP SPECIES AND PERCENT FREQUENCIES OF THREE UNDERSTORY ALGAE TAXA IN 1990 (OCTOBER ONLY AND ALL MONTHS) TO VALUES FROM 1981-1989. SEABROOK OPERATIONAL REPORT, 1990.

TAXON	STATION	df	Z	
			OCTOBER	ALL MONTHS
Alaria esculenta	19	1	-0.00 NS	-0.34 NS
	31	1	-0.67 NS	-0.34 NS
Agarum cribosum	19	1	0.67 NS	1.00 NS
	31	1	0.40 NS	0.45 NS
Laminaria digitata	17	1	-0.87 NS	-2.43*
	35	1	-0.19 NS	-0.48 NS
	19	1	0.40 NS	1.61 NS
	31	1	-1.47 NS	-2.37*
Laminaria saccharina	17	1	-1.45 NS	-1.95*
	35	1	-1.47 NS	-1.08 NS
	19	1	-1.35 NS	-1.45 NS
	31	1	0.13 NS	-1.61 NS
Chondrus crispus	17	1	-0.70 NS	0.07 NS
	19	1	1.36 NS	0.92 NS
			0.18 NS	0.95 NS
			-1.40 NS	-1.07 NS
Phyllophora sp.	17	1	-0.70 NS	-0.87 NS
	19	1	-0.97 NS	-1.08 NS
			-0.35 NS	0.14 NS
			0.35 NS	0.21 NS
Ptilota serrata	17	1	0.38 NS	0.43 NS
	19	1	0.00 NS	-0.10 NS
			-1.40 NS	-1.14 NS
			-1.40 NS	-1.04 NS

probability * = <.05

Laminaria species, are fast-growing, opportunistic plants. Consequently, they are among the "pioneer" species that colonize freshly exposed substrate, adding to the year-to-year variability in distribution.

Measurements of percent frequency of occurrence of the three understory algae that were dominant at transect sites (Figure 3.3.2-6), showed differences among depths that were similar to those observed from biomass collections (Figure 3.3.2-4). The understory community in the shallow zone historically has been dominated by *Chondrus crispus* with *Phyllophora* spp. a secondary dominant. A similar pattern occurred in 1990. Algal frequencies in October, 1990 (the only sampling period during plant operation) at the nearfield Station B17 were not significantly different from those observed historically (Table 3.3.2-3). Frequencies of *C. crispus* were lower at the farfield area (B35) in comparison to the nearfield (B17) but were similar for the other two taxa. The understory community at mid-depth stations differed among stations. *Phyllophora* spp. and *Ptilota serrata* predominated at the nearfield station (B19), whereas *C. crispus* was relatively rare. October frequencies in 1990 were not significantly different from previous years for any of the taxa (Table 3.3.2-3). The understory community at farfield Station B31 was predominated by *Phyllophora* spp., but *C. crispus* and *P. serrata* were also important constituents. Frequencies of *Phyllophora* spp. in 1990 were similar to previous years. *Ptilota serrata* continued to show fewer occurrences at Station B19 and B31 than in past years, a trend first observed in 1986 (NAI 1990b).

Intertidal Communities (Nondestructive Monitoring Program)

In situ counts of macroalgae in fixed quadrats at the intertidal stations (B1 and B5) were conducted at locations representing three tidal elevations between approximate MLW and MHW. The three quadrats were situated (from highest to lowest elevation) on bare ledge, fucoid-covered ledge, and *Chondrus*-covered ledge. These quadrats were set up to monitor fixed locations, thus eliminating small-scale spatial

variability and focusing on temporal variation. Appendix Table 3.3.2-2 shows the occurrence of the more commonly-occurring species.

The Bare Ledge Site, at the upper edge of the mid-tidal zone was characteristic of ledge not continuously covered by macroalgae. Although seasonally high in variability, barnacles have been common in this quadrat (see Section 3.3.3 for faunal coverage). Historically, during the spring the annual greens, *Urospora penicilliformis* and *Ulothrix flacca* (at both stations), and the red alga, *Bangia fuscopurpurea* (Station B5), were the most frequently occurring species (Appendix Table 3.3.2-2). *B. fuscopurpurea* has not been observed since 1986. Small, immature perennial *Fucus* spp. plants (mainly *F. vesiculosis* with some *F. distichas edentatus*) have also been found in this habitat in all seasons; although they occurred frequently, their percent cover was usually 23% or less. Until 1985, the bare rock quadrats were spatially similar. In the years since, the *Fucus* spp. percent cover dropped to less than one percent at Station B1 (accompanied by a decrease in *Balanus* sp.)(NAI 1988b). In contrast, increased amounts of *Fucus* spp. have appeared at Station B5 during the same time period, resulting in median values for the preoperational period that were >80%. During the spring and summer of 1990, *Fucus* spp. percent cover in the bare ledge site at Station B5 occurred in amounts greater than the historical median, but within the ranges established for each season. The more persistent annual red alga, *Porphyra* spp. continued to be unique to Station B1 during all seasons in frequencies similar to previous years.

The Fucoid Ledge Site, in the mid-tide zone, is situated in the area of maximum fucoid algae cover. The perennial, *Fucus* spp., has been the dominant taxon within the quadrats, although some *Ascophyllum nodosum* have been recorded at Station B5 (Appendix Table 3.3.2-2). These fucoids were quite persistent and occurred frequently, although relatively low (<40%) coverages have been occassionally recorded. The perennial red algae *Chondrus crispus* and *Mastocarpus stellatus* occurred

in the understory at both stations in low amounts (usually <10% frequency); the latter species was more persistent. Of the other algae occurring in these quadrats, only *Porphyra* sp. and *Spongomorpha* sp. were common (both at Station B1 only). With few exceptions, observations recorded during 1990 were similar to recent years and within established ranges.

Fixed line transects have also been surveyed in the mid-tide zone since 1983 to quantify the areal coverage of the fucoid algae. Historically in the fixed areas studied, *A. nodosum* has occurred more frequently at Station B5 than at B1. In 1990, the percent frequency of occurrence at both stations was slightly less than 1989 but within the confidence limits established for the preoperational period (Figure 3.3.2-7). *Fucus vesiculosus* was almost twice as frequent at nearfield Station B1 than at farfield Station B5. Frequencies recorded in 1989 (NAI 1990b) and 1990 for *F. vesiculosis* were similar and much lower than the historical mean. *F. distichus* var. *edentatus*, historically less frequent than the two other species, was also recorded at both stations in 1990. However, since 1989, the percent frequency of occurrence increased nearly twofold at nearfield Station B1 and decreased twofold at farfield Station B5 (NAI 1990b). The 1990 frequencies were outside the 95% confidence limits established for the preoperational period at both stations for the second consecutive year, suggesting that *F. distichus* may be replacing *F. vesiculosus* within the sample quadrat.

The *Chondrus* zone quadrat in the MLW (mean low water) zone is situated in the area of maximum red algae cover. *Chondrus crispus* and *Mastocarpus stellatus* dominated this zone; median percent frequencies exceeded 90% during preoperational period, with no differences noted between the two stations (Appendix Table 3.3.3-2). Spatial differences included the occurrence of understory taxa *Fucus* spp., which persisted only at B1, and *Corallina officinalis*, which was persistent only at B5. It is likely that small scale differences in topography between stations contributed to these differences in species distribution. The 1990

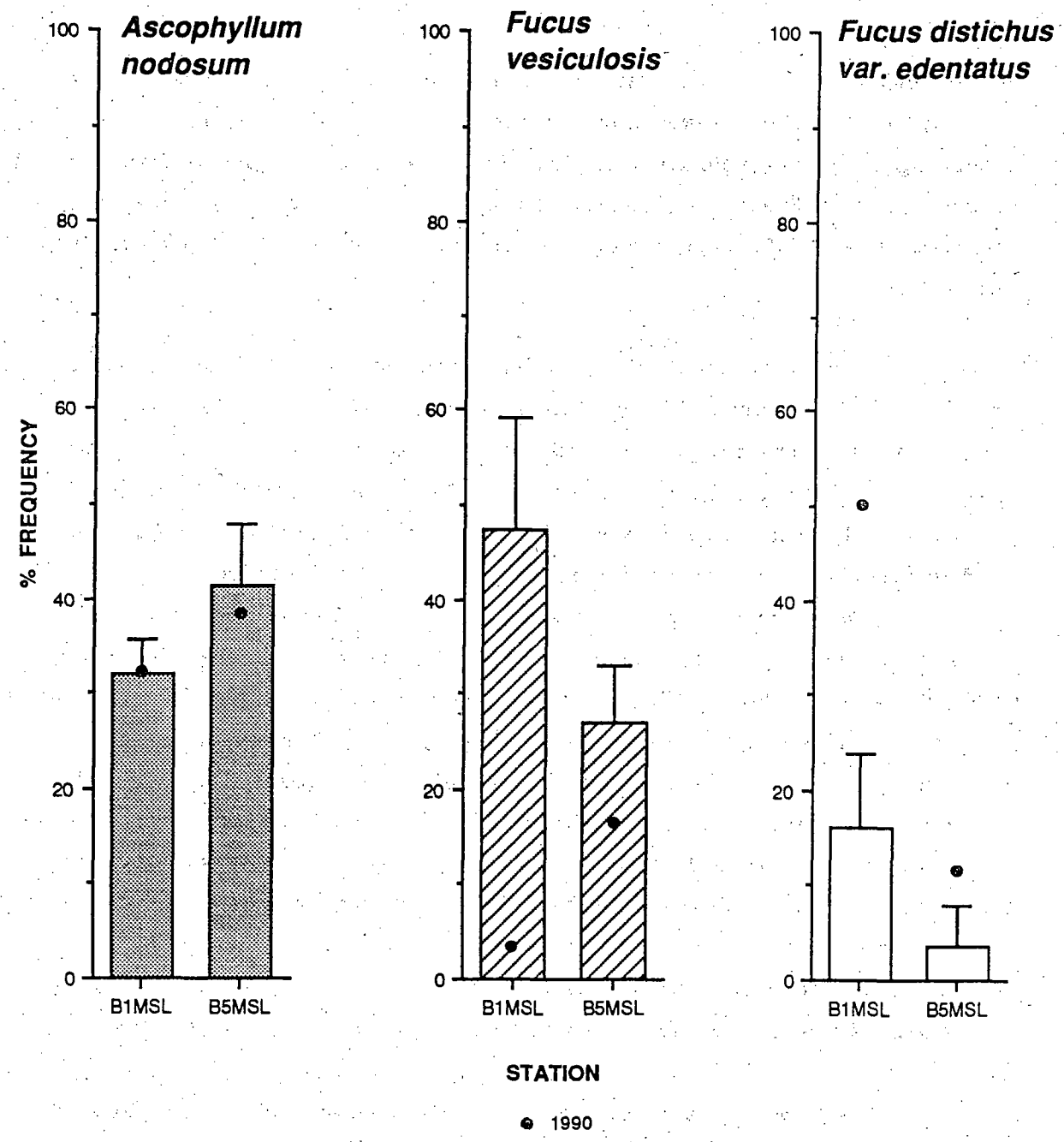


Figure 3.3.2-7. Mean percent frequency and 95% confidence limits of fucoid algae at two fixed transect sites in the mean sea level zone for the preoperational period (1983-1989) and mean percent frequency in 1990. Seabrook Operational Report, 1990.

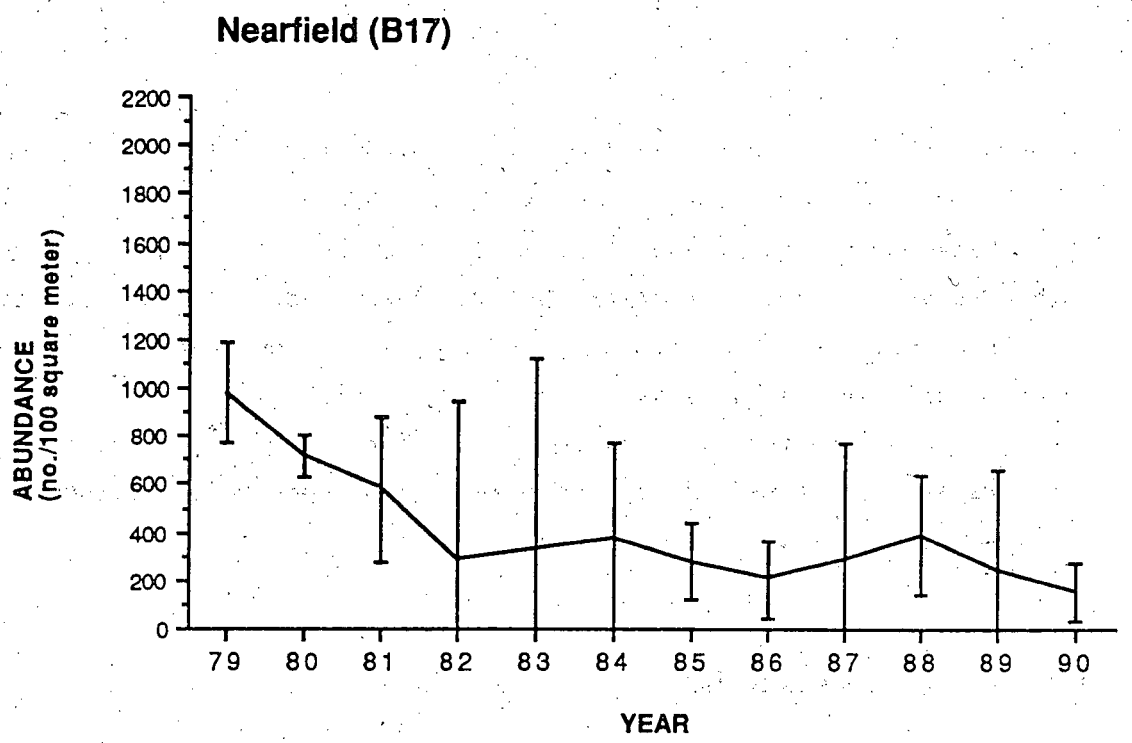
observations of perennial algal species showed frequencies similar to the most recent years with two exceptions: *Chondrus crispus* at Station B5 in December and *Corallina officinalis* at Station B5 in April were both observed in amounts greater than the ranges established historically. *Fucus* sp., which historically occurred throughout the year at B1, occurred only in July in 1990. Percent frequencies were lower than average, amounting to virtually no cover. The annual red algal genus *Porphyra* sp., which usually is observed in low frequencies in summer at Station B1, occurred well above the baseline range.

3.3.2.2 Selected Species

Laminaria saccharina

Laminaria saccharina has been one of two dominant canopy-forming kelps in the shallow subtidal zone (1 to 9 m deep) surrounding the Inner and Outer Sunk Rocks. Density varied greatly due to variability in the amount of substrate available for settlement combined with the contagious distribution of these plants. Numbers of *L. saccharina* have been affected by storm activities, particularly in 1979 and again in 1982 (NAI 1990b). Since that time, numbers of kelps have remained similar through 1989 (Figure 3.3.2-8).

In 1990, numbers of kelps at the nearfield shallow subtidal were significantly lower than previous years (Table 3.3.2-3, Figure 3.3.2-8). This difference, however, was not restricted to the operational period in 1990. Numbers of kelps were not significantly different in 1990 at the farfield shallow subtidal stations or either of the mid-depth stations.



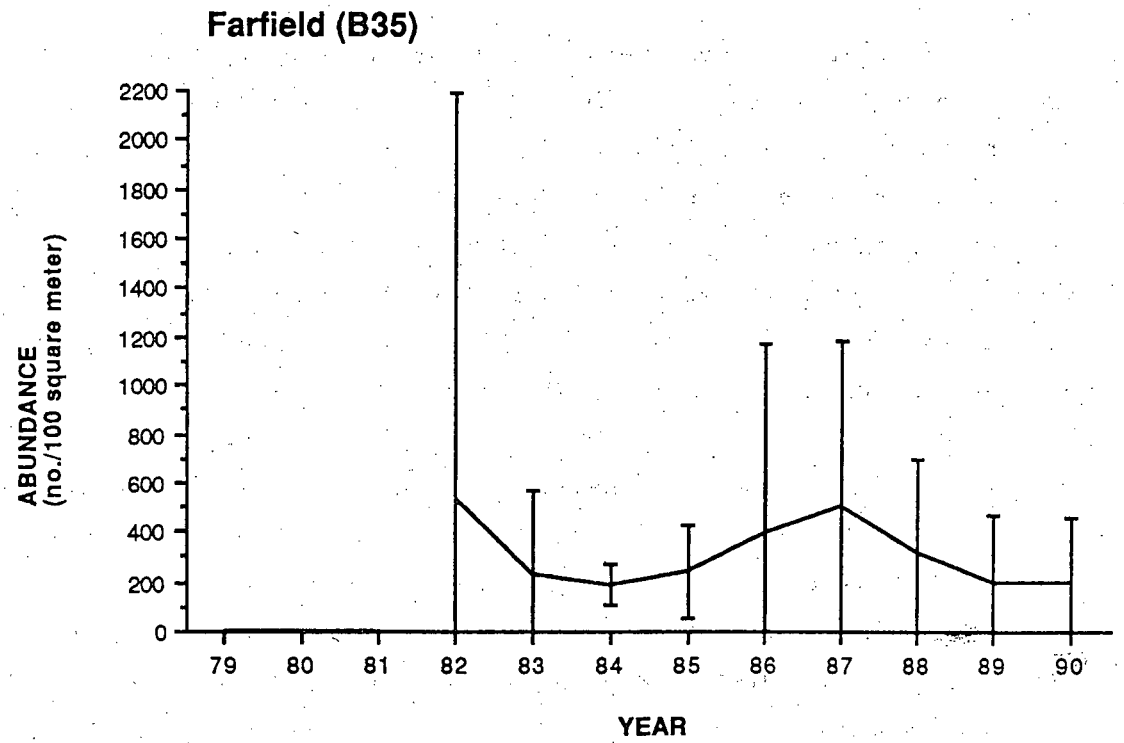


Figure 3.3.2-8. Annual mean abundance (no./100 m^2) and 95% confidence interval for *Laminaria saccharina* at Station B17 (1979-1990) and B35 (1982-1990). Seabrook Operational Report, 1990.

Chondrus crispus

Chondrus crispus (Irish moss), a red algae, is common to intertidal and shallow subtidal habitats from Nova Scotia to New Jersey (Taylor 1952). It was the dominant understory algal species in the lower intertidal and shallow subtidal zones near the Sunk Rocks (see Community Analysis section). *C. crispus* biomass was higher in the intertidal zone than in the subtidal zone, and annual differences were more pronounced there (Figure 3.3.2-9).

In 1990, intertidal biomass levels were significantly lower than previous years. However, this difference was not restricted to the operational period (indicated by the similarity of August/November results to results using all three sampling periods) nor was it unique to the nearfield station (indicated by a non-significant Station term in the ANOVA) (Table 3.3.2-4). Biomass levels were lower than the historical average at both intertidal stations, beginning in May at the nearfield station (Figure 3.3.2-10) and November 1989 at the farfield station (NAI 1990b). Typically this species does not exhibit a strong seasonal pattern in the intertidal zone.

Shallow subtidal *C. crispus* exhibited a trend of decreased abundance in May and August 1990 at the nearfield station (Figure 3.3.2-10). However, biomass during the operational period (August, November) and for the entire year was not significantly different from the same time period during previous years (Table 3.3.2-4).

3.3.3 Marine Macrofauna

3.3.3.1 Horizontal Ledge Communities (Destructive Monitoring Program)

General

Studies since 1978 of the macrofaunal invertebrates off Hampton Beach, New Hampshire have focused on the horizontal algae-

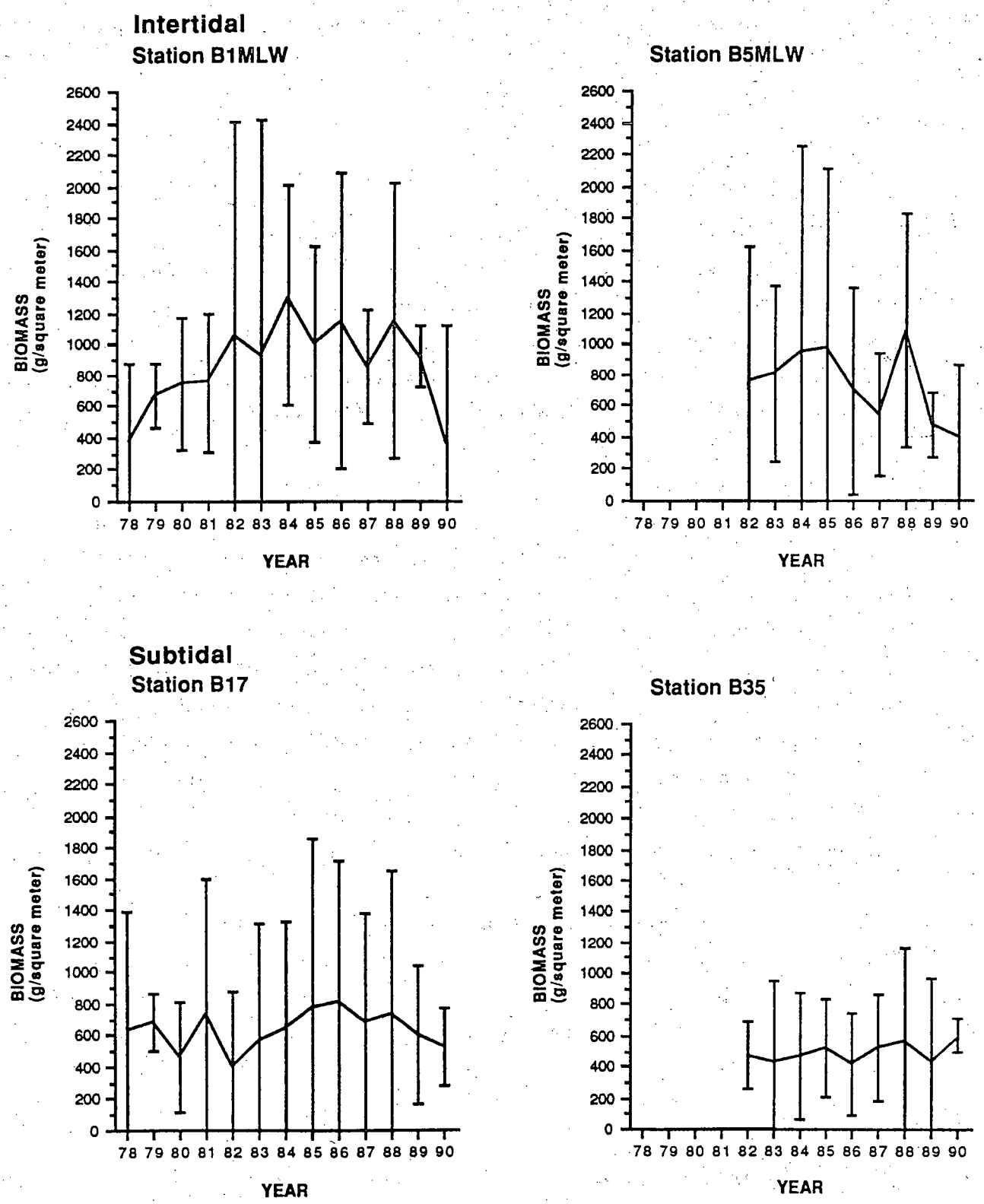


Figure 3.3.2-9. Annual mean biomass (g/m ^{2}) and 95% confidence intervals of *Chondrus crispus* collected in May, August and November at Stations B1MLW, B17: 1978-1990; B5MLW, B35: 1982-1990. Seabrook Operational Report, 1990.

TABLE 3.3.2-4. RESULTS OF ANALYSIS OF VARIANCE OF *CHONDRUS CRISPUS* BIOMASS (g/m^2) COMPARING COLLECTIONS IN 1990 AT INTERTIDAL AND SHALLOW SUBTIDAL STATION PAIRS WITH BIOMASS FROM 1978-89. SEABROOK OPERATIONAL REPORT, 1990.

PARAMETER	DEPTH ZONE	SOURCE OF VARIATION	df	SS	F[e]
Chondrus crispus	Intertidal Aug., Nov.	Preop-Op[a]	1	665.87	11.89***
		Station[b]	1	48.33	0.86 NS
		Year (Preop-Op)[c]	11	4,138.15	6.72***
		Station X Preop-Op[d]	1	209.85	3.75 NS
		Error	185	10,359.77	
	Intertidal All months	Preop-Op	1	1,980.17	38.19***
		Station	1	60.33	1.16 NS
		Year (Preop-Op)	11	4,602.99	8.07***
		Station X Preop-Op	1	360.19	6.95**
		Error	275	14,258.39	
	Shallow subtidal Aug., Nov.	Preop-Op	1	3.94	0.08 NS
		Station	1	171.90	3.49 NS
		Year (Preop-Op)	11	605.14	1.12 NS
		Station X Preop-Op	1	82.74	1.68 NS
		Error	185	9,100.83	
	Shallow subtidal All months	Preop-Op	1	1.75	0.04 NS
		Station	1	69.34	1.46 NS
		Year (Preop-Op)	11	612.07	1.17 NS
		Station X Preop-Op	1	153.18	3.22 NS
		Error	275	13,063.18	

[a]Preop-Op = 1990 vs. all previous years, regardless of station
[b]Station pairs within a depth zone: intertidal = B1I, B5I; shallow subtidal = B17, B35, regardless of year or period
[c]Year nested within preoperational and operational periods regardless of area
[d]Interaction of main effects
[e]NS = Not significant ($p>0.05$)
* = Significant ($0.05 \geq p > 0.01$)
** = Highly significant ($0.01 \geq p > 0.001$)
*** = Very highly significant ($p \leq .001$)

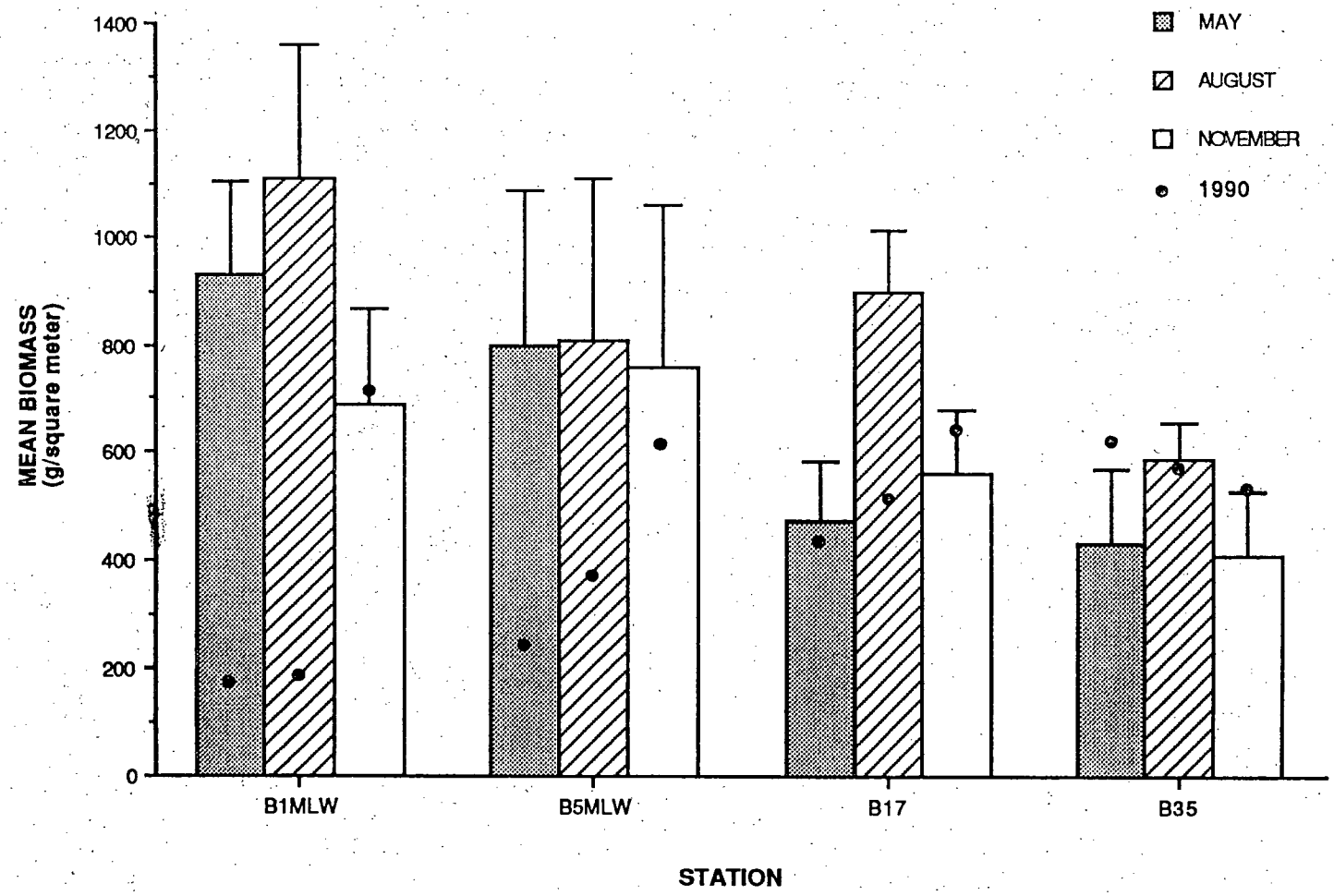


Figure 3.3.2-10. Mean biomass (g/m^2) and 95% confidence limits of *Chondrus crispus* at selected stations in May, August and November. Stations B1MLW, B17: 1978-1989 and 1990; Stations B5MLW, B35: 1982-1989 and 1990. Seabrook Operational Report, 1990.

covered rock/ledge habitat in near- and farfield areas in four depth zones. Macrofaunal studies include a community analysis of intertidal and subtidal habitats, as well as a detailed examination of populations of selected species (see Section 3.3.5 also), and an investigation of the near-surface (see Section 3.3.4) and bottom fouling community.

Numbers of Taxa and Total Density

Numbers of taxa and total density (number of noncolonial macrofauna/m^2) have been used to monitor spatial and annual trends in the macrofaunal community. These parameters have been measured in August beginning in 1978, and have shown broadscale changes in relation to depth. The number of taxa generally increased from intertidal through mid-depth stations, and declined slightly at the deep stations (Figure 3.3.3-1). The number of taxa ranged from 49 at intertidal Station B1MLW to 70 at mid-depth Station B16 during the baseline period, and no new taxa were collected in 1990. Total density showed a general decrease with increasing depth (Figure 3.3.3-1), mainly due to decreases in Mytilidae (primarily *Mytilus edulis*)(see Section 3.3.5).

In the intertidal area, the habitat at nearfield Station B1MLW was about 90% algae covered ledge and 10% mussel (mytilid) beds. Farfield Station B5MLW was similar, except for the presence of boulders (Table 2.1-2), and it was more protected. The predominant alga was *Chondrus crispus* (Irish moss)(Figure 3.3.2-4). The number of taxa in 1990 at both intertidal stations was just slightly lower than the baseline averages, thus the interaction term of the ANOVA model was not significant (Table 3.3.3-1). The baseline mean number of taxa at both stations was very similar (48.9 and 48.3; Figure 3.3.3-1). Although the 1990 mean number of taxa at each station was slightly lower than its corresponding baseline mean, each was well within the range of the preoperational period (Figure 3.3.3-2). The 1990 densities at both stations were above the baseline average at each intertidal station, and approached the all time high density set in 1986 (Figures 3.3.3-1,3).

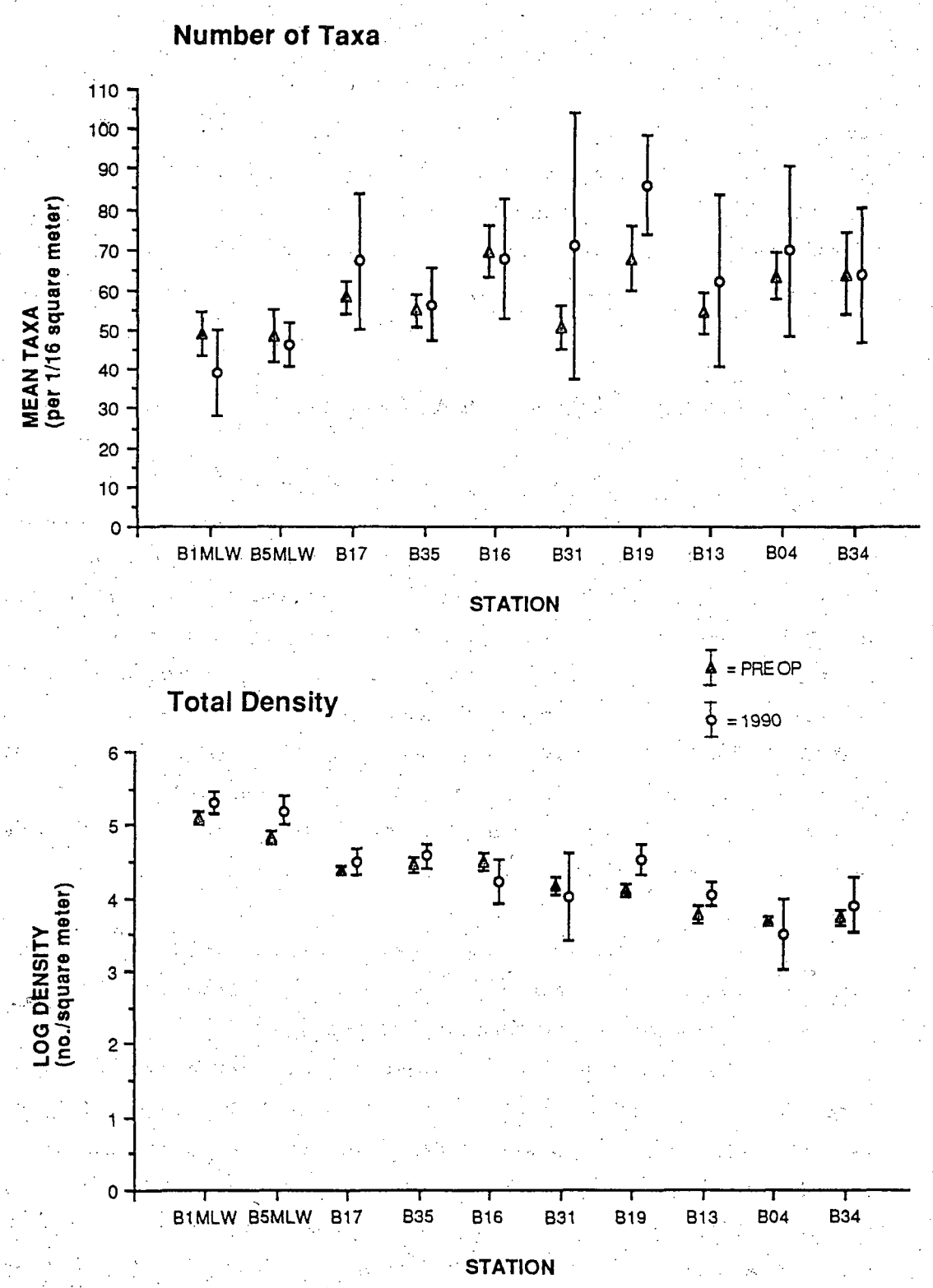


Figure 3.3.3-1. Mean number of taxa (per 1/16 m^2) and log (x+1) mean density (no./m^2) and 95% confidence limits of macrofauna collected in August during the preoperational period (1978-1989) and in 1990 at intertidal and subtidal benthic stations. Seabrook Operational Report, 1990.

TABLE 3.3.3-1. RESULTS OF ANALYSIS OF VARIANCE OF NUMBER OF TAXA (per 1/16 m^2) AND TOTAL DENSITY (per m^2) OF MACROFAUNA COLLECTED IN AUGUST AT INTERTIDAL, SHALLOW SUBTIDAL, AND DEEP STATION GROUPS, 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

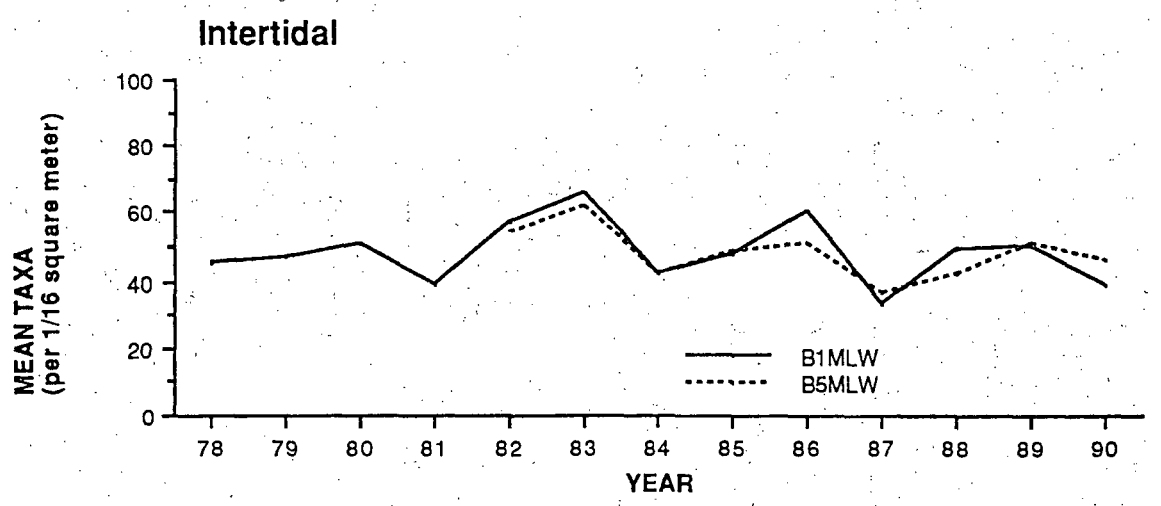
PARAMETER	STATION PAIRS	CLASS VARIABLE	df	SS	F[a]
Number of Taxa	B1I, B5I	Preop-Op[b]	1	221.8	2.86 NS
		Station[c]	1	46.3	0.60 NS
		Year (Preop-Op)	11	6,371.2	7.47***
		Station X Preop-Op[d]	1	196.1	2.53 NS
		Error	91	7,059.5	
	B17, B35	Preop-Op[b]	1	205.3	2.38 NS
		Station[c]	1	393.9	4.56*
		Year (Preop-Op)	11	2,445.5	2.58**
		Station X Preop-Op[d]	1	150.3	1.74 NS
		Error	91	7,852.5	
	B19, B31, B16	Preop-Op[b]	1	2,023.1	15.40***
		Station[c]	2	2,378.8	9.05***
		Year (Preop-Op)	11	8,889.4	6.15***
		Station X Preop-Op[d]	2	1,375.3	5.23**
		Error	158	20,755.1	
	B04, B34, B13	Preop-Op[b]	1	340.5	2.40 NS
		Station[c]	2	637.9	2.25 NS
		Year (Preop-Op)	10	10,678.0	7.53***
		Station X Preop-Op[d]	2	128.9	0.45 NS
		Error	159	22,535.5	

(continued)

TABLE 3.3.3-1. (Continued)

PARAMETER	STATION PAIRS	CLASS VARIABLE	df	SS	F[a]
Total Density	B1I, B5I	Preop-Op[b]	1	0.7	11.25**
		Station[c]	1	0.3	4.44*
		Year (Preop-Op)	11	4.7	6.69***
		Station X Preop-Op[d]	1	0.04	0.62 NS
		Error	91	5.8	
	B17, B35	Preop-Op[b]	1	0.1	2.61 NS
		Station[c]	1	0.1	1.15 NS
		Year (Preop-Op)	11	3.1	5.31***
		Station X Preop-Op[d]	1	0.001	0.02 NS
		Error	91	4.9	
	B19, B31, B16	Preop-Op[b]	1	0.002	0.02 NS
		Station[c]	2	0.7	3.21*
		Year (Preop-Op)	11	9.3	8.02***
		Station X Preop-Op[d]	2	1.2	5.77**
		Error	158	16.7	
	B04, B34, B13	Preop-Op[b]	1	0.1	1.48 NS
		Station[c]	2	1.0	5.25**
		Year (Preop-Op)	10	8.7	9.00***
		Station X Preop-Op[d]	2	0.6	3.01*
		Error	159	15.3	

[a]NS = Not significant ($p>0.05$)
* = Significant ($0.05 \geq p > 0.01$)
** = Highly significant ($0.01 \geq p > .001$)
*** = Very highly significant ($p \leq .001$)
[b]preoperational (through 1989) versus operational (1990) period, regardless of station
[c]nearfield = Stations B1I, B17, B19, B16, B04, B13; farfield = Stations B5I, B35, B31, B34, regardless of year/period
[d]interaction between main effects



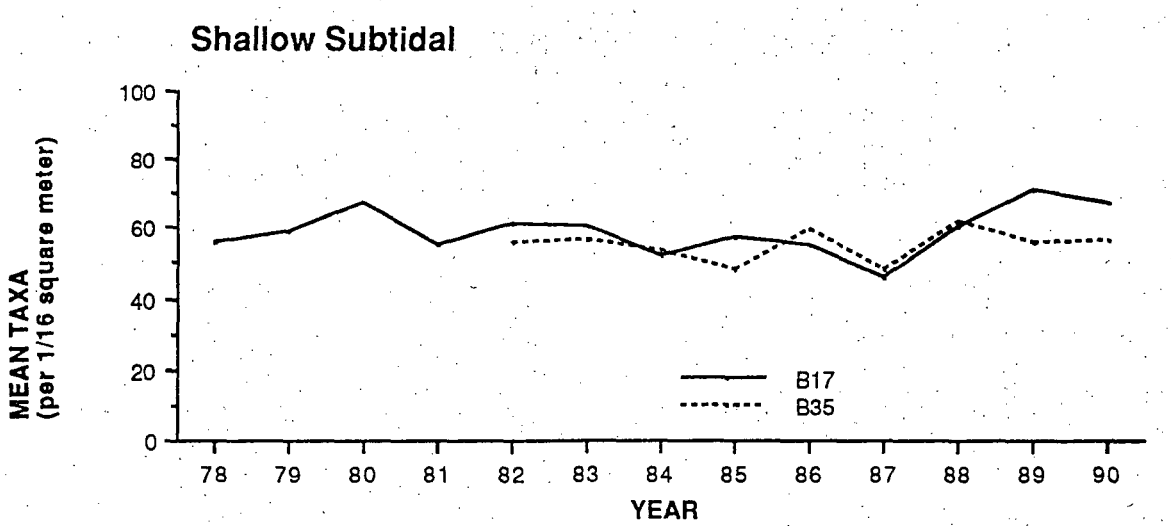
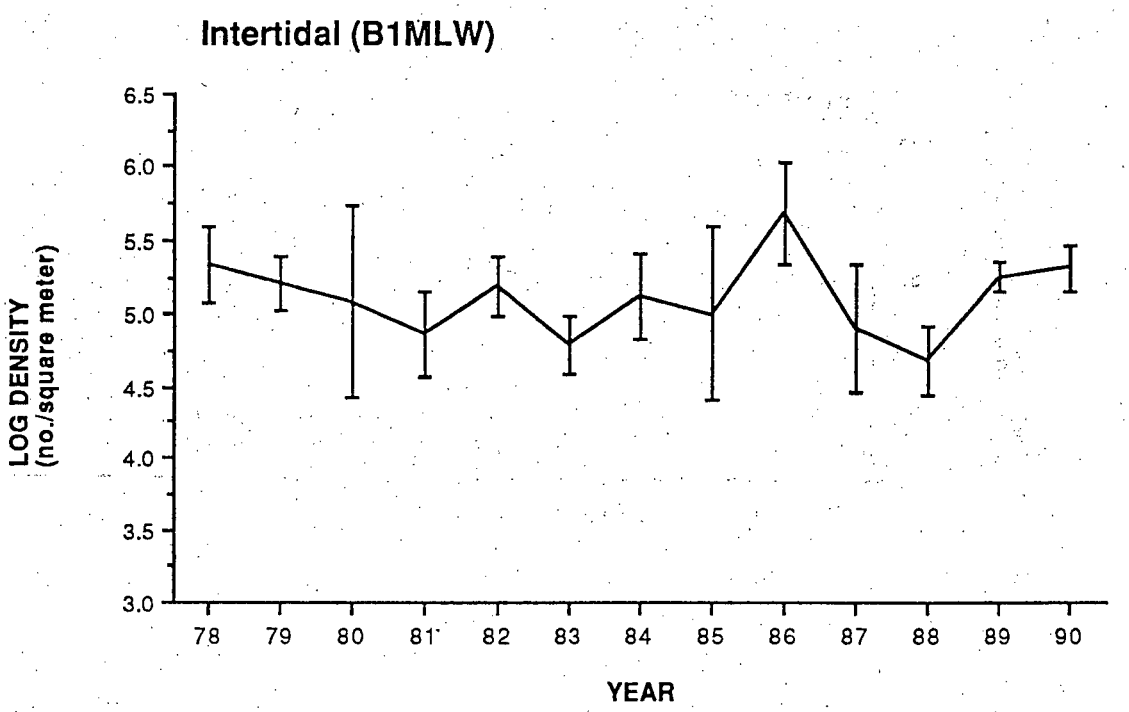


Figure 3.3.3-2. Annual mean number of noncolonial macrofaunal taxa (per 1/16 m^2) collected in August at intertidal Stations B1MLW and B5MLW and shallow subtidal Stations B17 and B35 from 1978-1990. Seabrook Operational Report, 1990.



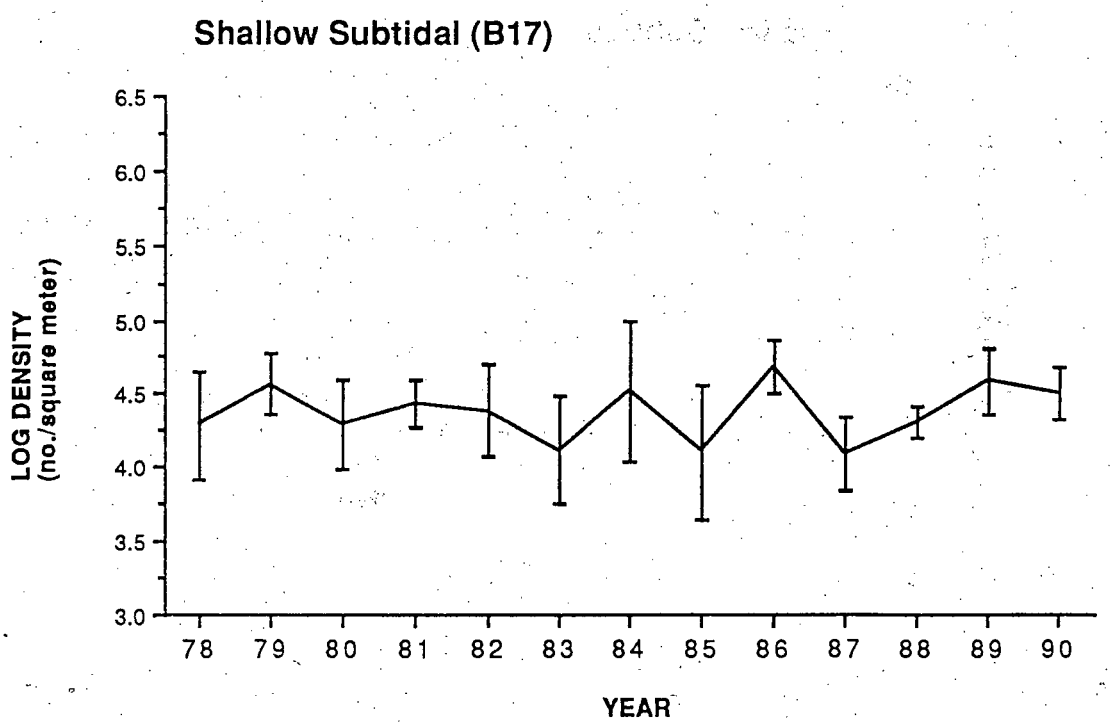


Figure 3.3.3-3. Annual means and 95% confidence limits for the log (x+1) density (no./m2) of macrofauna collected in August at nearfield Stations B1MLW (intertidal) and B17 (shallow subtidal) from 1978-1990. Seabrook Operational Report, 1990.

However, the interaction term was not significant, since both near- and farfield stations had above average densities in 1990 (Table 3.3.3-1).

In the shallow subtidal area (5 m), the habitat at nearfield Station B17 was about 95% algae covered ledge and 5% crustose algae-covered ledge. Farfield Station B35 was 85% algae covered ledge and 15% boulders. *Laminaria saccharina* is a canopy-forming kelp occurring at Stations 17 and 35 (Section 3.3.2.2). The understory during the preoperational period was dominated primarily by *Chondrus*, with about 10-20% *Phyllophora* spp. (Figure 3.3.2-4). The preoperational mean number of taxa at both stations was higher than their intertidal counterparts (Figure 3.3.3-1). Although the 1990 mean number of taxa at each station was higher than the preoperational mean (Figures 3.3.3-1,3), the interaction between the near- and farfield stations was not significant (Table 3.3.3-1). Shallow subtidal total density at both stations was lower than intertidal stations, but higher than all the deeper stations except for Station B16, the mid-depth station at the intake (Figure 3.3.3-1). The 1990 annual mean density at each station was slightly higher, but within the 95% confidence limits of the preoperational mean, and there was no significant interaction between the near- and farfield stations (Figure 3.3.3-1, Table 3.3.3-1).

In the mid-depth area (9-12 m), the habitat at nearfield Station B19 (discharge) included algae-covered ledge and boulders and horse mussel beds (40%), and its farfield counterpart, B31, had 60% horse mussel beds, algae covered rocks and about 10% cobble. The nearfield Station B16 (intake) had more similar substrate to the nearfield shallow subtidal station, and was primarily algae-covered ledge with mussel beds (25%) and lacked boulders or cobbles. The algae at all three mid-depth stations was composed of more species than the shallower stations, but generally was about 50% *Phyllophora* spp. (Figure 3.3.2-4). Significant differences in the number of taxa at the three mid-depth stations occurred between 1990 and the baseline period (Table 3.3.3-1). At both the discharge station (B19) and its farfield counterpart (B31), the number of taxa in 1990 showed a large increase (about 20

taxa) over the baseline period, while at intake Station B16 the 1990 and preoperational means were nearly the same (Figure 3.3.3-1), thus the interaction among the three stations was signficant (Table 3.3.3-1). In the 1990 operational period, the number of taxa was at its all time high at B31, and at B19 it was exceeded only in 1989 (Figure 3.3.3-4). At the intake, B16, the 1990 mean number of taxa was just slightly lower than the preoperational mean, but well within the 95% confidence limits. The total densities at all three mid-depth stations were intermediate between the intertidal and deep areas (Figure 3.3.3-1). The 1990 density was higher than the baseline averages at Station B19 (discharge station), but lower at Stations B31 and B16 (intake), and the interaction term was significant (Table 3.3.3-1, Figure 3.3.3-1). In 1990, the total density at each station had relatively wide confidence limits (Figure 3.3.3-1) and was higher than the 95% confidence limits of the preoperational mean at Station B19, and lower at Stations B16 and B31. Yet, mean density at each of the three stations was within the range observed during the study period (Figure 3.3.3-5). At Station B19, the mean density was exceeded only by the density values recorded in 1986.

In the deepest area (18-21 m), horse mussel beds comprised over 50% of the substrate at all three stations; algae-covered ledge was generally the next most frequent substrate. Boulders (40%) were present at B34 (farfield) and cobbles (5%) were present at B13 (intake). The discharge (B04) lacked both boulders and cobbles (Table 2.1-3). Algae at Station B13 were predominantly *Phyllophora* spp. (like the mid-depth stations), but at B04 and B34 *Ptilota serrata* was the numerical dominant (Figure 3.3.2-4). The 1990 mean number of taxa at farfield Station B34 was nearly the same as the baseline period, and at B04 and B13, the 1990 means were somewhat higher (Figure 3.3.3-1). The 1990 means were within the range of the preoperational period at all stations (Figure 3.3.3-4), and the interaction among the three stations was not significant (Table 3.3.3-1). In 1990, the means for total density were high (above the upper confidence limit of the preoperational mean) at Stations B13 (intake) and B34 (farfield), and just below the preoperational confidence limit at B04 (nearfield)(Figure 3.3.3-1). Thus, the interaction

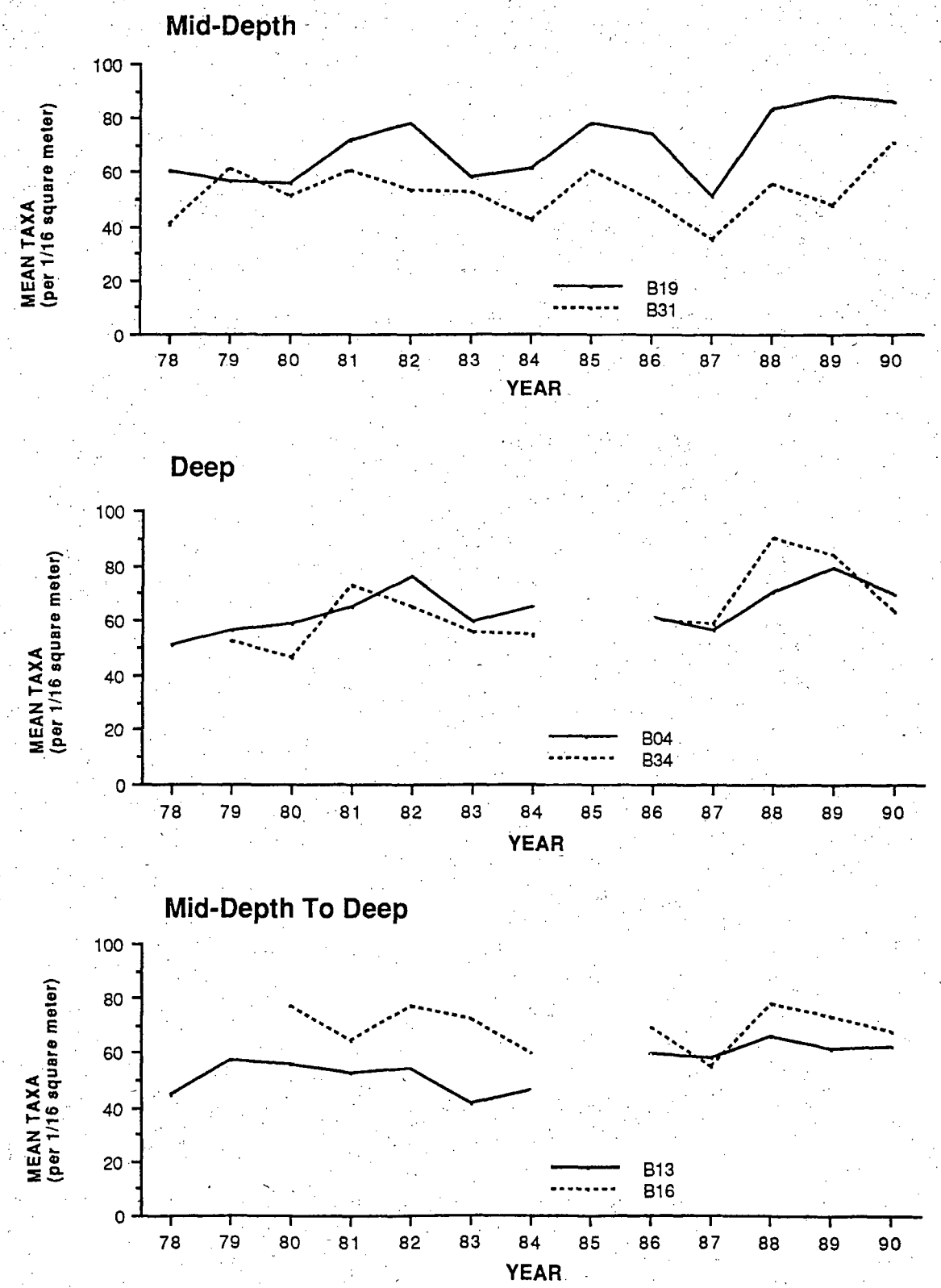


Figure 3.3.3-4. Annual mean number of noncolonial macrofaunal taxa (per 1/16 m^2) collected in August at mid-depth Stations B16, B19, and B31 and deep Stations B04, B13 and B34 from 1978-1990. Seabrook Operational Report, 1990.

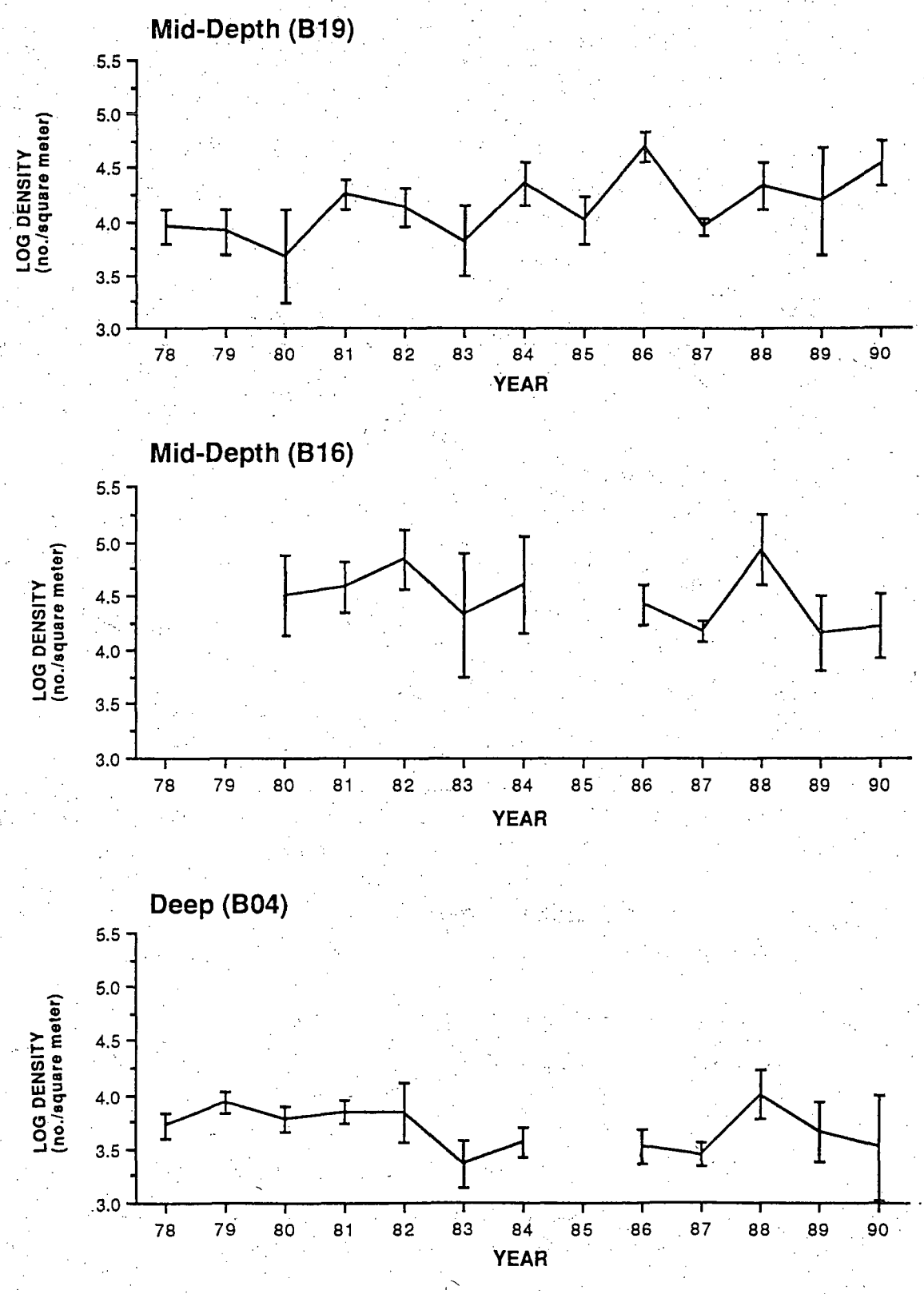


Figure 3.3.3-5. Annual means and 95% confidence limits for the log (x+1) density (no./m^2) of macrofauna collected in August at nearfield Stations B19 and B16 (mid-depth) and B04 (deep) from 1978-1990. Seabrook Operational Report, 1990.

among the three stations was significant (Table 3.3.3-1). Yet, 1990 mean densities at all stations were within the range of the baseline period (Figure 3.3.3-5).

Community Structure

The noncolonial, macrofaunal, hard-bottom community structure at all near- and farfield stations has historically shown changes related to depth (NAI 1990b). Intertidal (B1MLW, B5MLW), shallow subtidal (B17, B35), mid-depth (B16, B19, B31), and deep (B04, B13, B34) areas were distinct in both species distributions and abundances. In most cases, based on the similarity in species composition, the 1990 collections were placed in the group with the majority of preoperational collections from the same station (Table 3.3.3-2, Figure 3.3.3-6)). The intertidal, shallow subtidal, and mid-depth assemblages showed little year-to-year variation in their community structure. Benthic assemblages were less stable at deep stations, as evidenced by shifts in group assignment by the cluster analysis.

Differences in community structure among stations were indicated by differences in densities of dominant taxa as well as species composition. The cluster analysis used 89 species occurring in 6% or more of the samples. Very rare species, occurring in less than 6% (36 out of 562) of the samples, were not included. The most abundant taxon, Mytilidae spat, was ubiquitous, and contributed little to the discrimination among stations. Less-abundant species, such as peracarids *Calliopius laeviusculus, Jassa marmorata* (formerly *J. falcata*), *Jaera marina*, and gastropod *Lacuna vincta,* accounted for the majority of the among-station variability.

The intertidal habitat (Group 6) was the most distinct (between group similarity of only 0.436) of all areas because of the overwhelming predominance of Mytilidae spat (69,205/m^2 preoperationally) and the presence of species such as *Nucella lapillus*, *Turtonia minuta,*

TABLE 3.3.3-2. STATION GROUPS FORMED BY CLUSTER ANALYSIS[a] WITH PREOPERATIONAL AND OPERATIONAL (1990) GEOMETRIC MEAN DENSITY ± 95% CI FOR ABUNDANT MACROFAUNAL TAXA (NON-COLONIAL) COLLECTED ANNUALLY IN AUGUST FROM 1978 THROUGH 1990. SEABROOK OPERATIONAL REPORT, 1991.

GROUP NO./ NAME SIMILARITY[b]	STATIONS (YEARS)	DOMINANT TAXA	PREOPERATIONAL LOWER	PREOPERATIONAL MEAN	PREOPERATIONAL UPPER	N	1990 LOWER	1990 MEAN	1990 UPPER	N
1 Misc. .663/.609	B19 (1978) B31 (1978) B34 (1980)	Pontogeneia inermis	9	734	54501	3		-		0
		Mytilidae	5	359	21183			-		
		Caprella septentrionalis	98	228	532			-		
		Hiatella sp.	4	217	8628			-		
		Lacuna vincta	23	209	1824			-		
		Anomia sp.	37	187	928			-		
		Asteriidae	65	181	500			-		
2 Historical Deep .650/.630	B04 (1978-84, 86-87) B13 (1978-84) B34 (1979, 81-84, 87)	Pontogeneia inermis	233	332	474	22		-		0
		Asteriidae	177	253	362			-		
		Anomia sp.	124	202	326			-		
		Tonicella rubra	150	174	203			-		
		Caprella septentrionalis	97	153	242			-		
		Mytilidae	63	116	213			-		
3 Recent Deep .733/.680	B04 (1988-90) B13 (1986-90) B31 (1989) B34 (1986, 88-90)	Balanus crenatus	940	3191	10834	13	0	747	4017783	3
		Mytilidae	494	1211	2966		3	281	21310	
		Hiatella sp.	392	823	1726		386	505	660	
		Anomia sp.	386	709	1301		505	936	1734	
		Pontogeneia inermis	137	293	627		7	177	4196	
		Asteriidae	144	220	337		86	330	1253	
		Achelia spinosa	122	217	386		13	86	521	
4 Mid-depth .695-.680	B16 (1980-81, 83-84, 86-90) B17 (1990) B19 (1979-1990) B31 (1979-88, 90)	Mytilidae	3474	5966	10245	33	3190	8165	20896	4
		Pontogeneia inermis	1121	1696	2565		601	1688	4737	
		Caprella septentrionalis	748	1114	1659		470	1351	3879	
		Anomia sp.	544	789	1143		511	1359	3616	
		Hiatella sp.	447	678	1027		236	690	2013	
		Lacuna vincta	306	427	597		53	816	12358	
		Asteriidae	183	268	391		85	839	8227	

(continued)

TABLE 3.3.3-2. (Continued)

GROUP NO./ NAME SIMILARITY[b]	STATION (YEARS)	DOMINANT[c] TAXA	PREOPERATIONAL LOWER	PREOPERATIONAL MEAN	PREOPERATIONAL UPPER	N	1990 LOWER	1990 MEAN	1990 UPPER	N
5										
Shallow	B16 (1982)	Mytilidae	3128	5112	8353	21		6701		1
subtidal	B17 (1978-89)	Lacuna vincta	3512	5052	7268			12851		
.745/.574	B35 (1982-90)	Idotea phosphorea	1679	2125	2690			2221		
		Pontogeneia inermis	1320	1987	2991			931		
		Jassa marmorata	1150	1632	2316			755		
		Caprella septentrionalis	509	797	1247			413		
		Idotea balthica	324	689	1463			4461		
		Asteriidae	392	599	914			6449		
6										2
Intertidal	B1MLW (1978-90)	Mytilidae	47977	69205	99824	20		148998		
.693/.436	B5MLW (1982-90)	Jaera marina	2116	3626	6216			1930		
		Lacuna vincta	2035	3209	5060			2774		
		Turtonia minuta	1367	2707	5360			6236		
		Hiatella sp.	1464	2604	4631			1513		
		Nucella lapillus	925	1501	2432			5304		
		Gammarellus angulosus	181	572	1803			43		
		Gammarus oceanicus	241	564	1318			1237		
		Anomia sp.	373	493	650			1107		

[a]Bray Curtis similarity coefficient (Clifford and Stephenson 1975) with group average agglomeration for the clustering method (Sneath and Sokal 1973)
[b]within/between group similarity

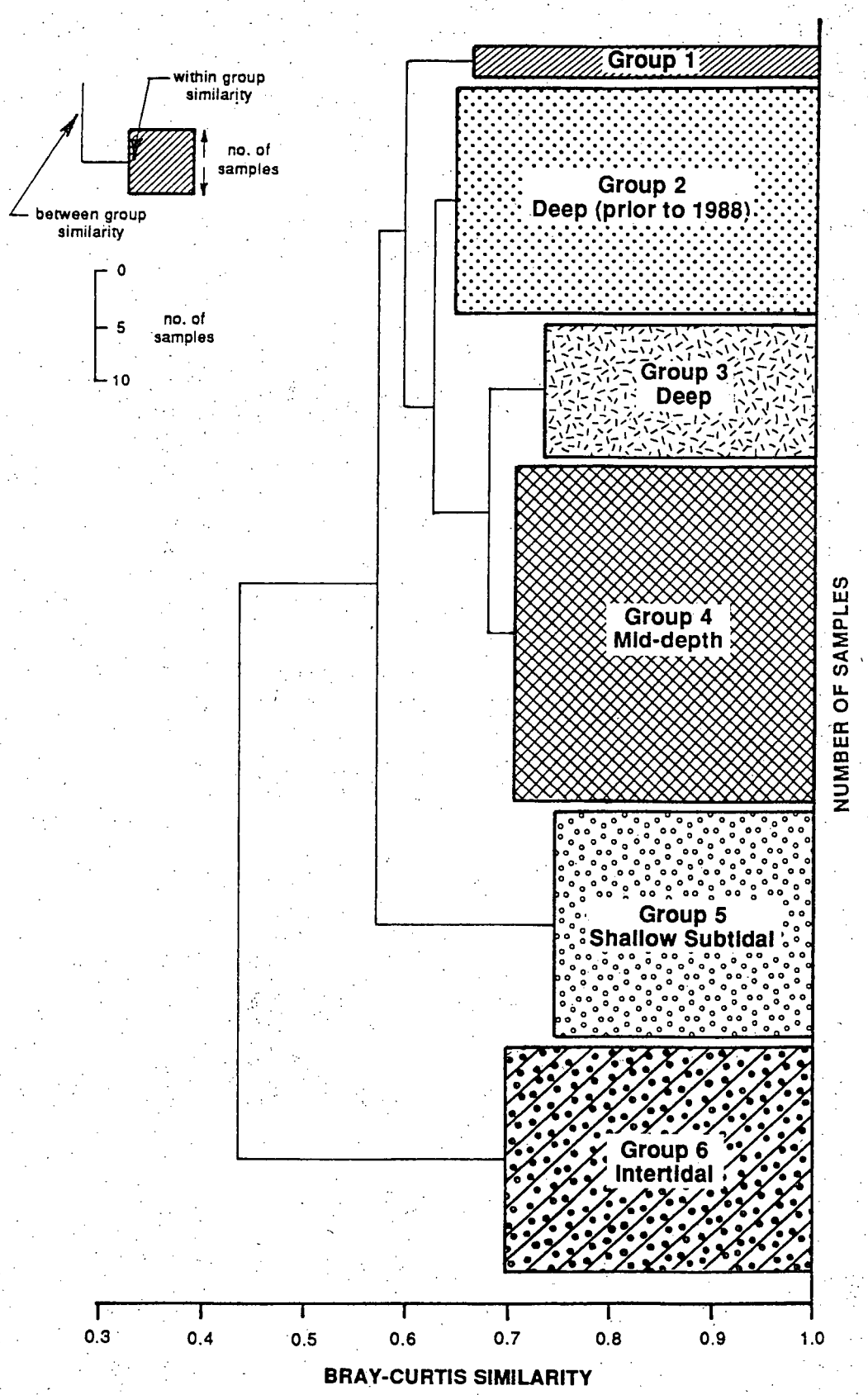


Figure 3.3.3-6. Dendrogram of normal classification of annual macrofaunal log (x+1) densities (no./m^2) taken in August at all nearfield and farfield stations from 1978-1990. Seabrook Operational Report, 1990.

Jaera marina, and *Hyale nilssoni* (less common) that are restricted to or most abundant in the intertidal zone (Table 3.3.3-2). Other dominants included the molluscs *Hiatella* sp. spat, and *Lacuna vincta,* and the amphipod *Gammarellus angulosus.* Intertidal collections made in 1990 were placed in this group based on similar species composition and abundance. In 1990, densities of mytilid spat, *Turtonia minuta, Nucella lapillus, Gammarus oceanicus*, and *Anomia* sp. were more than double the preoperational means (Table 3.3.3-2).

The shallow subtidal habitat (Group 5) has included Stations B17 and B35 in most years and Station B16 (mid-depth, intake) in 1982 (Table 3.3.3-2). Mytilidae was still the predominant taxon, although an order of magnitude less abundant than in the intertidal area. Aside from the herbivorous gastropod, *Lacuna vincta,* and juvenile Asteriidae, dominants were peracarid crustaceans such as *Pontogeneia inermis, Caprella septentrionalis, Idotea phosphorea, I. balthica*, and *Jassa marmorata* (formerly *J. falcata*) (Table 3.3.3-2). Relatively high densities of the latter three species, along with *Calliopius laeviusculus* distinguished the shallow subtidal area from other areas. Stations B17 and B35 were placed in this group every year, except in 1990 when B17 was more similar to the mid-depth habitat (Group 4). In 1990, the number of juvenile Asteriidae at Station B35 increased by an order of magnitude over the preoperational mean, and likewise numbers of *I. balthica* and *L. vincta* were very high.

Group 4 (the mid-depth stations) was usually characterized by a predominance of Mytilidae spat, and other molluscs (*Hiatella* sp., *Anomia* sp. and *Lacuna vincta*) and amphipods (*Pontogeneia inermis* and *Caprella septentrionalis*) that occurred in high numbers (Table 3.3.3-2). In most years, Stations B31, B19 (discharge) and B16 were characterized by this assemblage. The 1990 collections at all three stations were similar to previous years, and thus placed in the same group. The shallow subtidal Station B17 also was placed in Group 4 in 1990, due to

an abundance of mytilid spat and *Anomia* sp., as well as an increase in *Balanus crenatus* in 1990.

Stations with depths greater than 15 m had lower densities of macrofauna (Figure 3.3.3-1), and formed several loosely-associated deep station groups (Groups 1, 2 and 3). All differed from shallower stations in the decreasing influence of molluscs, particularly the lack of Mytilidae spat, and the increased importance of crustaceans and other taxa. These characteristics also occasionally occurred at mid-depth areas (9-14 m), leading to their appearance in the typically deep station groups. The majority of collections at deep stations (B04, B34, B13) were placed in two groups: Group 2 (prior to 1988) and Group 3. In 1990 and recent years, deep stations in Group 3 were characterized by the high abundance of the barnacle, *Balanus crenatus*, and by molluscs such as mytilids, *Anomia* sp., and *Hiatella* sp. Most samples from deep stations prior to 1988 (Group 2) lacked an abundance of barnacles, and were characterized by low numbers of the molluscs *Anomia* sp., *Tonicella rubra* (red northern chiton) and mytilids. Asteriidae were also present in comparatively high numbers.

Group 1 consisted of only three samples, two of which were mid-depth Stations B19 and B31, sampled in 1978, and one deep station. The group was characterized by relatively low abundances of the molluscs Mytilidae, *Hiatella* sp., *L. vincta* and *Anomia* sp., and high densities of *Pontogeneia inermis*. No stations have been similar to Group 1 since 1980.

3.3.3.2 Intertidal Communities (Non-destructive Monitoring Program)

Important intertidal species from the bare rock habitat (mean high water zone), the *Fucus* spp. habitat (mean sea level zone) and the *Chondrus crispus* habitat (mean low water zone) were monitored non-destructively at fixed stations on nearfield Outer Sunk Rocks (Station B1) and farfield Rye Ledge (Station B5) three times per year. The bare

rock areas at approximately mean high water supported low percentages of algae such as *Porphyra* spp. at intertidal Station B1 and *Fucus* spp. at farfield Station B5 (Section 3.3.2). The predominant macrofaunal resident was *Balanus* spp., which was most abundant in the bare rock habitat. *Balanus* spp. frequencies at both stations were slightly higher in April following the spring recruitment period, than in July and December (Table 3.3.3-3). Preoperationally and in 1990, the nearfield station had a lower frequency of *Balanus* spp. than the farfield station. Herbivorous gastropods, *Littorina littorea* (mainly at Station B5) and *Littorina saxatilis* (from both stations, but almost exclusively in the bare rock zone), were also important constituents of the bare rock community, showing lower frequencies in April than in July or December. Patterns of faunal distribution in 1990 were within the range of those observed in previous years, except for a large set of mytilid spat at farfield Station B5 in July, which was not sustained into the following season.

Fucoid-covered ledge areas at approximately mean sea level were characterized by a heavy cover (over 80%) of the perennial algae *Fucus* spp. (mainly *F. vesiculosus*), with an understory of perennial red algae (*Mastocarpus stellatus* and, less frequently, *Chondrus crispus*). Highly-seasonal annual algae occurred in spring or spring and summer, particularly at Station B1 (Section 3.3.2). During the preoperational period, Mytilidae spat was the most common taxon at nearfield Station B1, with high frequencies during all three sample periods (Table 3.3.3-3). Mytilidae usually did not show high frequencies at Station B5, where *Balanus* spp. was more common. *Nucella lapillus* occurred in the fucoid zone and was more frequent at B1. It was most commonly encountered in July. Other common gastropods were *Acmaea testudinalis*, *Littorina obtusata* and *Littorina littorea* (almost exclusively occurring at Station B5). Frequencies in 1990 were similar to previous years, except for *Littorina obtusata* which was more frequent at B1 than in previous years in April and December, although it was absent in July (Table 3.3.3-3).

TABLE 3.3.3-3. MEDIAN AND RANGE OF PERCENT FREQUENCIES[a] OF THE DOMINANT FAUNA AT BARE ROCK, FUCOID LEDGE, AND CHONDRUS ZONE INTERTIDAL SITES AT STATIONS B1 (OUTER SUNK ROCKS) AND B5 (RYE LEDGE) MONITORED NONDESTRUCTIVELY FROM 1982-1989 (PREOP) AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

				BARE ROCK[c]			FUCOID LEDGE[c]			CHONDRUS ZONE[c]		
	PERIOD[b]			APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Acmaea testudinalis	PREOP	B1	median	0	0	0	0	6	13	13	13	13
			(range)	(0)	(0)	(0)	(0-25)	(0-38)	(6-69)	(6-38)	(0-25)	(6-81)
	1990		% freq.	0	0	0	12	12	12	6	19	31
	PREOP	B5	median	0	0	0	6	6	10	0	0	0
			(range)	(0)	(0)	(0)	(0-19)	(0-38)	(0-38)	(0-44)	(0-13)	(0-25)
	1990		% freq.	0	0	0	12	38	25	12	0	0
Balanus spp.	PREOP	B1	median	61	51	9	10	8	1	0	0	0
			(range)	(<1-100)	(9-88)	(0-88)	(0-100)	(1-38)	(0-63)	(0-47)	(0-4)	(0)
	1990		% freq.	35	35	27	19	11	1	7	7	0
	PREOP	B5	median	89	85	72	31	23	5	0	0	0
			(range)	(58-100)	(24-100)	(5-100)	(6-100)	(12-100)	(1-88)	(0)	(0)	(0-3)
	1990		% freq.	96	88	59	31	21	9	0	0	0
Littorina littorea	PREOP	B1	median	0	0	0	0	0	0	0	0	0
			(range)	(0)	(0-13)	(0-13)	(0)	(0-6)	(0-6)	(0)	(0-13)	(0-6)
	1990		% freq.	0	0	6	0	0	0	19	25	19
	PREOP	B5	median	0	13	82	10	53	9	81	100	88
			(range)	(0-6)	(0-56)	(13-100)	(0-38)	(13-75)	(0-31)	(75-100)	(94-100)	(44-94)
	1990		% freq.	0	25	88	25	38	25	94	100	75
Littorina obtusata	PREOP	B1	median	0	0	0	3	10	6	0	0	0
			(range)	(0)	(0-19)	(0)	(0-6)	(0-25)	(6-19)	(0-13)	(0-44)	(0-13)
	1990		% freq.	0	0	0	25	0	25	0	0	6
	PREOP	B5	median	0	6	0	3	16	7	0	0	0
			(range)	(0-6)	(0-19)	(0-13)	(0-25)	(0-44)	(0-44)	(0-13)	(0)	(0)
	1990		% freq.	0	12	6	0	12	25	12	0	0
Littorina saxatilis	PREOP	B1	median	7	57	16	0	0	0	0	0	0
			(range)	(0-44)	(0-88)	(0-88)	(0)	(0)	(0-6)	(0)	(0)	(0)
	1990		% freq.	0	0	12	0	0	0	0	0	0
	PREOP	B5	median	50	66	75	0	0	0	0	0	0
			(range)	(0-100)	(38-94)	(6-100)	(0-6)	(0)	(0-6)	(0)	(0)	(0)
	1990		% freq.	100	100	88	0	0	0	0	0	0

(continued)

TABLE 3.3.3-3. (Continued)

	PERIOD[b]			BARE ROCK[c] APR	BARE ROCK[c] JUL	BARE ROCK[c] DEC	FUCOID LEDGE[c] APR	FUCOID LEDGE[c] JUL	FUCOID LEDGE[c] DEC	*CHONDRUS* ZONE[c] APR	*CHONDRUS* ZONE[c] JUL	*CHONDRUS* ZONE[c] DEC
Mytilidae	PREOP	B1	median	0	8	3	82	76	78	90	89	65
			(range)	(0-20)	(0-40)	(0-75)	(37-100)	(27-100)	(43-100)	(54-95)	(71-95)	(15-85)
	1990		% freq.	0	11	18	73	82	69	55	84	63
	PREOP	B5	median	0	15	33	8	1	5	49	63	26
			(range)	(0-38)	(0-38)	(1-75)	(2-100)	(0-100)	(0-100)	(10-72)	(23-80)	(0-49)
	1990		% freq.	30	47	26	9	16	8	46	69	15
Nucella lapillus	PREOP	B1	median	0	0	0	6	100	25	75	100	56
			(range)	(0)	(0)	(0-6)	(0-25)	(25-100)	(6-50)	(13-100)	(100)	(31-88)
	1990		% freq.	0	0	0	6	100	12	12	100	19
	PREOP	B5	median	0	0	0	0	28	0	94	38	69
			(range)	(0-94)	(0-44)	(0-56)	(0)	(6-81)	(0-6)	(75-100)	(13-56)	(56-81)
	1990		% freq.	0	6	0	0	19	0	100	75	75

[a]Method of computing percent frequency varies among species (point-contact method for Mytilidae and *Balanus* since July 1983, percent frequency of occurrence for all other instances).
[b]PREOP period is 1982-1989, except for *Chondrus* zone, where sampling began in April, 1985.
[c]Bare ledge station is at upper edge of MSL zone, at approximate mean high water. Fucoid station is at approximate mean sea level mark. *Chondrus* zone station, first sampled in 1985, is at approximate mean low water mark.

The *Chondrus* zone, at approximately mean low water, was characterized by rock ledge with a thick cover of red algae, mainly *Chondrus crispus* and *Mastocarpus stellatus*. *Fucus* spp. were also frequently encountered at Station B1 only (Section 3.3.2). Of the macrofaunal species that were monitored, *Nucella lapillus* and Mytilidae spat were the most frequently encountered at both stations (Table 3.3.3-3). During the preoperational period, Mytilidae had medium-to-high frequencies in April and July with generally lower percentages in December. At Station B1, *Nucella* was more abundant in July than in April or December. This is consistent with other studies which show adult *Nucella* to be active from May through October, while juveniles tend to be active throughout the year (Menge 1978). On Rye Ledge (Station B5), *Nucella* was the least frequently encountered in July during the preoperational period. In 1990, frequencies were higher than the median level in all seasons at the farfield station. No relationship between abundance levels of either Mytilidae or *Nucella* at mean low water or within the fucoid habitat at mean sea level has been noted (NAI 1987b). The gastropod, *Littorina littorea*, occurred in high frequencies at only Station B5 throughout the year, and was most numerous in the *Chondrus* zone. In 1990, it occurred with moderate frequencies at B1 also. *Acmaea testudinalis* was enumerated in low-to-moderate frequencies in the *Chondrus* zone at Station B1 in all years and occasionally at Station B5; frequencies followed the same pattern in 1990.

3.3.3.3 Subtidal Fouling Community (Bottom Panel Program)

Analysis of subtidal bottom panels at mid-depth Stations B19 and B31 (sampled triannually in April, August, and December) provides information on recruitment of sessile macrofaunal species. *Balanus* spp. (mainly *Balanus crenatus*, with some *Balanus balanus*) typically settled by April. Recruitment continued in some years after the April sampling period and densities were higher in the August samples, while in other years April sampling occurred near the settlement peak (Table 3.3.3-4). By December, densities were consistently low, as *Balanus* populations

TABLE 3.3.3-4. ESTIMATED DENSITY (PER 1/4 m^2) AFTER FOUR MONTHS' EXPOSURE OF SELECTED SESSILE TAXA ON HARD-SUBSTRATE BOTTOM PANELS AT STATIONS B19 AND B31 SAMPLED TRIANUALLY (APRIL, AUGUST, DECEMBER) FROM 1981-1989 AND IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

		PREOP (1981[a]-1984, 1986[b], 1987-1989)						1990		
		APR		AUG		DEC				
		MEAN	SD	MEAN	SD	MEAN	SD	APR	AUG	DEC
Balanus spp.	Sta. B19	17053	13793	6403	4973	9	13	46366	3350	0
	Sta. B31	40962	22611	7917	6166	14	17	53333	700	0
Anomia sp.	Sta. B19	<1	<1	31	68	1232	1136	6	125	3100
	Sta. B31	0	0	36	42	993	1246	6	345	1766
Hiatella sp.	Sta. B19	1	2	3966	2595	27	31	0	6117	36
	Sta. B31	<1	<1	11659	10594	16	21	12	16304	49
Mytilidae	Sta. B19	2	3	367	247	58	57	0	1083	44
	Sta. B31	8	11	5035	10054	36	36	20	4786	104

[a]In 1981 only Balanus spp. and Anomia sp. were counted at Sta. B19. In 1982 only Balanus spp. and Anomia sp. were counted at both stations. In 1983 counts of all four taxa at both stations began. No samples were taken in 1985.
[b]Only December collections were made in 1986.

disappeared due to mortality. In 1990, the *Balanus* set at both stations was high (above the baseline average) in April, and had virtually disappeared by December.

Anomia sp. was unique among the sessile taxa that were examined, showing a pattern of late summer-fall recruitment. Although low densities of *Anomia* sometimes occurred on panels by August, numbers were typically highest in December when abundances of all other sessile taxa was low (Table 3.3.3-4). In 1990, *Anomia* were very abundant, in comparison to the baseline average in December at both stations, indicating they had a "good" set.

Hiatella sp., another sessile bivalve, showed highest densities by August collections, with most disappearing from panels by December during the baseline period. Densities in 1990 were well above average at both stations and showed a similar seasonal pattern (Table 3.3.3-4).

During the preoperational period, Mytilidae spat generally had settled on bottom panels by August, with numbers greatly reduced by December (Table 3.3.3-4). Very high densities occurred in August 1990 at both stations. At B19, densities were at an all time high, and at B31 they were exceeded only in August 1984. Few of the newly-settled mytilids survived to December 1990, however at B31, the December density was above the baseline average.

3.3.3.4 *Modiolus modiolus* Communities (Subtidal Transect Program)

Shallow and mid-depth areas are monitored nondestructively to collect additional information on large invertebrates and macroalgae. Kelps and dominant understory algae species are discussed in Section 3.3.2. The green sea urchin, a key predator of kelps, is discussed in Section 3.3.5. As part of this program, *Modiolus modiolus* populations were enumerated triannually by divers along randomly pre-selected,

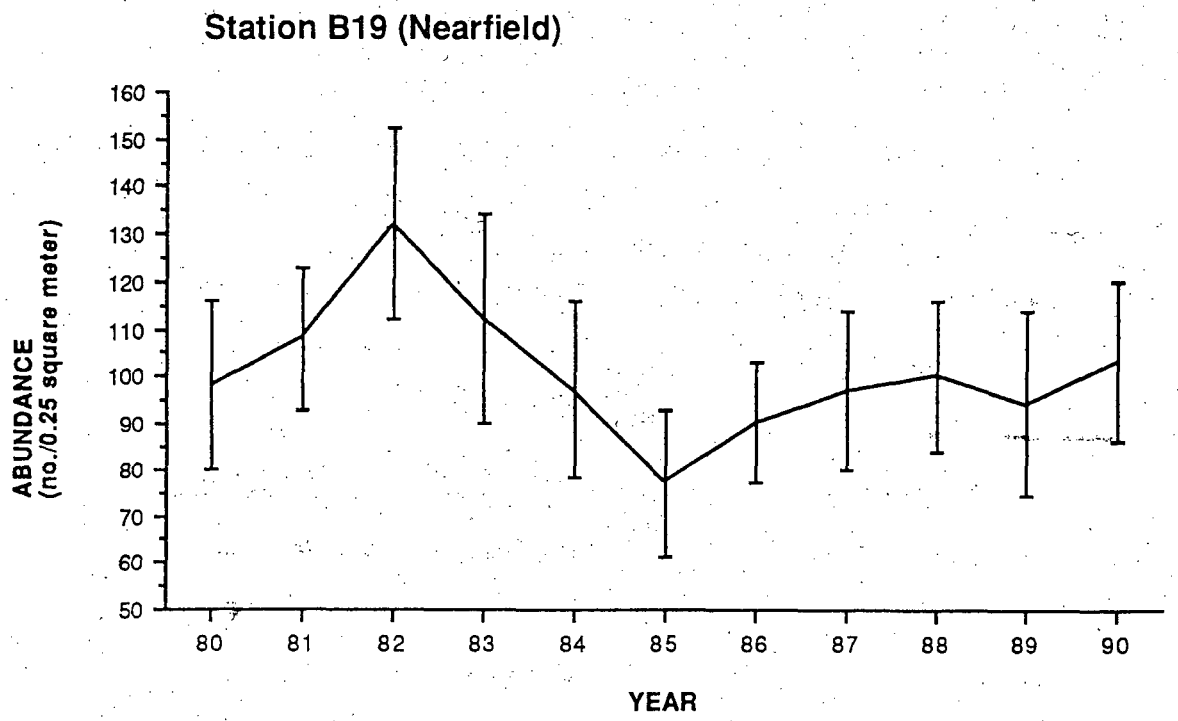
radiating transects at mid-depth Stations B19 (near the discharge), and its farfield counterpart, B31. No significant differences in *Modiolus* densities were found between 1990 and the preoperational period (1980-1989) when stations were tested separately with the Wilcoxon Signed Rank Test (at alpha = 0.05). Results using abundances from all three seasons, as well as those from October only (since October 1990 is the only operational collection) are:

	Wilcoxon's Signed Rank Z Statistic	
	OCTOBER	ALL MONTHS
Station 19	1.03 NS	0.51 NS
Station 31	0.26 NS	1.13 NS

Historically, abundances have been significantly higher at Station B19 than at B31 (NAI 1990b). This trend continued in 1990 (Figure 3.3.3-7), resulting in a significant difference over all years when tested with a Wilcoxon's two sample test ($p<0.001$). In 1990, the density of *Modiolus* increased over the previous year at both stations, as populations rebuilt after their 1989 decline (Figure 3.3.3-7). Despite year-to-year fluctuations in *Modiolus* density, the beds as a whole are relatively persistent, and form an important refuge for macroinvertebrates. As long as *Modiolus* survives the two main sources of mortality, predation by *Asterias vulgaris* and dislodgement by attached kelp, it can survive for several decades (Witman 1985).

3.3.4 Surface Fouling Panels

The surface fouling panels program was designed to study both settlement patterns and community development in the discharge plume area. Short-term panels, 10 x 10cm plexiglass squares submerged for one month, provided information on the temporal sequence of settlement activity, while monthly sequential panels, exposed from one to twelve months' duration, provided information on growth and successional patterns of community structure.



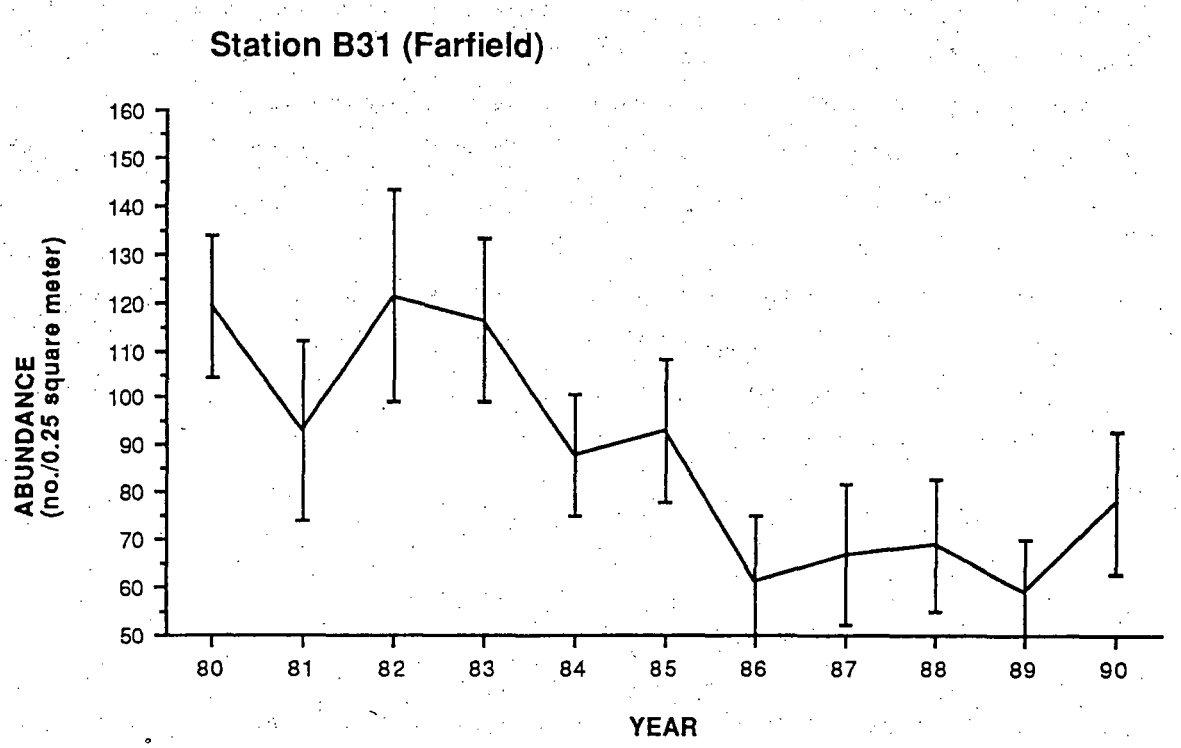


Figure 3.3.3-7. Annual mean density (no. per 0.25 square meter) and 95% confidence interval of *Modiolus modiolus* observed by divers triannually at subtidal transect stations from 1980-1990. Seabrook Operational Report, 1990.

3.3.4.1 Seasonal Settlement Patterns

Faunal Richness and Abundance

Development of a typical fouling community begins with bacterial invasion, followed by colonization by diatoms and other microorganisms that are apparently prerequisites to recruitment of larvae and spores (Wahl 1989). The intensity of recruitment on short-term panels, measured by the richness and abundance of noncolonial organisms, gives an indication of the potential for fouling community development. Historically, the number of noncolonial faunal taxa (or faunal richness) settling on short-term (exposed for one month) surface panels has been low from January through April (Figure 3.3.4-1). The number of taxa settling on panels increased dramatically in June, remained relatively high through September, then decreased in the remaining months. Seasonal patterns were similar at all four stations. In 1990, numbers of taxa were exceptionally high (and outside the 95% confidence limits) from June or July through October at all four stations, continuing a trend first observed in 1989 (NAI 1990b). Analysis of variance results indicate that the numbers of taxa in 1990 were significantly higher than previous years at both nearfield and farfield stations in the mid-depth (B19, B31) and deep (B04, B34) regions (Table 3.3.4-1). Numbers of taxa were similar between the nearfield and farfield station pairs. A variety of organisms including polychaetes, amphipods and molluscs, particularly nudibranchs, were responsible for the increased number of taxa (NAI 1991).

Over the baseline period, total abundance (noncolonial taxa only) was low through May, peaked in the summer (July) and declined through the fall at all stations (Figure 3.3.4-2). Seasonal patterns were similar at all stations. Peak abundances on panels located over mid-depth stations (B19, B31) were slightly higher but within the 95% confidence limits of abundances at deep stations (B04, B34). In 1990, abundances at all four stations peaked in June and again in September. Abundances from July through September or October were higher than average at all stations, a result of an exceptionally dense Mytilidae

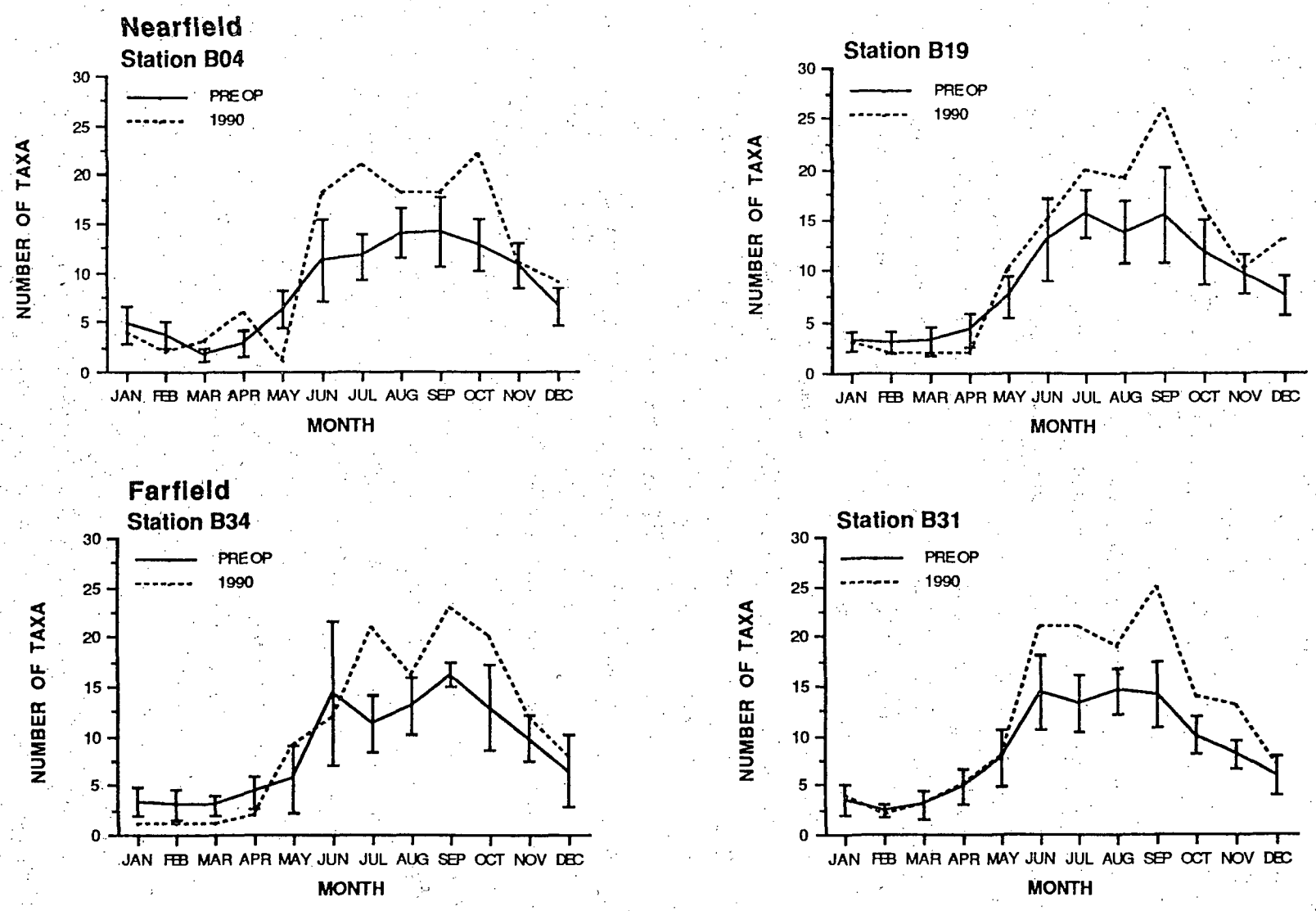


Figure 3.3.4-1. Faunal richness (number of noncolonial faunal taxa on two replicate panels) in 1990 compared to mean faunal richness and 95% confidence limits on short term panels during preoperational period (B19, B31, and B04 from 1978-1984 and July 1986-1989 and B34 from 1982-1984 and July 1986-1989). Seabrook Operational Report, 1990.

TABLE 3.3.4-1. RESULTS OF ANALYSIS OF VARIANCE COMPARING MONTHLY NUMBER OF TAXA, NONCOLONIAL ABUNDANCE, TOTAL BIOMASS, AND SELECTED SPECIES ABUNDANCE OR PERCENT FREQUENCY ON SHORT TERM PANELS AT MID-DEPTH (B19, B31) AND DEEP (B04, B34) STATION PAIRS FROM 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

PARAMETER	STATIONS	SOURCE OF VARIATION	df	SS	F[f]
Number of faunal taxa	B19, B31	Preop-Op[a]	1	138.13	24.26***
		Station[b]	1	0.45	0.08 NS
		Year (Preop-Op)[c]	10	832.75	14.62***
		Month (Year X Preop-Op)[d]	125	7,884.25	11.08***
		Preop-Op X Station[e]	1	3.38	0.59 NS
		Error	133	757.42	
	B04, B34	Preop-Op	1		21.45***
		Station	1	112.07	1.62 NS
		Year (Preop-Op)	10	8.46	13.61***
		Month (Year X Preop-Op)	125	711.04	9.64***
		Preop-Op X Station	1	6,296.03	0.01 NS
		Error	88	0.06	
				459.77	
Noncolonial faunal abundance	B19, B31	Preop-Op	1	1.25	11.76***
		Station	1	0.28	2.67 NS
		Year (Preop-Op)	10	20.38	19.23***
		Month (Year X Preop-Op)	125	293.79	22.18***
		Preop-Op X Station	1	0.00	0.00 NS
		Error	133	14.09	
	B04, B34	Preop-Op	1	1.31	14.78***
		Station	1	0.28	3.19 NS
		Year (Preop-Op)	10	12.84	14.53***
		Month (Year X Preop-Op)	125	200.21	18.12***
		Preop-Op X Station	1	0.23	2.59 NS
		Error	88	7.78	

(continued)

TABLE 3.3.4-1. (Continued)

PARAMETER	STATIONS	SOURCE OF VARIATION	df	SS	F[f]
Biomass	B19, B31	Preop-Op	1	5.43	5.38*
		Station	1	0.43	0.43 NS
		Year (Preop-Op)	8	18.00	2.23*
		Month (Year X Preop-Op)	103	408.96	3.94***
		Preop-Op) X Station	1	2.37	2.35 NS
		Error	111	111.89	
	B04, B34	Preop-Op	1	0.17	0.15 NS
		Station	1	0.20	0.19 NS
		Year (Preop-Op)	8	18.91	2.21*
		Month (Year X Preop-Op)	103	524.02	4.75***
		Preop-Op X Station	1	5.05	4.71*
		Error	88	94.34	
Mytilidae	B19, B31	Preop-Op	1	1.48	12.32***
		Station	1	0.22	1.87 NS
		Year (Preop-Op)	10	20.80	17.36***
		Month (Year X Preop-Op)	125	350.66	23.42***
		Preop-Op X Station	1	0.01	0.00 NS
		Error	133	15.93	
	B04, B34	Preop-Op	1	1.21	12.65***
		Station	1	0.40	4.12*
		Year (Preop-Op)	10	12.74	13.28***
		Month (Year X Preop-Op)	125	228.95	19.10***
		Preop-Op X Station	1	0.40	4.16*
		Error	88	8.44	

(continued)

TABLE 3.3.4-1. (Continued)

PARAMETER	STATIONS	SOURCE OF VARIATION	df	SS	F[f]
Jassa marmorata	B19, B31	Preop-Op	1	0.42	3.87 NS
		Station	1	1.02	9.41**
		Year (Preop-Op)	10	6.45	5.95***
		Month (Year X Preop-Op)	125	92.21	6.80***
		Preop-Op X Station	1	0.39	3.62 NS
		Error	133	14.43	
	B04, B34	Preop-Op	1	0.02	0.17 NS
		Station	1	0.10	0.78 NS
		Year (Preop-Op)	10	5.43	4.38***
		Month (Year X Preop-Op)	125	66.02	4.26***
		Preop-Op X Station	1	0.48	3.87 NS
		Error	88	10.90	
Balanus sp.	B19, B31	Preop-Op	1	0.35	15.53***
		Station	1	0.02	0.67 NS
		Year (Preop-Op)	10	3.46	15.23***
		Month (Year X Preop-Op)	125	34.05	11.98***
		Preop-Op X Station	1	0.00	0.04 NS
		Error	133	3.02	
	B04, B34	Preop-Op	1	0.02	1.51 NS
		Station	1	0.00	0.19 NS
		Year (Preop-Op)	10	0.95	7.96***
		Month (Year X Preop-Op)	125	13.23	8.85***
		Preop-Op X Station	1	0.00	0.40 NS
		Error	88	1.05	

(continued)

TABLE 3.3.4-1. (Continued)

PARAMETER	STATIONS	SOURCE OF VARIATION	df	SS	F[f]
Tubularia sp.	B19, B31	Preop-Op	1	0.02	0.12 NS
		Station	1	0.10	0.61 NS
		Year (Preop-Op)	10	9.74	6.19**
		Month (Year X Preop-Op)	125	95.11	4.84**
		Preop-Op X Station	1	0.08	0.49 NS
		Error	133	20.92	
	B04, B34	Preop-Op	1	0.00	0.05 NS
		Station	1	0.00	0.02 NS
		Year (Preop-Op)	10	9.74	10.78***
		Month (Year X Preop-Op)	125	98.57	8.73***
		Preop-Op X Station	1	0.01	0.09 NS
		Error	88	7.95	

[a]Preop-Op = 1990 v. all previous years (1978-84; July 1986-December 1989 except B34, which began in 1982)
[b]Station regardless of year or period
[c]Year nested within preoperational and operational periods regardless of station
[d]Month nested within year nested within preoperational and operational periods regardless of station
[e]Interaction of main effects
[f]NS = Not significant (.05>p)
* = Significant (.01<p≤.05)
** = Highly significant (.001<p≤.01)
*** = Very Highly Significant (p≤.001)

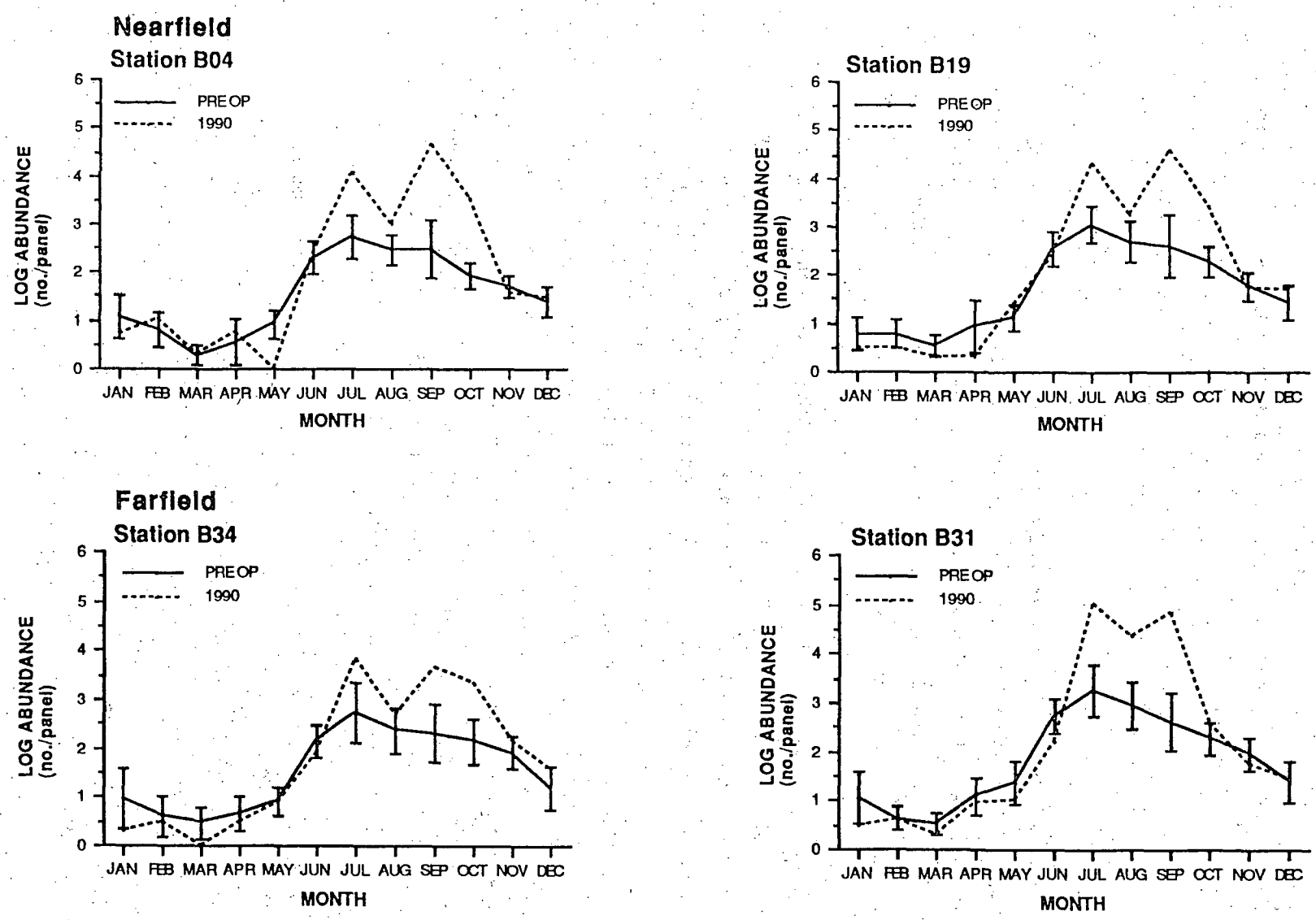


Figure 3.3.4-2. Log (x+1) abundance (no./panel) in 1990 compared to mean log (x+1) abundance and 95% confidence limits in 1990 and preoperational period (1978-1984 and July 1986-1989, B34 initiated in 1982) for noncolonial fauna on short term panels. Seabrook Operational Report, 1990.

settlement. As a result, faunal abundances in 1990 were significantly higher than previous years at both nearfield and farfield station pairs (Table 3.3.4-1).

Biomass

Seasonal settling patterns for the entire fouling community (motile fauna, colonial organisms, macroalgae) are best demonstrated by changes in biomass. The dry-weight biomass (g/panel) for short-term panels paralleled the pattern observed for the seasonal distribution of faunal abundance and richness, although it was compressed into a shorter period. Historically, biomass values have been highest during August, September, and October at all stations (NAI 1990b). Seasonal trends in 1990 were similar to baseline years (Figure 3.3.4-3). At the mid-depth stations, peak biomass occurred in September, exceeding previously-observed values. Biomass values for the entire year were significantly higher than previous years at both nearfield and farfield stations (Table 3.3.4-1). The primary cause was dense growth of the hydroid *Tubularia* sp. Molluscs including Mytilidae, *Anomia* sp., *Hiatella* sp., and predators such as Asteriidae and nudibranchs, also contributed to high biomass in September (NAI 1991). At the deep stations, only nearfield station B04 showed a similar pattern in 1990 to the mid-depth stations; biomass values at the farfield station were similar to previous years. The statistical significance of this result is demonstrated by a $p<.05$ in the Preop-Op X Station interaction term (Table 3.3.4-1). Decreased biomass is probably due to lower mytilid numbers (Table 3.3.4-2) and reduced *Tubularia* growth at B34 in comparison to B04. Panel photographs show *Tubularia* growth interspersed with bare spots at B34 in September, suggesting that grazing or mechanical disturbance may have caused reduced biomass. The other stations showed a thick cover of *Tubularia* sp.

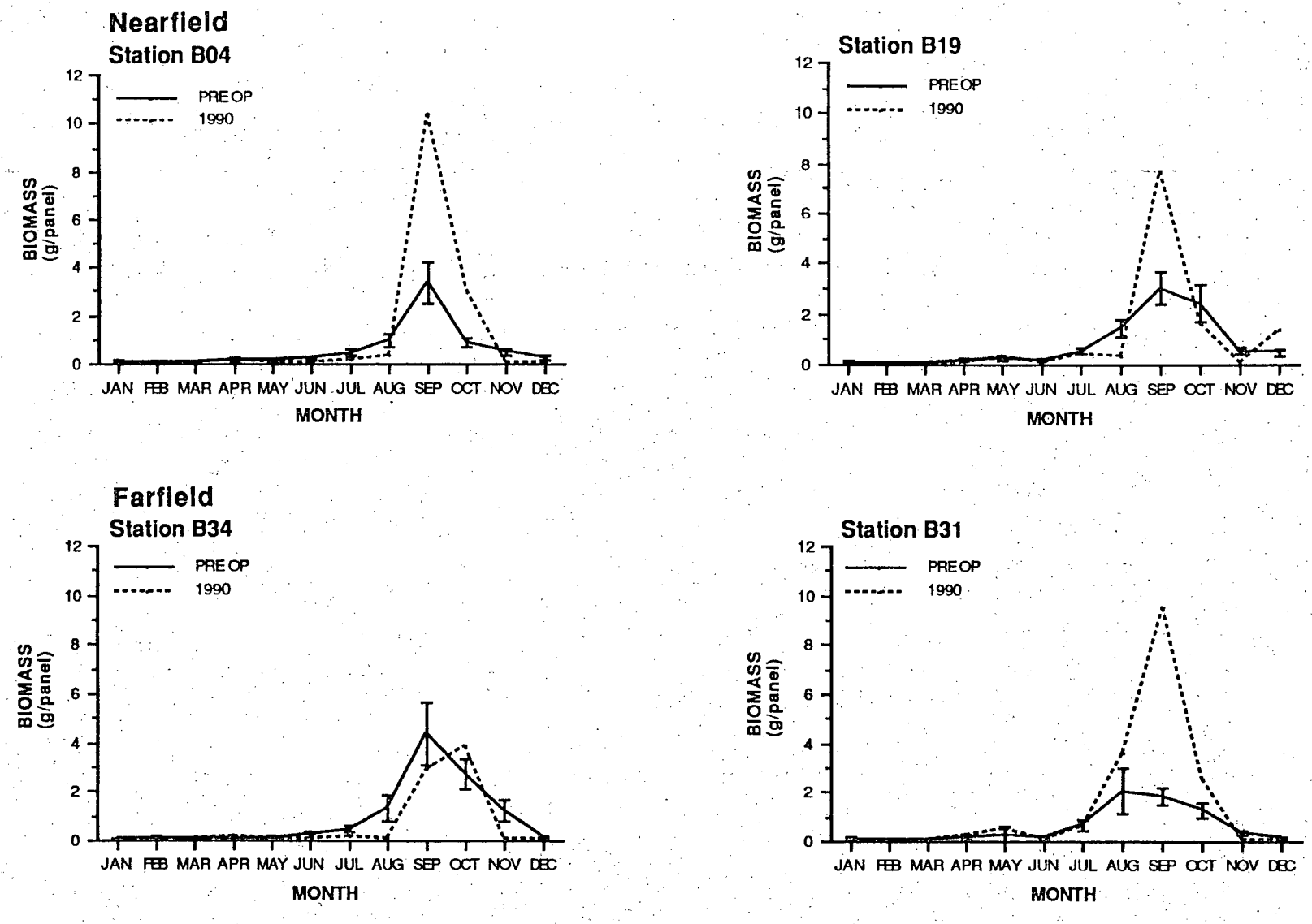


Figure 3.3.4-3. Biomass (g/panel) in 1990 compared to mean biomass and 95% confidence limits at Stations B04, B19, and B31 from 1980-1984 and July 1986-1989 and B34 from 1982-1984 and July 1986-1989 on short-term panels. Seabrook Operational Report, 1990.

TABLE 3.3.4-2. ANNUAL GEOMETRIC MEAN ABUNDANCE AND OVERALL GEOMETRIC MEAN AND 95% CONFIDENCE LIMITS FOR MYTILIDAE SPAT AND *JASSA MARMORATA* COLLECTED MONTHLY ON SHORT-TERM PANELS FROM 1978-1989 AND IN 1990 (EXCLUDING 1985 AND JANUARY-JUNE 1986). SEABROOK OPERATIONAL REPORT, 1990.

														PREOP		
TAXON	STATION	1978[a]	1979	1980	1981	1982	1983	1984	1986[b]	1987	1988	1989	$\bar{x}$	U	L	1990
Mytilidae	B19	10	30	76	79	20	20	21	133	17	27	37	29	46	18	59
	B31	17	45	88	122	22	13	32	147	35	27	37	37	60	23	74
	B04	5	18	41	37	13	11	15	48	21	18	25	18	28	12	50
	B34	--	--	--	--	8	15	14	141	26	16	20	19	32	11	27
Jassa	B19	3	2	3	6	5	3	4	4	4	1	3	3	4	2	1
marmorata	B31	3	4	3	3	8	2	5	8	10	2	2	4	5	3	4
	B04	1	1	2	4	3	3	6	1	3	0	5	2	3	2	2
	B34	--	--	--	--	2	2	2	2	3	1	4	2	3	1	3

[a]n = 24 for annual means and for overall mean 124 (B19, B31), 125 (B04) and 78 (B34)

[b]July-December only

Community Composition

Seasonal changes in the fouling community were further examined through the use of numerical classification. The focus of this assessment was to determine if the seasonal species assemblages observed in 1990 at the discharge station (B19) were similar to previous years. The similarity levels of the various seasonal groups are displayed in a dendrogram (Figure 3.3.4-4), and the months in each year that compose the groups are shown in Figure 3.3.4-5.

Seasonal changes in the noncolonial community structure at B19 parallelled those observed in total biomass and abundance. In winter (January-March, and, in some years, December) settlement activity on panels was low. The community was characterized by low densities of mytilids, either as the only dominant organism (Group 3), or in association with other species such as *Anomia* sp. (Group 1), the nudibranch *Coryphella* sp. (Group 2), and amphipod *Pontogeneia inermis* (Group 4; Table 3.3.4-3). The majority of collections from January through April were typified by this community (Figure 3.3.4-5).

In some years, spring settlement of *Balanus* sp. transformed the typical winter community. In most cases, the spring species assemblage was restricted to low densities of *Balanus* sp. (Group 9); in one instance, *Balanus* sp. densities exceeded 500 (Group 7), and in two other collections, *Balanus* occurred along with *Hiatella* sp. and amphipods *Ischyrocerus anguipes* and *Jassa marmorata* (formerly *J. falcata*; Group 8).

A summer community (Group 6), characterized by heavy bivalve settlement, occurred in every year, beginning in June and extending through September or October (Figure 3.3.4-4,5). Abundances of mytilids were exceptionally high, along with *Hiatella* sp. and *Anomia* sp. (Table 3.3.4-3). The summer community was replaced by a late fall/winter community (Group 5), characterized by moderate densities of Mytilidae

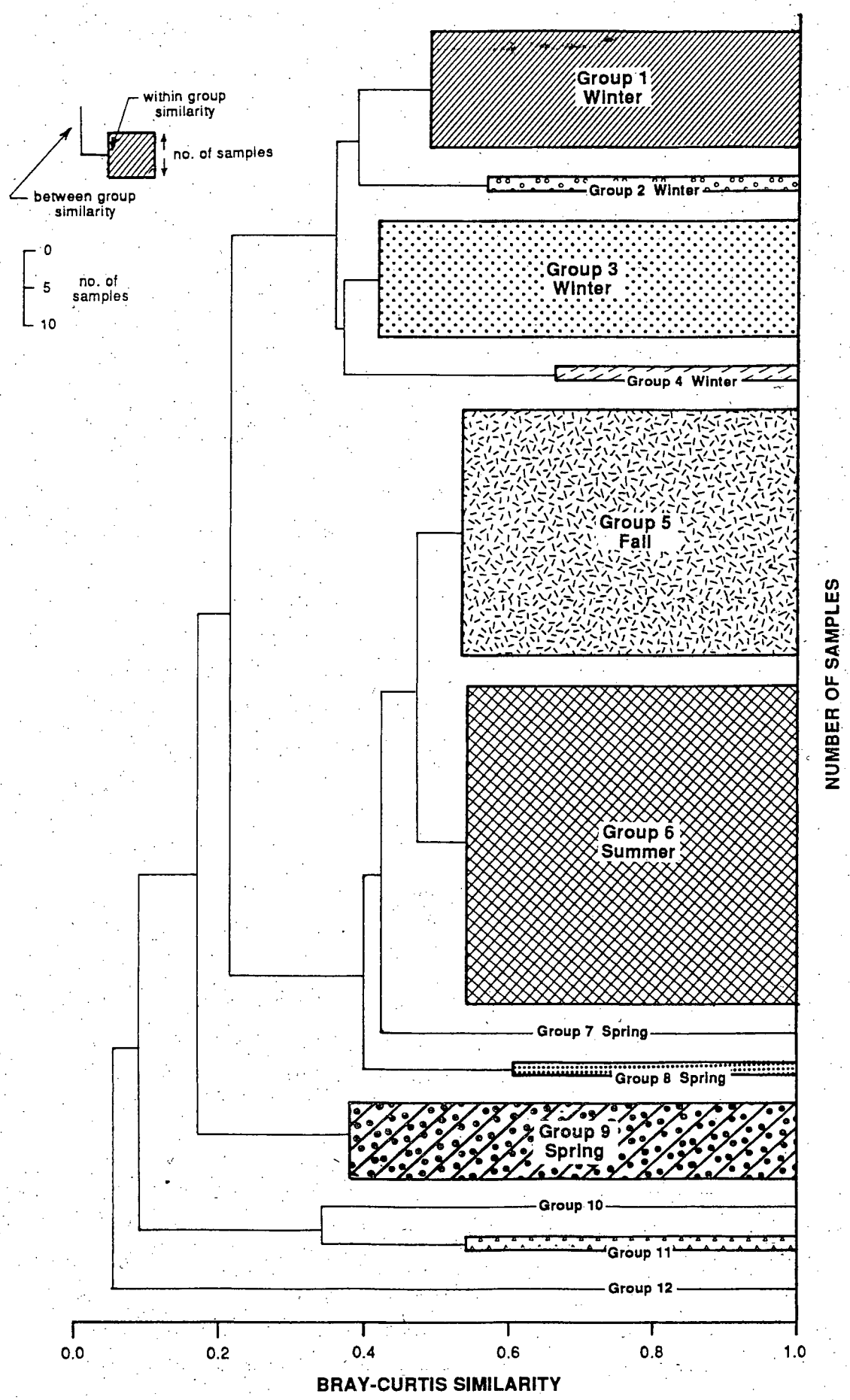


Figure 3.3.4-4. Dendrogram formed by numerical classification of noncolonial organisms collected from monthly short-term surface fouling panels set at nearfield Station B19, 1978-1984 and 1986-1990. Seabrook Operational Report, 1990.

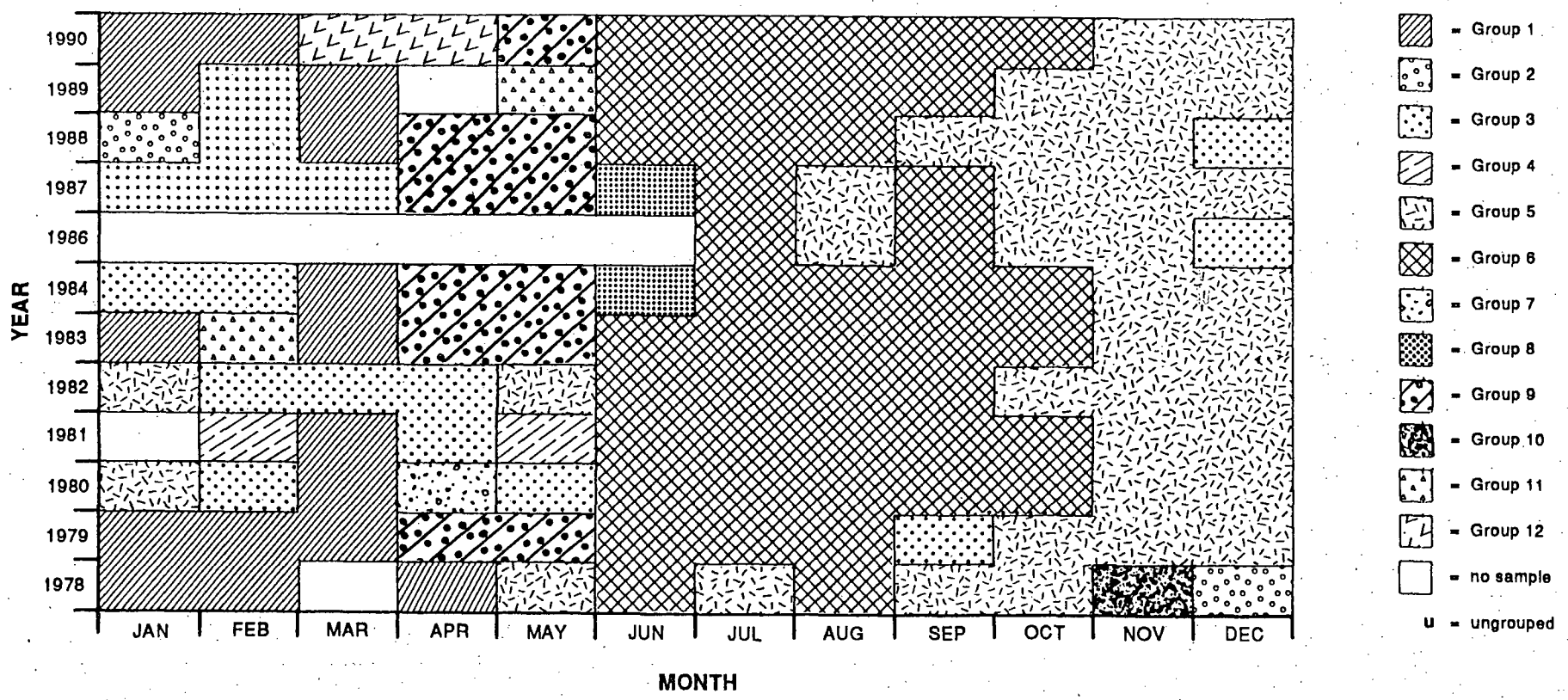


Figure 3.3.4-5. Seasonal groups formed by numerical classification of log (x+1) noncolonial abundances from short-term surface panels from Station B19 collected from 1978-1984 and July 1986-December 1990. Seabrook Operational Report, 1990.

TABLE 3.3.4-3. GEOMETRIC MEAN ABUNDANCE (NO./PANEL) AND 95% CONFIDENCE LIMITS OF DOMINANT NONCOLONIAL TAXA OCCURRING IN SEASONAL GROUPS FORMED BY NUMERICAL CLASSIFICATION OF MONTHLY SHORT-TERM SURFACE PANELS SET AT DISCHARGE STATION B19 FROM 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

GROUP NUMBER	SEASON	NUMBER OF SAMPLES PREOP	NUMBER OF SAMPLES 1990	WITHIN/BETWEEN GROUP SIMILARITY	DOMINANT TAXA	PREOPERATIONAL[a] $\bar{x}$	PREOPERATIONAL[a] C.I. L[b]	PREOPERATIONAL[a] C.I. U[b]	1990 $\bar{x}$
1	Winter	12	2	0.49/.39	Mytilidae	1.1	.8	1.3	0.5
					Anomia sp.	.2	0	.4	0.6
2	Winter	2	0	0.57/.39	Mytilidae	.5	--	--	--
					Coryphella sp.	.5	--	--	--
3	Winter/ Spring	16	0	0.42/.37	Mytilidae	7.0	4.2	11.3	--
4	Winter/ Spring	2	0	0.66/.37	*Pontogeneia inermis*	4.9	--	--	--
					Mytilidae	2	--	--	--
5	Fall	32	2	0.56/.47	Mytilidae	42.4	28.9	62.0	35.6
					Jassa marmorata	6.3	4.4	8.9	4.6
6	Summer	32	7	0.54/.47	Mytilidae	571.0	342.9	950.3	3395.3
					Hiatella sp.	25.4	15.0	42.6	262.5
					Anomia sp.	2.6	1.3	4.5	32.7
7	Spring	1	0	0.42/.42	*Balanus* sp.	531.5	--	--	--
					Mytilidae	52.0	--	--	--
8	Late Spring	2	0	0.61/.40	*Hiatella* sp.	43.2	--	--	--
					Balanus sp.	4.7	--	--	--
					Ischyrocerus anguipes	4.5	--	--	--
					Jassa marmorata	4.3	--	--	
9	Late Spring	9	1	0.38/.17	*Balanus* sp.	5.7	2.1	13.4	2.0
10	Winter	1	0	0.33/.09	*Coryphella* sp.	1.5	--	--	--
11	Winter/ Spring	2	0	0.54/.09	*Hiatella* sp.	0.7	--	--	--
12	Spring 1990	0	2	1.0/.049	*Anomia* sp.	--	--	--	0.5

[a]upper and lower confidence 95% limits included only if n>2
[b]preoperational = 1978-1984 and July 1986-December 1989

along with amphipod *Jassa marmorata*. This community occasionally preceded the period of heavy bivalve settlement as well (Figure 3.3.4-5).

The seasonal progression of the fouling community in 1990 was in most months similar to previous years. January and February samples were characterized by low densities of mytilids and *Anomia* sp., making them most similar to Group 1 samples. March and April samples were sparse except for *Anomia* sp., a situation that had not occurred historically. This led to the formation of Group 12, a group unique to 1990. Species composition from May through December progressed through typical spring (Group 9), summer (Group 6) and fall (Group 5) communities. In these months, species assemblages in 1990 were similar to those most common in previous years (Figure 3.3.4-5).

Dominant Taxa

Several dominant taxa on panels were monitored to determine their long-term recruitment patterns.

Mytilidae spat (mainly juvenile *Mytilus edulis*) was the most abundant noncolonial taxon on short-term panels. Although settlement took place throughout the year, activity was most intense from June through September (Figure 3.3.4-6), coincident with larval availability (Figure 3.1.4-3). Some of this recruitment may also be the result of secondary settlement by juveniles (Bayne 1964). In 1990, as in 1989, Mytilidae spat settled in exceptionally high numbers, peaking in June and again in August-September. The annual average in 1990 was double the average of previous years at B19, B31, and B04 (Table 3.3.4-2). Mytilid abundances in 1990 were significantly higher than previous years at both nearfield and farfield mid-depth stations (Table 3.3.4-1). At the deep stations, mytilid abundances were significantly higher in 1990 only at the nearfield station B04, demonstrated by the significant

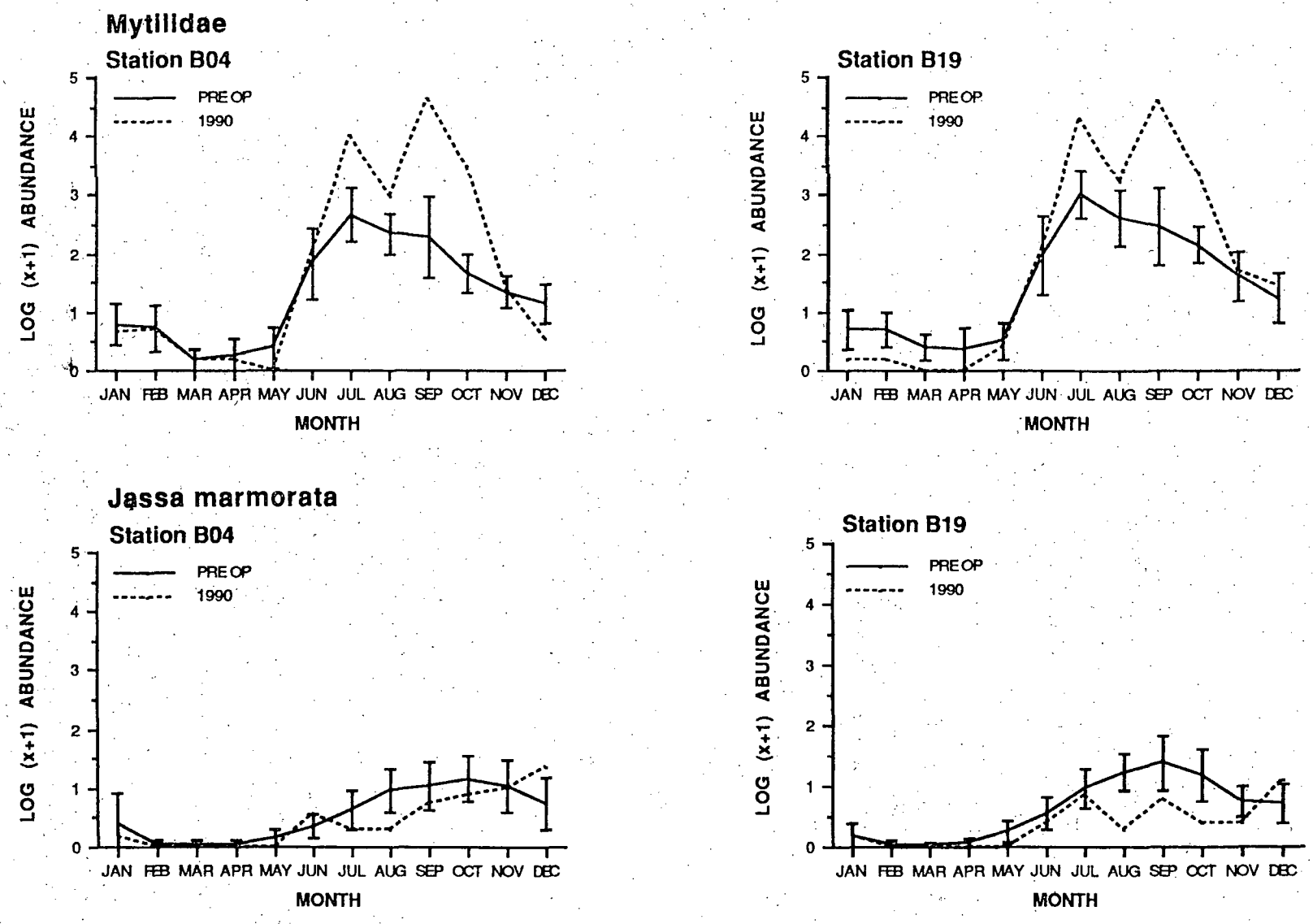


Figure 3.3.4-6. Log abundance (no. per panel) or monthly mean percent frequency of Mytilidae, *Jassa marmorata*, *Balanus* sp. and *Tubularia* sp. on short-term surface panels at Stations B04 and B19 in 1990 compared to mean abundance or percent frequency and 95% confidence limits during the preoperational period (1982-1984 and July 1986-December 1989). Seabrook Operational Report, 1990.

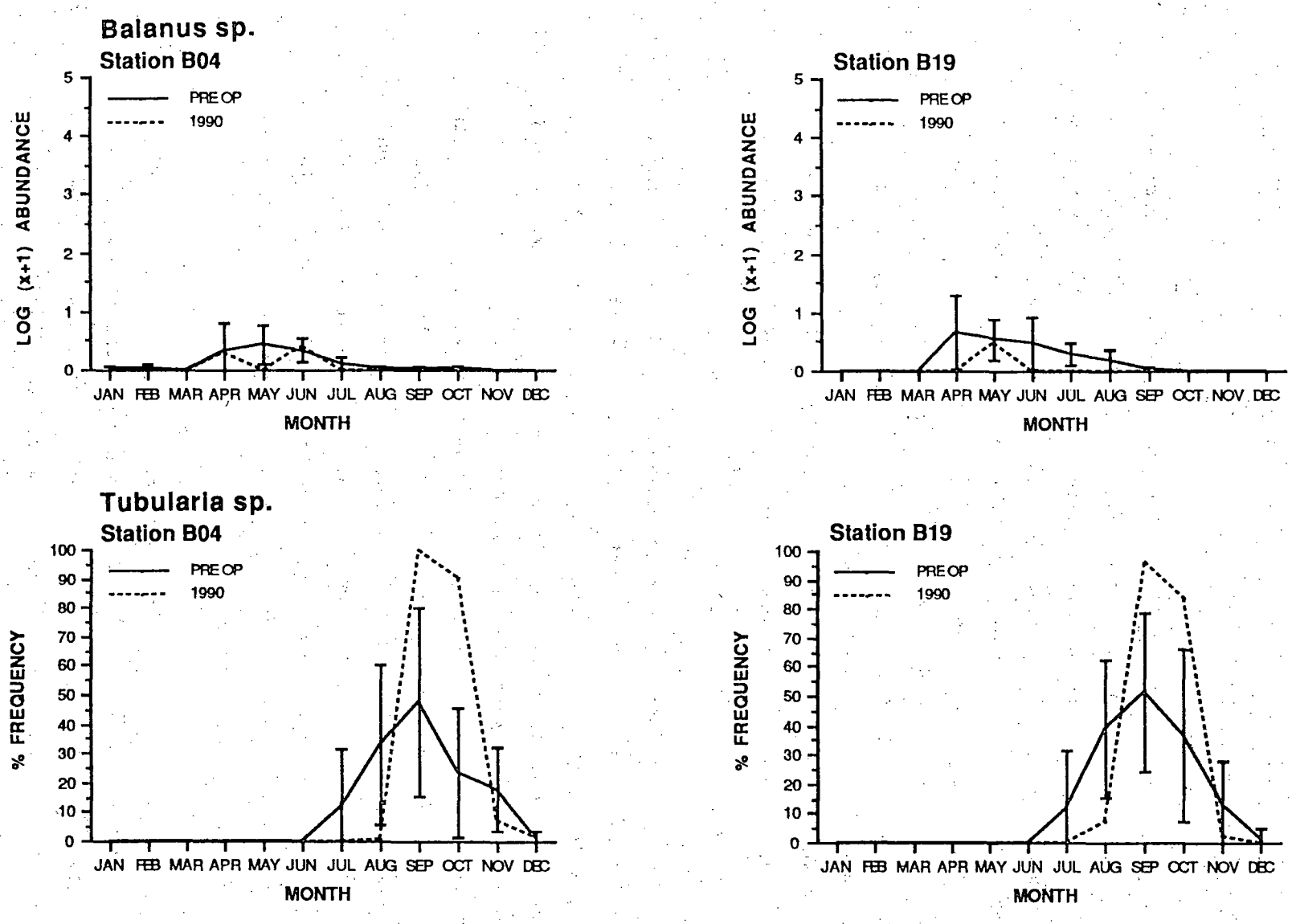


Figure 3.3.4-6. (Continued)

Preop-op-Station interaction term (Tables 3.3.4-1,2). This result is consistent with the biomass results.

The amphipod *Jassa marmorata* (formerly known as *J. falcata*) is a common fouling organism. As this species lacks a larval stage, recruitment occurs through dispersal of juveniles or adults through the water column. Historically, *Jassa* appeared on short-term panels throughout the year, but recruitment was heaviest in the latter half of the year (Figure 3.3.4-6). Gravid females historically have been most abundant from April through November (NAI 1985b). Seasonal patterns observed in 1990 at the two nearfield stations were similar to previous years (Figure 3.3.4-6). Despite lower-than-average peak abundances at the nearfield mid-depth station (B19), 1990 abundances did not differ significantly from previous years at any of the stations (Table 3.3.4-1).

Balanus sp. barnacles are among the first macro-organisms to colonize panels during the year. Settlement of planktonic larvae generally took place in March with barnacles appearing on the April panel collections (Figure 3.3.4-6). Historically, Cirripedia larvae in macrozooplankton tows have been most abundant in March and April (Section 3.1.5). Peak density levels on panels varied by two orders of magnitude, and in some years *Balanus* sp. were rare. In 1990, *Balanus* sp. appeared only in May at B19 (Figure 3.3.4-6). Abundances in 1990 were significantly lower than previous years at both mid-depth stations (Table 3.3.4-1). At B04, *Balanus* sp. occurred in April and June in 1990. Abundances in 1990 were similar to previous years at both deep stations (Table 3.3.4-1).

The hydroid *Tubularia* sp. is a dense summer colonizer. It is important not only because of its voluminous growth habits, which can prevent settlement and growth of other sessile organisms, but also as a substrate for epifaunal taxa. It is a favored prey of carnivores such as nudibranchs. *Tubularia* typically first appeared in July or August, reaching peak cover within two months (Figure 3.3.4-6). Percent cover

often reached 100% at this time. Cover levels decreased by December. In 1990, *Tubularia* cover peaked later than usual (September) and was denser than the historical average (Figure 3.3.4-6). However, 1990 *Tubularia* sp. cover was statistically similar to previous years (Table 3.3.4-1).

3.3.4.2 Patterns of Community Development

Biomass

Monthly sequential panels measure growth and successional patterns of community development. Seasonal patterns of community development are generally reflected in the monthly biomass levels. Historically, biomass values remained low through June, then increased sharply from August through October at all four stations (Figure 3.3.4-7). The general trend, as indicated by monthly values averaged for the preoperational period, was for biomass levels to continue to increase for the remainder of the year at the farfield stations (B31, B34), while biomass at nearfield stations leveled off or decreased slightly in November before increasing in December (Figure 3.3.4-7). However, peak biomass levels have occurred in October, November or December (NAI 1990b). Subsequent decreases in biomass did not appear to be related to decreased abundance or cover of dominants but instead probably reflected the decreased volume of the community. In 1990, total biomass did not increase as the year progressed but remained depressed in comparison to average values. Levels in 1990 were significantly lower than previous years at all four stations (Table 3.3.4-4). Panel photographs show little evidence of community development, unlike previous years. This suggests that either recruitment did not occur, or immediate grazing or disturbance removed newly-settled species.

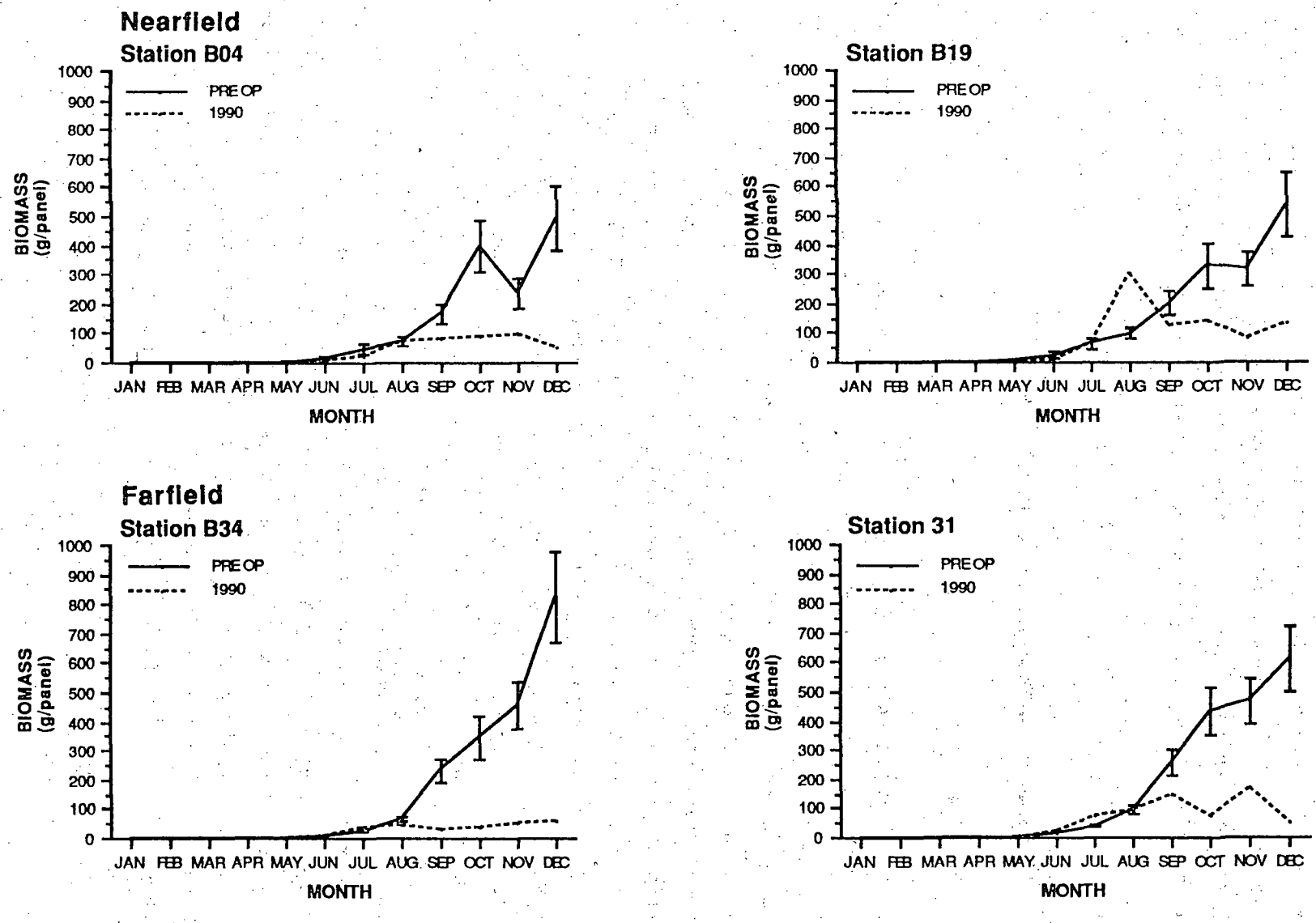


Figure 3.3.4-7. Biomass (g/panel) in 1990 compared to mean biomass and 95% confidence limits during the preoperational period (Stations B04, B19, and B31 from December 1978-1984 and July 1986-1989 and B34 from 1982-1984 and July 1986-1989) on monthly-sequential panels. Seabrook Operational Report, 1990.

TABLE 3.3.4-4. ANOVA RESULTS COMPARING MONTHLY SEQUENTIAL BIOMASS AT MID-DEPTH (B19, B31) AND DEEP (B04, B34) STATION PAIRS FROM 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

STATIONS	SOURCE OF VARIATION	df	SS	F[f]
Mid-depth B19, B31	Preop-Op[a]	1	385,535.1	36.44***
	Station[b]	1	890.8	0.08 NS
	Year (Preop-Op)[c]	10	3,229,896.2	30.53***
	Month (Year X Preop-Op)[d]	113	12,118,677.4	10.14***
	Preop-Op X Station[e]	1	13,442.4	1.27 NS
	Error	123	1,301,269.1	
Deep B04, B34	Preop-Op	1	528,746.8	56.56***
	Station	1	2,658.0	0.28 NS
	Year (Preop-Op)	10	2,953,711.2	31.60***
	Month (Year X Preop-Op)	113	11,264,509.0	10.66***
	Preop-Op X Station	1	11,540.4	1.23 NS
	Error	88	822,617.8	

[a]Preop-Op = 1990 v. all previous years (1978-84; July 1986-December 1989 except B34, which began in 1982)
[b]Station regardless of year or period
[c]Year nested within preoperational and operational periods regardless of station
[d]Month nested within year nested within preoperational and operational periods regardless of station
[e]Interaction of main effects
[f]NS = Not significant (.05>p)
* = Significant (.01<p≤.05)
** = Highly significant (.001<p≤.01)
*** = Very Highly Significant (p≤.001)

Annual Community Development

Year-to-year differences in community development were apparent, as indicated by the biomass, number of taxa, and abundance of organisms on surface panels exposed for one year. Biomass, which is a measure of the total community, occasionally varied by two orders of magnitude among years (Table 3.3.4-5). 1990 year-end biomass values were the lowest recorded to date at all four stations, parallelling trends observed in the monthly biomass data. However, given the high variability in the data, 1990 values were not found to be significantly different from previous years. Average values for the preoperational period were similar among stations, although yearly values often showed an order of magnitude difference among stations. In 1990, biomass at B19 was more than double that at the other stations.

Number of noncolonial taxa was a more stable measure of the community than biomass or abundance, showing lower variability among years and stations. In 1990, the number of taxa was similar to previous years at B31, B04, and B34. Number of taxa in 1990 at B19 was significantly higher than previous years (Table 3.3.4-5).

Historically, noncolonial abundance has been variable among years and stations. In 1990, noncolonial abundance was statistically similar to previous years at all stations, although abundances at B19 were the highest recorded to date (Table 3.3.4-5).

Dominant Taxa

Seasonal patterns of several species were examined to determine survival after settlement. Historically, mytilid spat first appeared as an important component of the fouling community in June. The percent frequency of occurrence had reached peak proportions by July or August, (Figure 3.3.4-8) coincident with the peak recruitment levels observed on short-term panels (Figure 3.3.4-6). Percentages remained high through December, exceeding more than 60% at both stations. While

TABLE 3.3.4-5. ANNUAL MEAN AND OVERALL MEAN DRY WEIGHT BIOMASS, NONCOLONIAL NUMBER OF TAXA, ABUNDANCE, AND *LAMINARIA* SP. COUNTS ON SURFACE FOULING PANELS SUBMERGED FOR ONE YEAR AT STATIONS B19, B31, B04, AND B34 DURING THE PREOPERATIONAL PERIOD (1982-1984 AND 1986-1989) AND IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

	STATION	1982	1983	1984	1986	1987	1988	1989	PREOPERATIONAL MEAN	PREOPERATIONAL S.D.	1990
BIOMASS (g/panel)	B19	133.3	714.9	1,117.6	698.1	170.8	1,408.1	387.4	661.5	476.88	132.8 NS
	B31	349.6	397.6	773.6	883.3	93.1	1,711.3	753.8	708.9	523.86	52.1 NS
	B04	108.6	665.7	1,035.5	1,071.3	85.2	1,082.7	157.0	600.9	474.66	51.1 NS
	B34	115.1	821.5	1,266.1	952.6	167.5	1,716.4	723.0	823.2	570.39	60.5 NS
NUMBER OF NON-COLONIAL TAXA (No./panel)	B19	25	14	21	19	19	27	24	21.3	4.42	34*
	B31	26	24	20	33	23	31	24	25.9	4.60	24 NS
	B04	19	23	17	25	27	26	28	23.6	4.16	24 NS
	B34	16	27	18	20	24	25	30	22.9	5.05	27 NS
NONCOLONIAL ABUNDANCE (No./panel)	B19	2,647	15,197	20,783	14,745	6,148	21,281	16,535	13,905.1	7,046.48	27,625 NS
	B31	1,983	14,127	14,945	31,159	11,185	58,300	22,074	21,967.6	18,398.27	23,265 NS
	B04	3,149	13,805	10,868	10,008	48,310	22,391	27,171	19,386.0	15,063.89	27,024 NS
	B34	822	12,702	11,931	12,532	62,537	21,002	13,026	19,221.7	19,986.38	5,693 NS
LAMINARIA SP. (No./panel)	B19	51	16	6	0	97	0	0	24.3	36.91	0 NS
	B31	64	78	13	11	48	56	5	39.3	29.24	4 NS
	B04	92	0	0	0	1	6	0	14.1	34.40	2 NS
	B34	65	0	0	1	43	2	0	15.9	26.83	0 NS

*.01<P≤.05 when tested with a single sample t-test (Sokol and Rolf 1969)

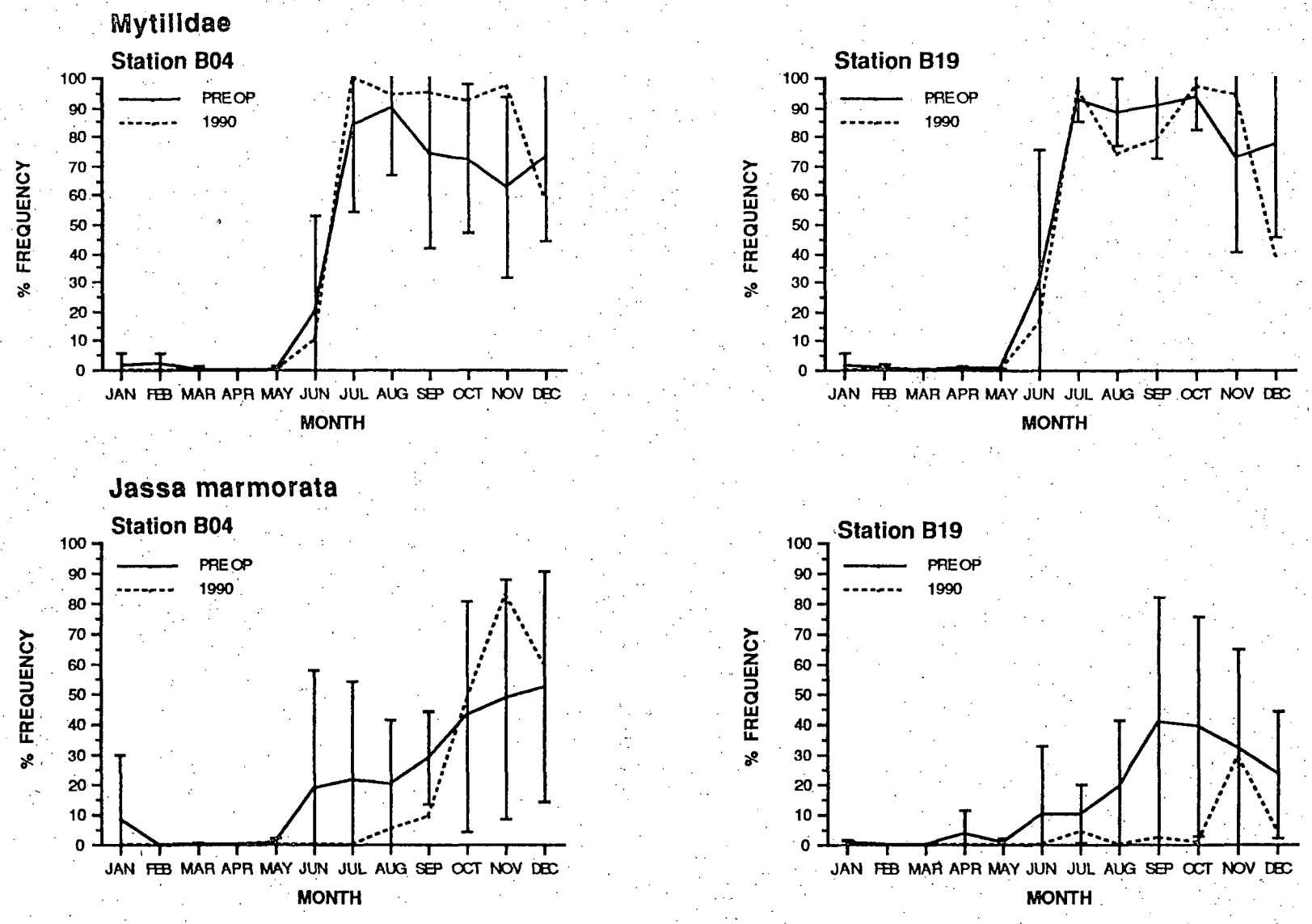


Figure 3.3.4-8. Monthly mean percent frequency or log transformed abundance (no. per panel) on monthly sequential surface panels for Mytilidae, *Jassa marmorata*, *Balanus* sp., *Tubularia* sp. and *Laminaria* sp. at Stations B04 and B19 in 1990, compared to mean and 95% confidence limits during preoperational period (1982-1984 and July 1986-December 1989). Seabrook Operational Report, 1990.

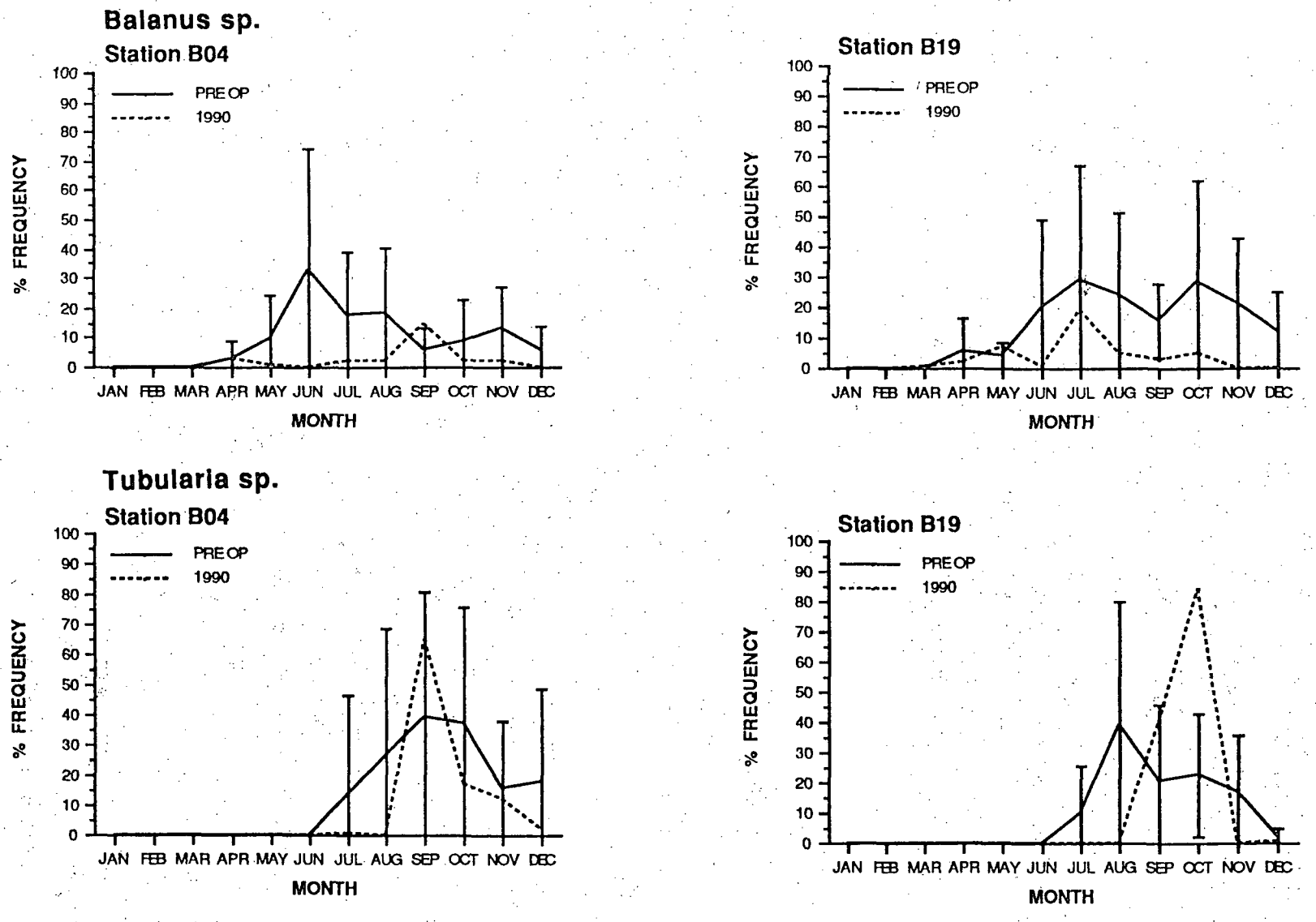
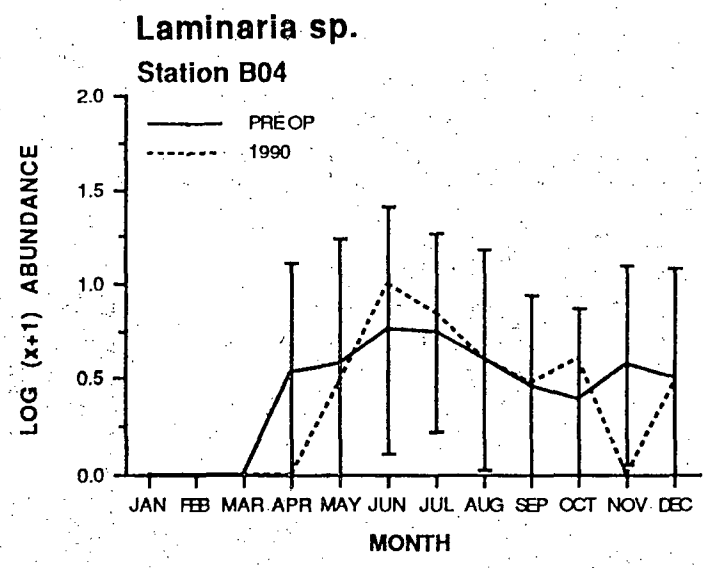


Figure 3.3.4-8. (Continued)



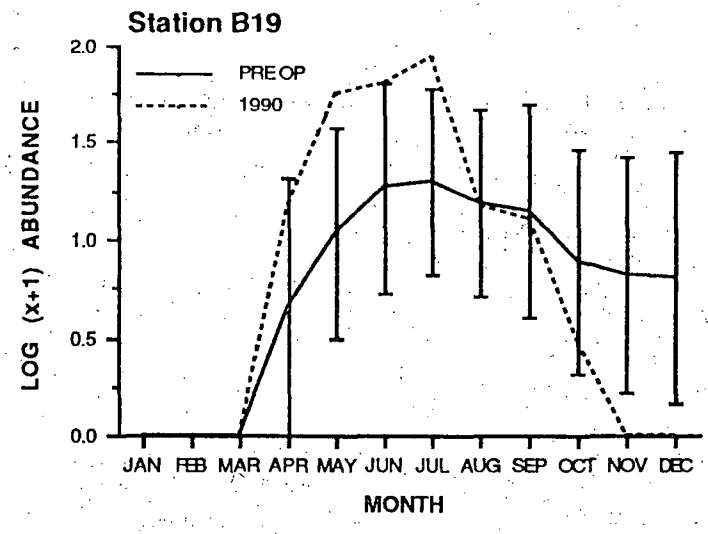


Figure 3.3.4-8. (Continued)

percentage frequencies remained stable in late summer and fall, mussel growth (as evidenced by larger lengths; Figure 3.3.4-9) contributed to the high biomass levels in the latter part of the year. Mussel growth also decreased available space, crowding out taxa such as *Balanus* sp. In 1990, seasonal patterns and frequency levels were similar to previous years at both nearfield stations (Figure 3.3.4-8). Mussel lengths were smaller than average for most of the year at both stations (Figure 3.3.4-9). This probably contributed to lower-than-average biomass levels (Figure 3.3.4-7).

Historically, the amphipod *Jassa marmorata* has occurred year-round, but had become an important constituent of the fouling community beginning in June, occurring with frequencies of at least 10% (Figure 3.3.4-8). Overall mean percent frequencies increased in September-October, remained high through December at B04 and decreased at B19. However, large confidence intervals indicate seasonal patterns were variable among years. Increased frequency of occurrence was most likely related to increased available substrate (as indicated by increased biomass levels), providing increased structural complexity, food, and refuge. In 1990, *Jassa* appeared at Station B19 in substantial frequencies only in November (Figure 3.3.4-8). At Station B04, *Jassa* occurred later than usual and was encountered frequently only from October to December (Figure 3.3.4-8). The diminished presence of *Jassa* may be related to decreased numbers of *Laminaria* sp. (Table 3.3.4-5), its preferred substrate on panels. In 1990, during the months when it was present on panels, *Jassa* lengths were similar to the historical average (Figure 3.3.4-9).

Historically, *Balanus* barnacles typically first appeared on monthly sequential panels in April, as observed on short-term panels (Figure 3.3.4-8). Percent frequency of occurrence increased in June at both stations. At B19, *Balanus* percentages stabilized at approximately 20% through December. Percentages at B04 remained high from June-August, then decreased. However, large confidence intervals around monthly means indicated large differences in seasonal patterns among

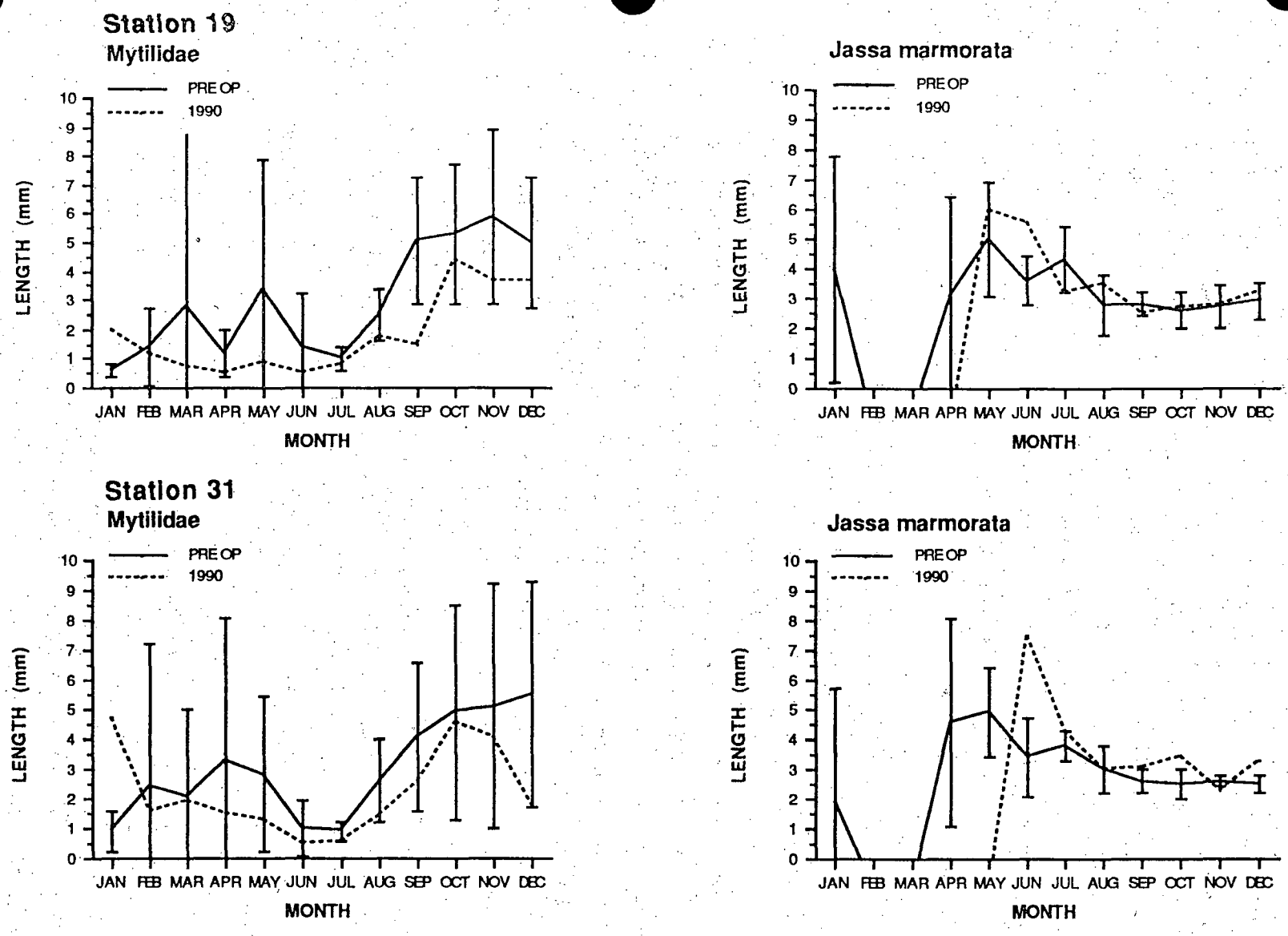


Figure 3.3.4-9. Mean length of Mytilidae and *Jassa marmorata* collected from monthly sequential surface panels in 1990, compared to mean and 95% confidence limits during preoperational period (1982-1989). Seabrook Operational Report, 1990.

years. Decreased frequencies probably reflected decreases in available space due to growth of other sessile taxa such as mytilids and *Laminaria* sp. As on short-term panels, *Balanus* frequencies were lower than average in 1990. Peak abundances (September, B04; July, B19) were later than has been typically observed.

Historically, *Tubularia* sp. has predominated in the latter half of the year. Peak frequencies reaching nearly 40% usually occurred in August at B19 and in September at B04 (Figure 3.3.4-8); November and December were generally periods of lower frequencies. However, large confidence limits suggest that seasonal patterns were not as consistent as indicated by the preoperational monthly mean. In 1990, *Tubularia* sp. occurred mainly in September and October. Peak densities occurred in September at B04, consistent with previous years. At B19, peak densities occurred in October, later than observed in previous years. *Tubularia* had higher than average peak frequencies in 1990, paralleling trends observed on short-term panels.

Kelp (*Laminaria* spp., mostly juvenile *L. saccharina* but occasionally *L. digitata*) are important members of the surface fouling panel community. Generally opportunistic in their settling patterns, kelp sporelings are among the first organisms to colonize new substrate. Once established, they provide habitat and a food source for other fouling organisms. Kelp settlement was highly variable among years. In some years, no juveniles settled on panels while in others, an annual average of up to 97 per panel was attained (Table 3.3.4-5). Numbers were generally higher on panels from mid-depth stations (B19, B31) in comparison to deep stations (B04, B34). In 1990, no *Laminaria* remained on panels placed at B19 and B34 after a year's exposure. Low numbers were collected at B04 and B31. Numbers of *Laminaria* in 1990 were statistically similar to previous years at all four stations.

The seasonal pattern of *Laminaria* sp. settlement and growth was variable from year to year. Sporelings first appeared from April to July (Figure 3.3.4-8). Peak abundances generally occurred in June or

July, and abundances stabilized for the remainder of the year. Numbers of *Laminaria* and their seasonal occurrence in 1990 were similar to previous years at B04. At B19, *Laminaria* numbers were higher than average from May-July in 1990, then decreased sharply in October.

3.3.5 Selected Benthic Species

Seven macrofaunal taxa from the area of the discharge (near-field) and from a control area off Rye Ledge (farfield) (Table 2.1-2, Figure 2.1-4) were selected for intensive monitoring from intertidal Stations B1MLW and B5MLW, shallow subtidal stations B17 and B35 and mid-depth Stations B19 and B31. Selection of taxa was based on abundance, and/or trophic level (Table 2.3-3). Sampling generally took place in May, August and November. Abundance data from short-term fouling panels at Stations B19 and B31 were compared to benthic data. Length data for Mytilidae spat and *Jassa marmorata* from monthly sequential panels were examined. Numbers of large sea urchins estimated by SCUBA divers from counts on subtidal transects were noted.

3.3.5.1 Mytilidae

Mytilidae, composed primarily of juvenile *Mytilus edulis*, was the most abundant taxon at all three nearfield/farfield station pairs. *Mytilus edulis* reaches 100 mm in length (Gosner 1978), and is an important prey species for fish, sea stars, lobsters, and gastropods. It clings to hard substrate with strong byssal threads, is an important fouling organism, and forms a habitat for many other species. The geometric mean density for the 1978-1989 preoperational period was over an order of magnitude higher at intertidal stations than subtidal depths (Table 3.3.5-1).

Densities in 1990 were higher than baseline averages at both near- and farfield stations in the intertidal and shallow subtidal depth

zones, and their interactions were not significant (Table 3.3.5-1,2). The annual trend at each shallow subtidal station, for example, was roughly similar, with the lowest density in 1985 at both near- and farfield stations, and the highest in 1984 during the 1982-1990 period (Figure 3.3.5-1). However, at the mid-depth station pair, the 1990 density at B31 was below the baseline average, but at B19 (discharge) it was above average, and the interaction was significant. Station B31 was the only station out of the six stations sampled to show a below average density in 1990.

The Mytilidae collected usually ranged from less than 1 mm to 30 mm in length, and averaged between 2 and 3 mm. Many of the smallest mytilids had settled on macroalgae rather than on the bottom or hard substrate, a pattern also observed by other investigators (Bayne 1965; Suchanek 1978). The preoperational mean length of intertidal mytilids was slightly larger than subtidal mytilids (Table 3.3.5-3) although intertidal population densities were much higher than subtidal densities. Yearly differences in mean length for each of the nearfield/farfield station pairs historically have not been significant (NAI 1987b). In 1990, the lengths at all three station pairs were within the range of previous years.

The level of mytilid settlement at mid-depth Stations B19 and B31 is indicated by the abundance on subsurface short-term fouling panels (Section 3.3.4). Monthly densities suggest that some primary or secondary settlement takes place throughout the year, but is heaviest from June through November. In 1990, the heaviest sets occurred from early summer through early fall (Figure 3.3.4-8) and nearly equaled or exceeded any previous all time high. Mytilid lengths at Stations B19 and B31 ranged from <1 mm to 44 mm in 1990 (NAI 1991), greater than previous years. Monthly measurements indicate 99% of the mytilids measured in June at both stations in 1990 were 1 mm or less (NAI 1991). The all years' mean monthly length was about 1.0 mm at both stations in July, indicating settlement of new recruits occurred (Section 3.3.4). From September through December the monthly mean length over all years

TABLE 3.3.5-1. ANNUAL GEOMETRIC MEAN DENSITY (NO./m^2) OF SELECTED BENTHIC SPECIES SAMPLED TRIANNUALLY IN MAY, AUGUST, AND NOVEMBER FROM 1978 THROUGH 1990. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	STA	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	PREOP[a]			1990[b]		
		MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	LOWER	MEAN	UPPER	LOWER	MEAN	UPPER
Mytilidae	B1MLW	178931	135333	76830	117038	217205	51811	84696	63307	227020	121566	140499	176676	105260	123874	145780	90590	151386	252982
	B5MLW					39282	47738	78963	57505	123203	98711	85673	65360	60128	72491	87397	90643	126900	177659
	B17	2098	8940	1674	1704	3975	963	7980	566	6071	4214	1299	3714	2090	2731	3570	2861	6774	16041
	B35					1764	7328	13416	1055	8511	7834	3834	4052	3514	4667	6198	3211	5583	9710
	B19	166	268	955	2323	1695	1247	6493	6651	7868	4780	3471	3245	1322	1816	2495	3651	6568	11816
	B31	1171	3501	12144	14042	1743	1095	17842	81457	3704	6537	17192	3261	4513	5878	7657	792	1555	3056
Nucella	B1MLW	1385	3492	3815	1821	759	1568	5633	3250	2347	1166	1122	1456	1647	1928	2256	1485	3361	7606
lapillus	B5MLW					669	530	888	1378	824	1146	681	1026	711	855	1029	891	1411	2234
Asteriidae	B17				1832	743	208	392	592	393	508	748	827	534	632	748	643	1238	2382
	B35					655	39	167	198	71	299	284	241	148	195	256	761	1680	3708
Pontogeneia	B19	882	561	715	617	949	562	386	604	595	280	935	702	509	623	762	352	643	1174
inermis	B31	189	429	510	458	659	470	512	280	606	174	862	260	326	399	487	160	281	494
Jassa	B17	1209	907	727	2950	2881	398	660	1622	2047	841	326	900	818	1034	1307	170	502	1479
marmorata	B35					5699	4980	2031	1465	1881	946	967	944	1187	1673	2358	771	1196	1856
Ampithoe	B1MLW	344	508	505	357	134	36	9	3	<1	0	<1	0	13	22	36	0	0	0
rubricata	B5MLW					136	20	<1	0	0	0	2	11	2	3	6	8	25	76
Strongyloce-	B19	37	58	173	279	94	15	29	188	175	112	23	26	51	71	97	3	9	27
ntrotus	B31	20	53	66	89	74	55	33	34	34	19	22	1	22	30	40	7	20	51
droebachien-																			
sis																			

[a]PREOP = preoperational period = May, August, and November through 1989; LOWER/UPPER = 95% (geometric) confidence interval
[b]1990 = operational period = May, August, and November 1990; LOWER/UPPER = 95% (geometric) confidence interval

TABLE 3.3.5-2. RESULTS OF TWO-WAY ANALYSES OF VARIANCE COMPARING LOG-TRANSFORMED DENSITIES OF SELECTED BENTHIC SPECIES AT NEAR- AND FARFIELD STATION PAIRS (1MLW/5MLW, B17/B35, B19/B31) DURING PREOPERATIONAL (THROUGH 1989) AND OPERATIONAL (1990) PERIODS. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	STATIONS	SOURCE OF VARIATION[a]	SAMPLED IN MAY, AUGUST, NOVEMBER df	SS	F[a]	SAMPLED IN AUGUST, NOVEMBER df	SS	F[b]
Mytilidae	B1MLW	Month (Year (Preop-Op))	26	22.72	8.98***	13	10.19	7.11***
	B5MLW	Year (Preop-Op)	11	4.66	4.35***	11	9.62	7.93***
		Station	1	0.64	6.62*	1	0.68	6.15**
		Preop-Op	1	0.77	7.91**	1	0.48	4.31**
		Preop-Op X Station	1	0.17	1.74 NS	1	0.10	0.86 NS
		Error	249	24.24		172	18.97	
	B17	Month (Year (Preop-Op))	26	45.64	7.13***	13	15.62	5.93***
	B35	Year (Preop-Op)	11	21.01	7.76***	11	23.99	10.77***
		Station	1	0.14	0.56 NS	1	0.30	1.47 NS
		Preop-Op	1	1.72	7.00**	1	1.94	9.56**
		Preop-Op X Station	1	0.64	2.60 NS	1	1.18	5.84*
		Error	241	59.29		164	33.21	
	B19	Month (Year (Preop-Op))	26	36.53	4.07***	13	15.57	3.52***
	B31	Year (Preop-Op)	11	64.73	17.06***	11	33.45	8.94***
		Station	1	0.04	0.11 NS	1	0.25	0.74 NS
		Preop-Op	1	0.00	0.01 NS	1	0.39	1.13 NS
		Preop-Op X Station	1	9.41	27.27***	1	5.53	16.25***
		Error	294	101.41		200	68.05	

(continued)

TABLE 3.3.5-2. (Continued)

SPECIES	STATIONS	SOURCE OF VARIATION[a]	SAMPLED IN MAY, AUGUST, NOVEMBER df	SS	F[a]	SAMPLED IN AUGUST, NOVEMBER df	SS	F[b]
Nucella lapillus	B1MLW	Month (Year (Preop-Op))	26	17.14	5.62***	13	7.06	4.27***
	B5MLW	Year (Preop-Op)	11	6.46	5.01***	11	8.21	5.87***
		Station	1	2.94	25.08***	1	1.42	11.15***
		Preop-Op	1	1.00	8.14**	1	1.65	12.98***
		Preop-Op X Station	1	0.04	0.37 NS	1	0.05	0.39 NS
		Error	249	29.21		172	21.85	
Asteriidae	B17	Month (Year (Preop-Op))	20	21.18	10.17***	10	4.07	3.83***
	B35	Year (Preop-Op)	8	14.68	17.62***	8	15.81	18.61***
		Station	1	0.60	5.80*	1	0.34	3.17 NS
		Preop-Op	1	9.75	93.63***	1	13.43	126.41***
		Preop-Op X Station	1	2.11	20.25***	1	2.72	25.57***
		Error	205	21.34		140	14.87	
Pontogeneia inermis	B19	Month (Year (Preop-Op))	26	28.59	5.36***	13	19.11	6.97***
	B31	Year (Preop-Op)	11	6.74	2.99***	11	6.00	2.58***
		Station	1	1.92	9.37**	1	1.65	7.80**
		Preop-Op	1	0.08	0.41 NS	1	0.03	0.16 NS
		Preop-Op X Station	1	0.23	1.14 NS	1	0.32	1.54 NS
		Error	294	60.30		200	42.18	

(continued)

TABLE 3.3.5-2. (Continued)

SPECIES	STATIONS	SOURCE OF VARIATION	SAMPLED IN MAY, AUGUST, NOVEMBER df	SS	F[a]	SAMPLED IN AUGUST, NOVEMBER df	SS	F
Jassa marmorata	B17	Month (Year X Preop-Op)	26	23.70	2.50***	13	10.78	1.81*
	B35	Year (Preop-Op)	11	16.01	4.00***	11	16.48	3.26***
		Station[b]	1	2.62	7.18**	1	2.40	5.23*
		Preop-Op[c]	1	1.92	5.27**	1	1.18	2.57 NS
		Preop-Op X Station[d]	1	0.09	0.25 NS	1	0.27	0.59 NS
		Error	241	87.76		164	75.33	
Ampithoe rubricata	B1MLW	Month (Year X Preop-Op)	26	33.96	3.23***	13	24.48	4.66***
	B5MLW	Year (Preop-Op)	11	236.02	53.04***	11	169.07	38.00***
		Station[b]	1	13.99	34.59***	1	16.52	40.84***
		Preop-Op[c]	1	9.30	22.99***	1	3.25	8.04**
		Preop-Op X Station[d]	1	12.32	30.46***	1	13.65	33.75***
		Error	249	100.72		172	69.56	
Strongylocentrotus droebachiensis	B19	Month (Year X Preop-Op)	26	36.50	2.89***	13	13.99	2.61**
	B31	Year (Preop-Op)	11	39.67	7.42***	11	32.92	7.27***
		Station[b]	1	0.05	0.11 NS	1	0.32	0.77 NS
		Preop-Op[c]	1	7.07	14.56***	1	4.59	11.15***
		Preop-Op X Station[d]	1	3.20	6.58*	1	3.80	9.23**
		Error	294	142.88		200	82.34.	

[a]NS = not significant ($p>0.05$)
* = significant ($0.05 \geq p > 0.01$)
** = highly significant ($0.01 \geq p > 0.001$)
*** = very highly significant ($p \leq 0.001$)
[b]nearfield = Stations 1MLW, B17, and B19; farfield = Stations B5MLW, B35, B31, regardless of year/period
[c]preoperational (through 1989) versus operational (1990) period, regardless of station
[d]interaction between main effects

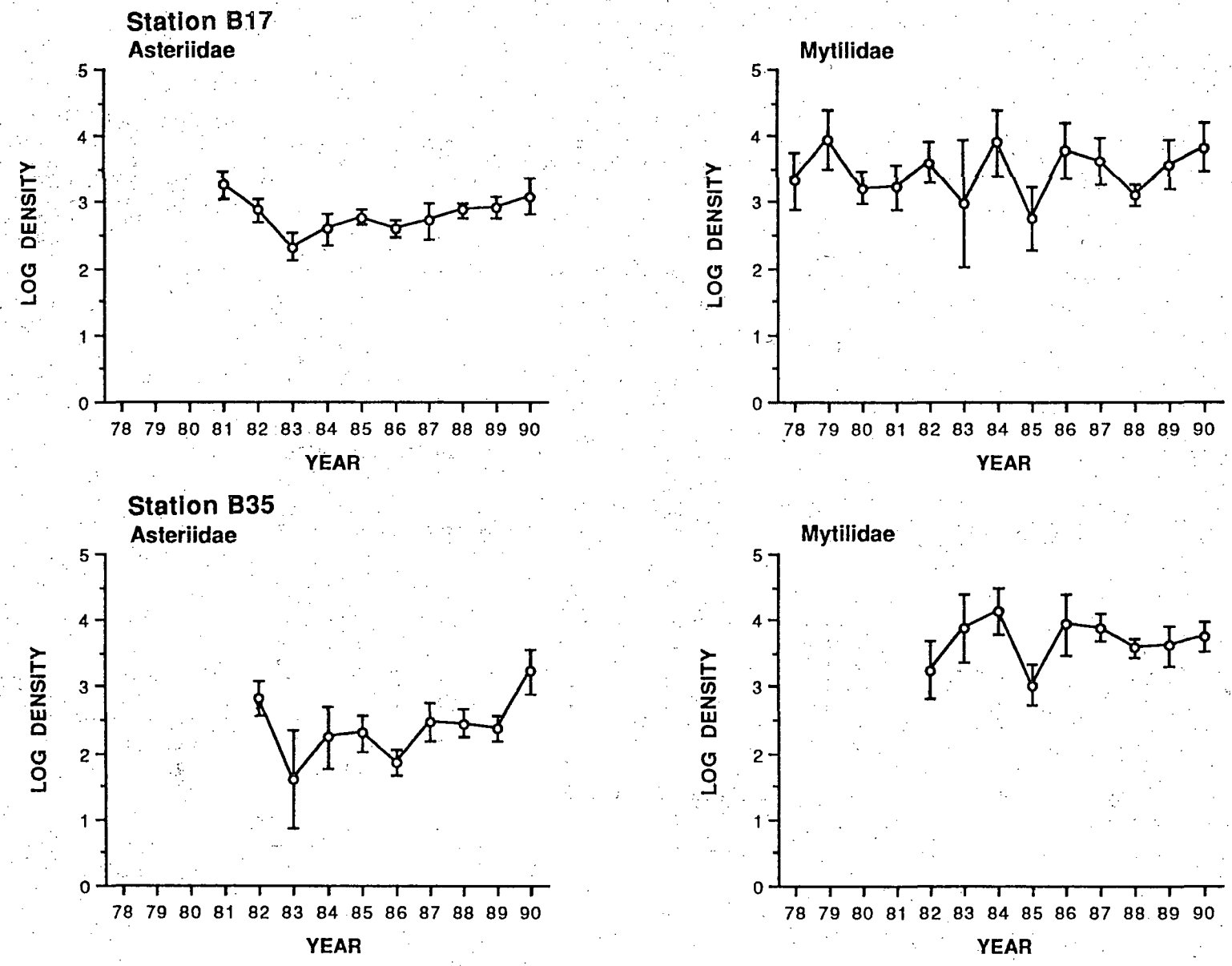


Figure 3.3.5-1. Yearly means and 95% confidence limits for the log (x+1) density (no./m^2) of Asteriidae and Mytilidae from Stations B17 and B35 sampled three times per year from 1978 through 1990. Seabrook Operational Report, 1990.

TABLE 3.3.5-3. ANNUAL MEAN LENGTH (MM) AND 95% CONFIDENCE INTERVAL FOR SELECTED BENTHIC SPECIES SAMPLED TRIANNUALLY IN MAY, AUGUST, AND NOVEMBER AT SELECTED BENTHIC STATIONS FROM 1982 THROUGH 1990. SEABROOK OPERATIONAL REPORT, 1990.

TAXA	STATION	1982		1983		1984		1985		1986		1987		1988		1989		PREOP.		1990	
		MEAN[a]	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
Mytilidae	1MLW	2.7	0.1	4.5	0.2	2.7	0.1	2.6	0.2	2.8	0.1	3.1	0.2	3.2	0.2	3.7	0.2	3.2	0.1	3.1	0.1
	5MLW	2.8	0.1	3.2	0.2	2.9	0.1	3.0	0.1	4.0	0.2	3.1	0.1	3.5	0.2	3.5	0.1	3.3	<0.1	3.5	0.1
	17	1.9	0.1	2.1	0.1	2.8	0.1	2.4	0.2	2.5	0.1	1.9	0.1	2.8	0.1	2.1	0.1	2.3	<0.1	2.2	0.1
	35	1.8	0.1	2.1	0.1	3.1	0.2	2.4	0.1	2.7	0.2	2.3	0.1	2.9	0.2	2.4	0.1	2.5	<0.1	2.5	0.1
	19	2.0	0.1	2.3	0.1	2.1	0.1	2.4	0.2	2.3	0.1	1.8	0.1	3.7	0.2	2.3	0.2	2.4	0.1	3.0	0.1
	31	2.2	0.2	1.9	0.1	2.1	0.1	3.5	0.1	4.1	0.3	2.0	0.1	2.4	0.1	4.0	0.2	2.8	0.1	2.7	0.2
Nucella lapillus	1MLW	8.0	0.3	3.3	0.2	4.0	0.2	5.0	0.3	7.7	0.5	11.9	0.6	11.5	0.6	8.5	0.4	6.9	0.2	5.4	0.4
	5MLW	5.7	0.5	6.2	0.6	6.9	0.6	6.3	0.5	6.2	0.5	4.3	0.4	7.1	0.6	5.2	0.6	6.0	0.2	5.9	0.6
Asteriidae	17	4.0	0.3	5.4	0.7	7.8	0.8	7.5	0.4	7.3	0.6	3.1	0.3	4.7	0.3	3.2	0.2	5.0	0.2	3.3	0.2
	35	5.3	0.5	11.4	3.4	5.7	0.9	10.1	1.0	13.1	2.6	4.6	0.6	8.4	0.6	6.0	1.0	6.7	0.3	3.0	0.2
Pontogeneia inermis	19	4.4	0.3	5.2	0.3	4.9	0.2	5.3	0.3	4.7	0.3	4.7	0.3	6.2	0.3	5.2	0.3	5.1	0.1	5.2	0.2
	31	4.6	0.2	5.2	0.3	4.6	0.2	5.8	0.3	5.2	0.2	5.6	0.4	5.7	0.2	5.6	0.3	5.3	0.1	6.0	0.4
Jassa marmorata	17	3.3	0.2	4.3	0.2	4.4	0.2	4.5	0.2	4.4	0.2	3.8	0.2	4.6	0.3	4.1	0.2	4.2	0.1	3.9	0.2
	35	3.5	0.2	3.7	0.2	3.7	0.1	4.5	0.2	4.1	0.2	3.5	0.1	4.4	0.2	4.2	0.2	3.9	0.1	4.0	0.2
Ampithoe rubricata	1MLW	6.7	0.3	7.7	0.6	6.9	1.5	10.9	4.1	-[b]	-	-	-	12.9	-	-	-	7.0	0.3	-	-
	5MLW	7.6	0.5	8.5	0.8	8.9	-	-	-	-	-	-	-	6.9	3.2	8.0	1.0	7.8	0.4	6.1	0.8
Strongylocentrotus droebachiensis	19	1.8	0.3	1.8	0.5	1.7	0.3	2.7	0.4	1.5	0.3	1.7	0.2	2.7	0.8	1.7	0.5	1.9	0.1	2.0	0.7
	31	1.7	0.2	2.3	0.3	1.7	0.2	2.5	0.6	1.5	0.2	1.7	0.3	2.3	0.4	1.2	1.9	1.9	0.1	2.3	0.5

[a]MEAN=SUM OF THE LENGTHS OF ALL INDIVIDUALS MEASURED IN MAY, AUGUST, AND NOVEMBER ÷ TOTAL NUMBER OF INDIVIDUALS MEASURED IN THAT YEAR

[b]NONE COLLECTED

ranged from about 4-6 mm at both stations (Figure 3.3.5-2), indicating that a smaller percentage of new recruits (1-2 mm) settled, and secondary settlement and growth occurred.

3.3.5.2 *Nucella lapillus*

Nucella lapillus reaches 51 mm in length (Abbott 1974), and is an abundant intertidal gastropod (drill) and an important predator, particularly on mytilid spat and barnacles (Gosner 1978). It ranges from eastern Long Island Sound to the Arctic, and also northern Europe (Gosner 1978). When 1990 mean densities were compared to the preoperational means at the intertidal station pair, the interaction term was not significant (Table 3.3.5-1,2). The 1990 densities at both stations were higher than the baseline averages. The nearfield density was within the range of previous years, and the farfield density was at the all time high (Table 3.3.5-1).

Nucella collected during 1990 ranged in length from about 1-27 mm, (NAI 1991) and averaged about 6-7 mm in length at both stations during the preoperational period. In 1990, mean length was below average (about 5.5 mm at both stations), but within the baseline ranges (Table 3.3.5-3). In 1987 and 1988, the mean length was unusually large due primarily to the occurrence of substantial numbers of large (14-18 mm) individuals. Previous studies have shown adult snails to be active only from May through October, retreating into crevices in the winter; while juveniles (2-5 mm) are more evenly dispersed throughout the year (Menge 1978).

3.3.5.3 Asteriidae

The Asteriidae collected are juveniles, too small to be assigned to genera. Two species of both *Asterias* and *Leptasterias* can

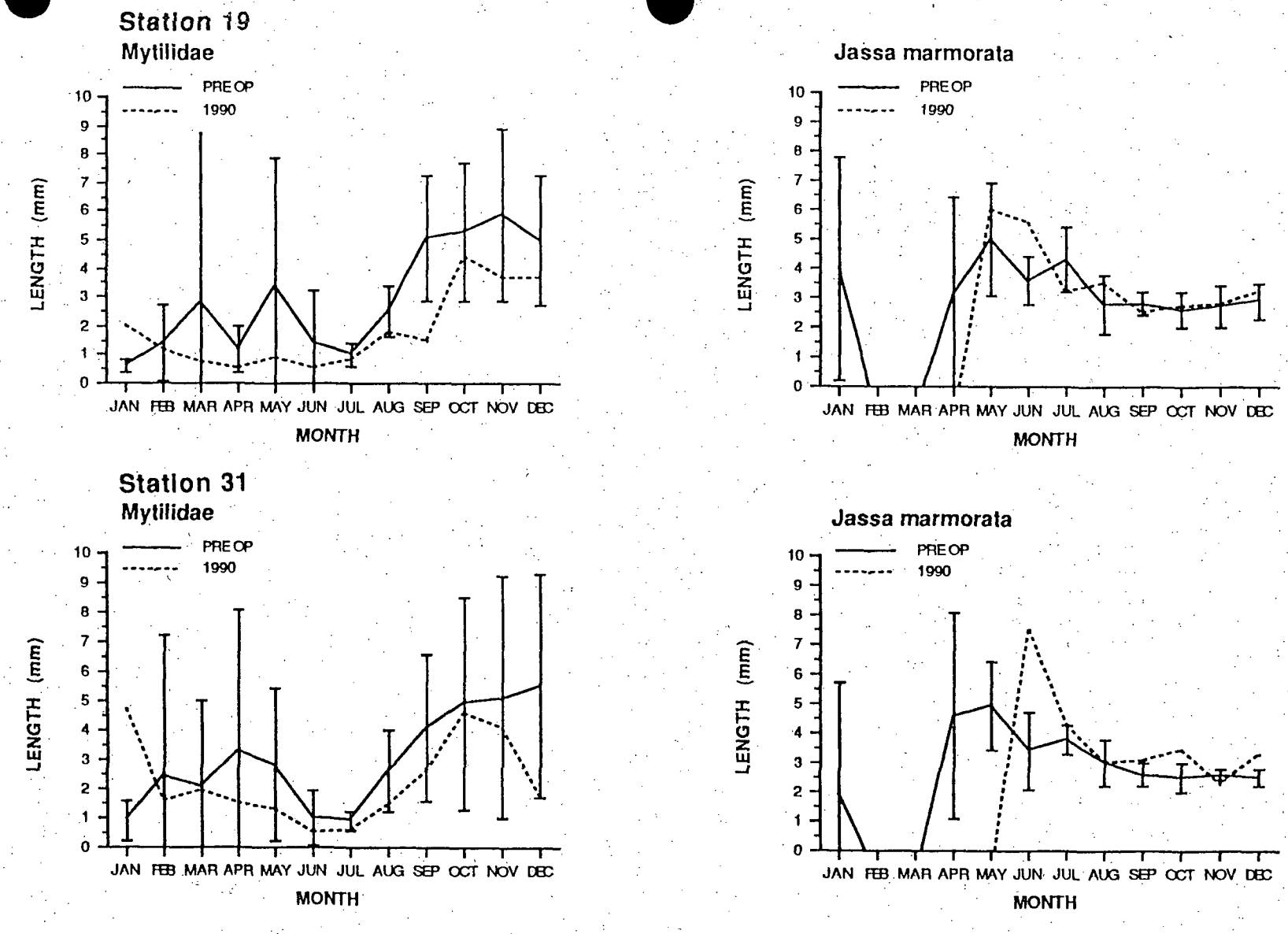


Figure 3.3.5-2. Mean length of Mytilidae and *Jassa marmorata* collected from monthly sequential surface panels in 1990, compared to mean and 95% confidence limits during preoperational period (1982-1989). Seabrook Operational Report, 1990.

occur within the study area (Gosner 1978). Asteriidae are important predators on bivalves, particularly on the recently-settled stages, as well as other mollusks and barnacles (Gosner 1978).

Asteridae densities at both near- and farfield stations were higher in 1990 than their baseline averages, but the farfield station had a much greater increase than the nearfield station (Table 3.3.5-1), as indicated by the significant Preop-Op X Station interaction term (Table 3.3.5-2). As in previous years, differences between stations and among years, were significant, with more sea stars usually occurring at the nearfield station. The 1990 density reached the all-time high at the farfield station (not sampled in 1981), and was exceeded only by the 1981 density at the nearfield station (Figure 3.3.5-1). The all-time low densities occurred in 1983 at both stations.

The preoperational average length at Station B17 was 5.0 mm, and at Station B35 it was 6.7 mm (Table 3.3.5-3). In 1990, the annual average length was only about 3 mm at both near- and farfield stations, due to large numbers of recently settled juveniles. Over 50% of the specimens collected were 1 mm or less at both stations, and most of these were collected in August (NAI 1991).

A few recently-settled Asteriidae were collected on short-term surface fouling panels from 1978 through 1990, and only occurred from July through October. All years except 1981 and 1990 had very low monthly densities, and averaged less than one specimen per panel per year. In 1990, as in 1981, a heavy set of sea stars (at least 28 per panel) occurred at Station B19 in September. Likewise, September 1990 numbers were somewhat elevated (7 per panel) at Station B31 (NAI 1991).

3.3.5.4 *Pontogeneia inermis*

Pontogeneia inermis (maximum length, 11 mm) is a pelagic, cold water amphipod (Bousfield 1973), and a dominant species in both benthic

and macrozooplankton collections (Section 3.1.5). It clings to submerged algae from the lower intertidal to depths greater than 10 m (Bousfield 1973). The 1990 densities at both near- and farfield stations were close to the baseline averages, and the interaction (Preop-Op X Station) was not significant (Table 3.3.5-1,2). Differences between stations were significant with the nearfield (B19) having a higher density than the farfield (B31) in most years (Table 3.3.5-1). Substrate preferences may provide an explanation, since *P. inermis* often clings to algae and Station B19 is about 60% algae covered and Station B31 has only about 30% coverage (Table 2.1-3).

During the preoperational period, ovigerous and brooding females have been collected in low numbers from January through September (NAI 1985b). Historically, recruitment, as indicated by a sharp increase in density and increased numbers in the 1 to 3 mm size class, has taken place between May and July. In fall and winter, abundance decreased, but average size increased as the population grew (NAI 1985b). The overall mean length for the preoperational period was 5.1 mm at Station B19 and 5.3 mm at Station B31, and the 1990 mean lengths were similar at the nearfield but larger than average at the farfield (Table 3.3.5-3).

3.3.5.5 *Jassa marmorata*

Jassa marmorata (formerly *J. falcata*) is a tube-building amphipod, and a dominant fouling organism on hard substrates in areas with strong tidal and wave currents (Bousfield 1973). It is a suspension feeder and also preys on small crustaceans. The 1990 annual densities of *Jassa* at both stations were lower than the preoperational means (Tables 3.3.5-1,2). No significant interaction occurred between 1990 and baseline averages at the near- farfield station pair (Table 3.3.5-2).

Most lifestages of *Jassa* were collected at Stations B17 and B35, ranging from gravid females to newly-hatched young (NAI 1985b). In 1990, no ovigerous specimens occurred in August, although they were taken in May and November. The baseline average length for the preoperational period was 4.2 mm at Station B17 and 3.9 mm at Station B35. In 1990, the yearly annual mean length at both stations was similar to the preoperational average (Table 3.3.5-3), and the length ranged from about <1 to 9 mm at both stations. In 1990, about 7% of the specimens were classified as ovigerous or with brood (NAI 1991).

Densities on short term fouling panels give an indication of recruitment or settlement activity (Section 3.3.4, Figure 3.3.4-6). During the preoperational period from 1978-1989, substantial numbers of young began appearing in June or July and continued to settle through October, and in some years through December (Section 3.3.4). The 1990 monthly pattern was similar to previous years at mid-depth stations, but at Station B19, densities were lower than preoperational monthly means. In 1990, settlement as indicated by the abundance of ≤1 mm size classes, began in June or July and was heaviest from September through December (NAI 1991). On monthly sequential panels in 1990, average monthly lengths were about 6-7 mm in late spring, and decreased to about 3 mm by December, indicating recruitment of young had occurred (Figure 3.3.5-2).

3.3.5.6 *Ampithoe rubricata*

Ampithoe rubricata (maximum length, 14-20 mm) is an amphi-Atlantic boreal amphipod that constructs a nest of tubes among macroalgae (fucoids) and in mussel beds (Bousfield 1973). It is found primarily in intertidal areas. Yearly densities have fluctuated significantly during the study period, and have steadily declined from about 1980 through 1987 (Table 3.3.5-1). The most dramatic decrease in density occurred at intertidal Station B1MLW where densities fell from $344/m^2$ in 1978 to near zero from 1987 through 1990 (Table 3.3.5-1). In

1988, populations at the farfield station showed a slight increase in abundance that continued through 1990. Densities in 1990 were lower than average at B1MLW, but higher than average at B5MLW, as reflected by the significant Preop-op X Station interaction (Table 3.3.5-2).

Ovigerous and brooding females were rare, but during the preoperational period were collected from April through September (NAI 1985b). The largest numbers of small (1-3 mm) individuals were collected from April through September, suggesting recruitment occurred during this time period. In 1983 and 1984, recruitment appeared depressed, accounting for both lower overall densities and larger mean size (NAI 1985b), and the trend continued through 1990. The overall mean length for the preoperational period was 7.0 mm at Station B1MLW, and 7.8 mm at Station B5MLW (Table 3.3.5-3). In 1990, the average length measured 6.1 mm at B5MLW, and no *Ampithoe* were present at the nearfield station.

3.3.5.7 *Strongylocentrotus droebachiensis*

Strongylocentrotus droebachiensis, the green sea urchin, reaches 75 mm in diameter, and is an important prey species for lobsters, cod and other fish, and sea stars (Gosner 1978). It is an omnivore, but prefers grazing on *Laminaria saccharina* over other common algal species (Larson *et al.* 1980; Mann *et al.* 1984). When the macroalgae supply is depleted, it will prey on *Mytilus edulis* (Briscoe and Sebens 1988). It is subject to population "explosions" that can denude large areas of macroalgae, leaving barren rock (Breen and Mann 1976). Although average abundances during the preoperational period at B19 were double those at B31 (Table 3.3.5-1) these inter-station differences are not significant. Density in 1990 was lower at each station, but at the nearfield station, the difference was greater, as indicated by the significant interaction (Table 3.3.5-1,2). The 1990 differences were not restricted to the operational period (August, November).

Most of the individuals collected subtidally were juvenile, measuring less than 3 mm in diameter. Recruitment of newly-settled young through 1984 has historically occurred in August and September (NAI 1985b). The average length for the 1982 through 1989 pre-operational period was 1.9 mm at both stations. 1990 average lengths were 2-2.3 mm (Table 3.3.5-3). The average yearly length ranged from 1.2 mm at Station B31 in 1989 to 2.7 mm at Station B19 in 1985 and in 1988.

In order to account for adult individuals that were too large to be collected in the benthos sampling program, sea urchins were enumerated by SCUBA divers in the subtidal transect program. No more than a total of 13 large (>10 mm) sea urchins per year were counted ($0.02/m^2$) in the first three years of sampling (NAI 1986a, 1987a, 1988a). However, in 1988 there was an increase to a total of 32 observed ($0.06/m^2$ annual density for entire study area), and the increase was sustained through 1989 (NAI 1989a, 1990a). The gradual increase continued into 1990, when the annual density for the entire study area was $0.14/m^2$. The increase was due to the large number observed in July at farfield Station 35, and was not sustained into the fall (NAI 1991). The extremely low densities of adult urchins in comparison to juveniles indicate that natural forces are keeping this potential nuisance species under control.

3.3.6 Epibenthic Crustacea

3.3.6.1 American Lobsters (*Homarus americanus*)

Lobster Larvae

Lobster larvae have been relatively rare during the thirteen-year study period at Station P2. Mean density of lobster larvae at the intake site was highest in 1978 ($1.45/1000\ m^2$) and lowest in 1980 ($0.46/1000\ m^2$) during the 1978-1989 period (Table 3.3.6-1). The mean number of lobster larvae caught in 1990 ($5.04/1000\ m^2$) at Station P2,

TABLE 3.3.6-1. NUMBER, PERCENT COMPOSITION AND MEAN DENSITY OF LOBSTER LARVAE BY LIFESTAGE AT STATIONS P2, P5 AND P7, 1978-1990. SEABROOK OPERATIONAL REPORT, 1990.

YEAR	STATION[a]	PERCENT PER STAGE I	II	III	IV	TOTAL % OF STAGES I AND IV	NO. OF LARVAE COL-LECTED	MEAN DENSITY NO./1000m^2
1978	P2	10.1	0.0	0.6	89.3	99.4	169	1.45
1979	P2	70.8	2.5	1.7	25.0	95.8	120	1.18
1980	P2	86.5	0.0	0.0	13.5	100.0	57	0.46
1981	P2	31.8	1.9	6.5	59.8	91.6	107	0.86
1982	P2	3.2	0.0	0.0	96.8	100.0	161	1.17
	P7	3.8	0.0	0.5	95.6	99.4	185	1.32
1983	P2	41.4	0.8	4.9	52.9	94.3	115	0.79
	P7	47.5	0.6	3.5	48.4	95.9	162	1.10
1984	P2	14.6	11.5	21.8	52.1	66.7	79	0.57
	P7	37.2	1.0	2.8	59.0	96.2	101	0.73
1985	P2	1.5	2.9	2.9	92.6	94.1	68	0.85
	P7	7.0	2.1	2.1	88.8	95.0	143	1.91
1986	P2	--	--	1.4	98.6	98.6	69	0.84
	P5	3.5	--	--	96.5	100.0	102	1.79
	P7	21.6	--	--	78.4	100.0	156	2.01
1987	P2	13.0	--	1.4	85.5	98.5	69	0.92
	P7	7.5	--	--	92.5	100.0	146	1.94
1988	P2	20.3	2.9	5.8	71.0	91.3	69	0.84
	P5	20.4	7.4	13.9	58.3	78.7	108	1.34
	P7	5.9	2.0	--	92.2	98.1	51	0.66
1989	P2	8.3	0.0	0.0	91.7	100.0	72	0.91
	P5	0.0	0.0	0.0	100.0	100.0	199	2.48
	P7	0.0	0.0	0.0	100.0	100.0	85	1.09
1990	P2	16.6	4.1	3.0	76.3	92.9	367	5.04
	P5	6.1	0.7	0.7	92.6	98.7	444	6.44
	P7	33.9	1.6	2.5	62.0	95.9	434	5.71

[a] = In 1986, Station P5 sampled only from July 1 through October 14.

however, was nearly 3.5 times greater than in 1978. The maximum density of lobster larvae usually occurred from July through September (Figure 3.3.6-1). During 1990, lobster larvae first appeared in late June at Station P2, a trend which was similar to other sampling years, and peaked in early July and again in mid-August. No larvae were collected after August in 1990 (Figure 3.3.6-1).

At the farfield sampling site, Station P7, the density of lobster larvae declined from 1982 through 1984, then steadily increased through 1986, which up to that year was the highest level recorded in this study (Table 3.3.6-1). In 1988, however, the density of larvae fell to 0.66/1000 m^2, the lowest level since this station has been sampled. Density in 1989 increased to moderate levels of 1.09/1000 m^2. However, in 1990, the mean density was 5.71/1000 m^2, nearly three times greater than in 1986. With the exception of 1988, densities have historically been higher at Station P7 than P2. This difference was most pronounced in 1985, 1986 and 1987, when abundances at Station P7 were more than twice those at Station P2. In 1988, however, densities at P7 were lower than at P2. Mean density in 1990 at Station P7 was greater than that at P2. Larvae first appeared at Station P7 in early June and peaked in early August during 1990. No larvae were collected after August (NAI 1991).

In 1986, P5, located in the vicinity of the discharge structure, was added to the sampling regime. This station was sampled only from July 1 through October 14, 1986 and for the entire sampling program in 1988, 1989 and 1990. In 1990, the density observed was 6.44/1000 m^2, the highest density at all three stations and the greatest density over all sampling years. Prior to 1990, the highest density of larvae had occurred at Station P5 in 1989 (2.48/1000m^2). Lobster larvae were more abundant at Station P5 than at Stations P2 or P7 from 1988 through 1990, three out of the four years Station P5 was sampled. Larvae at Station P5 in 1990 first appeared in early June and peaked in early August, much like Stations P2 and P7. No larvae were collected after August in 1990 (NAI 1991).

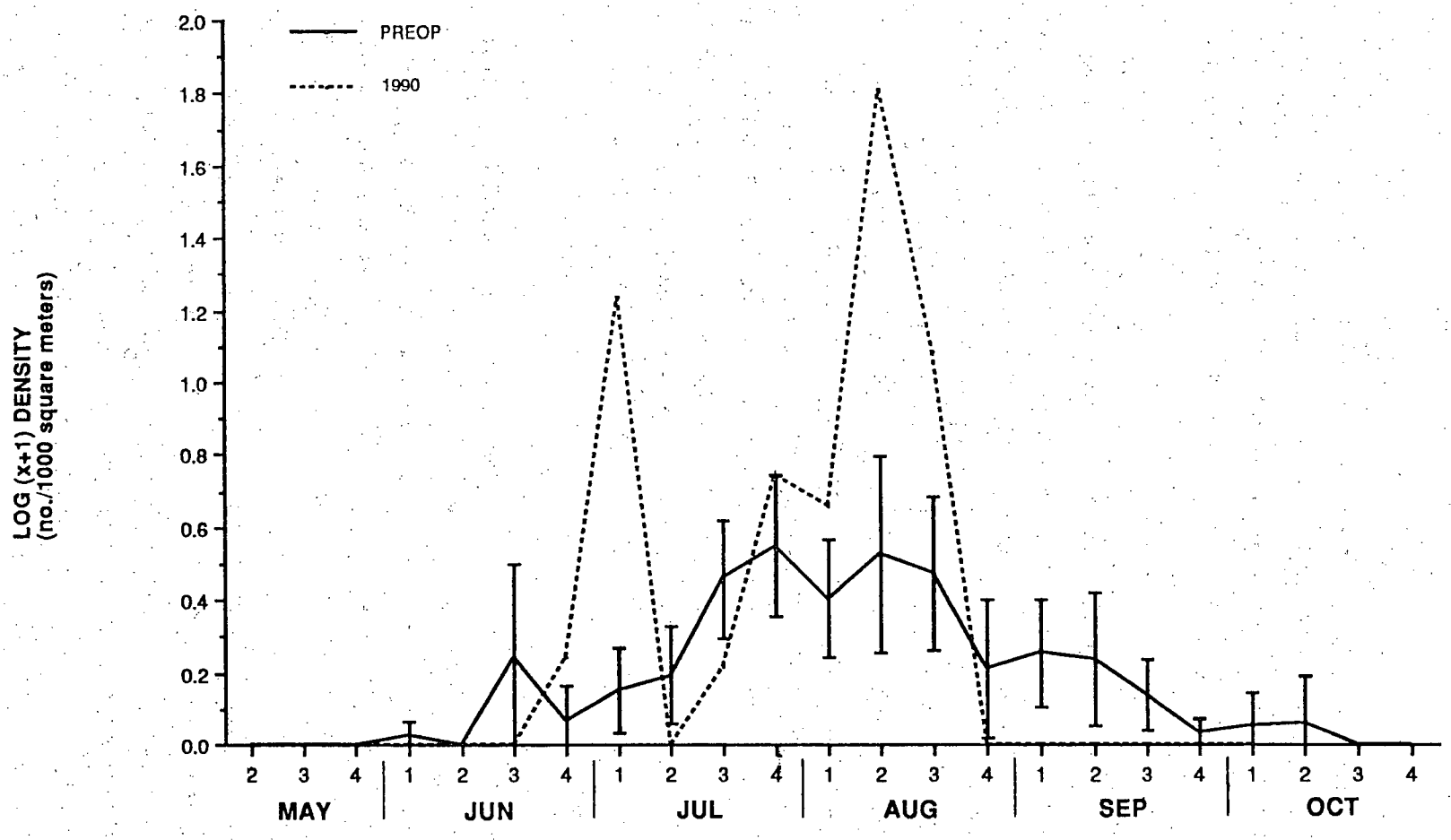


Figure 3.3.6-1. Weekly mean log (x+1) density (no./1000 m^2) of lobster larvae at Station P2 in 1990 compared to all years' mean and 95% confidence interval during the preoperational period (1978-1989). Seabrook Operational Report, 1990.

Analysis of variance results indicate that densities in 1990 were significantly higher than previous years (Table 3.3.6-2). This difference was not restricted to the operational period (August-December) but occurred during the entire sampling year (May-October). Densities were statistically similar at intake, discharge, and farfield areas.

Historically, Stage I and IV larvae have dominated the collections at both Stations P2 and P7, with few Stage II or III larvae collected (Table 3.3.6-1). Stage I larvae dominated the collections in 1979 and 1980, while Stage IV larvae dominated the collections in all other years. Stage II and III larvae collectively constituted 8.7% or less of the larvae collected for all years except in 1984, when they made up 33% and 21% of the total densities at Stations P2 and P5, respectively (Table 3.3.6-1). In 1989, at Station P2, a few Stage I larvae were collected; but more than 90% of the larvae were Stage IV. At Station P5 and P7, only Stage IV larvae were collected (Table 3.3.6-1). During 1990, 93% or more of the larvae collected were either Stage I or State IV at all stations. At Station P7, 33% of the larvae were Stage I (Table 3.3.6-1).

Generally, lobster larvae densities have peaked for all years between late July and mid-August (Figure 3.3.6-1). Stage I larvae usually first appeared in late May or June in low numbers at Stations P2 and P7. Peak density of Stage IV larvae varied in occurrence between July and August (NAI 1988b). The variation in larval density between years may be due, in part, to low larval densities and the patchy distribution (Cobb 1976). Seasonal occurrences of lobster larvae Stages I and IV at all stations in 1990 were generally consistent with previous years. Stage I larvae at Station P2 were first observed in late June, but slightly earlier at Stations P5 and P7. Stage IV larvae appeared at all three stations in late July. Large numbers of Stage I larvae in early July, particularly at Station P7, and even larger numbers of Stage IV larvae in early August at all stations resulted in the collection of

TABLE 3.3.6-2. RESULTS OF ANALYSIS OF VARIANCE COMPARING DENSITIES OF LOBSTER LARVAE COLLECTED AT INTAKE, DISCHARGE, AND FARFIELD STATIONS, AND CATCHES OF TOTAL AND LEGAL SIZED LOBSTERS, JONAH CRAB, AND ROCK CRAB AT THE DISCHARGE STATION AND RYE LEDGE. SEABROOK OPERATIONAL REPORT, 1990.

SPECIES	SOURCE OF VARIATION	ALL MONTHS df	ALL MONTHS SS[a]	ALL MONTHS F[b]	OPERATIONAL MONTHS df	OPERATIONAL MONTHS SS[a]	OPERATIONAL MONTHS F[b]
			MAY - OCTOBER			AUGUST - OCTOBER	
Lobster larvae	Preop-Op	1	0.84	5.81**	1	0.79	5.08*
	Station	2	0.0008	0.00 NS	2	0.01	0.03 NS
	Preop-Op X Station	2	0.027	0.10 NS	2	0.023	0.08 NS
	Year (Preop-Op)	1	0.001	0.01 NS	1	0.43	2.80 NS
	Error	191	26.81		92	13.51	
Lobster larvae (P2 only)	Preop-Op	1	0.40	4.21*	1	0.42	4.27*
	Year (Preop-Op)	11	5.42	5.13***	11	5.19	4.73***
	Week (Preop-Op)	40	16.84	4.38***	19	9.24	4.88***
	Error	320	30.74		162	16.17	
			JUNE - NOVEMBER			AUGUST - NOVEMBER	
Lobster (total catch)	Preop-Op	1	26,145.10	26.40***	1	18,415.82	13.93***
	Station	1	26,954.22	27.22***	1	44,110.46	33.36***
	Preop-Op X Station	1	24.50	0.02 NS	1	286.28	0.22 NS
	Year (Preop-Op)	7	147,389.09	21.26***	7	205,119.70	22.16***
	Month (Preop-Op (Year))	45	1,411,246.34	31.66***	27	425,260.84	11.91***
	Error	1115	1,104,312.90		721	953,348.19	
Lobster (legal size)	Preop	1	1,262.88	104.72***	1	1,264.75	89.93***
	Station	1	1.23	0.10 NS	1	0.33	0.02 NS
	Preop-Op X Station	1	0.21	0.02 NS	1	1.83	0.13 NS
	Year (Preop-Op)	7	3,647.79	43.21***	7	3,185.51	32.36***
	Month (Preop-Op (Year))	45	6,965.41	12.83***	27	2,122.52	5.59***
	Error	1115	13,459.09		721	10,154.23	
Jonah crab	Preop	1	45.98	0.55 NS	1	228.48	2.27 NS
	Station	1	3,804.06	45.66***	1	3,589.53	35.60***
	Preop-Op X Station	1	893.39	10.72**	1	656.13	6.51*
	Year (Preop-Op)	7	15,301.34	26.24***	7	12,778.09	18.11***
	Month (Preop-Op (Year))	45	60,876.31	16.24***	27	44,784.66	16.45***
	Error	1094	91,139.90		712	71,787.38	
Rock crab	Preop	1	599.98	45.90***	1	4.41	0.54 NS
	Station	1	15.78	1.21 NS	1	103.02	12.64*
	Preop-Op X Station	1	32.68	2.50 NS	1	0.01	0.00 NS
	Year (Preop-Op)	7	3,169.06	34.64***	7	1,224.04	21.46***
	Month (Preop-Op (Year))	45	5,057.76	8.60***	45	2,708.96	12.31***
	Error	1094	14,299.45		712	5,801.84	

[a]Preop-Op = Preoperational period (Lobster Larvae, all stations: 1988, 1989; P2 only, 1980-1989; Adult lobster and crabs: 1982-1989) vs. 1990 regardless of Station or month.
Station = Station differences)Lobster Larvae: P2, P5, P7; Adult lobster: Discharge and Rue Ledge) regardless of year, month or period.
Preop-Op X Station = Interaction of main effects.
Year (Preop-Op)-= Year nested within preoperational and operational periods regardless of year, month or Station.
Month (Preo-Op (Year)) = Month nested within Preop-Op and Year, regardless of Station.
[b]NS = Not significant
* = Significant (p>0.05)
** = Highly significant (0.05≥p>0.01)
*** = Very Highly Significant (0.001≥p)

1245 larvae, 3.5 times greater than 1989, the most abundant collection of larvae since all three stations have been collected (Table 3.3.6-1).

Eighty-six percent of the larvae collected in 1990 were observed on two dates: July 2 and August 13 (NAI 1991). Unusually large aggregations of lobster larvae have been associated with convergence areas and sea fronts (Cobb 1983). This may have been a factor in the large numbers of larvae in 1990, although no evidence of a convergence area was observed at the time of collection. Warmer than average temperatures throughout the study area may also have contributed to large numbers of larvae. Figure 3.1.1-1 shows that surface and bottom temperatures were on average warmer at Station P2 in 1990 compared to the 1978-1989 period, particularly during June and August and continuing through the end of the year. Since the collection of such large numbers of larvae occurred at all stations on the same dates in July and August, the seasonally warmed waters of the study area may have provided an optimum condition for larvae. Other factors such as food availability and light intensity may have also contributed to this occurrence. Studies have also indicated that light intensity may influence lobster larvae distribution. Harding et al. (1987) reported that Stage I larvae were photopositively influenced by a maximum light intensity, while Stage IV larvae appeared to show no significant differences between day and night abundances in offshore waters. The high catches may also have simply been a fortuitous capture of larvae which despite their relative rarity, have a patchy distribution.

In contrast to the above, a New Hampshire Fish and Game study (1991) found few lobster larvae in the Piscataqua River-Great Bay estuarine area north of this study area in 1989 and 1990. The few larvae collected were taken during mid-July to mid-August, coinciding with occurrences of larvae for this study.

Historically, trends in the occurrence of lobster larvae in this study have generally agreed with other lobster larvae studies in

New England (Sherman and Lewis 1967; Lund and Stewart 1970). An extensive review of New England regional lobster larvae studies (Fogarty and Lawton 1983) indicated that the period of peak abundance coincided with that observed off New Hampshire waters as described by this study. The long-term variability in the predominance of Stage I and Stage IV larvae observed off coastal New Hampshire has also been documented in other New England studies (Fogarty and Lawton 1983). Abundances and occurrence of lobster larvae in inshore areas have been associated with wind direction. Grabe et al. (1983) reported that 67% of Stage IV larvae were collected off the New Hampshire coast when winds were on- or alongshore. Air temperature differences between water and land masses, combined with predominantly light westerly summer winds, produced onshore winds during the day and offshore winds at night. In addition, hydrographic studies in the Hampton/Seabrook area indicated a net drift northward or southward along the New Hampshire coastline. Combined, these two actions suggested that lobster larvae may be moved by nontidal water mass movements into New Hampshire waters and then transported onshore by winds.

A synthesis of lobster larvae distribution studies by Harding et al. (1983) supports this explanation. They noted that lobster landings for all regions neighboring on the Gulf of Maine have been very similar since the mid-1940s, and concluded that a single lobster stock with common recruitment exists. They further concluded that warm southwestern waters of the Gulf of Maine and Georges Bank supply the Maine coast and adjoining areas with advanced larval stages, evidenced by a preponderance of Stage IV larvae in the surface waters from southwestern Nova Scotia to Hampton, New Hampshire. A recent examination of hydrographic drift studies (Harding and Trites 1988) also supports the suggestion that lobster larvae are carried into the New England region through current transport.

Adults

Total lobsters (legal and sublegal sizes combined) have been collected in the vicinity of the discharge site (L1) from 1975 to 1990 (Table 3.3.6-3). During that period, high monthly catches usually occurred from August through November. However, catches were usually highest in September and October. Data from 1945 to 1973 reported by the New England Fishery Management Council (1983) for the Maine lobster fishery also indicate August, September and October as peak months in lobster abundance. Average yearly catches per fifteen-trap trips at the discharge station ranged from 46.0 to 93.0. The average yearly catch for 1990 was 88.1 per fifteen-trap trip, significantly higher than previous years at both discharge and farfield stations (Table 3.3.6-2). This is consistent with increased lobster landings reported for New Hampshire as well as the New England region (NOAA 1991b).

Among stations, lobster catch was significantly greater at the farfield station (L7) than at the discharge site (L1) (Table 3.3.6-2). The pattern of peak monthly abundances and the greater abundance of lobster catch at the farfield station has been consistent throughout the study since sampling at Station L7 was begun in 1982.

Adult lobster abundances have been related to seawater temperature (McLeese and Wilder 1958, Dow 1969, Flowers and Saila 1972, and NAI 1975b). Low temperatures act in two ways to reduce lobster catches. Low winter temperatures may increase mortality of first year juveniles, leading to lower adult catches after a 6 to 8 year lag period. Low temperatures in the first half of the year may also affect timing and magnitude of molting and decrease catchability, reducing catches of adult lobsters (Dow 1969). In the Hampton/Seabrook study area, bottom temperatures, continuously monitored from 1978-1984 near the discharge area, were significantly correlated with lobster catches in only two of the six months sampled. In June, catch declined as bottom water temperature increased, probably caused by the onset of molting, which

TABLE 3.3.6-3. MONTHLY, ANNUAL, AND PREOPERATIONAL MEAN AND UPPER AND LOWER 95% CONFIDENCE LIMITS OF TOTAL AND LEGAL-SIZE LOBSTER CATCH PER TRIP EFFORT AT THE DISCHARGE SITE FROM 1975-1990 SEABROOK OPERATIONAL REPORT, 1990

TOTAL

		MONTH								
		JUN	JUL	AUG	SEP	OCT	NOV	LOWER	ALL	UPPER
PREOP	1975	41.1	42.5	73.9	74.2	71.6	55.2	55.5	59.9	64.3
	1976	35.0	40.7	68.9	69.8	63.7	48.0	50.5	54.5	58.6
	1977	46.1	29.8	63.4	67.3	54.5	61.3	48.6	53.0	57.4
	1978	49.7	35.6	63.4	87.2	79.1	65.5	57.9	63.2	68.5
	1979	54.1	57.6	61.5	68.1	69.9	58.8	58.9	61.5	64.0
	1980	33.2	30.2	70.4	59.6	41.5	43.4	42.8	47.5	52.2
	1981	38.0	43.3	80.5	94.2	65.7	59.3	56.7	62.6	68.6
	1982	35.7	52.3	83.8	71.7	88.8	79.1	60.6	67.5	74.5
	1983	49.2	39.9	89.3	128.2	96.3	29.6	59.5	70.0	80.4
	1984	49.9	28.2	72.1	117.9	146.6	140.5	79.6	93.0	106.4
	1985	25.4	45.2	81.3	121.3	131.2	130.4	74.8	86.6	98.4
	1986	35.5	42.7	86.0	96.4	86.1	106.0	65.1	73.4	81.6
	1987	39.5	26.3	33.3	57.2	83.2	48.1	38.7	46.0	53.3
	1988	41.5	32.8	69.4	98.9	84.5	73.2	58.1	65.5	72.8
	1989	42.4	40.3	46.4	110.5	79.0	67.5	55.3	63.7	72.0
	LOWER	38.9	37.1	65.9	82.6	76.2	64.5			
	ALL	41.1	39.4	69.6	87.2	81.7	70.2	62.1	64.1	66.1
	UPPER	43.3	41.6	73.3	91.8	87.2	75.9			
OP	1990	63.2	55.6	89.0	114.7	108.6	101.3	79.2	88.1	97.0

LEGAL-SIZE

		MONTH								
		JUN	JUL	AUG	SEP	OCT	NOV	LOWER	ALL	UPPER
PREOP	1975	2.7	5.4	9.5	8.0	10.0	10.1	6.6	7.6	8.5
	1976	3.3	8.9	10.3	7.5	9.2	10.3	7.4	8.2	9.1
	1977	5.9	3.5	13.9	9.9	7.3	9.4	7.1	8.2	9.3
	1978	7.1	4.0	13.1	14.5	11.4	9.4	8.8	9.9	11.1
	1979	6.1	8.4	8.8	8.8	12.4	11.3	8.5	9.2	9.9
	1980	3.0	4.5	12.5	7.3	6.3	7.7	6.0	7.0	8.0
	1981	4.7	8.9	11.1	12.5	10.0	10.9	8.3	9.5	10.7
	1982	2.1	9.6	9.7	7.6	10.0	8.5	6.6	8.0	9.3
	1983	2.5	4.6	10.9	7.0	13.8	4.2	5.5	6.9	8.4
	1984	2.3	1.8	11.0	4.3	10.8	9.0	5.5	6.9	8.2
	1985	1.4	8.6	5.9	7.7	7.8	7.6	5.5	6.5	7.4
	1986	3.6	6.8	7.1	6.7	8.9	12.3	6.2	7.2	8.1
	1987	2.0	1.7	4.8	3.3	3.6	3.2	2.5	3.1	3.6
	1988	2.0	2.7	7.9	5.5	4.8	11.5	4.6	5.7	6.7
	1989	2.6	2.7	3.3	5.8	3.1	3.9	2.9	3.5	4.2
	LOWER	3.1	4.9	8.7	7.3	7.9	8.0			
	ALL	3.5	5.5	9.4	7.9	8.6	8.6	6.9	7.2	7.5
	UPPER	4.0	6.2	10.1	8.6	9.3	9.2			
OP	1990	2.3	1.4	3.4	2.6	3.1	2.3	1.9	2.6	3.2

NOTE: Lower and upper represent the 95% confidence limits around the monthly and yearly mean.

would reduce the catchability of lobsters. Peak catch of adult lobsters usually occurred after bottom water temperatures reached approximately 10°C and lobsters had molted to legal size (NAI 1985b). As bottom temperatures cooled, catch declined in November, perhaps reflecting seasonal inshore movement patterns (Ennis 1984) or decreased activity level. Lobsters typically show a seasonal migration pattern which is thought to maintain the population at the highest local water temperature (Campbell 1986). It is uncertain, however, whether New Hampshire lobsters undergo seasonal migrations (NHFG 1974). The New Hampshire Fish and Game Department conducted similar studies off the New Hampshire coast and concluded that bottom water temperature did affect lobster catch, along with other factors such as molting and food availability (NHFG 1974).

Variations in catches of legal-sized lobsters can be related to fluctuations in total catch as well as changes in the definition of a legal-sized lobster. In 1984, an increase in the legal size limit from 79 mm (3 1/8") to 81 mm was enacted, followed by a second increase to 82 mm (3 7/32") in 1989. Legal size was increased again in 1990 to 83 mm (3 1/4 "). Monthly catches of legal-sized lobsters have ranged from less than 2 to about 14 individuals per 15-trap trip from 1979-1990 (Table 3.3.6-3). Significant differences in annual catches of legal-sized lobsters were detected (Table 3.3.6-2). Total catches of legal-sized lobsters prior to 1984 were generally higher than those after the change in legal-size limit (Table 3.3.6-3). The proportion of legal sized lobsters, which averaged 14% of the total catch in 1984, decreased slightly after the first change in legal size limit to 7-10%. More dramatic decreases were noted in a study by the New Hampshire Fish and Game Department (Grout et al. 1989), where legal catches decreased by 33% in 1984. However, only 6% of the decrease was due to the change in size limit and the rest was due to lower than average catches throughout New England. In that study, percentages of legal-sized lobsters dropped from 28% of the total catch in the five months prior to the legal size change to 18% in the subsequent two years. In 1989, after the second size limit change, legal size catches decreased to nearly half of the

1988 level, and composed only 5% of the total catch. During 1990, legal size catches were the lowest recorded to date (2.6); only 3% of the total catch were of legal size (Table 3.3.6-3; Figure 3.3.6-2). Legal catches in 1990 were significantly lower than previous years at both the discharge station and Rye Ledge (Table 3.3.6-2).

Changes in the size class distribution in 1984, 1985, and 1990 show the effects of the changes in legal-size limits. The 79-92 mm size class was composed solely of legal-sized lobsters prior to 1984, but since that time has contained in part individuals protected by the new legal size limits (Figure 3.3.6-3). Proportions of lobsters measuring 79-92 mm have increased since 1984 from 11% to 17% of the total catch, reflecting an increase in CPUE of this size class from 6.8 to 12.4. These changes suggest that new size limits for fishing have allowed the survival of some of the lobsters in this size class. Since 1987, an increase in the <54 and 54-67 mm size classes is also evident.

Female lobsters made up slightly more than half of the total lobster population. In 1990, female lobsters composed 54% of the total catch at the discharge station. This is similar to the 1984-1989 period which ranged from 54-56%. Prior to 1984, females composed nearly 60% of the catch for most years, ranging from 55% in 1981 to 62% in 1978 (Figure 3.3.6-4). NHFG studies found that females constituted 52% of the total legal-sized population (Grout et al. 1989).

Egg-bearing female lobsters represented a small component of the lobster population for 1990; berried females composed 0.6% of the total catch at the discharge station. The percent of egg-bearing female lobsters has been quite variable, ranging from 0.5% in 1977 to 1.5% in 1975. Changes in legal size limits for fishing do not appear to have affected the proportion of egg-bearing females. NHFG studies (Grout et al. 1989) found that 0.3% of the total lobsters examined during lobster surveys from 1983-1985 were berried.

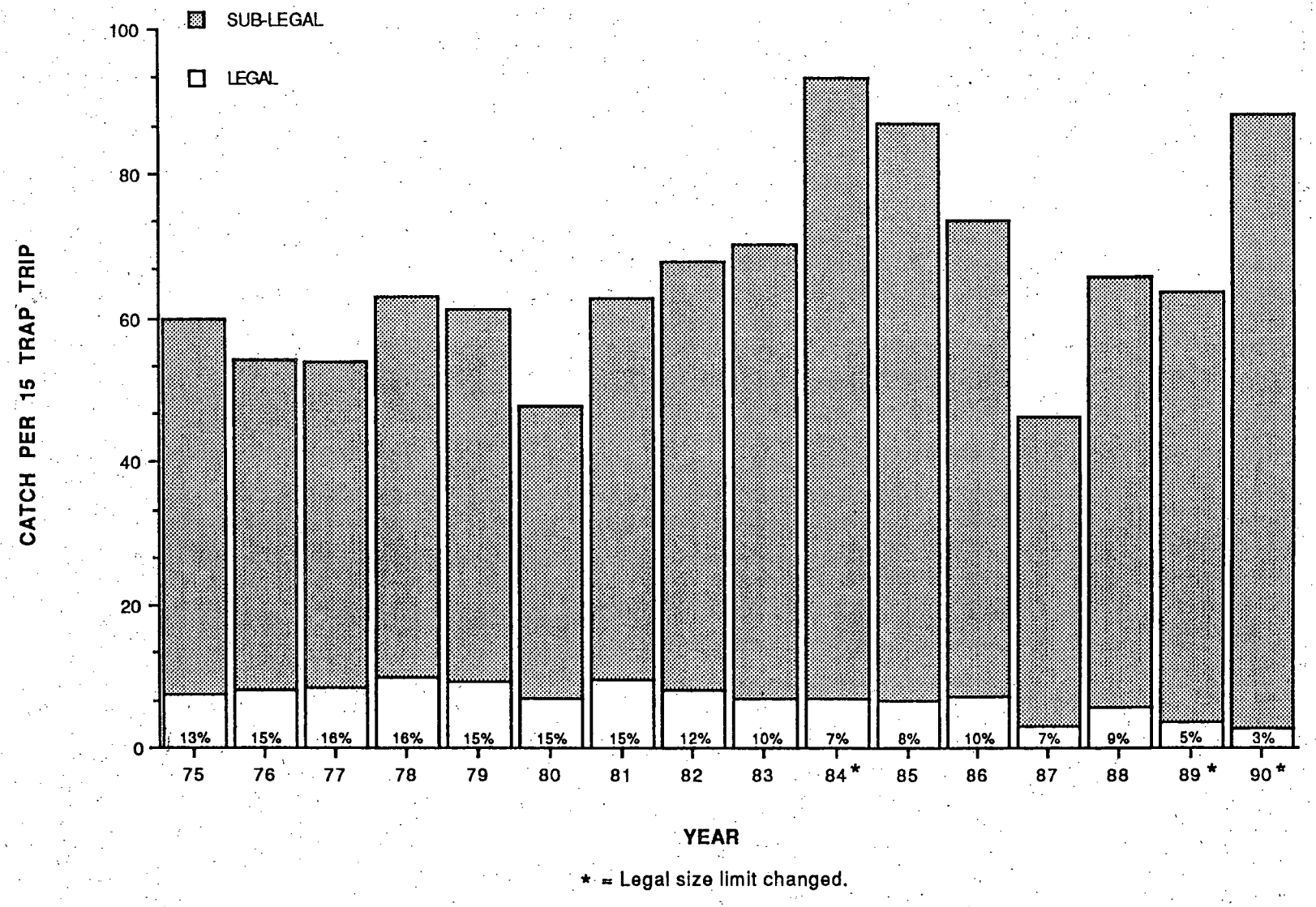


Figure 3.3.6-2. Comparisons of legal and sub-legal sized catch of *Homarus americanus* at the discharge site, Station L1, 1975-1990. Seabrook Operational Report, 1990.

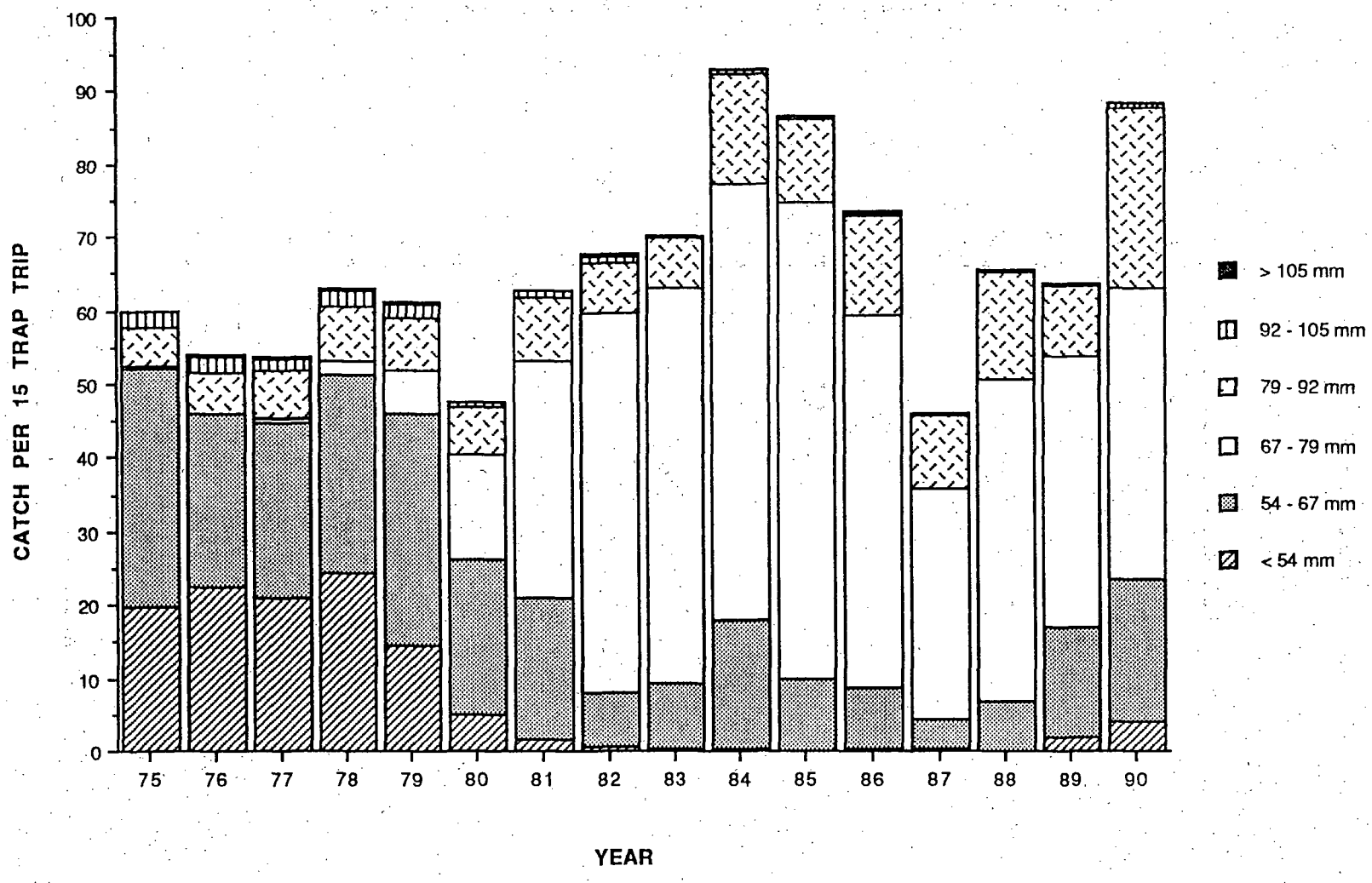


Figure 3.3.6-3. Size-class distribution (carapace length) of *Homarus americanus* at the discharge site, Station L1, 1975-1990. Seabrook Operational Report, 1990.

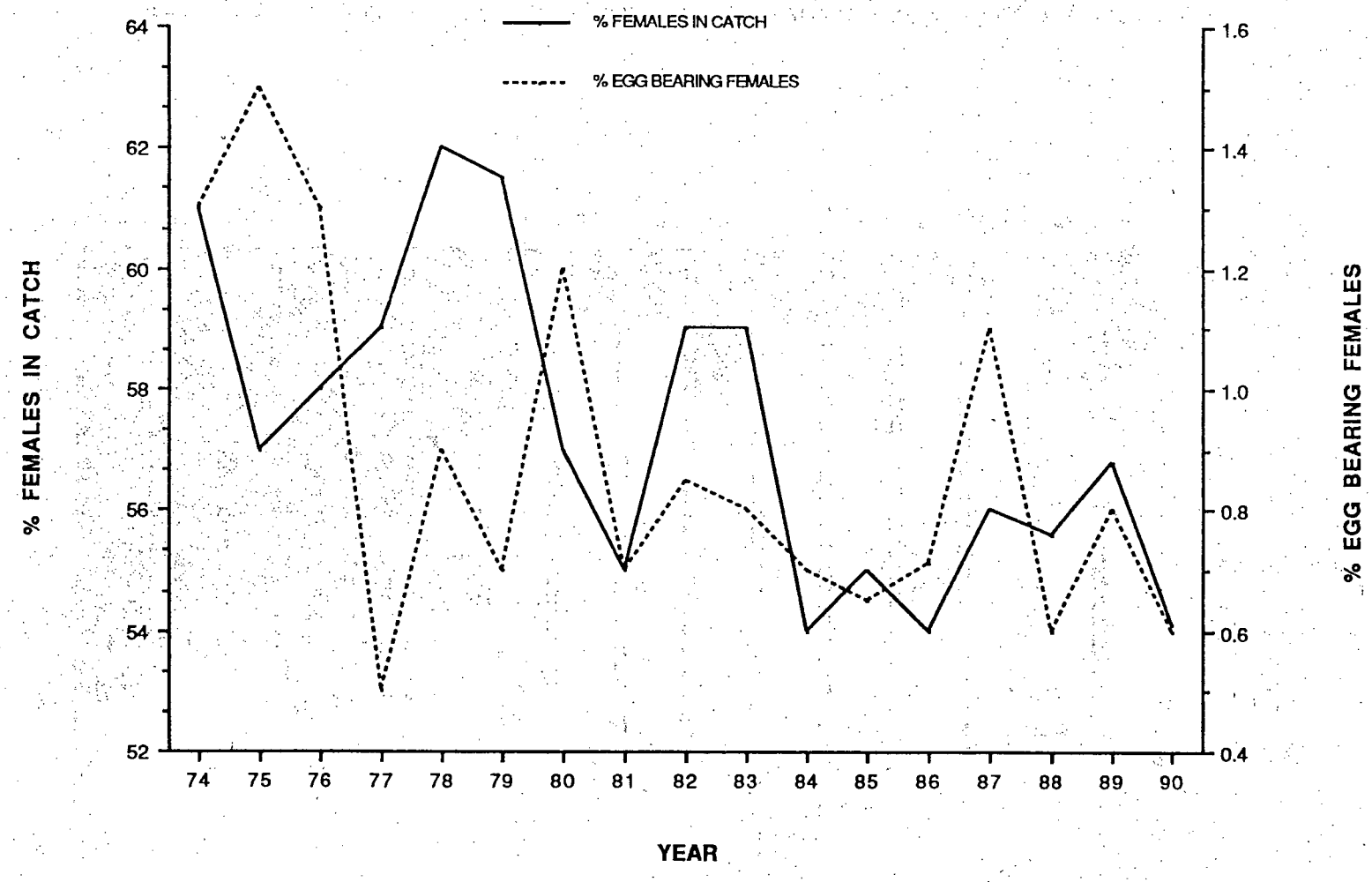


Figure 3.3.6-4. Summary of female lobster catch data at the discharge site, Station L1, 1974-1990. Seabrook Operational Report, 1990.

In 1990, one lobster was impinged in the plant's cooling water system during the months of February, July, August and October . No size-class information was obtained. It is possible that these individuals were seeking cover at the intake structure and subsequently became entrained.

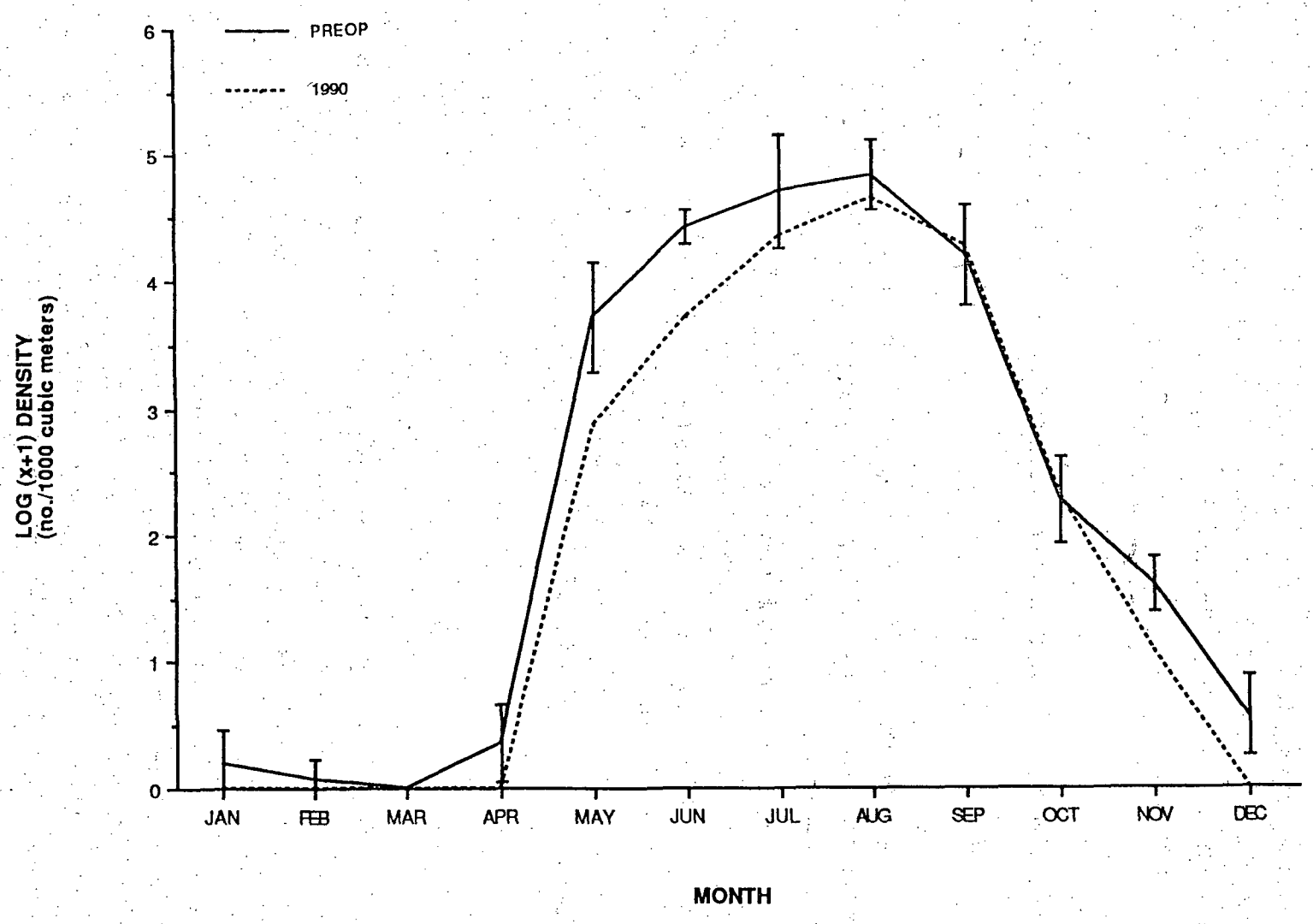
3.3.6.2 Jonah Crab (*Cancer borealis*) and Rock Crab (*Cancer irroratus*)

Larvae

Cancer spp. (*Cancer borealis* and *Cancer irroratus*) larvae generally exhibited a pattern for all sampling years of very low or near-zero density from January through April with rapidly increasing numbers in May, reaching peak abundance in August and declining in density from October through December. At plankton Station P2, *Cancer* spp. larvae in 1990 were most abundant during August, similar to the 1978-1989 period. In 1990, from September through December, the observed pattern was very similar to previous years (Figure 3.3.6-5), although densities in May, June, November and December were lower.

Adults

Adult Jonah crab (*C. borealis*) and rock crab (*C. irroratus*) catches have been monitored since 1975 at the discharge site (NAI 1985b). Since 1982, these populations have been monitored at two stations, the discharge site (L1) and at Rye Ledge (L7). Historically, catches of Jonah crabs have been significantly greater in August and September in comparison to all other months sampled (NAI 1990b, Table 3.3.6-4). Average monthly catches per fifteen-trap trip have ranged from 5 to 25 at the discharge station and from 4 to 17 at Rye Ledge from 1982 through 1990 (Table 3.3.6-4). The total annual catch of Jonah crabs increased from 1982 through 1985, and declined from 1986 to 1987



[a] Excluding January 1985 through June 1986.

Figure 3.3.6-5. Monthly mean log (x+1) density and 95% confidence intervals (no./1000 m^3) of *Cancer* spp. larvae at Station P2, 1978-1989 [a] and monthly mean for 1990. Seabrook Operational Report, 1990.

TABLE 3.3.6-4. COMPARISON OF CATCH PER UNIT EFFORT OF JONAH CRAB AND ROCK CRAB AT THE DISCHARGE SITE AND RYE LEDGE, 1982-1989 AND 1990. SEABROOK OPERATIONAL REPORT.

DISCHARGE STATION

		PREOP											OP			
		1982	1983	1984	1985	1986	1987	1988	1989	LOWER	ALL	UPPER	1990	LOWER	ALL	UPPER
JONAH	JUN	3.5	2.8	3.6	9.3	7.5	0.6	4.5	8.9	3.9	5.2	6.6	5.3	1.8	5.3	8.7
	JUL	4.5	6.4	4.5	14.3	9.6	9.2	7.1	32.4	8.5	11.0	13.5	19.9	11.6	19.9	28.2
	AUG	5.7	12.1	11.5	26.7	26.6	25.5	29.1	60.8	20.1	24.5	29.0	32.0	20.5	32.0	43.5
	SEP	8.3	8.4	9.3	11.4	18.5	26.2	28.4	22.8	13.9	16.8	19.7	12.5	8.1	12.5	16.9
	OCT	2.7	3.8	7.3	9.7	5.6	2.5	12.1	14.5	6.1	7.5	9.0	7.1	4.7	7.1	9.5
	NOV	3.4	1.6	8.9	11.7	6.2	1.4	17.9	7.8	6.1	7.7	9.2	8.0	6.3	8.0	9.7
	LOWER	3.8	4.8	6.2	11.6	10.4	8.0	13.6	18.2		11.3		11.2		11.2	
	ALL	4.8	6.1	7.8	14.0	13.3	11.3	16.6	24.8		12.6		14.8		14.8	
	UPPER	5.8	7.3	9.3	16.3	16.2	14.5	19.6	31.4		13.8		18.4		18.4	
ROCK	JUN	0.0	0.2	0.9	2.7	2.3	0.2	1.0	2.8	0.9	1.3	1.7	6.7	1.4	6.7	12.1
	JUL	0.8	0.8	2.6	5.3	3.7	4.2	5.0	9.8	3.0	4.0	5.1	8.8	3.0	8.8	14.5
	AUG	0.0	1.0	3.4	6.7	3.2	2.5	6.8	15.3	3.5	4.8	6.2	6.2	1.7	6.2	10.6
	SEP	0.0	0.2	1.5	0.6	1.2	1.2	0.8	4.8	0.7	1.3	1.9	0.9	-0.2	0.9	2.0
	OCT	0.1	0.0	0.2	3.3	1.7	0.1	0.9	0.8	0.6	0.9	1.2	0.7	0.3	0.7	1.1
	NOV	0.3	0.1	0.2	5.7	2.2	0.0	3.6	1.2	1.0	1.7	2.4	1.9	0.5	1.9	3.2
	LOWER	0.0	0.2	1.1	3.2	1.9	1.0	2.3	3.7		2.1		2.7		2.7	
	ALL	0.2	0.4	1.6	4.1	2.4	1.6	3.2	5.9		2.5		4.4		4.4	
	UPPER	0.4	0.6	2.0	5.0	3.0	2.2	4.2	8.0		2.9		6.0		6.0	

RYE LEDGE

		PREOP											OP			
		1982	1983	1984	1985	1986	1987	1988	1989	LOWER	ALL	UPPER	1990	LOWER	ALL	UPPER
JONAH	JUN	5.3	4.4	5.9	7.7	5.9	1.3	2.1	3.8	3.6	4.5	5.4	3.2	1.6	3.2	4.8
	JUL	3.8	11.7	6.4	16.0	8.6	7.7	4.4	16.3	7.8	9.4	11.0	8.4	5.2	8.4	11.7
	AUG	4.7	13.6	17.9	31.5	7.5	27.4	15.8	24.6	15.2	17.7	20.3	9.6	4.3	9.6	14.8
	SEP	5.6	9.8	11.4	9.8	11.4	17.9	10.8	10.1	9.1	10.8	12.6	6.0	2.0	6.0	10.0
	OCT	3.4	4.1	8.3	7.7	7.4	1.6	9.6	3.5	4.8	5.8	6.8	3.8	2.9	3.8	4.7
	NOV	4.0	3.0	8.5	13.1	7.3	1.3	5.3	9.3	5.5	6.6	7.7	3.6	2.4	3.6	4.9
	LOWER	3.8	6.3	8.4	11.9	6.8	7.2	6.4	8.4		8.7		4.5		4.5	
	ALL	4.4	8.2	10.2	14.5	8.1	10.1	8.1	11.3		9.5		5.9		5.9	
	UPPER	5.1	10.1	12.0	17.2	9.4	13.1	9.9	14.2		10.3		7.3		7.3	
ROCK	JUN	0.0	0.4	0.2	1.5	0.5	0.1	0.5	12.5	0.9	2.2	3.5	9.9	5.8	9.9	14.0
	JUL	1.6	0.8	1.7	1.3	2.0	0.8	0.8	11.3	1.4	2.5	3.6	11.2	2.7	11.2	19.7
	AUG	0.1	1.3	1.4	2.9	0.2	2.3	1.3	8.5	1.5	2.2	2.9	3.4	1.3	3.4	5.6
	SEP	0.1	0.2	1.6	0.8	0.2	1.2	0.1	1.1	0.4	0.7	1.0	0.3	-0.0	0.3	0.6
	OCT	0.0	0.0	0.6	1.6	0.5	0.1	0.4	0.7	0.2	0.5	0.8	0.4	0.0	0.4	0.8
	NOV	0.1	0.2	0.2	1.9	0.0	0.0	0.1	3.1	0.4	0.8	1.2	1.1	0.2	1.1	2.1
	LOWER	0.0	0.3	0.6	1.2	0.3	0.5	0.3	4.3		1.2		2.8		2.8	
	ALL	0.4	0.5	1.0	1.7	0.6	0.8	0.6	6.3		1.6		4.5		4.5	
	UPPER	0.7	0.8	1.4	2.1	0.9	1.2	0.9	8.4		1.9		6.3		6.3	

NOTE: Lower and upper represent the confidence limits around the monthly and yearly mean.

at both stations. In 1988, the catch increased at the discharge station, but was about average at Rye Ledge. For 1989, the yearly average of 24.8 was the highest recorded at the discharge station during this study. The average catch of 11.3 in 1989 at Rye Ledge was an increase over the previous three years. In 1990, catch declined to 14.8 and 5.9 at the discharge station and Rye Ledge, respectively.

Historically, Jonah crabs were significantly higher at the discharge station (12.6) than at Rye Ledge (9.5). In 1990, catches at the discharge station (14.8) represent an increase over the preoperational average, whereas at Rye Ledge, 1990 catches (5.9) were lower than the preoperational average (Table 3.3.6-4). These trends are reflected in a significant interaction (Preop-Op X Station) in the ANOVA result. Differences occurred throughout the 1990 sampling year and were not restricted to the operational period (August-December) (Table 3.3.6-2).

Average monthly catch of rock crabs has ranged from <1 to 5 per fifteen-trap trip at the discharge station and from <1 to 3 at Rye Ledge from 1982 through 1990 (Table 3.3.6-4). The catch of rock crabs had also been generally increasing from 1982 through 1985, when catches were significantly higher than all other previous years (Table 3.3.6-2); catches then decreased in 1986 and 1987 at the discharge and increased in 1988 and 1989. At Rye Ledge, rock crab catch has remained stable from 1986 through 1988 (Table 3.3.6-4). During 1989, rock crab monthly catches exceeded all previous, years reaching 15.3 in August at the discharge site and 12.5 in June at Rye Ledge. Yearly averages were also greater than previous years, reaching 5.9 at the discharge station and 6.3 at Rye Ledge. As with the Jonah crab, both stations experienced a decline during 1990. ANOVA results indicate 1990 catches were statistically similar during the operational period, when rock crabs are not very abundant. However, higher-than-average catches in June and July resulted in significant differences between 1990 and preoperational catches at both discharge and Rye Ledge stations (Table 3.3.6-2).

Total catch of rock crabs has been low at both stations relative to the catch of Jonah crabs; this may be due to intra-specific competition between the two species of crabs (Richards et al. 1983). Also, rock crabs prefer sandy habitat which is available near the discharge site compared to rocky habitat located at Rye Ledge preferred by Jonah crabs (Jefferies 1966; Bigford 1979).

The percent of female crabs in the catch has also been monitored since 1982 (Table 3.3.6-5). The highest catches of Jonah crab females at the discharge station occurred during August and September in most years, composing from 83% to 96% of the total catch. In 1990, catches of female crabs were highest in August. Annual mean catch of female Jonah crabs generally increased from 1982 through 1989; in 1990, catches of females decreased but the annual mean was similar to the preoperational average. Trends of female rock crab occurrence were less defined than Jonah crabs due to the low overall catch of rock crabs. Catches of female rock crabs were generally greatest in the fall, from August-November. Catches of female Jonah crabs in 1990 were higher than the preoperational average from June-August.

Egg-bearing Jonah crabs were most abundant in June in 1990 at Rye Ledge (about 17% of the total catch), compared to generally about 2% of the total catch at both stations from 1982 to 1989 (Table 3.3.6-5, NAI 1990b). Ovigerous rock crabs were collected for the first time in 1989 and averaged less than 1% of the catch in 1990. Considering the increased catches of rock crabs in 1989, greater numbers of ovigerous females were probably available resulting in their first-time capture. However in 1990, although rock crab catch declined, egg-bearing females were collected in June at the discharge station.

TABLE 3.3.6-5. ANNUAL AND MONTHLY MEAN CATCH PER UNIT EFFORT AND 95% CONFIDENCE INTERVALS OF JONAH AND ROCK CRAB FEMALES AND OVIGEROUS FEMALES AT THE DISCHARGE SITE FROM 1982-1989 AND 1990.

FEMALES

		PREOPERATIONAL											OPERATIONAL			
		1982	1983	1984	1985	1986	1987	1988	1989	LOWER	ALL	UPPER	1990	LOWER	ALL	UPPER
JONAH	JUN	2.0	1.7	1.9	6.0	4.8	0.2	2.4	3.8	2.2	2.9	3.7	2.9	0.2	2.9	5.6
	JUL	2.4	4.5	2.5	8.5	6.9	5.8	4.8	19.0	5.3	6.8	8.3	10.9	5.0	10.9	16.8
	AUG	4.9	9.0	8.3	21.8	23.8	19.8	24.8	44.0	16.0	19.4	22.8	23.0	14.8	23.0	31.2
	SEP	7.0	7.8	7.7	10.0	17.7	22.9	26.3	19.8	12.4	15.0	17.7	10.3	5.9	10.3	14.7
	OCT	2.1	3.3	5.9	8.3	5.0	2.1	10.6	13.0	5.2	6.5	7.9	5.4	3.3	5.4	7.6
	NOV	2.6	1.3	6.2	8.5	5.0	1.3	14.6	5.0	4.5	5.8	7.1	5.1	3.6	5.1	6.6
	LOWER	2.7	3.7	4.3	8.5	8.6	6.1	11.2	12.7		8.7		7.5		7.5	
	ALL	3.6	4.7	5.7	10.6	11.4	8.8	14.0	17.6		9.7		10.2		10.2	
	UPPER	4.5	5.7	7.0	12.6	14.2	11.6	16.8	22.4		10.7		12.8		12.8	
ROCK	JUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	-0.1	0.1	0.3	1.6	-0.8	1.6	4.0
	JUL	0.2	0.1	0.2	0.1	0.0	0.8	1.2	3.5	0.1	0.8	1.4	1.1	-0.0	1.1	2.2
	AUG	0.0	0.0	0.3	0.0	0.1	1.0	1.7	5.4	0.5	1.0	1.6	2.8	-0.4	2.8	6.1
	SEP	0.0	0.0	0.2	0.0	0.1	0.3	0.1	0.8	0.1	0.2	0.3	0.1	-0.1	0.1	0.3
	OCT	0.0	0.0	0.1	1.9	0.6	0.0	0.0	0.0	0.1	0.3	0.5	0.2	-0.1	0.2	0.6
	NOV	0.0	0.0	0.1	2.6	1.0	0.0	0.0	0.2	0.1	0.5	0.8	0.4	-0.1	0.4	0.8
	LOWER	-0.0	-0.0	0.1	0.3	0.1	0.2	0.3	0.7		0.3		0.4		0.4	
	ALL	0.0	0.0	0.1	0.7	0.2	0.4	0.6	1.8		0.5		1.2		1.2	
	UPPER	0.1	0.0	0.2	1.1	0.4	0.6	0.8	2.9		0.7		1.9		1.9	

OVIGEROUS FEMALES

		PREOPERATIONAL											OPERATIONAL			
		1982	1983	1984	1985	1986	1987	1988	1989	LOWER	ALL	UPPER	1990	LOWER	ALL	UPPER
JONAH	JUN	0.1	0.0	0.2	0.2	0.1	0.0	0.5	0.1	0.1	0.1	0.2	0.1	-0.1	0.1	0.3
	JUL	0.0	0.1	0.2	0.0	0.4	0.5	0.2	1.0	0.1	0.3	0.4	0.3	-0.2	0.3	0.9
	AUG	0.1	0.2	0.2	0.0	0.0	1.2	0.6	1.9	0.3	0.5	0.8	0.6	0.1	0.6	1.1
	SEP	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
	OCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	NOV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	-0.0	0.0	0.1	0.0	0.0	0.0	0.0
	LOWER	-0.0	0.0	0.0	-0.0	-0.0	0.2	0.1	0.3		0.1		0.1		0.1	
	ALL	0.0	0.1	0.1	0.0	0.1	0.4	0.2	0.6		0.2		0.2		0.2	
	UPPER	0.1	0.1	0.3	0.1	0.2	0.5	0.4	0.9		0.3		0.3		0.3	
ROCK	JUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JUL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
	AUG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	-0.0	0.0	0.1	0.0	0.0	0.0	0.0
	SEP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OCT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	NOV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.0	0.0	0.0	0.1	-0.2	0.1	0.4
	LOWER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		-0.0		-0.0	
	ALL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		0.0		0.0		0.0	
	UPPER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2		0.0		0.1		0.1	

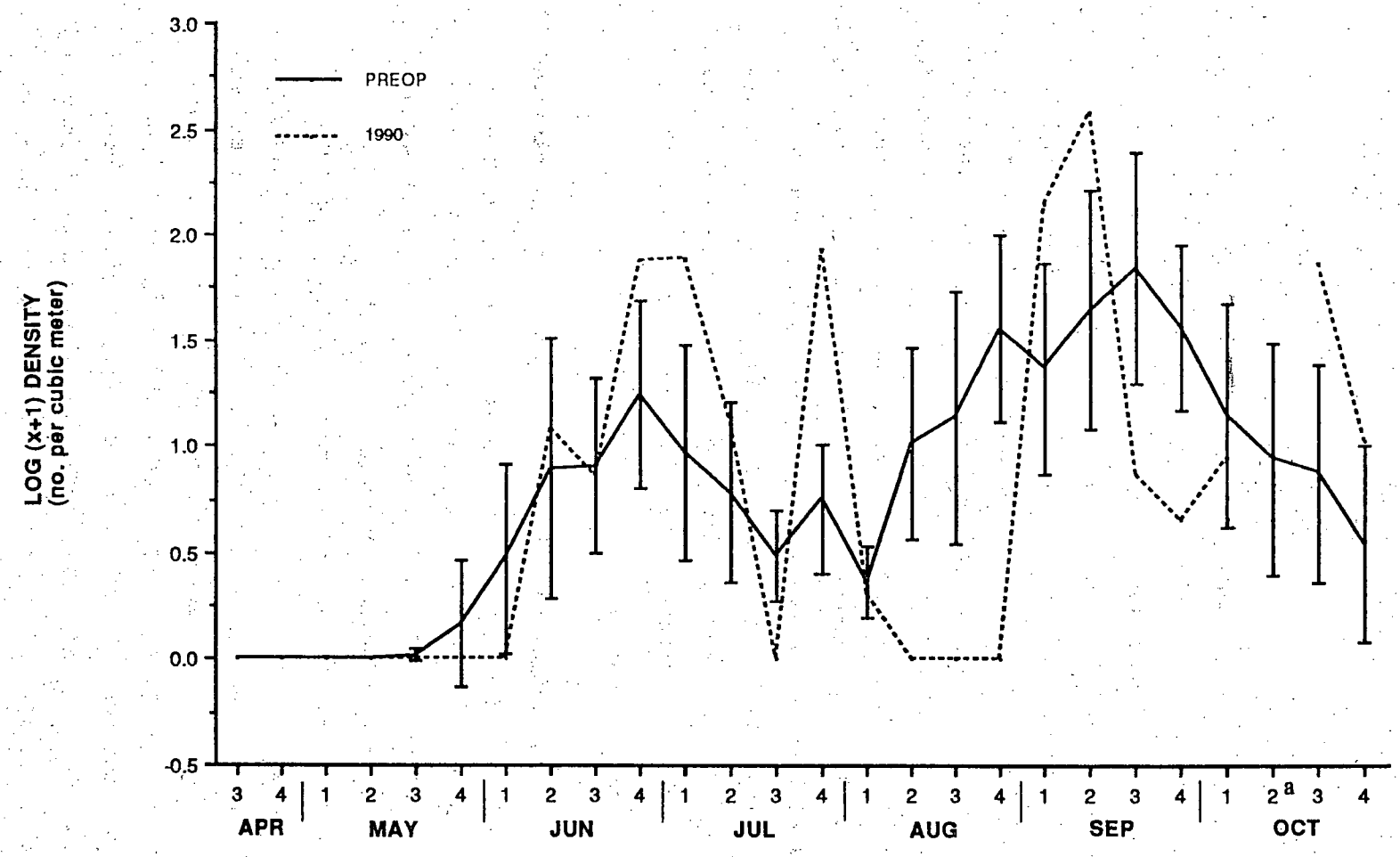
Lower = Lower limit of 95% confidence interval.
Upper = Upper limit of 95% confidence intervals.

3.3.7 *Mya arenaria* (Soft-shell Clam)

3.3.7.1 Larvae

Mya arenaria larvae occurred in plankton samples May through October from 1978 to 1989 at nearfield Station P2 (Figure 3.3.7-1). Each year, maximum abundances were recorded in late summer or early fall, while in many years a secondary peak also occurred in early summer. The lowest peak densities observed in the study occurred in 1985 ($63/m^3$) (NAI 1986). Peak larval abundances in 1990 ($755/m^3$) ranked sixth over the past nine years, 1982-1990 (NAI 1991). The highest peak abundance was observed in 1982 ($1,505/m^3$) (NAI 1985b). Peak abundances in 1990 were observed in September with lesser peaks in June, July and October (Figure 3.3.7-1). Comparison of 1990 *Mya* larval abundances with previous years at Station P2, using a one-way ANOVA, revealed no significant differences (Table 3.3.7-1). Similarly, a two-way nested ANOVA comparing 1990 *Mya arenaria* larval abundances with previous years at Nearfield (P2, P5) and Farfield (P7) stations found no significant spatial differences (Table 3.3.7-1).

Factors influencing the timing and magnitude of the observed pattern of larval abundance are not fully understood. *M. arenaria* is known to spawn in the spring at temperatures greater than 4-6°C with summer spawning at 15-18°C (Brosseau 1978). Maximum larval abundances in August and September coincided with water temperatures in Hampton Harbor that regularly exceeded 15-18°C. However, these temperatures also occurred frequently in June and July, which were characterized by much lower larval abundances, suggesting that temperature is a minimum requirement for spawning. In addition, recruitment of larvae of non-local origin is likely due to currents in the Gulf of Maine, which may move water masses and their entrained larvae significant distances before larval settlement (NAI 1979f). The late-summer peaks have been observed to be coincident with northward-flowing currents. This implies that these offshore larval peaks may in part have a more southern



[a] No data collected in 2nd week of Oct., 1990.

Figure 3.3.7-1. Weekly log (x+1) density (no. per cubic meter) of *Mya arenaria* larvae at Station P2 in 1990 compared to all years' mean and 95% confidence interval during the preoperational period (1978-1989). Seabrook Operational Report, 1990.

TABLE 3.3.7-1. RESULTS OF ANALYSIS OF VARIANCE[a,b] COMPARING *MYA ARENARIA* LARVAL, SPAT, JUVENILE AND ADULT ABUNDANCES DURING PREOPERATIONAL[c] AND OPERATIONAL PERIODS. SEABROOK OPERATIONAL REPORT, 1990.

LIFESTAGE	STATION/FLAT	SOURCE OF VARIATION	APR-OCT df	APR-OCT SS	APR-OCT F	F	AUG-OCT[c] df	AUG-OCT[c] SS	AUG-OCT[c] F
Mya arenaria larvae[a]	P2	Year	12	5.38	0.66 NS				
		Error	299	202.25					
Mya arenaria larvae[a]	Nearfield (P2, P5) Farfield (P7)	Preop-Op[d]	1	0.03	0.04 NS		1	1.37	2.18 NS
		Area[e]	1	0.09	0.14 NS		1	0.04	0.06 NS
		Year (Preop-Op)[f]	7	3.26	0.71 NS		7	10.70	2.43*
		Week (Preop-Op X Year)[g]	27	7.65	0.43 NS		27	14.91	0.88 NS
		Preop-Op X Area[h]	1	0.32	0.48 NS		1	0.08	0.13 NS
		Error	477	312.20			199	125.03	
Young of year (1-5 mm)[b]	1, 2, 4	Preop-Op	1	3.20	6.77**				
		Area	2	3.02	3.20*				
		Year (Preop-Op)	15	156.13	22.07***	Preop: Flat 2 = Flat 4 > Flat 1			
		Preop-Op X Area	2	2.90	3.08*	1990: Flat 2 = Flat 4 = Flat 1			
		Error	1269	825.28					
Regional spatfall (1-12 mm)[b]	Hampton Harbor Plum Island Sound	Preop-Op	1	0.09	0.13 NS				
		Area	1	3.29	4.73*				
		Year (Preop-Op)	2	1.59	1.14 NS	Plum Island > Hampton Harbor			
		Preop-Op X Area	1	0.25	0.37 NS				
		Error	74	51.45					
Hampton Harbor spat (13-25 mm)[b]	1, 2, 4	Preop-Op	1	0.03	0.11 NS				
		Area	2	8.26	16.43***				
		Year (Preop-Op)	13	106.49	32.60***	Flat 4 > Flat 1 = Flat 2			
		Preop-Op X Area	2	0.18	0.37 NS				
		Error	923	231.92					
Hampton Harbor juveniles and adults (≥26 mm)[b]	1, 2, 4	Preop-Op	1	1.30	6.71***				
		Area	2	14.25	36.71***	Preop: Flat 1 = Flat 4 > Flat 2			
		Year (Preop-Op)	15	192.32	66.06***	1990: Flat 4 > Flat 1 > Flat 2			
		Preop-Op X Area	2	2.95	7.60***				
		Error	2275	441.51					

[a]Larval comparisons based on weekly sampling periods, mid-April through October
[b]Spat, juvenile and adult comparisons based on annual October field surveys
[c]Commercial operation began in August 1990
[d]1990 versus preoperational period regardless of area. Larval preoperational period 1978-1989; spat, juvenile and adult preoperational period 1974-1989
[e]Station or flat, regardless of year or period
[f]Year nested within preoperational and operational periods, regardless of area
[g]Week nested within year nested within preoperational and operational periods, regardless of area
[h]Interaction of main effects

NS = Not significant (p>0.05)
* = Significant (0.05≥p>0.01)
** = Highly significant (0.01≥p>0.001)
*** = Very highly significant (0.001≥p)

estuarine component. Overall, factors controlling the occurrence of *M. arenaria* larvae off Hampton Harbor Beach are complex, the result of environmental and biological factors including: adult condition at the time of spawning, temperature at spawning sites, location of spawning sites relative to prevailing coastal currents, water column stratification and larval behavior.

3.3.7.2 Reproductive Patterns

Mya arenaria with developing gonads were collected in the Hampton estuary in March or early April during most years from 1978-1984, the years when *Mya* reproduction was studied. Ripe individuals have been observed between the second week in April and the third week in June. In most years, ripe individuals occurred at similar times at both Hampton Harbor and Plum Island Sound, with the exception being 1984 (NAI 1985b).

The onset of spawning in Hampton Harbor and Plum Island Sound, as indicated by the gonadal studies, usually occurred following the appearance of larvae in offshore tows, presumably from *Mya* populations further south. Only in 1980 and 1981 was spawning detected before larval occurrence. The peak larval abundance always occurred well after spawning had commenced, suggesting both Hampton Harbor and Plum Island Sound clams may contribute to the large nearshore larval densities of late summer (NAI 1985b).

3.3.7.3 Hampton Harbor and Regional Population Studies

Hampton Harbor Spatfall

The soft-shell clam population has been studied through intensive surveys of spat and adults in Hampton Harbor (Appendix Table 3.3.7-1). These surveys have been supplemented by quantitative studies

of regional spatfall in nearby estuaries. Over a 17-year period, the Hampton Harbor population has gone through substantial changes in abundance (Figures 3.3.7-2 through 3.3.7-7). The age distribution in 1974-1977 at Flat 1 indicated a declining juvenile and adult (>25 mm) population despite presence of the young-of-the-year (1-5 mm). The *Mya* population structure during the 1984-1989 period at Flat 1 resembled that observed in 1974-1977, suggesting long-term trends based on the interaction of spatfall and disturbance, possibly due to natural and human predation (Figure 3.3.7-2). The decline in 1983-1988 in juvenile and adult (>25 mm) clam densities at Flat 1 was partially the result of light spatfalls during this period with the exception of 1984.

In 1976, a large spatfall (indicated by young-of-the-year spat) (Figure 3.3.7-3), occurred at all flats, which initiated changes in the population structure during the 1976-1982 period. The 1976 spatfall was the largest observed in the study; however, other important spatfalls (indicated by young-of-the-year) occurred in 1975, 1977, 1980, 1981 and in 1984 (Figure 3.3.7-3). The recruitment (defined as survivorship of one-year old clams into the 13-25 mm size class) of the 1976 year class was successful on Flat 1 (Figure 3.3.7-2) and Flat 4 (Figure 3.3.7-7), while the 1980 year class and, to a lesser extent, the 1981 year class were successful on all flats (Figures 3.3.7-2, 6, 7). Spat settling in 1984 failed to survive on any flat. Successful recruitment of light spatfalls have been observed on all flats for the 1987 year class and on Flat 2 and Flat 4 for the 1988 year class. Poor recruitment and light spatfalls were observed 1974-75, 1982-83 and 1985-86. Spatfall in 1989 was the highest observed since 1984, though still lower than observed historically. Spatfall in 1990 was similar to 1989 at Flats 2 and 4, and was higher at Flat 1 (Figure 3.3.7-3, Appendix Table 3.3.7-1). Analysis of variance results suggest that spatial differences in 1990 differed from previous years (Table 3.3.7-1). Historically, young-of-the-year densities have been lower at Flat 1 in comparison to Flats 2 and 4. In 1990, densities were roughly equivalent. The change in spatial differences in 1990 is reflected in the significant Preop-Op x Area interaction term (Table 3.3.7-1).

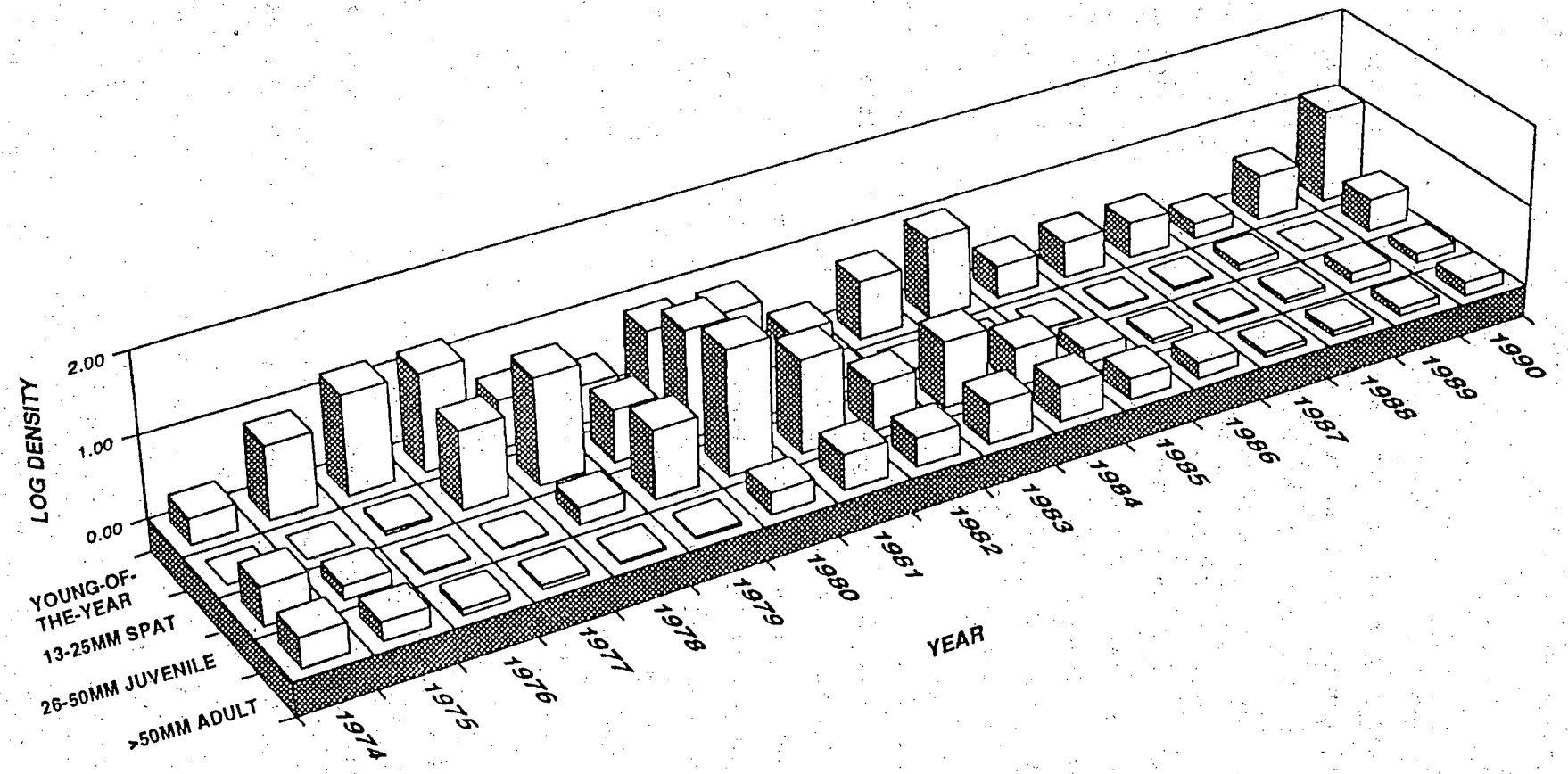


Figure 3.3.7-2. Annual log (x+1) mean density (number per square foot) of young-of-the-year (1-5 mm), spat (13-25 mm), juvenile (26-50 mm), and adult (>50 mm) *Mya arenaria* at Hampton-Seabrook Harbor Flat 1 from 1974-1990. Seabrook Operational Report, 1990.

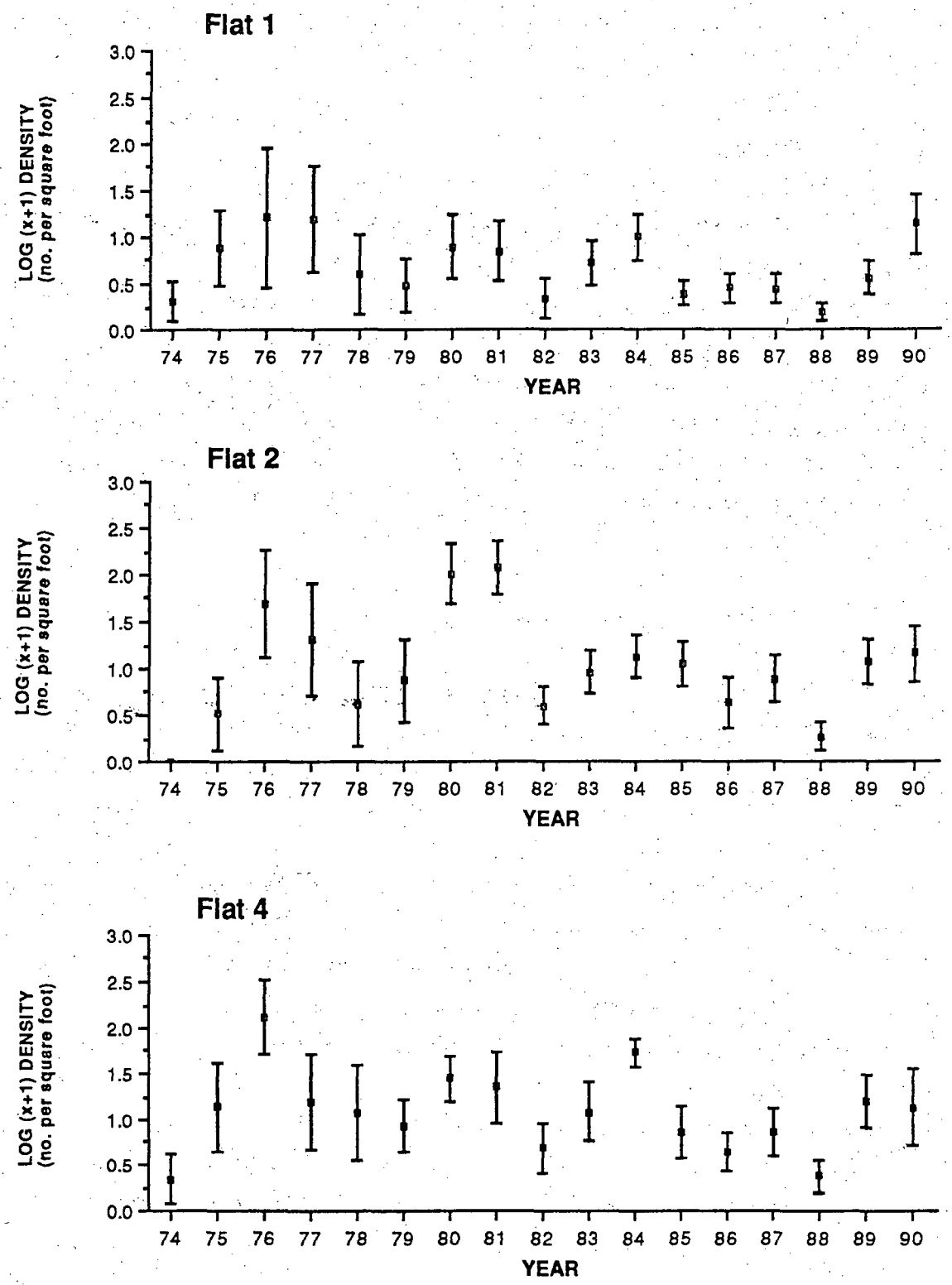


Figure 3.3.7-3. Annual log (x+1) mean density (number per square foot) and 95% confidence limits of young-of-the-year *Mya arenaria* spat (1-5 mm) at Hampton-Seabrook Harbor, 1974-1990. Seabrook Operational Report, 1990.

Regional Spatfall

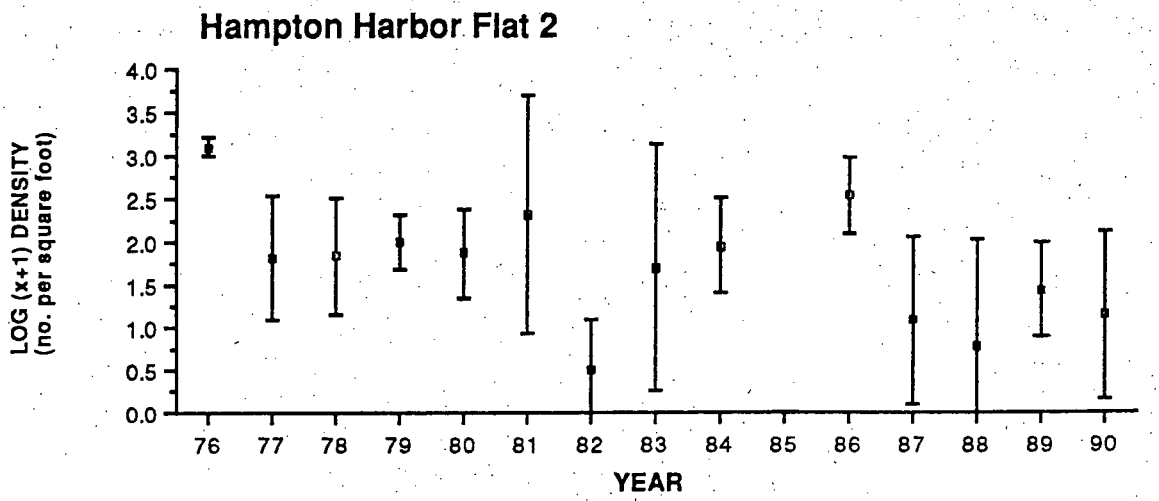
The regional spatfall study (clams 1-12 mm) verified that the heavy recruitment occurred in 1976 occurred throughout the region (Figure 3.3.7-4). However, annual densities, including 1990, were statistically similar (Table 3.3.7-1). A comparison of spatfall at Hampton Harbor and Plum Island Sound MA indicates that spatfall has been significantly higher at Plum Island Sound (Table 3.3.7-1). ANOVA results found no significant difference in spatial spatfall patterns between 1990 and preoperational years (Table 3.3.7-1).

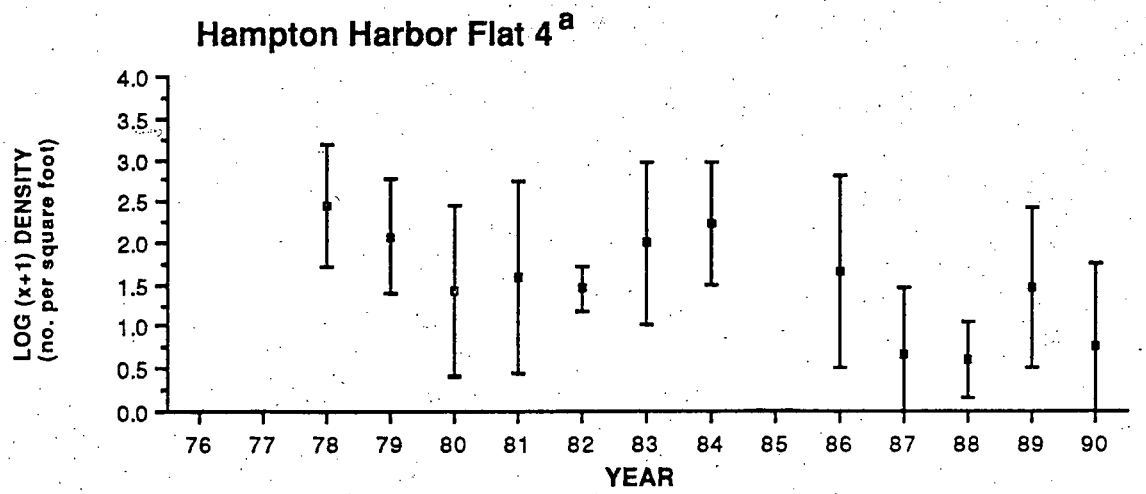
Yearling and Adult Clams

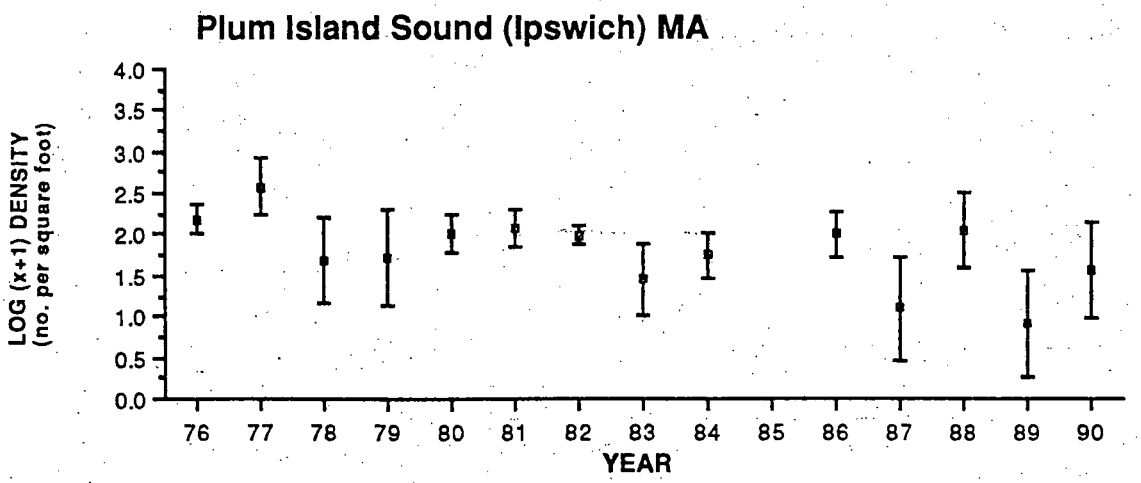
Trends in 13-25 mm yearling clams indicate the survival success of young-of-the-year spat. Yearling clams (10-12 mm) became numerous in 1977 following the 1976 spatfall and began showing a decline in 1981 at Flat 1 and 1982 at Flat 2 and Flat 4 (NAI 1982b, NAI 1983a).

Since that time, survival of young-of-the-year spat to the 13-25 mm yearling clams has been low until 1990 at Flat 1 (Figures 3.3.7-2,5). Older spat (13-25 mm) densities at Flat 2 showed small increases in 1988-1990 over previous years (Figure 3.3.7-6). At Flat 4, 13-25 mm spat densities were higher in 1988 and 1989 in comparison to previous years; in 1990, densities were the highest since 1982. Although annual differences were statistically different, 1990 densities were not significantly different from previous years (Table 3.3.7-1). Densities at Flat 4 over the entire study have been significantly higher than those at Flats 1 and 2 (Table 3.3.7-1).

Juveniles (26-50 mm), two to four years old, were relatively scarce from 1976 to 1978, but became abundant from 1979 to 1981 at all three flats (Figures 3.3.7-5, 6, 7). This pattern reflects the growth of the large sets of 1976 and 1977. The large spat sets of 1980 and 1981 did not result in increased densities of juveniles.







a. Flat 4 not sampled in 1976 and 1977.

Figure 3.3.7-4. Mean and 95% confidence limits of *Mya arenaria* spat (shell length ≤ 12 mm) densities (no./ft^2) at two northern New England estuaries, 1976 through 1984 and 1986 through 1990. Seabrook Operational Report, 1990.

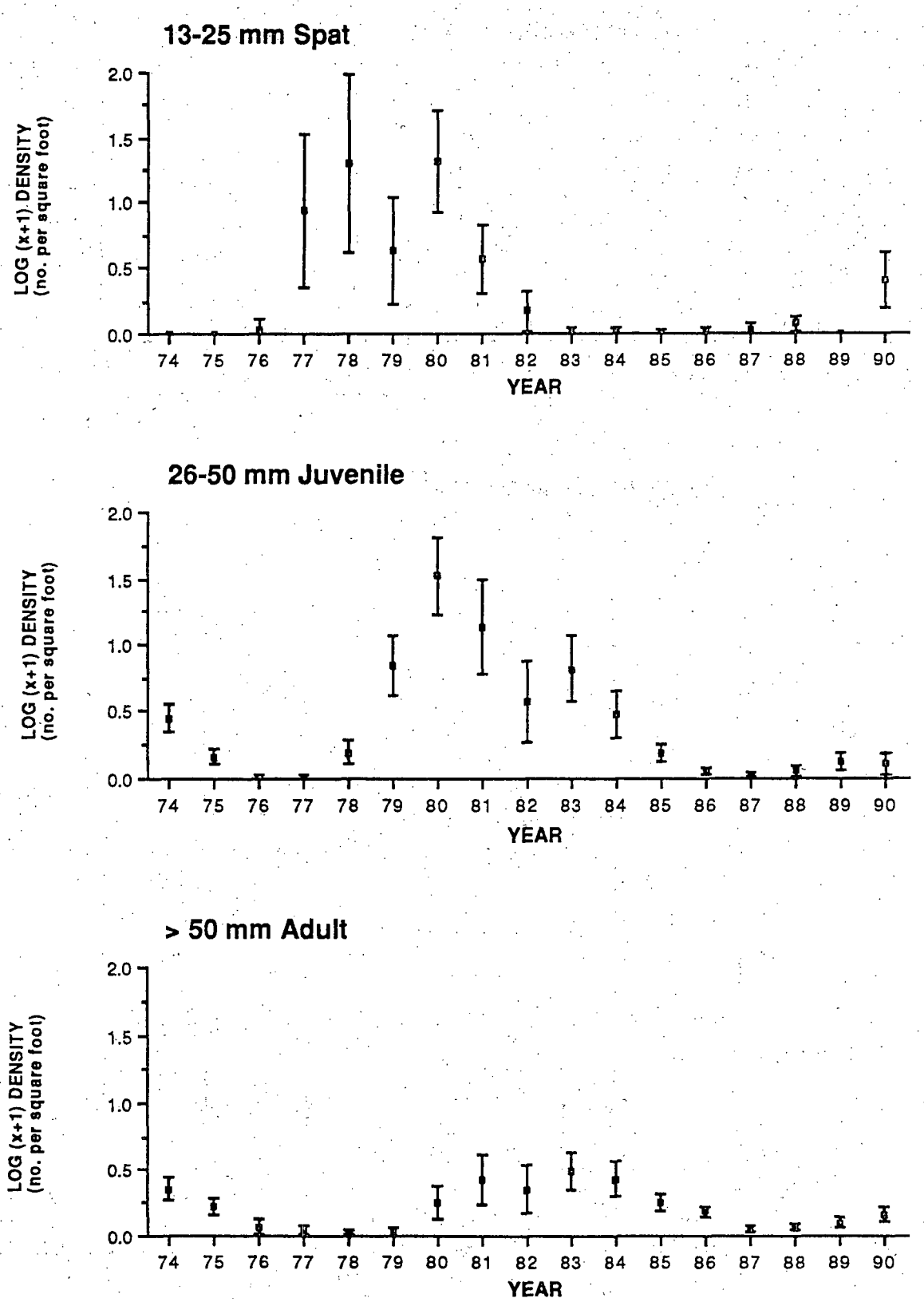


Figure 3.3.7-5. Means and 95% confidence limits of *Mya arenaria* spat, juvenile and adult log (x+1) densities at Flat 1, Hampton-Seabrook Harbor, 1974 through 1990. Seabrook Operational Report, 1990.

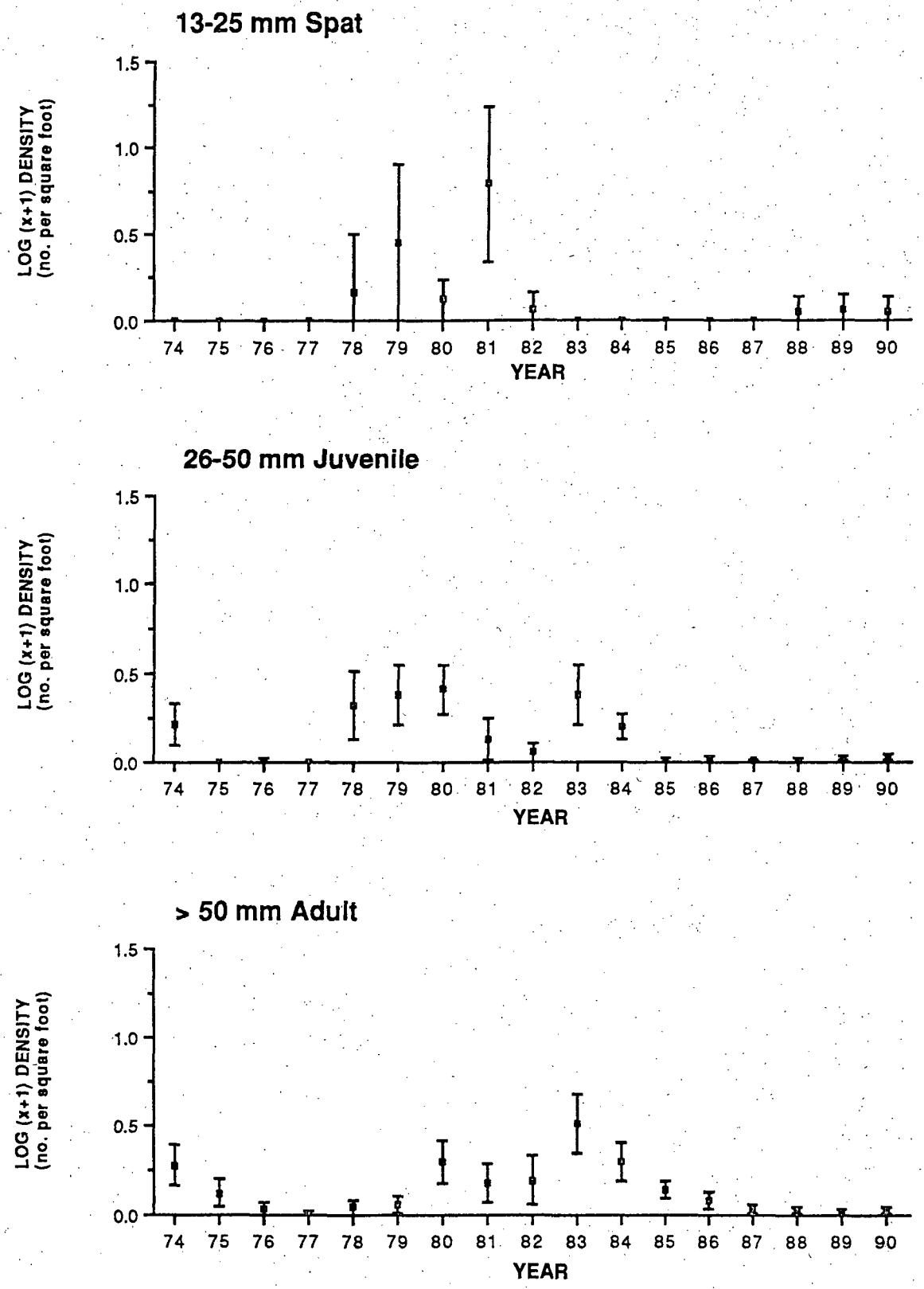


Figure 3.3.7-6. Means and 95% confidence limits of *Mya arenaria* spat, juvenile and adult log (x+1) densities at Flat 2, Hampton-Seabrook Harbor, 1974 through 1990. Seabrook Operational Report, 1990.

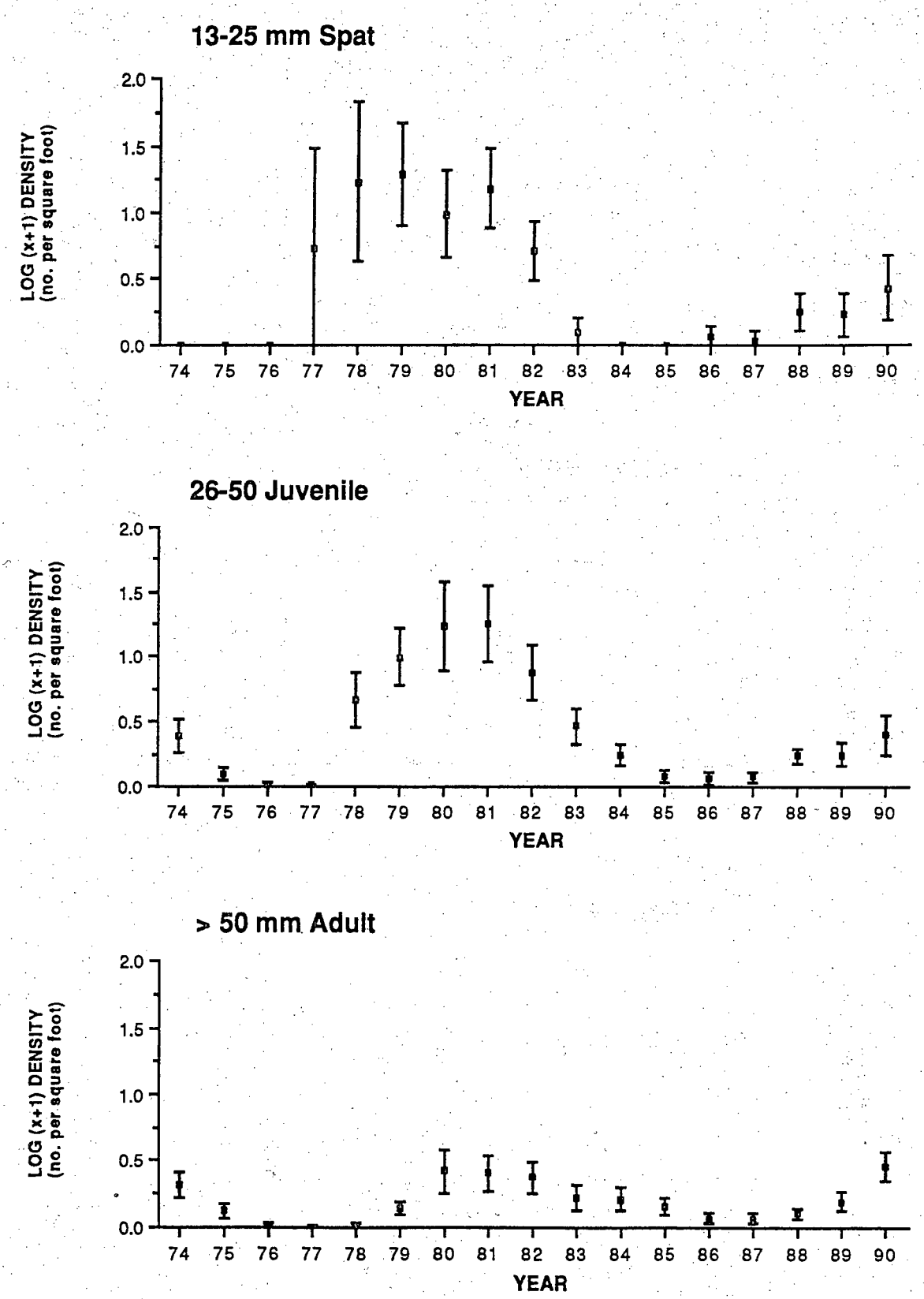


Figure 3.3.7-7. Means and 95% confidence limits of *Mya arenaria* spat, juvenile and adult log (x+1) densities at Flat 4, Hampton-Seabrook Harbor, 1974 through 1990. Seabrook Operational Report, 1990.

High adult densities (>50 mm) were recorded in 1980 and have declined from 1983 through 1987. The 1980-1982 adult densities reflected the success of the 1976 and 1977 year classes; subsequent decline resulted from the harvesting of these clams and the failure to recruit the spatfalls of 1980, 1981 and 1984 into the juvenile and adult size clams.

In 1987 and 1988, attempts by the New Hampshire Fish and Game Department to augment natural recruitment by seeding juvenile clams at Flat 5 were not successful (Morris 1989). The local 4-H organization has also produced seed clams on a small-scale (30,000 juveniles in 1988) for reseeding Hampton Harbor clam flats. Juvenile densities, 1988-1990, remained low at Flat 2, but increased slightly at Flat 1 and Flat 4. Adult densities at Flat 2 remained relatively unchanged from 1987-1990, while increasing gradually at Flat 1 and Flat 4 (Figures 3.3.7-5, 6, and 7). Differences among flats in juvenile and adult densities in 1990 were not consistent with previous years, as indicated by a significant interaction between Preop-Op and Area terms in the ANOVA (Table 3.3.7-1). Historically, densities at Flats 1 and 4 were similar and an order of magnitude higher than densities at Flat 2. In 1990, Flat 4 densities were highest, followed by Flat 1; Flat 2 densities were an order of magnitude lower than those at Flats 1 and 4.

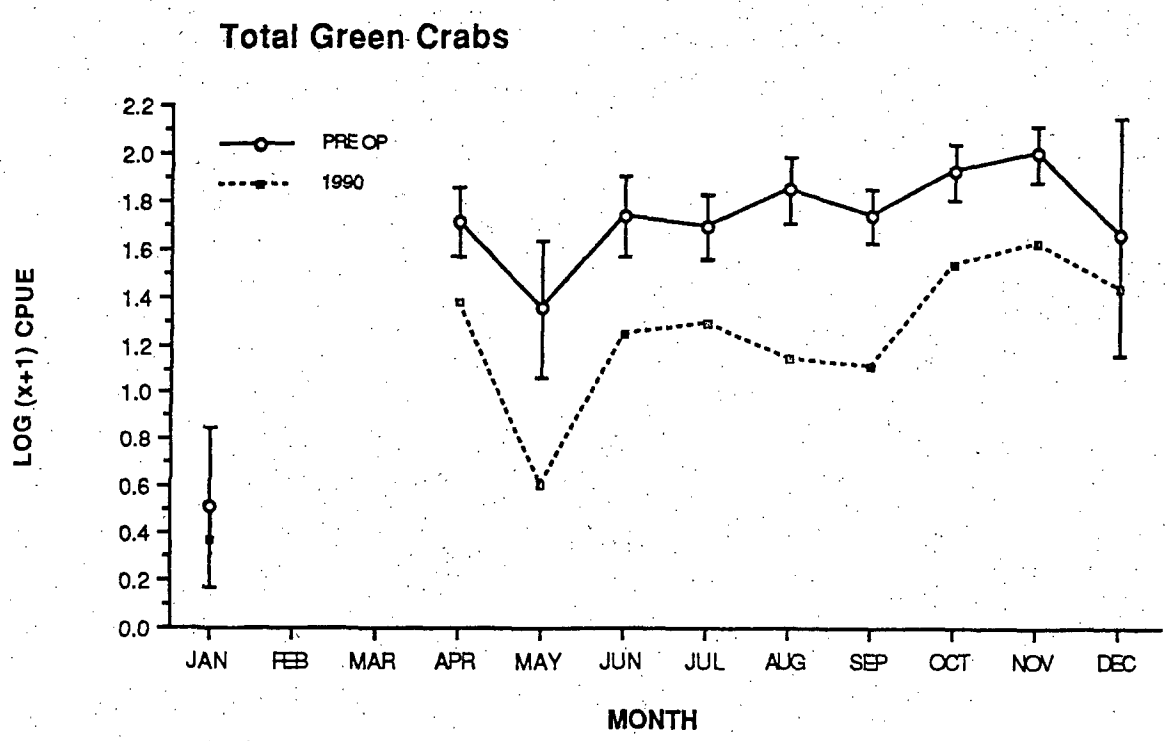
3.3.7.4 Effects of Predation, Perturbation and Disease on Harvestable Clam Resources

Clams in Hampton Harbor are subject to predation pressure from two major sources: green crab consumption of spat (1-25 mm) and juvenile (26-50 mm) *Mya*, and humans who dig adult *Mya* (>50 mm) and also cause mortality to smaller clams by disturbing the flat. Sea gulls may also be major predators, as they are commonly observed picking over clam digger excavations for edible invertebrates, including spat and juvenile clams. The green crab (*Carcinus maenas*) is a major predator of *Mya*, with clams being a major source of food particularly in the fall months (Ropes 1969). Green crab catches in Hampton Harbor have shown a

substantial increase in abundance since 1980 (NAI 1990b). Maximum abundances usually occurred in the fall, with the highest number recorded in 1984. Green crab numbers from 1983 to 1989 appear to have stabilized somewhat at higher densities (Figure 3.3.7-8), with fall abundances fluctuating between 69.3 (1985) and 123.9 (1984) catch per unit effort (CPUE). The fall 1990 green crab CPUE was the lowest observed since 1981; the April through November catches in 1990 were substantially lower than those for the same months in previous years (Figure 3.3.7-9).

Green crabs generally feed more actively at temperatures above 9°C, and females are more active predators on *Mya* than males (Ropes 1969). The presence of more females in the catch in Hampton Harbor from July through September historically (NAI 1990b) and in 1990 (NAI 1991) indicated greater predation pressure for the newly-settled spat in the estuary. Continued high catches of males and females occurred until late November or December, when temperatures declined below 7°C and activity decreased.

Welch (1969) and Dow (1972) have shown that green crab abundances increased markedly during relatively warm winters. Seasonal CPUE for green crab from 1978-1989 showed an increase from fall of 1980 through 1984 and again in 1986. The increase in green crab abundance corresponded to elevated winter minimum temperatures observed from 1981-1984 (Figure 3.3.7-8); a significant correlation ($p<0.01$) was obtained between fall abundances (time of peak activity), 1980-1988, and the previous winter minimum temperature. Close examination of the yearly data indicated the type of response proposed by Welch (1969). Following the winter of 1979-1980 when the temperature minimum was high, the fall crab population showed a marked increase (Figure 3.3.7-8). A much lower minimum temperature in winter 1980-1981, and a somewhat higher one in 1981-1982, resulted in a noticeable decrease in crab density in the fall of 1981 followed by a moderate increase in fall 1982. Higher minimum winter temperatures in 1983, 1984, 1986 and 1988 were associated with a marked rise in fall green crab catches. In 1987 and 1989, green crab



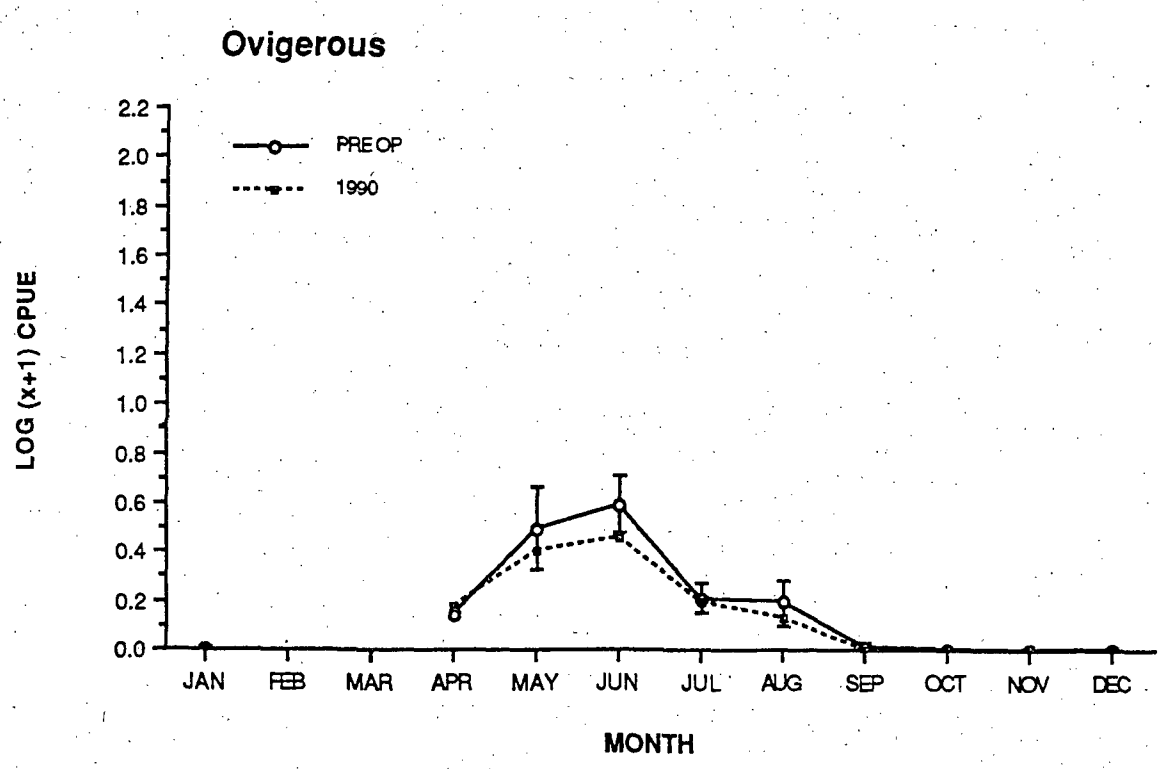


Figure 3.3.7-8. Monthly means and catch per unit effort [log (x+1)] and 95% confidence intervals for total green crabs *(Carcinus maenas)* and ovigerous green crabs collected at estuarine stations from preoperational years (1983-1989) compared to monthly means in 1990. Seabrook Operational Report, 1990.

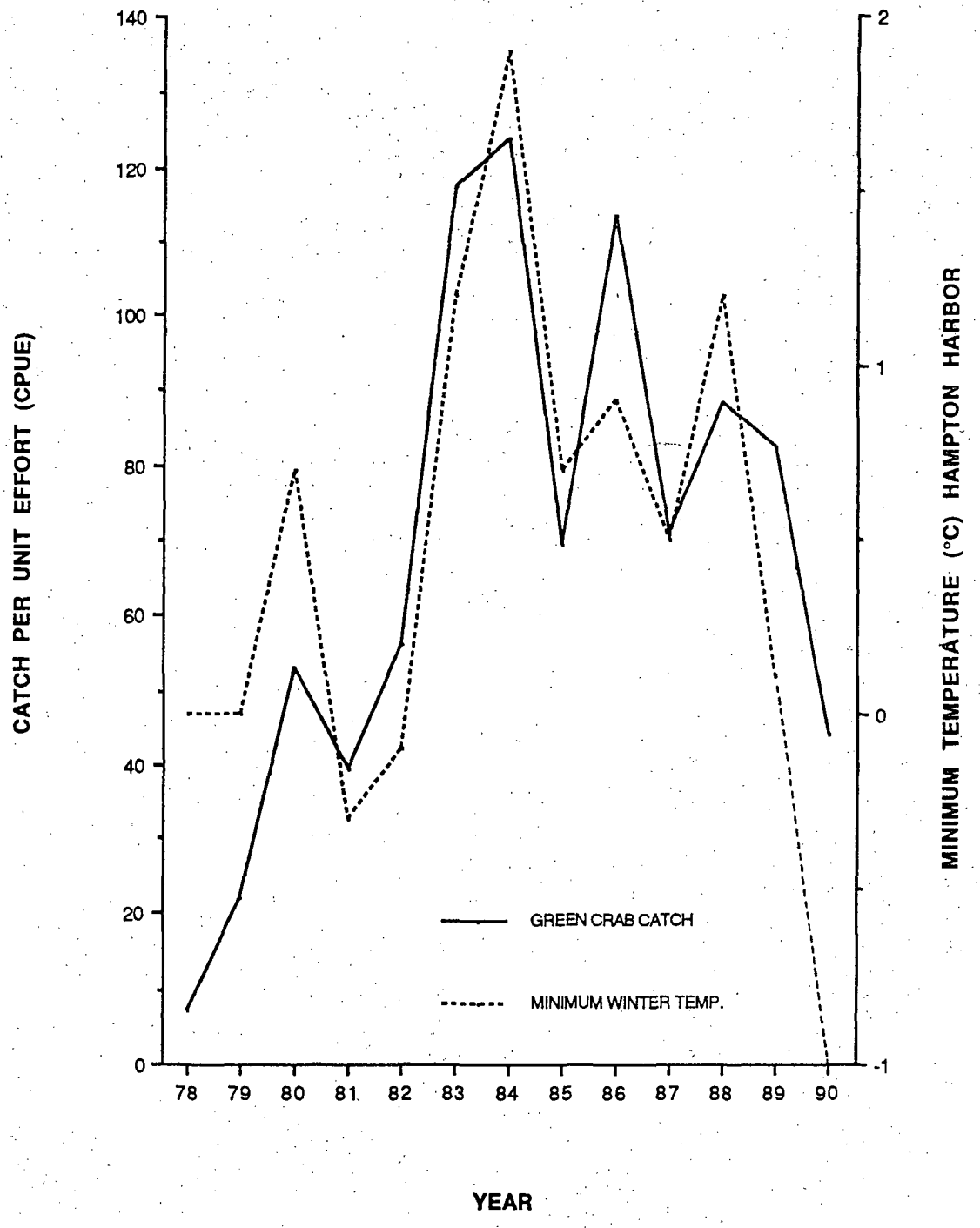


Figure 3.3.7-9. Fall (October-December) mean catch per unit effort for green crabs *(Carcinus maenas)* in Hampton-Seabrook Harbor and its relationship to minimum winter temperature, 1978-1990. Seabrook Operational Report, 1990.

CPUE decreased following a decrease in previous minimum winter temperature. The decrease in green crab CPUE in 1989 was less than expected, considering that the minimum winter temperature was the lowest since 1982 (Figure 3.3.7-8). One possible explanation is that local or regional green crab populations may be adapting to the northern portion of their range. Green crab abundances in 1990 were nearly one half those of 1989, reflecting the lowest minimum winter temperature observed from 1980 to 1990 (Figure 3.3.7-8).

The increase in green crab CPUE, and associated predation in the years 1980-1989 can be observed in examination of the 1981-1988 *Mya* year classes, as estimated by densities of young-of-the-year clams (Figure 3.3.7-3). The 1981 year class, which was relatively large, showed decreased survivorship and substantially-reduced densities of first and second year clams (Figure 3.3.7-2). In 1982, spatfall was the poorest since 1974 (Figure 3.3.7-3) and the subsequent mortality, related in part to green crab predation, has virtually eliminated this year class (Figure 3.3.7-2). Recruitment into Hampton Harbor clam populations, 1983-1988, has been very low, corresponding to high green crab abundances and low spat recruitment. The 1989 year class appears to have recruited with some success into the 13-25 mm size class at Flats 1, 2 and 4 (Figures 3.3.7-5, 3.3.7-6, 3.3.7-7), despite abundant green crabs in the fall of 1989. Recruitment success of the 1990 year class will not be evident until the 1991 population survey.

Welch and Churchill (1983) reported an increase in near-surface temperature at Boothbay Harbor, Maine in the early 1970s along with an increase in green crab abundance. Although no green crab or temperature data are available for Hampton Harbor for this time period, catches from Kittery, Maine, showed a maximum crab occurrence (1973-1975) corresponding to the reduction in younger *Mya* year classes observed in Hampton Harbor prior to the 1976 settlement. Subsequent reductions in the reported sea surface temperature and related decreases in green crab abundance along the southern Maine coast (Welch and

Churchill 1983) may have also occurred in Hampton Harbor, contributing to the high survivorship of the 1976 and 1977 *Mya* year classes.

Recreational clam digging on the Hampton Harbor flats has been the most significant source of mortality for clams of >45 mm, but also is a source of mortality to spat and juvenile clams due to disturbance. Mortality to younger clams (<50 mm) from digging is dependent on the depth of burial, the size of the clams, the time of the year (Glude 1954), and the substrate (Robinson and Rowell 1990). Glude (1954) found that survival is inversely proportional to depth of burial; the deepest burial tested (13 cm) resulted in the lowest survival. Clams 9-20 mm suffered the greatest mortality (51%) with 36-50 mm clams having only 31.5% mortality. More recently, Robinson and Rowell (1990) have suggested that digging related mortality is usually less than 20%, though actual mortality rates can vary due to substrate (lower in sandy sediment and higher in clay sediment) and temperature (highest in summer). Field observations indicate that substrate types do vary across Hampton Harbor flats, thus some flats may be more susceptible to digging related mortality than others. No data have been collected on the amount of disturbance caused by digging on the Hampton Harbor flats; however, Flat 1 and Flat 4, with the highest historical usage by clammers, would likely have suffered substantial mortality to young clams due to digging.

Census figures indicate digging activity tripled from 1980 to 1981 (Table 3.3.7-2). Effort remained high through 1982 before undergoing successive reductions from 1983-1985. Digging activity increased slightly in 1986 over 1985 levels, but remained lower than in previous years, 1982-1984. Digging activity declined further from 1987-1989 to the lowest levels observed in the study since 1980. Hampton Harbor Flats were closed from April 1989 through December 1990 by the New Hampshire Department of Health and Human Services due to coliform contamination.

TABLE 3.3.7-2. ESTIMATED DISTRIBUTION (PERCENT OF TOTAL) OF CLAM DIGGERS BY FLAT AT HAMPTON HARBOR, SPRING 1980 THROUGH FALL 1990. SEABROOK OPERATIONAL REPORT, 1990.

SEASON	FLAT 1	2	3	4	5	ESTIMATED[a] TOTAL DIGGER TRIPS	ESTIMATED[b] NUMBER OF BUSHELS HARVESTED
Spring[c] 1980	12.5	17.9	1.7	52.5	15.4	3,860	1,200
Fall[d] 1980	11.3	18.4	3.3	55.1	11.8	2,700[e]	840
Spring 1981	9.7	15.6	0.8	65.9	7.9	12,500	3,900
Fall 1981	13.9	12.9	0.2	63.8	9.1	7,060	2,200
Spring 1982	12.6	13.0	0.8	67.1	6.4	10,800	3,400
Fall 1982	26.6	8.5	0.7	60.7	3.5	9,300	2,900
Spring 1983	30.7	7.1	1.3	58.6	2.2	7,700	2,400
Fall 1983	29.4	14.7	0.5	54.7	0.7	6,690	2,100
Spring 1984	22.1	26.4	0.6	49.9	1.0	6,200	1,950
Fall 1984	26.9	28.9	0.3	43.2	0.8	5,850	1,830
Spring 1985	51.6	11.3	0.4	36.1	0.8	6,940	2,169
Fall 1985	63.1	5.0	0.4	31.5	0.0	2,873	898
Spring 1986	59.3	6.4	0.3	33.4	0.6	6,210	1,941
Fall 1986	58.1	6.4	0.4	34.7	0.4	4,713	1,473
Spring 1987	39.4	8.1	1.5	49.0	2.0	1,763	551
Fall 1987	38.8	6.9	0.8	49.8	3.8	1,541	482
Spring 1988	13.2	14.3	3.7	66.4	2.4	574	179
Fall 1988	22.8	10.9	4.2	57.4	4.7	1,386	433
Spring 1989	22.1	10.6	0.0	65.3	2.0	357	112
Fall[f] 1989	--	--	--	--	--	--	--
Spring[g] 1990	--	--	--	--	--	--	--
Fall[g] 1990	--	--	--	--	--	--	--

[a]Based primarily on Friday head counts at time of low slack water; most Saturday counts are assumed from observed Fri:Sat ratio (n=14 pairs) of 2.24 ± SD 0.96; seasonal totals have approximate error of ± 18%
[b]Assumes each clammer takes 10 quarts per trip; 1 bushel = 32 quarts or 3.2 clammer trips
[c]Includes the period 1 January through weekend before Memorial Day
[d]Includes the weekend after Labor Day through 31 December
[e]Based on average Spring:Fall ratio for 1981 and 1982 (0.68 ± SD 0.02)
[f]Data collected January - March only. Flats closed April - December.
[g]Flats closed January - December

The changing pattern of clam abundance on the Hampton Harbor flats is reflected in the number of licenses issued by the State of New Hampshire (Figure 3.3.7-10). Changes in the number of licenses generally lag behind the changes in standing crop by one to two years, illustrating a typical predator-prey cycle. In 1989, the number of clam licenses issued did not reflect clam abundance but rather the aborted harvesting season. With the Hampton Harbor flats closed, the few licenses issued (lowest in at least twenty years) in 1990 were for digging elsewhere in New Hampshire, in flats associated with Great Bay and the Piscataqua River Estuary.

The distribution of clam diggers and therefore, fishing pressure, has varied among flats since observations were first recorded in 1980. In 1980 - 1983, 50-70% of all clam diggers harvested on Flat 4, where clams were abundant and easily accessible by foot (Table 3.3.7-2). Diggers shifted some of their activity in late 1983 and 1984 from Flat 4 to Flat 2, probably in response to declining resources overall, particularly at Flat 4. As clam densities continued to sharply decline in 1985 and 1986 digger activity again shifted, from Flat 2 and Flat 4 to Flat 1, possibly due to slightly greater densities at Flat 1. From 1987 - 1989, 80-90% of digging activity was confined to Flat 1 and Flat 4, which had the highest remaining standing crop.

Effect of Disease on Harvestable Clam Resources

Sarcomatous neoplasia, a lethal form of cancer in *Mya arenaria*, has been observed in Hampton Harbor *Mya* populations (Hillman 1986, 1987). A virus, similar to the B-type retroviruses, is known to initiate the disease in *Mya* (Oprandy et al. 1981). Although the infection has been observed in regions of relatively-pristine waters, the rate of infection may also be enhanced by pollution-mediated deterioration of the environment (Reinisch et al. 1984). The infection rate in some *Mya* populations may reach 100 percent with 100 percent mortality of infected clams (Farley et al. 1986). The incidence of sarcomatous neoplasms in

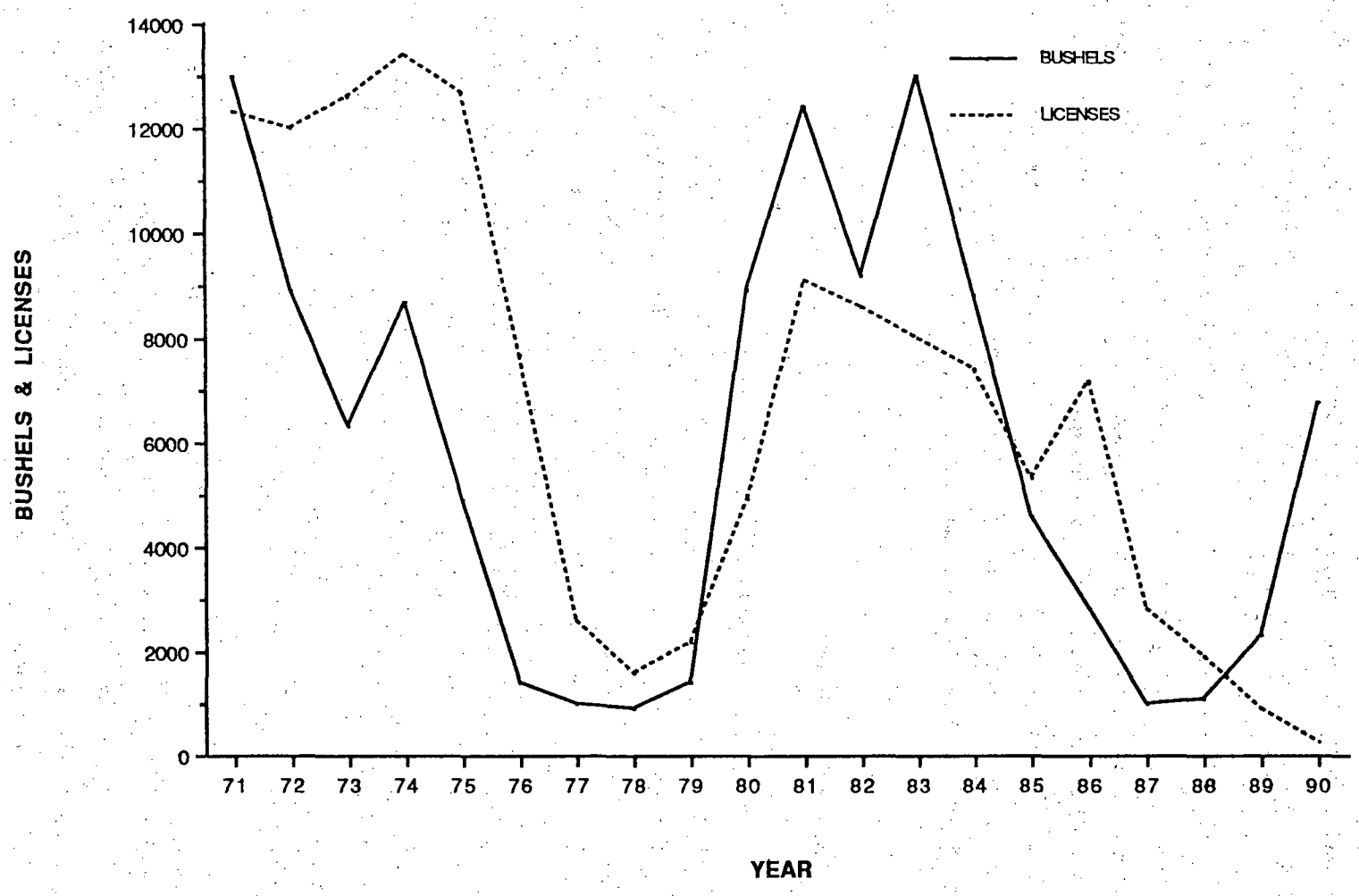


Figure 3.3.7-10. Number of adult clam licenses issued and the estimated adult clam standing crop (bushels) in Hampton-Seabrook Harbor, 1971-1990. Seabrook Operational Report, 1990.

Hampton Harbor *Mya* populations was observed in October 1986 and February 1987 (Hillman 1986, 1987). Neoplastic infections were more prevalent in February, reaching 6% at Flat 1 and 27% at Flat 2. Infections were absent from Flat 4. Assuming 100 percent mortality of infected clams (Farley et al. 1986), Flats 1 and 2 may suffer significant disease-related reductions in clam production. However, since no historical data are available on the incidence of neoplasms in Hampton Harbor clam population, it is not known if 1986-1987 infection rates are typical or indicative of an increasing trend. In 1987 clam flat surveys did indicate, however, that juvenile and adult densities fell by over 50% at Flat 1 and Flat 2 while Flat 4 remained unchanged.

3.3.7.5 Harvestable Clams

The patterns discussed above have resulted in substantial changes in the number of harvestable clams on the Hampton flats (Table 3.3.7-3). The greatest adult standing stock in Hampton Harbor was reported by Ayer (1968) for 1967. Subsequent years indicated a gradual decline in available adult clams to a low of six bushels/acre in 1977 and 1978. In 1976, the State of New Hampshire applied more stringent clamming regulations, closing the flats for the summer (Memorial Day to Labor Day) and eliminating digging on Sundays and holidays. Survival of the 1976 year class made a substantial increase in the standing crop in 1980, four years after settlement. The number of harvestable clams continued to increase in 1981 as more of the 1976 and part of the 1977 year class became harvestable.

Through 1984, the number of harvestable bushels had not decreased substantially. However, in 1985 through 1987, the harvestable standing crop dropped precipitously (Table 3.3.7-3), reflecting poor recruitment observed in 1980-1984, increased predation by green crabs, and continued human disturbance. Standing crop increased slightly in 1988, followed by substantial increases in 1989 and 1990, probably due to reduced digging pressure on adult clams as well as decreased disturbance

TABLE 3.3.7-3. SUMMARY OF STANDING CROP ESTIMATES OF ADULT[a] *MYA ARENARIA* IN HAMPTON HARBOR, 1967 THROUGH 1990. SEABROOK OPERATIONAL REPORT, 1990.

DATE	ESTIMATED NUMBER OF BUSHELS PER ACRE	TOTAL ESTIMATED NUMBER OF OF BUSHELS
November 1967	152[b]	23,400[b]
July 1969	103	15,840
November 1971	94	13,020
November 1972	58	8,920
November 1973	41	6,310
November 1974	56	8,690
November 1975	29	4,945
November 1976	11	1,350
November 1977	6	1,060
November 1978	6	940
November 1979	9	1,400
October 1980	54	8,890
October 1981	75	12,400
October 1982	55	9,200
October 1983	78	13,020
October 1984	54	8,821
November 1985	39	4,615
October 1986	23	2,793
October 1987	8	976
October 1988	10	1,137
October 1989	19	2,295
October 1990	57	6,752

[a]Shell length >50 mm
[b]From Ayer (1968)

and mortality of smaller size classes. The estimated adult standing crop of Hampton Harbor flats in 1990 is the fifth highest observed, 1971-1990.

The distribution of clams by flat has changed since 1980 when the 1976 year class became harvestable (Table 3.3.7-4). Flat 1 showed a continuous increase in its percentage of adult clams through 1984, while Flat 4 showed a steady decrease. In 1985 the percentage of harvestable clams decreased on Flat 1 and increased on Flat 4, followed by increases on Flats 1 and 2 and a decrease on Flat 4 during 1986 (Table 3.3.7-4). In 1987, the percentage of harvestable clams increased at Flat 4, while decreasing at Flat 1 and Flat 2, reflecting the stabilization of clam populations at Flat 4 at low levels, while populations on Flat 1 and Flat 2 continued to decline (Appendix Table 3.3.7-1). In 1988, the distribution of harvestable clams changed little, as Flat 2 dropped slightly, Flat 4 increased slightly and Flat 1 remained unchanged. In 1989 and 1990, the percentage of harvestable clams continued to increase on Flat 4 while decreasing at both Flat 1 and Flat 2.

TABLE 3.3.7-4. DISTRIBUTION (PERCENT OF TOTAL STANDING CROP) OF HARVESTABLE CLAMS BY FLAT AT HAMPTON HARBOR, 1979 THROUGH 1990. SEABROOK OPERATIONAL REPORT, 1990.

YEAR	FLAT				
	1	2	3	4	5
1979	33.3	6.2	2.2	55.7	2.5
1980	45.1	10.5	1.0	39.5	3.9
1981	53.0	7.3	1.5	34.4	3.7
1982	52.2	7.0	1.0	38.4	1.3
1983	62.9	25.6	0.5	10.5	0.5
1984	72.0	13.6	1.9	11.5	0.9
1985	60.2	14.6	NS	25.1	NS
1986	63.0	21.9	NS	15.1	NS
1987	40.0	15.9	NS	44.2	NS
1988	40.9	9.0	NS	50.1	NS
1989	30.1	3.1	NS	66.8	NS
1990	24.6	1.6	NS	73.8	NS

NS = not sampled

APPENDIX TABLE 3.3.1-1. MEAN MONTHLY SEAWATER SURFACE TEMPERATURE (°C) AND SALINITY (ppt) TAKEN IN BROWNS RIVER AND HAMPTON HARBOR AT HIGH AND LOW TIDE, MAY 1979 - DECEMBER 1990. SEABROOK OPERATIONAL REPORT, 1990.

TEMPERATURE	BROWNS RIVER				HAMPTON HARBOR			
	HIGH TIDE		LOW TIDE		HIGH TIDE		LOW TIDE	
	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
JAN	1.5	1.2	1.0	0.6	2.6	0.7	1.0	0.5
FEB	1.7	1.0	1.8	0.8	2.5	0.7	1.7	0.5
MAR	4.2	0.9	5.1	0.6	3.7	0.4	4.3	0.6
APR	7.0	0.7	9.6	0.6	6.3	0.6	8.2	0.5
MAY	12.7	1.4	14.5	0.8	9.9	0.5	12.4	0.7
JUN	16.1	0.9	19.3	0.8	13.5	0.6	16.3	0.7
JUL	18.3	0.8	22.1	1.1	15.8	0.6	18.5	0.7
AUG	19.1	0.9	21.2	1.1	17.0	0.8	18.8	0.7
SEP	16.2	0.8	18.0	0.8	14.8	0.8	16.3	0.7
OCT	11.9	0.8	12.5	1.3	12.0	0.6	12.1	0.7
NOV	8.3	0.8	7.6	1.3	9.0	0.6	8.3	0.8
DEC	4.5	1.0	2.4	1.0	5.3	0.7	3.5	0.9

SALINITY	BROWNS RIVER				HAMPTON HARBOR			
	HIGH TIDE		LOW TIDE		HIGH TIDE		LOW TIDE	
	MEAN	CI	MEAN	CI	MEAN	CI	MEAN	CI
JAN	31.5	0.8	23.7	2.3	32.2	0.5	28.7	1.4
FEB	29.5	2.1	19.3	3.2	31.8	0.6	27.4	2.0
MAR	29.0	1.4	17.7	2.6	31.3	0.7	25.7	2.0
APR	27.1	2.3	17.0	3.4	30.1	1.3	24.5	2.7
MAY	28.7	1.5	19.1	2.8	30.0	0.8	26.3	1.5
JUN	28.9	1.4	21.1	2.4	30.4	0.8	27.6	1.7
JUL	30.1	0.8	23.9	1.4	31.0	0.4	28.8	0.7
AUG	30.2	0.5	25.1	1.3	31.3	0.3	29.5	0.5
SEP	30.7	0.9	24.4	2.0	31.5	0.2	29.6	0.7
OCT	30.5	0.6	22.8	1.7	31.6	0.2	29.0	0.7
NOV	29.9	1.2	20.1	2.7	31.7	0.3	27.9	1.2
DEC	30.5	1.5	20.4	3.0	31.8	0.5	27.7	1.8

APPENDIX TABLE 3.3.1-2. ANNUAL MEAN[a] WITH 95% CL[b] FOR TEMPERATURE (°C) AND SALINITY (ppt) TAKEN AT BOTH HIGH AND LOW SLACK TIDE FROM BROWNS RIVER AND HAMPTON HARBOR FROM 1980-1990. SEABROOK OPERATIONAL REPORT, 1990

	BROWNS RIVER							
	LOW TIDE				HIGH TIDE			
	TEMPERATURE	CL	SALINITY	CL	TEMPERATURE	CL	SALINITY	CL
1980	10.9	5.2	25.1	1.9	9.6	4.4	31.0	1.6
1981	10.6	4.4	25.5	1.6	10.3	4.6	30.0	1.7
1982	10.7	4.5	22.8	1.8	9.9	4.1	30.0	1.2
1983	11.9	5.0	19.4	3.6	11.0	4.2	28.0	1.9
1984	11.9	5.1	18.1	3.3	10.6	3.9	28.4	1.8
1985	11.3	5.0	21.7	2.1	10.1	4.4	30.6	0.7
1986	10.3	4.8	20.4	3.1	9.6	4.0	30.2	0.9
1987	-	-	20.1	2.9	-	-	28.7	1.9
1988	10.6	5.1	20.5	2.2	10.3	4.0	29.8	0.7
1989	11.5	5.4	20.2	2.5	10.1	3.9	30.0	0.7
1990	-	-	-	-	-	-	-	-
OVERALL	11.3	1.4	21.4	0.8	10.2	1.1	29.7	0.4

	HAMPTON HARBOR							
	LOW TIDE				HIGH TIDE			
	TEMPERATURE	CL	SALINITY	CL	TEMPERATURE	CL	SALINITY	CL
1980	9.6	4.4	29.9	1.4	9.1	3.6	32.0	0.5
1981	10.1	4.4	28.9	1.1	9.3	3.8	31.5	0.4
1982	10.2	4.1	27.3	1.5	9.2	3.5	31.2	0.6
1983	10.4	4.3	25.5	2.4	9.9	3.4	30.1	0.9
1984	10.4	4.1	25.8	2.3	9.4	3.1	30.2	0.9
1985	10.6	4.2	29.1	1.0	10.1	3.3	32.2	0.3
1986	10.0	3.9	27.7	1.3	9.4	3.0	31.5	0.4
1987	10.0	4.3	27.5	2.2	8.9	3.5	30.7	0.9
1988	9.7	3.9	27.8	1.0	9.2	3.3	31.3	0.4
1989	10.2	4.4	28.0	1.2	9.2	3.3	31.4	0.7
1990	10.3	4.3	27.2	1.2	9.7	3.6	31.3	0.6
OVERALL	10.1	1.1	27.7	0.5	9.4	0.9	31.2	0.2

[a]Annual mean=mean of 12 monthly means, except where footnoted.
[b]Confidence limits expressed as half the confidence interval.
[c]No data were taken in February, therefore n=11 months.
[d]Overall mean=mean of monthly means; does not include data from 1987 and 1990 in Browns River (except for salinity in 1987).

APPENDIX TABLE 3.3.2-1. A COMPARISON OF SPARSELY OCCURRING MACROALGAE TAXA IN AUGUST BENTHIC DESTRUCTIVE SAMPLES, 1978-1989 AND 1990. SEABROOK OPERATIONAL REPORT, 1990.

TAXA	1978-1989[a]	1990[b]
Monostroma grevillei	x	
Monostroma oxyspermum	x	
Enteromorpha sp.	x	
Enteromorpha intestinalis	x	
Enteromorpha linza	x	
Enteromorpha prolifera	x	
Ectocarpus siliculosus	x	x
Giffordia granulosa	x	
Sphacelaria cirrosa	x	x
Desmarestia viridis	x	x
Petalonia fascia	x	x
Scytosiphon lomentaria	x	
Dumontia contorta	x	
Ceramium deslongchampii	x	
Pilayella littoralis	x	
Plumaria elegans	x	
Polysiphonia sp.	x	
Polysiphonia denudata	x	
Polysiphonia harveyi	x	
Porphyra miniata	x	x
Entocladia viridis	x	
Spongonema tomentosum	x	
Cladophora sericea	x	
Spongomorpha spinescens	x	
Bonnemaisonia hamifera	x	o
Palmaria palmata	x	

[a]less than 9 occurrences out of 512 samples (1.8%)
[b]x = occurred once out of 55 samples (1.8%)
o = occurred eight times out of 55 samples (14.5%)

APPENDIX TABLE 3.3.2-2. MEDIAN AND RANGE OF PERCENT COVER AND PERCENT FREQUENCY OF PERENNIAL AND ANNUAL MACROALGAE SPECIES PER 0.25 m^2 AT FIXED INTERTIDAL NON-DESTRUCTIVE SITES DURING THE PREOPERATIONAL PERIOD (1982-1989) AND IN 1990. SEABROOK OPERATIONAL REPORT, 1990.

				PERENNIAL ALGAE								
				BARE LEDGE[b]			FUCOID LEDGE[b]			CHONDRUS ZONE[b]		
	STATION			APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Percent Cover[a,g]												
Fucus spp.[c]	B1	1982-89	median	1	<1	<1	93	93	68	25	18	18
			(range)	(0-8)	(0-10)	(0-40)	(25-98)	(60-100)	(25-95)	(4-38)	(13-69)	(0-38)
		1990		0	4	2	92	0	25	0	0	0
	B5	1982-89	median	6	11	23	94	94	93	0	0	0
			(range)	(0-50)	(<1-75)	(0-80)	(60-98)	(65-100)	(2-98)	(0)	(0)	(0)
		1990		18	77	25	60	65	50	0	0	0
Percent frequency[a,f]												
Fucus spp.[c]	B1	1982-89	median	6	19	6	94	88	88	13	13	16
			(range)	(0-81)	(0-94)	(0-94)	(69-100)	(75-100)	(69-94)	(0-44)	(2-75)	(0-60)
		1990		0	0	0	94	100	94	0	6	0
	B5	1982-89	median	82	97	100	85	85	91	0	0	0
			(range)	(0-100)	(12-100)	(0-100)	(62-100)	(69-100)	(31-100)	(0)	(0)	(0)
		1990		100	100	100	88	87	88	0	0	0
Chondrus[d] crispus	B1	1982-89	median	0	0	0	2	1	2	45	34	45
			(range)	(0)	(0)	(0)	(0-8)	(0-13)	(0-7)	(20-53)	(20-38)	(28-53)
		1990		0	0	0	15	2	3	41	23	53
	B5	1982-89	median	0	0	0	<1	<1	0	45	48	41
			(range)	(0)	(0)	(0)	(0-5)	(0-8)	(0-2)	(0-72)	(41-55)	(39-48)
		1990		0	0	0	0	0	5	50	39	61
Mastocarpus[d] stellatus	B1	1982-89	median	0	0	0	9	7	13	47	66	48
			(range)	(0)	(0)	(0)	(0-29)	(0-19)	(0-32)	(21-69)	(65-71)	(32-67)
		1990		0	0	0	37	19	22	61	59	49
	B5	1982-89	median	0	0	0	6	5	10	47	51	44
			(range)	(0)	(0)	(0)	(0-15)	(0-13)	(0-19)	(0-53)	(41-63)	(43-56)
		1990		0	0	0	10	10	13	26	63	44
Corallina officinalis	B1	1982-89	median	0	0	0	0	0	0	0	0	0
			(range)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
		1990		0	0	0	0	0	0	0	0	0
	B5	1982-89	median	0	0	0	0	0	0	30	52	52
			(range)	(0)	(0)	(0)	(0)	(0)	(0)	(15-57)	(33-61)	(31-65)
		1990		0	0	0	0	0	0	63	40	51

(continued)

APPENDIX TABLE 3.3.2-2. (Continued)

STATION				ANNUAL ALGAE								
				BARE LEDGE[b]			FUCOID LEDGE[b]			CHONDRUS ZONE[b]		
				APR	JUL	DEC	APR	JUL	DEC	APR	JUL	DEC
Percent Frequency[a,f]												
Porphyra sp.	B1	1982-89	median	<1	5	<1	2	7	<1	0	0	0
			(range)	(0-15)	(0-78)	(0-21)	(0-9)	(0-17)	(0-5)	(0)	(0-9)	(0)
		1990		1	3	2	0	5	0	0	36	0
	B5	1982-89	median	0	0	0	0	0	0	0	0	0
			(range)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
		1990		0	0	0	0	0	0	0	0	0
Urospora penicilliformis/ Ulothrix flacca	B1	1982-89	median	45	0	0	0[e]	0	0	0	0	0
			(range)	(0-99)	(0)	(0)	(0-P[e])	(0)	(0)	(0)	(0)	(0)
		1990		79	0	0	0	0	0	0	0	0
	B5	1982-89	median	73	0	0	0	0	0	0	0	0
			(range)	(0-100)	(0)	(0)	(0-5)	(0)	(0)	(0)	(0)	(0)
		1990		0	0	0	0	0	0	0	0	0
Bangia fuscopurpurea	B1	1982-89	median	0	0	0	0	0	0	0	0	0
			(range)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
		1990		0	0	0	0	0	0	0	0	0
	B5	1982-89	median	25	0	0	0	0	0	0	0	0
			(range)	(0-100)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
		1990		0	0	0	0	0	0	0	0	0

[a]Based on fixed quardrats
[b]Bare ledge station is at upper edge of MSL zone, at approximate mean high water. Fucoid station is at approximate mean sea level mark. Chondrus zone station, first sampled in 1985, is at approximate mean low water mark.
[c]Percent frequency of fucoid algae is based on presence of holdfasts only.
[d]% frequency recorded using different method in 1982.
[e]Present, % frequency not recorded.
[f]Based on point contact line sampling.
[g]Percent cover of fucoid algae is based on whole plant.

APPENDIX TABLE 3.3.7-1. SUMMARY OF MYA ARENARIA POPULATION DENSITIES FROM ANNUAL FALL SURVEYS IN HAMPTON-SEABROOK HARBOR, 1971 THROUGH 1990. SEABROOK OPERATIONAL REPORT, 1990.

		NUMBER OF SAMPLES COLLECTED		MEAN DENSITY (No./ft^2)		
LOCATION	YEAR	ADULTS	SPAT	SPAT (1 to 25 mm)	JUVENILES (26 to 50 mm)	ADULTS (>50 mm)
Flat 1	1971	18	18	48	6.8	2.1
	1972	18	18	110	8.1	3.3
	1973	36	18	44	2.5	1.3
	1974	64	18	2	3.7	2.1
	1975	57	18	31	0.8	1.1
	1976	49	18	580	>0.1	0.3
	1977	60	14	437	>0.1	0.2
	1978	63	14	209	1.4	>0.1
	1979	62	20	40	30.4	0.1
	1980	30	20	90	72.0	1.7
	1981	25	25	45	44.7	3.7
	1982	25	25	6	13.1	2.8
	1983	40	40	21	21.1	4.2
	1984	40	45	57	6.2	3.4
	1985	106	71	5	1.4	1.6
	1986	75	70	9	0.2	0.7
	1987	70	55	7	0.1	0.2
	1988	70	62	3	0.3	0.2
	1989	65	60	11	0.8	0.4
	1990	65	32	114	0.5	0.8
Flat 2	1971	9	9	91	4.8	3.8
	1972	9	9	152	2.2	1.4
	1973	18	9	136	3.8	1.1
	1974	25	9	0	1.3	1.3
	1975	25	9	5	0.0	0.5
	1976	19	9	198	>0.1	0.1
	1977	33	7	49	0.0	>0.1
	1978	29	7	8	3.9	0.2
	1979	32	9	31	3.5	0.2
	1980	40	25	253	3.9	2.2
	1981	25	25	519	1.0	0.9
	1982	15	25	7	0.2	0.9
	1983	40	25	19	4.4	5.4
	1984	40	25	25	0.9	1.7
	1985	51	25	21	>0.1	0.5
	1986	53	20	9	>0.1	0.3
	1987	55	20	13	>0.1	0.1
	1988	55	25	2	>0.1	0.1
	1989	80	30	25	0.1	0.1
	1990	70	25	40	0.1	0.1

(continued)

APPENDIX TABLE 3.3.7-1. (Continued)

LOCATION	YEAR	NUMBER OF SAMPLES COLLECTED ADULTS	SPAT	MEAN DENSITY (No./ft²) SPAT (1 to 25 mm)	JUVENILES (26 to 50 mm)	ADULTS (>50 mm)
Flat 3	1971	6	6	74	4.7	4.6
	1972	6	6	39	1.6	0.4
	1973	12	6	8	3.6	2.2
	1974	16	6	1	0.7	1.5
	1975	17	6	1	0.0	0.5
	1976	24	5	321	>0.1	0.3
	1977	20	6	43	>0.1	>0.1
	1978	23	6	71	2.1	0.1
	1979	12	4	6	1.0	0.0
	1980	40	25	56	0.5	0.4
	1981	25	25	51	0.1	0.4
	1982	15	25	4	0.2	0.3
	1983	40	25	12	0.1	0.2
	1984	40	30	32	0.1	0.4
	1985	NS	25	12	NS	NS
	1986	NS	24	8	NS	NS
	1987	NS	25	9	NS	NS
	1988	NS	30	2	NS	NS
	1989	NS	21	11	NS	NS
	1990	NS	20	28	NS	NS
Flat 4	1971	12	12	106	17.6	2.8
	1972	12	12	138	10.6	2.3
	1973	24	12	18	3.8	0.6
	1974	39	12	3	2.8	1.7
	1975	38	12	39	0.3	0.4
	1976	68	18	475	>0.1	>0.1
	1977	42	11	245	>0.1	>0.1
	1978	51	11	172	16.8	>0.1
	1979	66	18	97	36.3	0.6
	1980	25	25	96	47.2	3.2
	1981	25	25	236	49.4	2.3
	1982	25	25	24	12.3	2.2
	1983	25	25	45	2.8	1.0
	1984	25	25	82	1.0	0.9
	1985	36	25	16	0.3	0.6
	1986	38	30	12	0.2	0.2
	1987	40	20	12	0.3	0.2
	1988	40	28	6	0.9	0.4
	1989	30	21	35	1.1	0.7
	1990	30	21	97	3.1	2.6

(continued)

APPENDIX TABLE 3.3.7-1. (Continued)

LOCATION	YEAR	NUMBER OF SAMPLES COLLECTED ADULTS	SPAT	MEAN DENSITY (No./ft^2) SPAT (1 to 25 mm)	JUVENILES (26 to 50 mm)	ADULTS (>50 mm)
Flat 5	1971	9	9	176	1.3	1.6
	1972	9	9	196	3.8	2.3
	1973	21	11	23	1.0	0.4
	1974	33	12	2	>0.1	0.1
	1975	20	8	5	0.0	>0.1
	1976	14	12	309	0.0	>0.1
	1977	38	9	64	>0.1	>0.1
	1978	38	7	32	4.8	>0.1
	1979	28	8	8	2.0	>0.1
	1980	40	20	65	2.2	0.8
	1981	25	25	409	0.3	0.7
	1982	15	25	43	>0.1	0.2
	1983	40	25	25	0.0	0.1
	1984	40	25	16	>0.1	0.1
	1985	NS	33	15	NS	NS
	1986	NS	35	7	NS	NS
	1987	NS	20	23	NS	NS
	1988	NS	25	3	NS	NS
	1989	NS	20	21	NS	NS
	1990	NS	20	40	NS	NS
All Flats	1971	54	54	92	7.7	2.7
	1972	54	54	130	6.2	2.2
	1973	111	56	47	2.8	1.0
	1974	177	57	2	2.2	1.5
	1975	157	53	21	0.4	0.6
	1976	174	62	421	>0.1	0.2
	1977	193	47	207	>0.1	>0.1
	1978	204	45	123	6.3	>0.1
	1979	200	59	49	22.3	0.3
	1980	175	115	115	20.6	1.5
	1981	125	125	252	19.1	1.6
	1982	95	125	17	6.7	1.5
	1983	185	140	24	5.9	2.3
	1984	185	150	46	1.7	1.3
	1985	193	179	12	0.8	1.1
	1986	166	179	9	0.2	0.5
	1987	165	140	11	0.1	0.2
	1988	165	170	3	0.4	0.2
	1989	175	152	18	0.5	0.3
	1990	165	118	68	0.8	0.8

4.0 METHODS

4.1 GENERAL

The purpose of this report is to evaluate the effect of Seabrook Station on the balanced, indigenous population of shellfish, fish, and wildlife in the waters in and around the discharge. Previous reports have documented the natural temporal and spatial variability of communities and selected species. Data collected in 1990, particularly during the months when Seabrook Station was operational (August-December), were compared to the historical data base. Differences observed in 1990 were further investigated to determine if they were restricted to nearfield areas or occurred only during the period of operation. A change was potentially deemed the result of plant operation only if these criteria were met and then only if other causes were eliminated.

The Seabrook Environmental Program has evolved from a series of individual studies to a consistent and highly unified sampling regime. Prior to 1975, the Seabrook Environmental Program involved studies of specific sites (e.g., the estuary, the discharge area, the intake area) or specific species (e.g., *Mya arenaria*) in order to (1) characterize their physical and/or biological environment and (2) assess impact of proposed plant design. The results of these studies were reviewed and discussed during the Environmental Protection Agency's hearings on Seabrook Station's open cycle cooling-water system (NAI 1977e; EPA 1977).

From July 1975 through 1989, the focus of the program has been to provide preoperational characterization of the environment in potentially impacted areas. Field and laboratory methods that were used for data collected during 1980 through 1990 were thoroughly described in the data reports for those years (NAI 1981c, 1981f, 1982a, 1982b, 1983a, 1984a, 1985a, 1986, 1987a, 1988a, 1989a, 1990a, 1991). Methods used prior to 1980 were summarized and explained in detail in previous annual

reports for Seabrook Environmental Studies (NAI 1976a, 1976b, 1977a, 1977b, 1977c, 1977d, 1978a, 1978b, 1979a, 1979b, 1979c, 1979d, 1979e, 1979f, 1980a, 1980b, 1980c, 1981a, 1981b, 1981c, 1981d, 1981e, 1981f).

In-depth reports describing baseline conditions were written for data collected through 1981 (NAI 1982c), 1982 (NAI 1983b) and 1983 (NAI 1984b). A complete assessment of preoperational conditions was made in the 1984 Seabrook Baseline Report (NAI 1985b). Subsequent baseline reports (NAI 1987b, 1988b, 1989b, 1990b) have built on conclusions made in that report, updating results with additional data for those programs which had been maintained without interruption.

All studies performed during the 1989 program were continued unchanged in the 1990 program. Phytoplankton and microzooplankton sampling programs were reinstated in 1990, along with ichthyoplankton and bivalve larvae entrainment collections. Methods and data tables results for the 1990 program are presented in NAI (1991).

Over the several years of this study there were instances in which some sample types were collected for only part of a year, or discontinued for a whole year or years, due to program modifications (particularly in 1985 and 1986). This report does not include data from partial sampling years if they erroneously influence sample statistics. For example, annual means of macrozooplankton selected species have not been calculated for 1986 because samples were not collected from January through June (a period of peak abundance) in that year. However, these data could be used in numerical classification and analysis of variance since samples are partitioned seasonally. Data not presented in a table or figure means that they were either not collected or were incomplete for that period.

As in previous baseline reports, conditions in the Hampton-Seabrook area were examined in this report at the community and species levels, both useful indicators of environmental change. Community structure and its variation in time and/or space were investigated using

numerical classification or multivariate analysis of variance. Abundance of various key species (of numerical or commercial importance) previously identified as "selected species" were compared temporally or spatially using analysis of variance (ANOVA) or non-parametric techniques. In several cases, the size or growth of a selected species was examined in addition to abundance or biomass in order to provide a basis for detecting potential sublethal effects. These methods are effective in describing general patterns and magnitudes of variability that have occurred. Analyses have focused on a single species or several species grouped together in a higher taxonomic category. Components of and rationale for species "complexes" were discussed in the 1984 Data Report (NAI 1985a).

4.2 COMMUNITY STRUCTURE

Community analyses included numerical classification (Table 4.2-1), multivariate analysis of variance (Table 4.2-2), and qualitative comparison of the relative abundances of dominant species (adult finfish, phytoplankton).

4.2.1 Numerical Classification

Numerical classification (Boesch 1977) was used to examine community structure either spatially (using data collected from different areas), and/or temporally (using data collected over time); comparisons were made based on species composition. Plankton (bivalve larvae, microzooplankton, macrozooplankton, ichthyoplankton eggs and larvae, and benthos (macroalgae, macrofauna, surface fouling panels) species assemblages were analyzed in this way (Table 4.2-1).

The "normal" classification forms groups of stations and/or sampling periods based on similarity levels calculated for all possible combinations of stations/sampling periods and the species that occur there. Normal classifications were performed using the Bray-Curtis

TABLE 4.2-1. SUMMARY OF COMMUNITIES AND METHODS USED IN NUMERICAL CLASSIFICATION. SEABROOK OPERATIONAL REPORT, 1990.

COMMUNITY	STATIONS	DATES	DATA CHARACTERISTICS[a]
Macrozooplankton (505 micron net)	P2	1/78-12/84, 7/86-12/90	Monthly $\bar{x}$; separated tychoplankton and holo/-meroplankton. Tychoplankton: used all taxa except Mysidacea and Amphipoda (22 taxa). Holo/mero: deleted taxa occurring in ≤5% of samples and general taxa. 50 taxa used in analysis.
Microzooplankton	P2	1978-1984, 7/86-12/86 4/90-12/90	$\bar{x}$, surface and bottom tows. Taxa excluded with frequency of occurrence <20% and total abundance <0.1%. 35 taxa used in analysis.
Bivalve larvae	P2	Apr-Oct, 1982-1984 1986-1990	$\bar{x}$ of duplicate tows. Deleted 1 general taxon (Bivalvia).
Fish eggs (505 micron net)	P2	1/76-12/90	Mean of 4 tows/date (Jan 76-Feb 83, except for non-selected species Jan-Dec 82, 1 tow); 2 tows (Mar 83-Dec 90); dates averaged within month; excluded taxa with total percent composition <0.1% or percent frequency <5%; excluded 2 months with <20 eggs. 11 taxa used in analysis

(continued)

TABLE 4.2-1. (Continued)

COMMUNITY	STATIONS	DATES	DATA CHARACTERISTICS[a]
Fish larvae (505 micron net)	P2	1/76-12/90	Data treated as for eggs; excluded species with total percent composition <0.1% or frequency of occurrence <5%. 21 taxa used in analysis; excluded 3 months with <20 larvae.
Benthic macroalgae and macrofauna	B17,B19,B31, B1MLW	Aug 1978-1990	Algae: Mean of replicates; excluded taxa with <2.0% frequency of occurrence. 34 taxa used in analysis. Square root transformation. Macrofauna: Mean of replicates; excluded noncolonial species with 36 occurrences based on 1978-90 data (6.4%) and all colonials. 89 taxa used in analysis.
	B34	Aug 1980-1984; 1986-1990	
	B04,B13	Aug 1978-1984; 1986-1990	
	B35,B5MLW	Aug 1982-1990	
	B16	Aug 1979-1984; 1986-1990	
Short-term surface panels	B19	1978-1990	Monthly mean abundance of noncolonials. Excluded taxa with <8 occurrences (5%). 20 taxa used in analysis.

[a]All data log (x+1) transformed unless otherwise noted

TABLE 4.2-2. SUMMARY OF COMMUNITIES AND METHODS USED IN MULTIVARIATE ANALYSIS OF VARIANCE. SEABROOK OPERATIONAL REPORT, 1990.

COMMUNITY	STATIONS	DATES	DATA CHARACTERISTICS[a]
Phytoplankton	P2,P5,P7	1990	Mean of replicates. Taxa deleted if % comp. <1%. 8 taxa included in analysis.
Macrozooplankton (505 micron net)	P2, P5, P7	1990	Mean of 3 replicate tows; excluded taxa with $\bar{x}$ annual abundance for all 3 stations <20 plus 4 general taxa. All months used in analysis.
Bivalve larvae	P1, P2, P5, P7	1990	Mean of duplicate tows. All taxa included except Bivalvia.
Microzooplankton	P2, P5, P7	1990	$\bar{x}$, surface and bottom tows. Deleted taxa <25% frequency of occurrence (all stations combined).
Fish eggs, Fish larvae (505 micron net) Fish larvae	P2, P5, P7	Aug-Dec, 1990; Jan-Dec 1990	Mean of two tows per date. Deleted dates <20 eggs or larvae. Taxa deleted if % comp. <0.1% or percent frequency of occurrence <5%.

[a]All data log (x+1) transformed unless otherwise noted

similarity index (Clifford and Stephenson, 1975; Boesch, 1977). Values of the indices vary from 0 for absolute dissimilarity to 1 for complete similarity. Samples which contained very few organisms were excluded from the analysis because they usually contribute little to the community description. Rare species, which generally have no consistent pattern of occurrence and contribute little information to the overall analysis, were excluded from the classification based on their low frequency of occurrence or low total abundance over the period of study (Table 4.2-1). In all cases, abundance data were log- or square-root transformed to reduce differences between large and small values and thus avoid overemphasizing the abundant species. The classification groups were formed from arithmetic averages by the unweighted pair - group method (UPGMA: Sneath and Sokal, 1973). Results were simplified by combining the entities based on their similarity levels, determined by both the within-group and between-group similarity values. Results were presented graphically by dendrograms, which show the within-group similarity, and the similarity levels at which they link to the other groups. The groups were characterized in terms of the mean abundance of dominant taxa and total abundance (sum of all taxa) during the preoperational period and in 1990. Communities in 1990 were judged to be similar to previous years if collections were placed in the group with the majority of seasonal (plankton, surface panels) or station (macrofauna, macroalgae) collections from previous years. A potential impact was suggested if community differences in 1990 occurred solely during the operational period (August-December) and were restricted to the nearfield area. This situation would trigger additional investigations.

4.2.2 Multivariate Analysis of Variance

Multivariate analysis of variance (MANOVA, Harris 1985) was utilized to assess simultaneously the similarity in abundances of dominant taxa among nearfield and farfield stations. Historically, there have been few differences in planktonic species assemblages among nearfield intake, discharge, and farfield stations. Continuation of the

preoperational trend in 1990 during plant operation would suggest that there were no effects of plant operation on these communities. MANOVA was used for the macrozooplankton, bivalve larvae, microzooplankton and fish larvae communities (Table 4.2-2) Probabilities associated with the Wilks' lambda, Pillai's trace and Hotelling Lawley trace test statistics are reported (SAS 1985a).

4.2.3 Other Community Methods

Demersal, pelagic, and estuarine fish communities are composed almost exclusively of a few dominant species, many of which are designated as selected species. Previous use of multivariate analyses such as numerical classification indicated that there were two seasonal assemblages (summer and winter), which changed based on seasonal movements of the most abundant taxa (NAI 1982c, 1983b). Since that time, seasonal, annual and spatial changes in the fish community have been monitored using relative abundance (percent composition) of dominant taxa. For demersal and estuarine fish, spatial differences have been evaluated by comparing relative abundances among stations both during the preoperational period and in 1990. Historically, pelagic fish have not shown area-wide differences, undoubtedly because of their mobility. Therefore, differences among stations for the pelagic fish have not been evaluated. Relative abundances in 1990 for all dominant species of fish were compared to previous years. Differences in 1990 that were outside the range of previous years warranted further scrutiny, using analyses outlined for selected species (Section 4.3). For demersal fish, potential changes in 1990 at the nearfield station (T2) only, occurring during the operational period, were examined carefully. Impact assessment for demersal fish is complicated by the difficulty in obtaining trawls at T2 in late summer because of lobster fishing activities.

4.3 SELECTED SPECIES/PARAMETERS

Temporal and spatial differences for the selected species and water quality parameters were quantitatively evaluated for the preoperational and operational periods. Many of the selected species and physical/chemical parameters monitored in the Hampton-Seabrook area have shown year-to-year differences that are part of natural environmental variability. Given this framework, values in 1990 were compared to previous years using analysis of variance or non-parametric techniques. Most of the organisms and physical/chemical parameters show seasonal patterns as well. These within-year patterns are shown graphically in plots of the mean and 95% confidence limits over all preoperational years for each month. Monthly mean values in 1990 were plotted on the same graph to provide a visual comparison of their magnitude and seasonality.

Many of the tables comparing organism abundances among years or months show geometric means and confidence limits. These are calculated by (1) log (x+1) transforming the data, (2) calculating the mean and confidence limits of the transformed data, and (3) back-transforming to the original units. Geometric means are generally somewhat lower than arithmetic means (averages of untransformed data), and the difference between the two means is greater in data sets exhibiting a high degree of variability. An outlier in a data set, such as an unusually high abundance in a single sample, will have less influence on a geometric mean than on an arithmetic mean. Thus a geometric mean is, in effect, a weighted mean, in which extreme values are given less weight than are typical values. For data sets that require logarithmic transformation to meet the assumptions of a normal distribution for statistical analysis, the geometric means faithfully portray the relationships within the data (among years, for example), whereas arithmetic means would sometimes show a different pattern than that detected by the analysis.

Differences in substrate, water mass movement, temperature, light penetration, depth, food availability, reproductive success or any combination of these factors can cause variation in species abundance and growth among stations or areas. As part of our experimental design, farfield stations beyond the influence of potential impact were established as "control" stations in areas as similar as possible to the nearfield areas. Any change observed during the operational phase at nearfield stations can be compared with these farfield areas to ascertain whether the change is occurring throughout the coastal area or just at the nearfield area. Spatial differences in the selected species were evaluated as part of the ANOVA design, by utilizing a paired t-test (nearfield vs. farfield stations), or the non-parametric Wilcoxon's summed ranks (or "two-sample") test.

4.3.1 Analysis of Variance (ANOVA)

Analysis of variance was used to evaluate spatial or temporal variability in abundance of selected species and values of water quality parameters. Analysis of variance is a statistical technique which subdivides the total variability into portions attributable to different sources (Lentner 1972). In this study, the major sources of variability have been (1) spatial, among stations or areas within stations, (2) temporal, among years, seasons, or sampling dates, and (3) residual, any variability not explainable by the first two sources.

The initiation of plant operation introduced a new source of potential variation. All ANOVAs sought to test the null hypothesis that values collected in 1990 were statistically similar to previous years. An ANOVA design was developed with the assistance of Dr. Roger Green (University of Western Ontario), using the following variables:

Preop-Op: Partitions data into the operational year (1990) and all previous years, regardless of station, testing whether the operational observations fall within the historical variability.

Year (Preop-Op): Partitions data into years nested within operational and preoperational periods, regardless of station or sampling period, testing the variability among years.

Station or Area: Partitions data into stations or areas representing nearfield and farfield areas, where applicable, regardless of year or sampling period, testing whether there has been a consistent relationship spatially.

Sampling period (Year): For data that show seasonal trends, a variable was included, such as months, weeks, or sampling period nested within years, testing whether there are significant differences seasonally.

All appropriate class variables were used in the ANOVAs along with the pertinent interactions. The discrete operational period (August-December) as well as the entire year were analyzed in cases where the species' or parameters' peak period occurred during the operational period, or when seasonality was not pronounced.

The beauty of this ANOVA design is that it specifically tests for potential impacts of plant operation. Differences occurring at one of the paired stations would be reflected in a significant result for the Preop-Op Station interaction term (Preop-Op X Station). Significant Preop-Op X Station results were further investigated to determine if the change occurred at the nearfield station (rather than the farfield station) and if changes were restricted to the August-December time period. If these conditions were met, a potential impact was suggested, triggering further investigation.

The variables for each selected species or parameters are listed in Table 4.3-1, along with the data manipulations that preceded the analysis.

In some cases, differences in 1990 were evaluated by a one-way analysis of variance among years at a nearfield station or station group. In some data sets that have been shown in previous baseline reports to exhibit no differences among stations (e.g., pelagic fish),

TABLE 4.3-1. SELECTED TAXA AND PARAMETERS USED IN ANALYSIS OF VARIANCE OR NONPARAMETRIC ANALOGUE. SEABROOK OPERATIONAL REPORT, 1990.

COMMUNITY	PARAMETER/TAXON	LIFESTAGE[a]	STATIONS	DATES USED IN ANALYSIS	DATA CHARACTERISTICS[b]	SOURCE OF VARIATION[c]
Water quality	Surface and bottom temperature	--	P2	1978-1990	Monthly mean, no transformation	Year
	Surface, bottom temperature	--	P2, P5, P7	1990	Monthly mean, no transformation	Station
	Surface, bottom dissolved oxygen; Surface, bottom salinity; Orthophosphorus, Total phosphorus, nitrate, nitrite, ammonia	--	P2, P5, P7	1990	$\bar{x}$ of sample periods, no transformation	Station
Phytoplankton	*Skeletonema costatum*	—	P2, P5, P7	1982-84; 4/86-12/86 4/90-12/90	Monthly $\bar{x}$ abundance Grouped P2, P5 as nearfield; P7 as farfield	Preop-Op, Area, Month Year
			P2, P5, P7	1990	$\bar{x}$ of reps.	Station
Bivalve larvae	*Mytilus edulis*	L	P2 P7	1982-1990	Weekly $\bar{x}$, Group P2, P5 as nearfield; P7 as farfield	Preop-Op, Area, Year, Week
		L	P2	1978-1990	Weekly $\bar{x}$ abundance	Year
Microzooplankton	*Eurytemora* sp.	C	P2, P7	1982-1984	Mean, surface and bottom tows	Preop-Op, Year, Area (=Station)
	Eurytemora herdmani	A	P5	4/86-12/86		
	Pseudocalanus/Calanus	N		4/90-12/90	Grouped P2, P5 as nearfield; P7 as farfield	
	Pseudocalanus sp.	C,A				
	Oithona sp.	N,C,A				

(continued)

TABLE 4.3-1. (Continued)

COMMUNITY	PARAMETER/TAXON	LIFESTAGE[a]	STATIONS	DATES USED IN ANALYSIS	DATA CHARACTERISTICS[b]	SOURCE OF VARIATION[c]
Macrozooplankton	*Calanus finmarchicus* *Cancer* sp. *Carcinus meanas* *Crangon septemspinosa* *Neomysis americana*	C,A L L L All	P2, P7 P5	1982-90	Grouped P5, P2 as nearfield & P7 as farfield. Mean abundances per sample period.	Preop-Op, Area Year Month
Ichthyoplankton	Winter flounder Yellowtail flounder American sand lance Atlantic cod Atlantic mackerel Hake Atlantic herring Pollock Cunner	L L L L L L L L L	P2,P7	7/75-12/90, selected months	Mean abundance per sample period for months which together composed over 90% of the total annual abundance	Preop-Op, Year, Station
Demersal fish (Otter trawl)	Winter flounder Yellowtail flounder Atlantic cod Hakes Rainbow smelt	J/A J/A J/A J/A J/A	T1, T2 T3	1/76-12/90	$\bar{x}$ CPUE (no. per haul) per date, all months used in analysis	Preop-Op, Station, Month, Year
Pelagic fish (Gill net)	Atlantic herring Pollock Atlantic mackerel	J/A J/A J/A	mean of all 3 stations	1/76-12/90	$\bar{x}$ CPUE (no. per 24-hr set) per date, surface bottom nets averaged, all months used in analysis	Preop-Op, Month Year

(continued)

TABLE 4.3-1. (Continued)

COMMUNITY	PARAMETER/TAXON	LIFESTAGE[a]	STATIONS	DATES USED IN ANALYSIS	DATA CHARACTERISTICS[b]	SOURCE OF VARIATION[c]
Estuarine fish (Beach seine)	Winter flounder Rainbow smelt Atlantic silverside	J/A J/A J/A	mean of all 3 stations	1/76-12/84, 1/87-12/90	$\bar{x}$ CPUE (no. per seine haul), all months used in analysis	Preop-Op, Year, Month
Estuarine benthos	*Streblospio benedicti* *Capitella capitata* Oligochaeta *Mya arenaria* *Nereis diversicolor* *Caulleriella* sp. B Total abundance No. of taxa	J/A J/A J/A J/A J/A J/A -- --	3, 9; 3MLW, 9MLW;	1978-1990 (except 1985)	Mean per sample period; all months used in analysis	Year
Benthic macroalgae	*Laminaria saccharina* *Laminaria digitata* *Alaria esculenta* *Agarum cribosum*	-- -- -- --	B17 B35; B19, B31 B19, B31	1979-1990 1982-1990 1978-1990	Mean number per sample period and station, no transformation. Wilcoxon's summed ranks by station	Preop-Op
	Chondrus crispus *Phyllophora* spp. *Ptilota serrata*	-- -- -- --	B17, B19, B31 B35	1981-1990 1982-1990	Mean % frequency per year. No transformation. Wilcoxon's summed ranks test.	Preop-Op, Station Year
	Chondrus crispus	--	B17, B1MLW B5MLW, B35	1978-1990 1982-1990	Mean biomass per sample period, square root transformation	Preop-Op, Station, Year
	Number of taxa Total Biomass	-- --	B1MLW, B5MLW; B17, B35; B19, B31, B16	August, 1978-1990	Mean per station and year; no transformation	Preop-Op, Station Year

(continued)

TABLE 4.3-1. (Continued)

COMMUNITY	PARAMETER/TAXON	LIFESTAGE[a]	STATIONS	DATES USED IN ANALYSIS	DATA CHARACTERISTICS[b]	SOURCE OF VARIATION[c]
Marine benthos, selected species	*Ampithoe rubricata*, *Nucella lapillus*, Mytilidae spat	J/A J/A J/A	B1MLW, B5MLW	5/78-11/90 5/82-11/90	Abundance averaged over replicates; 3 dates per year	Preop-Op, Station, Year, Month
	Jassa falcata, Mytilidae spat,	J/A J/A	B17, B35	5/78-11/90 5/82-11/90		
	Asteriidae	J/A	B17, B35	5/81-11/90 5/82-11/90		
	Pontogeneia inermis, Mytilidae spat, *Strongylocentrotus droebachiensis*	J/A J/A J/A	B19,B31	5/78-11/90		
	Number of taxa, Total Abundance	-- --	Station Groups: B1MLW, B5MLW; B17, B35; B19, B31, B16; B04, B34, B13	August, 1978-1990 (see above for years)	$\bar{x}$ per year and station; No transformation	Preop-Op, Station Year
	Modiolus modiolus	J/A	B19, B31	1980-1990	Mean per sample period, Wilcoxon's summed ranks test, No transformation	Preop-Op

(continued)

TABLE 4.3-1. (Continued)

COMMUNITY	PARAMETER/TAXON	LIFESTAGE[a]	STATIONS	DATES USED IN ANALYSIS	DATA CHARACTERISTICS[b]	SOURCE OF VARIATION[c]
Surface panels, short-term	Number of taxa Noncolonial abundance Biomass Mytilidae abundance *Jassa marmorata* abundance *Balanus* sp. % frequency *Tubularia* sp. % frequency	-- -- -- J/A J/A J/A J/A	Station pairs: B19, B31; B04, B34	1978-1984 1985-1990 (B34 initiated in 1982).	$\bar{x}$ per station and sampling period. All months used in analysis. No transformation for No. of taxa, Biomass, *Balanus*, *Tubularia*	Preop-Op, Year Month Station
Surface panels, monthly sequential	Biomass	--	B19, B31	1978-1984 1986-1990	$\bar{x}$ per station and sampling period. No transformation. All months used in analysis	Preop-Op, Year, Month, Station
	Biomass, No. of taxa, Noncolonial abundance *Laminaria* sp. counts	-- -- -- J/A	B19, B31, B04, B34	1982-1984, 1986-1990 Dec. only	$\bar{x}$ per station and year. No transformation Single sample t-test by station	Preop-Op
Epibenthic crustaceans	*Homarus americanus*	L	P2, P5, P7	1982-1990	Weekly mean	Preop-Op, Year, Week, Station
		L	P2	1978-1990	Weekly mean	Preop-Op, Year, Week
	Homarus americanus *Cancer borealis* *Cancer irroratus*	LE, A A A	L1, L7	6/82-11/90	Mean CPUE (per 15 traps) per month, no transformation,	Preop-Op, Station, Year, Month

(continued)

TABLE 4.3-1. (Continued)

COMMUNITY	PARAMETER/TAXON	LIFESTAGE[a]	STATIONS	DATES USED IN ANALYSIS	DATA CHARACTERISTICS[b]	SOURCE OF VARIATION[c]
Estuarine	*Mya arenaria*	J/A	Hampton, Flats 2 & 4; Plum Is. Sound	1987-1990	Mean per year and station. Operational (Oct.) data only	Preop-Op, Station, Year
		Y, J/A	Hampton Flats 1, 2, 4	1974-1990	Mean per year and station. Operational (Oct.) data only	Preop-Op, Station, Year
		S		1976-1990		
		L	P2 P2, P5, P7	1978-1990 1982-1990	Mean per week.	Year

[a]Life Stages: N = nauplii, C = copepodite, L = larvae, A = adult, All = all, J/A = juveniles and adults, LE = legal-sized, S = spat, Y = young-of-year
[b]log (X+1) transformation unless otherwise stated.
[c]Operational months (Aug-Dec) and all months in 1990 tested against same time period in previous years unless otherwise noted. Preop-Op = 1990 vs. all previous years.

or if stations are of essentially equal distance from the intake and discharge locations (e.g., estuarine fishes), data from all stations were combined. For those data sets that exhibit a high degree of within-year variability because of seasonal fluctuations (i.e., no specimens found during certain seasons as, for example, fish larvae), a subset of the data was chosen to represent the peak period, and samples from that period in each of the years were used in the analysis.

Analysis of variance and related parametric techniques make the following assumptions: (1) all samples are randomly collected, (2) samples come from a normally-distributed population, (3) error terms are normally and independently distributed, and (4) variances of samples are equal or homogeneous (Sokal and Rohlf 1969). Random and independent collection of samples is a function of experimental design. Normality of data was tested using the Kolomogorov-Smirnov test when sample size was greater than 50 and the Shapiro-Wilk statistic when sample size was 50 or less (SAS 1985b). Homogeneity of variances was tested using the F-max test (Sokal and Rohlf 1969). If one or both of these two assumptions was not met, the data were transformed and re-evaluated. In most cases, transformation of the data improved the distribution sufficiently to allow the use of analysis of variance. Logarithmic transformations were performed by adding 1 to the data used in the analysis and taking the base-10 logarithm. Where sample sizes were unequal, a general linear model was used for the ANOVA (SAS 1985a).

4.3.2 Multiple Comparisons

If a significant difference among means was discovered using analysis of variance, the Waller-Duncan k-ratio t-test was used to test which means or groups of means were significantly different from each other. This test is less conservative than several other commonly used multiple comparisons tests (i.e., more likely to find significant differences between means). It was selected because more conservative

tests failed in several cases to detect any significant differences among means even when the overall F-test of the ANOVA was highly significant.

Several types of non-parametric tests of significance were also used. Differences in ranks were assessed by using the Wilcoxon two-sample test (Sokal and Rohlf 1969; equivalent to Wilcoxon's sum of rank test, SAS 1985a) or the Kruskal-Wallis test (Sokal and Rohlf 1969). Wilcoxon's two-sample test is a ranking procedure by which two samples of unequal size can be compared. All data are ranked, then ranks are summed within samples. The differences between the summed ranks are compared using the Z statistic. The Kruskal-Wallis test was used as a non-parametric alternative to one-way ANOVA to test among-year differences or among-station differences. This procedure ranks all pooled data, then sums ranks within a group and compares differences using an H-statistic, distributed approximately as chi square (Sokal and Rohlf 1969).

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